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AGRICULTURAL AND BIOLOGICAL SCIENCES

FOUNDATIONS AND APPLICATIONS

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Parasitic fauna in tambaqui (*Colossoma macropomum*) from fish farms in the municipality of Rorainópolis-Roraima-Brazil

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ABSTRACT

Fish farming is a promising activity in the Western Amazon. The tambaqui (*Colossoma macropomum*) stands out for its good zootechnical performance, supply of fingerlings, rusticity and consumer market, being the most cultivated species (90% of all production) and consumed in Roraima. Like all confined animal production, there is a risk of pathogens and diseases emerging. The tambaqui can be affected by a wide variety of parasites, bringing irreversible damage both economically and healthily. The objective of this study was to identify and quantify parasites present in gills, intestine and tambaqui muscle from five fish farms in Rorainópolis-RR, as well as to correlate results with biometric variables and to estimate parasite prevalence and abundance. For this, 25 tambaqui specimens were acquired in five fish farms in the municipality of Rorainópolis-RR. Parasites of the class Monogenea (*Girodactilideo* sp.), Phylum Nematoda (*Procamallanus* (*Spirocamallanus* sp.) and *Klossinemella* sp.) and the class Myxozoa (*Myxobolus* sp.) were recorded. In two farms there was a 100% prevalence of infestation by Monogenea. The standard weight-length ratio curve ($y=0.01x^{3.27}$ ($R^2=0.84$)) was calculated, where the relative condition factor between parasitized and non-

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parasitized individuals was calculated, whose values did not differ statistically ($p=1$) by the Mann Whitney 'U' test. In this sense, it is important to properly manage and maintain the sanitary status of tambaqui production in the southern region of Roraima.

Keywords: Monogenea, Myxobolus, Procamallanus, Aquicultura.

INTRODUCTION

Fish farming has the potential to establish itself as a great example of sustainability in the Amazon, with a focus on the production of tambaqui, an Amazonian fish whose meat continues to appreciate in the domestic and foreign markets (Oliveira et al., 2023).

The Western Amazon has a great diversity of ichthyofauna, yet only 36 species are commercialized, of which only eighteen have significant production, among which the tambaqui, *Colossoma macropomum*, stands out for its acceptability and rusticity (BRASIL, 2003). Tambaqui is the main species of fish farming (90% of all production) and also the most consumed in Roraima, justified by its acceptability by consumers and mastery of technology in reproduction (EMBRAPA, 2009).

With the growth of production, the appearance of diseases is favored, as well as in any large concentration of animals, this factor is more explicit in super intensive fish farms where the animals are concentrated in high density. Due to the favoring of the development of several species of pathogens and the high stocking density and the problems caused by inadequate management and contamination of water, transmission and consequent infection/infestation becomes facilitated (Pavanelli & Takemoto, 2008; Onaka, 2009).

Naturally, fish live in equilibrium with parasites, but this balance can be disrupted by environmental disturbances, such as reduced dissolved oxygen, increased toxic ammonia and carbon dioxide, and these phenomena are more conducive in intensive fish farms where the reduction in water quality is associated with a poor feeding program (Kubiza & Kubiza, 2013). The excessive growth of the quantity and varieties of pathogens combined with poor water quality, contributes to the appearance of diseases and parasitosis, resulting in losses to the producer.

According to Jerônimo et al. (2012) and Luque (2004), the main fish parasites in fish farming are protozoa (*Ichthyophthirius multifiliis*, *Piscinodinium pilulare* and *Tricondina* spp), Myxoporides (*Myxobolus* sp, *Henneguya* ssp and *Kudoa* ssp), Monogenoids (main families Dactylogyridae and Gyrodactylidae), Digenetic (main families Diplostomidae and Clinostomidae), Cestodes (main families Diplostomidae and Clinostomidae), Cestodes (main families Parasites belong to the order Proteocephalidea), Nematodes (Species with zoonotic importance, Eustrongylides), Acanthocephalus and Crustaceans (*Argulus* sp, *Dolops* sp, *Perulernaea* sp and *Lernaea* sp), and most of these have the integument and gills as a preference for their fixation.

Different groups of parasites have been recorded in tambaqui from Brazilian fish farms, the main groups being: protozoa, myxoporids, crustaceans and helminths (Eiras et al., 2006; Valladão et al., 2014; Jerônimo et al., 2017).

Thus, the objective of this work was to identify and quantify parasites present in gills, intestine and tambaqui muscle from five fish farms in the municipality of Rorainópolis-Roraima-

Braisl and to correlate the results with the biometric variables, weight and length, as well as to estimate parasite prevalence and abundance.

METHODOLOGY

A total of 25 specimens of tambaqui (*Colossoma macropomum*) were acquired from five fish farms in the municipality of Rorainópolis-RR, with five specimens per farm. In each property, a semi-structured, complementary questionnaire of productive activity was carried out. The properties were named P1, P2, P3, P4 and P5. The aforementioned activities were carried out in April 2017.

After capture, each fish was immediately stunned/sacrificed through the sectioning of the marrow performed in the area of the first vertebra of the spine and placed in a plastic bag with the identification of a small pvc plate and accommodated in an isothermal box with ice.

The specimens were transported to the Federal Institute of Roraima- *Novo Paraíso Campus* (IFRR-CNP), where they were frozen and stored at -18°C for further analysis. The fish were transported in an isothermal box to the Laboratory of Applied Zoology (LABZOA) of the Federal University of Roraima (UFRR) - *Cauamé Campus*, where the necropsy was performed. A fish necropsy script for parasitology studies used at LABZOA was followed. After thawing at room temperature, the specimens were weighed (Economic® electronic scale, accuracy $\pm 5\text{g}$) and the standard and total length were verified, and then the integument was scraped in the anteroposterior direction with the aid of a glass slide, and the scraping was collected in a beaker and analyzed under a stereomicroscope (Jerônimo, 2012). The muscles were cut to verify the presence of parasites. The cuts were made in the anteroposterior direction of the dorsal muscles. When a parasite was detected, it was immediately placed between the slide and coverslip, with a small drop of water for verification under an optical microscope (Eiras, 2006). The gills were individualized, placed in a glass container, 1:4000 formaldehyde was added and shaken for 10 seconds, leaving this material to be evaluated at the end of the necropsy (Eiras, 2006). To verify the internal organs, evisceration was performed, and the stomach, intestine, liver and swim bladder were individualized in Petri dishes and visualized under stereomicroscope. When nematodes were found, they were preserved in 70% alcohol (Eiras, 2006).

The identification for Monogenea and *Myxobolus* sp. was carried out according to Thatcher (2006), for nematode according to Moravec (1998).

The indices that estimated the size of the population were prevalence, mean intensity and abundance (Bush et al., 1997). Calculated as follows: Prevalence = number of hosts infected with 1 or more individuals of a parasite species (or taxonomic group) divided by the number of hosts examined multiplied by 100. Average intensity = total number of parasites of a given species divided by the number of hosts infected by that given species. Average abundance = is the total number of

individuals of a parasite species in a sample of a host species divided by the total number of host species examined (infected and uninfected).

For the relative condition factor (Kn), standard length (Ls) and total weight (Wt) values of each host were adjusted to the Wt/Ls ratio curve ($Wt = a.Lsb$) and the values of the regression coefficients a and b were estimated. The values of a and b were used in the estimates of the expected weight values (We), using the equation: $We = a.Lsb$. The relative condition factor (Kn) was then calculated, which corresponds to the quotient between observed weight and expected weight for a given length ($Kn = Wt/We$) (Le Cren, 1951).

Statistical data were processed and graphs were generated with the free software BioEstat.5.3 and LibreOffice.calc. 24.2.3, respectively.

RESULTS AND DISCUSSION

The questionnaires of productive activity in the fish farms evaluated are presented in Table 1. This analysis is important for data comparison, since the presence of parasites may be associated with such variables.

Table 1 - Summary of the questionnaire on the productive activity of fish farms in the municipality of Rorainópolis.

Property	No. of nurseries	Origin of the water used	Sample nursery area (m ²)	Sample nursery biomass (kg)	Age of the sample nursery	Date of fishing	Number of meals per day
Page 1	03	Igarapé	1500	750	02 years	11/2016	1
Page 2	06	Igarapé	2250	2000	02 years	03/2015	Sporadic
Page 3	03	Nonexistent	300	25	16 years	01/2017	Sporadic
Page 4	05	Nonexistent	2000	1000	03 years	10/2016	1
Page 5	03	nonexistent	2000	1200	02 years	11/2016	2

Source: Authors

The origin of the water is a relevant factor, as the producer may do prophylaxis in the tanks, but his water source is contaminated. Knowing the size of the pond area is necessary to correlate with the biomass present in the tank, and once this biomass is above the recommended level, there may be a drop in the immunity of the fish and they may be affected by diseases. The age of the nursery can be taken into account as to the emergence of diseases due to the substrate. The parasitological indices (prevalence, abundance and intensity) are described in Table 2.

Tabela 2- Índices parasitológicos (Mon.=Monogenea; Nen. = Nematóide; Myx. =Myxobolus;)

Propriedade	Prevalence (%)			Medium abundance			Medium Intensity		
	Itself	Nen	Myx	Itself	Nen	Myx	Itself	Nen	Myx
Page 1	100	0	0	76	0	0	76	0	0
Page 2	40	40	20	8.2	1.2	0.2	19	3	1
Page 3	80	0	0	25.4	0	0	31.75	0	0
Page 4	100	0	0	184	0	0	184	0	0
Page 5	0	0	0	0	0	0	0	0	0

Source: Authors

There was a 100% prevalence in P1 and P4 fish farms. Several factors can contribute to this occurring, including the disinfection of the tanks after each production cycle. Among the hypotheses of high prevalence, there is that the fingerlings may come infested from the places where they are purchased, because the cultivation sites did not have water renewal. If the presence of monogenea persists, breeding may become unfeasible due to these places not having water renewal. According to Martins (2004), monogenea are the first causes of mortality in fish farms in Brazil, so attention should be paid to the host-parasite interaction between tambaqui and monogenea. Santos et al. (2013) found an average intensity of 73.2 and an average abundance of 69.5 of monogenea in tambaqui gills in a cage fish farm in the Matapi River, municipality of Santana, state of Amapá.

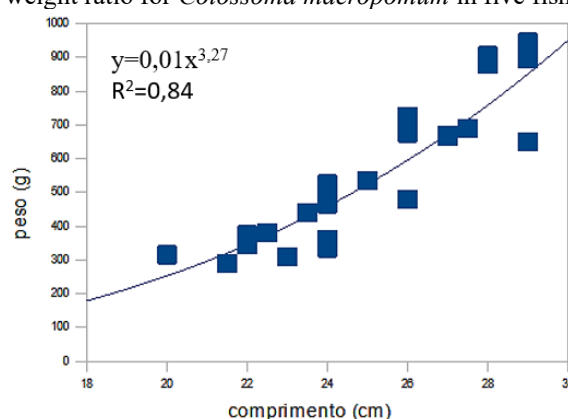
In the P5 property there was no record of parasites, and in this one there was feeding of the fish daily, twice a day and the water was being fertilized with cattle manure.

The parasite family found in all specimens evaluated was Girodactylids. Fujimoto et al. (2015) listed the main risk factors (Odds ratio-OR analysis) for tambaqui parasitism in the Lower São Francisco region, which are: Water scarcity (OR: 13.3, i.e. 13.3 times more risk of having monogenea), intercropping with other animals (OR: 17.9), communication of water from one nursery to another (OR: 5.64), nurseries without fertilization (OR:4.3), nurseries that did not disinfect and scrape the bottom (OR:70.0), high stocking density (>1kg/m³) (OR:4) and biometrics performed without adequate technique (OR:17.8). Table 2 shows that the biomass of the tanks of the two farms was adequate, as well as the age of the vivieros that are not old, so these factors may not be the cause of this high prevalence of monogenea in these two farms. According to Paraguassú (2006), due to their monoxene life cycle, monogenetic fish reproduce very quickly and the confinement of fish of the same species can make these parasites a major problem in fish farming and losses due to parasitic diseases represent, in many cases, the determining factor for the success of the activity.

The weight-length ratio can be an indicator of zootechnical performance for fish, and under normal conditions it is expected that this correlation is high, otherwise some abnormality will be

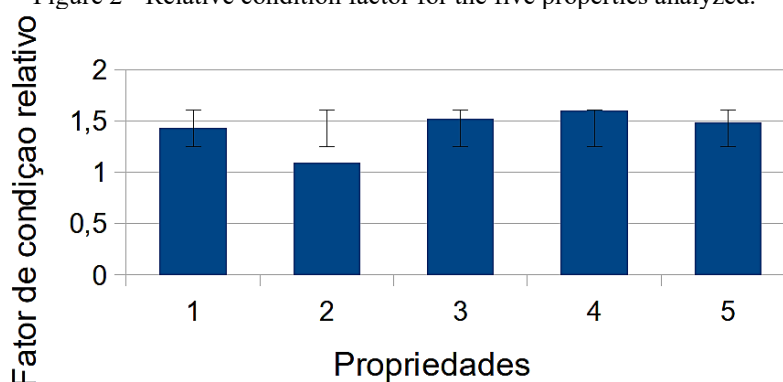
occurring and must be verified, one of them being the presence of parasites. Figure 1 shows the relationship between standard length and total weight.

Figure 1 - Standard length x total weight ratio for *Colossoma macropomum* in five fish farms in Rorainópolis-RR.



Due to the strong correlation presented, it is suggested that the fish did not have their performance affected. The relative condition factor (kn) is shown in Figure 2. There was no statistical difference ($p=1$) by the Mann-Whitney 'u' test between individuals parasitized and not parasitized by *Monogenea*. Similar results, where there were no statistical differences between parasitized and non-parasitized individuals, were also found by Yamada et al. (2008) and Zanolo et al. (2009). It is expected that parasitism brings imbalance in weight gain and growth, but the rusticity of the tambaqui may be responsible for the ability to resist these degrees of infestations.

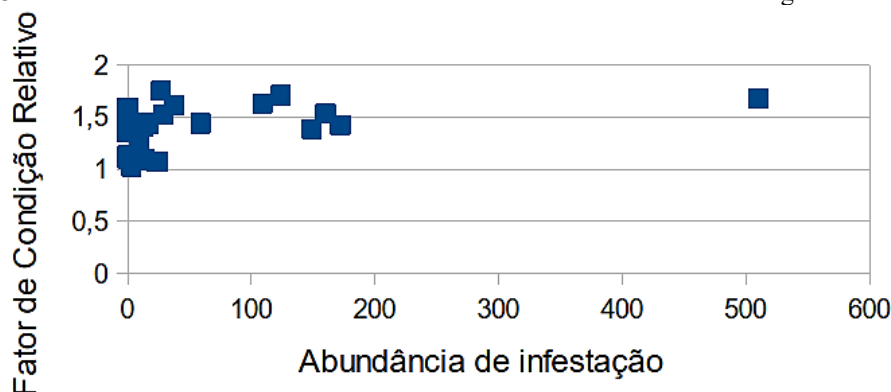
Figure 2 - Relative condition factor for the five properties analyzed.



Source: Authors

Graphically, the P2 farm presented a Kn below the others, probably due to the lack of adequate feeding of the animals, and even so they are above the expected weight curve, on average. In this property, the average weight was 0.427 kg, and age was two years, and at this age the fish should be more than 3.0 kg, but the standard length was proportional to this weight. Figure 3 shows the correlation between relative condition factor and abundance of *Monogenea* infestation.

Figure 3 - Correlation between relative condition factor and abundance of Monogenea infestation.



Source: Authors

It can be observed that the parasites may not be causing damage to the hosts, this indicates that the hosts are growing and gaining weight, or paralyzed growth independent of parasitism, and/or have a low pathogenicity, which did not influence the relative condition factor, as would happen if they were highly pathogenic parasites (Poulin, 1996).

Two genera of nematodes were found in the P2 estate, one of the genus *Klossinemella* sp. and another individual of the genus *Procamallanus* (*Spirocamallanus* sp.).

Fischer et al. (2003) studying the parasitic fauna in tambaqui and its potential as a biological indicator in the middle Solimões River (Amazonas) and in the lower Amazon River (Pará), verified the presence of *Procamallanus* sp. and *Spirocamallanus* sp., and none of these species showed statistical differences between the mean intensities compared by Student's 't' test. According to Pavanelli et al. (2013), species of *Procamallanus* sp. can cause lesions and inflammation in the intestinal mucosa due to fixation and feeding on the blood and can cause primary anemia, and in intentional infections in small fish there may be low growth rates and intestinal obstruction. According to Costa et al. (1968), species of the genus *Klossinemella* sp. have a monoxene evolutionary cycle, where reproduction can occur in the lumen of the host's intestine, and larvae may be released later. Infection by *klossinemella* sp. occurs through the elimination of larvae and adults through feces, which makes contamination very easy in a confined aquatic environment (Costa et al., 1968).

Only in the two farms were found spores of *Myxobolus* sp, in one specimen only, in the dorsal muscle. Feltran et al. (2017) made the first record for *Myxobolus* sp. found in *Colossoma macropomum* in the municipality of Cantá-RR, being the first record in Roraima. Maciel et al. (2011) have already found spores of *Myxobolus colossomatis* in the circulating blood of *Colossoma macropomum*, in the municipality of Manaus-AM. Capodifoglio et al. (2016) observed the presence of *Myxobolus* sp. in the operculum serosa of 15 tambaqui from the Amazon River basin. Senteno et al. (2004) found *Myxobolus* sp. in *Colossoma macropomum*, when they analyzed the

ectoparasitophage associated with *Colossoma macropomum* and the hybrid *Colossoma macropomum* x *Piaractus brachipomus*, cultivated in the State of Deuta Amacuro-Venezuela.

These records show the presence of this myxozoan in the State of Roraima and in the neighboring country (Venezuela), reporting the concern in preventive work and sanitary surveillance so that this parasite does not cause future damage to fish farms in the northern region.

CONCLUSION

It was possible to observe the presence of parasites in four of the five fish farms evaluated, most of which were of the Monogenea class, and the highest diversity of parasites (Monogenea, Nematoda, Myxosporidia) was found in the P2 farm. It was observed a common practice of extensive fish farming with a low degree of technology, factors that can favor the appearance of diseases. The parasites that had the highest prevalence rates were the Monogenea, reaching 100% in farms one and four.

These parasites are already widely spread in rivers and fish farms throughout Brazil, and in the case evaluated they showed low pathogenicity demonstrated by the relative condition factor. In the P5 property there was no record of parasites.

This study listed some parasites in fish farms in the municipality of Rorainópolis-Roraima-Brazil, reporting the concern to maintain the sanitary status of tambaqui production in this region, requiring more studies, at a higher level of taxonomic depth.

The knowledge of the tambaqui parasitofauna enables decision-making in fish enterprises, and in prophylaxis and therapeutic programs, as well as in State and National health defense standards.

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Revitalizing the countryside: The transformative potential of genetic improvement in livestock for municipalities in Minas Gerais

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ABSTRACT

The article highlights the importance of the livestock sector in Minas Gerais and the need for public policies that support genetic improvement in this sector. Raising awareness and training rural producers in the use of genetic reports, such as Expected Progeny Differences (EPD), for selecting breeders is essential for modernizing livestock farming. Thus, the study proposes the creation of robust educational programs and continuous technical support to integrate genetic improvement practices into daily operations, aiming to increase productive efficiency and sector competitiveness. The adoption of advanced genetic improvement practices can significantly enhance the productivity and quality of livestock production, better meeting internal demand. This stimulates job creation in various related sectors and drives local economic development. The need for training in genetics also promotes educational advancement and attracts investment in research, contributing to robust and sustainable economic growth in the municipality and region.

Keywords: Genetic improvement, Livestock, Minas Gerais, Public policies, Productive efficiency.

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INTRODUCTION

Agriculture and livestock are fundamental pillars of the economy in Minas Gerais, generating both income and employment. In 2020, the Gross Added Value (GAV) of these sectors amounted to BRL 39.99 billion, representing 6.65% of the state's total GAV. In the labor market, approximately 1.34 million people were employed in activities related to these sectors in the third quarter of 2022, corresponding to 12.58% of workers in Minas Gerais. In terms of trade, the revenue from agricultural and livestock product exports reached USD 15.3 billion in 2022, accounting for 38.2% of the state's exports.

This article evaluates the importance of agriculture and livestock in the municipalities of Minas Gerais, using the GAV of these sectors in relation to the total GAV of each municipality. In 2020, 100 municipalities in Minas Gerais had these sectors as their main economic segment, indicating a comparative advantage. Economic development in these sectors can be enhanced through investments in research, technical assistance, rural credit, sectoral policies, and support for small producers.

For small towns where livestock predominates, various strategies can increase productivity and economic advantages, such as adopting modern technologies, improving local infrastructure, and forming cooperatives. Product diversification and investment in genetic improvement are crucial, allowing the development of more productive and disease-resistant breeds. Training and education on best practices in management and animal welfare are also essential for improving productivity.

This study focuses on the proposal of genetic improvement and the effectiveness of public policies in raising awareness among rural producers about the importance of this practice, mainly through the use of artificial insemination technology and genetic reports (Expected Progeny Differences - EPD) for selecting ideal breeders. Artificial insemination provides access to high-quality genetics, ensuring greater consistency and predictability in productive outcomes. Thus, public policies that promote awareness and training of producers can transform the productive efficiency of livestock activities in small and medium-sized properties.

MATERIALS AND METHODS

This study adopted a methodology based on a comprehensive literature review to identify effective genetic improvement practices in livestock and propose solutions through public policies. The critical analysis of these studies allowed for the identification of the main barriers faced by rural producers in adopting these technologies, such as the technical complexity of genetic reports and the associated costs.

Based on this information, public policies were proposed focusing on the education and technical training of producers, as well as financial incentives for the adoption of genetic

improvement technologies. These proposals aim to increase the productive efficiency and competitiveness of the livestock sector, promoting sustainable economic development in rural areas of Minas Gerais.

GENETIC MERIT

Expected Progeny Difference (EPD) is an essential tool in the field of cattle genetic improvement, serving as a crucial indicator of an animal's genetic value as a breeder. This tool allows breeders to compare the genetic merit of different animals concerning various hereditary traits, which are fundamental for herd selection and improvement.

EPD provides an estimate of how well an animal can transmit its genetic characteristics to its offspring. This is extremely valuable for producers aiming to enhance specific aspects of their herds, such as feed efficiency, weight gain, fertility, and more. The utility of EPDs lies in their ability to offer a relatively fair comparison base, allowing animals from different herds to be evaluated uniformly. This capability is highlighted by EUCLIDES FILHO (2009) in his analysis of the impact and application of these tools in genetic improvement.

One of the major advantages of EPDs is that they are calculated considering various factors that help isolate the genetic value from environmental and management effects. This means EPDs can reflect an animal's true genetic potential, minimizing distortions caused by external conditions. Consequently, producers can make more informed and strategic decisions regarding breeding and herd management.

Moreover, EPDs play a significant role in defining groups of animals with similar characteristics, facilitating the analysis of relationships between genetic values and economically important traits, as noted by LOPES et al. (2013). This usage allows producers to fully exploit the available genetic potential, contributing to a better understanding and optimization of EPD use in the production system.

In summary, EPDs are fundamental not only for genetic selection within a herd but also for the overall evolution of the beef cattle industry. They enable producers to plan breeding better, promote the use of superior genetics, and achieve significant improvements in efficiency and profitability. Therefore, the continuous adoption and enhancement of genetic evaluation techniques based on EPDs are crucial for the economic and genetic advancement of the livestock sector. Below are detailed descriptions of the main genetic variables, as provided in the Geneplus Technical Manual.

- **Birth Weight (BW) – kg:** The calf's birth weight is an important evaluation characteristic. This trait should be monitored carefully to avoid significant increases that could result in higher chances of dystocia or calving difficulties.

- **Weaning Ratio (WR) - %:** This is the ratio between the calf's weight and the cow's weight at weaning. According to SCHWENGBER et al. (2001), the calf's weight at weaning is the best predictor for evaluating cow productivity in beef cattle. However, JONHSON et al. (2007) found that weaning ratios above 0.50% indicate more economically efficient and viable cows.
- **Post-Weaning Weight Gain (PWG) – kg:** This variable provides a good indication of the calf's weight accumulation and fattening capacity.
- **120-Day Weight (W120) - kg:** Evaluated at 120 days of age, this characteristic indicates the genetic potential of an animal to produce daughters with superior (or inferior) maternal ability, expressed by the weight of the calves.
- **Yearling Scrotal Circumference (YSC) – cm:** Scrotal circumference measures the bulls' scrotal circumference. YSC indicates the animal's potential to produce sons with larger (or smaller) scrotal circumference at 450 days of age. Studies by MCGOWAN et al. (2002) and GARMYN et al. (2001) confirm that scrotal circumference is strongly related to fertility and semen quality, with high genetic transmission rates.
- **Age at First Calving (AFC):** A reproductive characteristic measured in days, indicating the animal's potential to produce daughters that calve earlier (or later) than the average daughters of other animals.
- **Stayability (STAY) %:** An indicator representing the probability of an animal producing daughters capable of delivering at least three viable calves by 76 months. This is crucial for evaluating reproductive precocity in cattle.
- **Weaning Weight (WW) - kg:** WW indicates the animal's potential to produce offspring with superior (or inferior) performance compared to the average offspring of other animals at weaning (210 days old).
- **Yearling Weight (YW) – kg:** Evaluated at 450 days, this characteristic indicates the animal's potential to produce offspring with superior (or inferior) performance compared to the average offspring of other animals at yearling age. It reflects the growth and fattening potential of the offspring.
- **Ribeye Area (REA) - cm²:** This measure indicates the animal's potential to produce offspring with larger (or smaller) ribeye area. It is an indicator of bovine muscling, reflecting the amount of muscle covering the animal's body and is a crucial quality indicator for beef cattle, affecting carcass yield and meat production.
- **Backfat Thickness (BFT) - mm:** An important indicator of carcass finishing, BFT relates to the precocity of finishing and reproduction. According to BONIN et al. (2015),

it also affects the gustatory experience of beef consumers, relating to flavor and juiciness characteristics.

- **Marbling (MARB) - %:** A finishing measure indicating the percentage of intramuscular fat in beef.
- **Genetic Qualification Index (GQI):** The Genetic Qualification Index (GQI) aims to aggregate an animal's genetic contribution into a single classification value for selected traits, assigning an importance weight to each trait. It is an empirical value where the Expected Progeny Differences (EPDs) are standardized, multiplied by relative weights, and summed to form the index. The suggested GQI formula is:

$GQI = (10\% * MPW + 15\% * WW + 20\% * TMW + 15\% * YW + 15\% * PWG + 15\% * AFC + 5\% * I2C + 5\% * YSC)$; where: MPW = maternal phase weight, WW = weaning weight, TMW = total maternal weaning weight, YW = yearling weight, PWG = post-weaning weight gain, AFC = age at first calving, I2C = interval between the first and second calving, YSC = yearling scrotal circumference.

INTERPRETATION OF EPD - AN EXAMPLE

Table 1 reports the estimated EPDs for the Nellore bull "REM USP," renowned as a prominent breed sire. The price of this animal's semen is the highest in our sample, at R\$ 200.00 (BRL - all economic values are given in Brazilian Real) per dose, which is more than 500% higher than the sample's average price (R\$ 38.05).

The interpretation of the EPD results, such as those in Table 1, indicates the expected difference in the offspring of this bull compared to the offspring of other evaluated bulls of the same breed. Taking the variable Weaning Weight (WW) as an example, according to its EPD, it is expected that the offspring of this bull (REM USP) will weigh 9.16 kg more than the offspring of other Nellore bulls when they reach the weaning age. As for the variable Yearling Scrotal Circumference (SCY), the EPD indicates that the offspring of this bull will have, on average, 1.71 cm more scrotal circumference than the offspring of other Nellore bulls. Additionally, the table indicates that the progeny of the evaluated Nellore bull ranks in the top 1% for the WW characteristic and in the top 10% for SCY among the best-evaluated bulls.

Table 1. Estimated Expected Progeny Differences (EPD) for the Nellore bull "REM USP".

	EPD	Percentile (%)
Weight at 120 days	4.46	0.50%
Weaning Weight	9.16	1.00%
Yearling Weight	23.28	0.10%
Yearling Scrotal Circ.	1.71	0.10%
Age at First Calving	-23.76	2.00%
Stayability	41.48	0.10%
Ribeye Area	0.11	51.00%
Subcutaneous Fat T.	-1.37	95.00%
Marbling	0.08	44.00%
Genetic Qualification Index	33.77	0.10%

Source: Alta Genetics agency and GENEPLUS.

Note: EPD represents the values of Expected Progeny Differences for the bull "REM USP".

The interpretation of EPD results, as shown in Table 1, indicates the expected difference in the offspring of this bull compared to the offspring of other evaluated bulls of the same breed. Taking the variable Weaning Weight (WW) as an example – according to its EPD, it is expected that the offspring of this bull, REM USP, will weigh, on average, 9.16 kg more than the offspring of other Nellore bulls at weaning age. For the variable Yearling Scrotal Circumference (YSC), the EPD indicates that the offspring of this bull will have, on average, 1.71 cm more scrotal circumference than the offspring of other Nellore bulls. Additionally, the table indicates that for the WW characteristic, the evaluated Nellore bull's progeny ranks among the top 1%, and for YSC, among the top 10% of the best-evaluated bulls.

RESULTS AND DISCUSSION

IDENTIFYING THE PROBLEM

The principal issue in the utilization of Expected Progeny Differences (EPD) by rural producers is their lack of familiarity with these reports. Despite the significant utility of EPDs for genetic improvement, many producers are hesitant to adopt them primarily due to the technical complexity of the reports, which can be challenging to understand without specialized training in genetics.

Beyond the complexity, other factors such as the costs associated with obtaining and interpreting EPDs, the preference for traditional selection and herd management methods, and a lack of clear perception of the economic benefits can discourage producers from using these tools. Many producers remain attached to practices passed down through generations, viewing them as sufficiently effective, which creates resistance to transitioning to genetically based approaches.

In fact, findings by DETONI (2024) suggest that genetic reports have little influence on the variation in semen prices in the Nelore beef cattle market in Brazil. These results align with the findings of IRSIK et al. (2008), which similarly indicated that EPD data do not exert a strong influence on bull prices. Furthermore, as highlighted by VESTAL et al. (2013), producers still need

time to familiarize themselves and build confidence in the available genetic reports. BRAGA (2021) and ABREU (2017) investigated the factors influencing the pricing of Nelore bulls at beef cattle auctions in Brazil. Their evidence indicates that the Genetic Quality Index (GQI) provides little explanation for these price determinations.

Possibly, other aspects not considered, such as exhibition awards and the breeder's reputation, generate strong appeal for producers when selecting their breeding bull. To support this conjecture, Table 2 presents the EPD results for the Nelore bull Alarme, whose semen price is R\$80.00, approximately 110% above the average.

Table 2. EPDs of Bull "Alarme".

	EPD	Percentile (%)
Weight at 120 days	-7.68	0,99
Weaning Weight	5.88	0,06
Yearling Weight	8.83	0,11
Yearling Scrotal Circumference	-0.33	0,79
Age at First Calving	7.08	0,8
Stayability	23.5	0,98
Weaning Ratio	-2.7	0,99
Ribeye Area	-0.11	0,59
Subcutaneous Fat Thickness	-0.65	0,8
Marbling	-0.76	0,83
GQI	-1.39	0,64
Semen price - R\$80.00		

Source: Alta Genetics agency and GENEPLUS.

Note: EPD's represents the Expected Progeny Differences.

As presented in Table 2, the EPD results for the bull Alarme are not among the best in almost any category. However, according to discretionary comments from Alta Genetics Agency, this bull was a champion at Expozebu in 2012 and reproduces racial beauty in its offspring.

The principal challenge faced by rural producers in adopting Expected Progeny Differences (EPD) lies in the technical complexity of these reports. Despite their value, this information is based on advanced genetic concepts that can be intimidating for those without specific training in the field. This technical barrier is exacerbated by the fact that many producers still rely on traditional methods of selection and herd management, which have been passed down through generations. Therefore, the resistance to changing to practices based on detailed genetic information is not only a matter of training but also of culture and habit.

In addition to the complexity, other factors such as the cost of obtaining and interpreting EPD reports and the unclear perception of their direct economic benefits further discourage the use of these advanced tools. Recent studies, such as those by DETONI (2024) and BRAGA (2021), indicate that even in the Nelore beef cattle market, where one would expect such data to have a significant impact, genetic reports have little influence on pricing decisions. This scenario suggests an urgent need to improve producers' familiarity and confidence in genetic reports, aiming for greater

transparency and effectiveness in communicating the real benefits that genetics can offer to livestock farming.

PUBLIC POLICY GUIDELINES

The principal barrier to the utilization of Expected Progeny Differences (EPD) by rural producers is the lack of familiarity with these reports. The technical complexity of EPDs and the need for specialized genetic training make the adoption of these essential genetic improvement tools challenging. Additionally, the costs associated with obtaining and interpreting EPDs, the preference for traditional selection and herd management methods, and the unclear perception of economic benefits also discourage producers from using these tools.

To overcome these obstacles, it is essential to develop robust training programs that demystify the complexity of genetic data and concretely demonstrate how this information can lead to economic gains. Educational programs that teach producers to interpret and apply EPDs through workshops, seminars, and informational materials are crucial. Demonstrating success stories of other producers who have adopted EPDs with significant benefits can encourage the adoption of these practices.

Continuous support is also essential, providing technical assistance to help producers integrate EPDs into their daily operations practically. Partnerships between universities, research institutions, breeder associations, and the government can strengthen this initiative, promoting and facilitating the use of EPDs. Furthermore, financial incentives or subsidies should be considered to reduce the economic barriers to accessing these technologies.

Implementing public policies focused on education and technical support can significantly transform the perception and utilization of EPDs by rural producers. Training programs should be practical, accessible, and frequent, allowing a large number of producers to participate and benefit. Collaboration between local and state governments, academic institutions, and research centers is fundamental for the development and delivery of these educational programs.

An effective communication campaign that highlights the economic and productive benefits of EPDs is also necessary. This campaign could include local case studies and testimonials from producers who have successfully adopted these practices, reinforcing the message with economic analyses that show the return on investment of adopting genetic improvement practices. Continuous technical support through genetic consultants and specialized veterinarians would help producers integrate EPDs into their daily operations, addressing doubts and providing constant support.

In addition to education and technical support, public policies must consider the cost associated with acquiring high-quality semen. The price of semen can be a significant factor influencing rural producers' decisions to adopt these practices. To overcome this barrier, public policies could include subsidies or financial incentives for the acquisition of high-quality semen,

making it more accessible. Reducing costs for producers facilitates the adoption of genetic improvement practices and ensures that the benefits of these practices are widely distributed.

In summary, addressing the lack of familiarity with EPDs can improve herd productivity efficiency and promote greater sustainability and competitiveness in the agricultural sector. The key lies in education, technical support, and clearly demonstrating the benefits of these advanced genetic improvement practices. Implementing public policies that encourage the use of genetic improvement practices in livestock not only enhances herd productivity efficiency but also promotes greater sustainability and competitiveness in the agricultural sector. When well-executed, these initiatives can significantly transform local livestock farming, benefiting the entire community.

CONCLUSION

The effective implementation of public policies for genetic improvement in livestock can have significant positive impacts beyond the agricultural sector, benefiting the local and regional economy in various ways. Firstly, the adoption of these practices can increase farm productivity and efficiency, resulting in higher quality and greater quantities of meat and other livestock products. This not only better meets internal demand but also enhances export potential, generating more revenue for producers.

Moreover, more productive and profitable farms create a growing demand for qualified workers, not only in the agricultural sector but also in related areas such as agro-industrial processing, logistics, sales, and specialized technical services. This increased demand for labor generates a virtuous cycle of employment and income, strengthening the agricultural sector and driving local economic development. The increase in employment and income stimulates consumption, generating greater demand for goods and services in various sectors, which in turn encourages economic growth on a broader scale.

The growing need for specialized knowledge in genetics and genetic improvement techniques catalyzes the development of advanced educational programs at both technical and university levels. The expansion of these programs elevates the educational level of the population and better prepares individuals for a variety of professional opportunities, fostering a more qualified and adaptable workforce.

The development and implementation of advanced genetic technologies can attract significant investments for research and development from both governmental and private sources. This influx of resources is fundamental for creating research centers and startups focused on biotechnology and advanced technological solutions for agriculture, enhancing the region's innovative and competitive potential. These initiatives can transform the agricultural sector into an innovation hub, attracting more investments and promoting a dynamic and prosperous economic environment.



In summary, public policies that encourage the use of genetic improvement practices in livestock not only increase the quality and quantity of agricultural production but also drive economic development, increase job opportunities, improve local education, and attract more investments. These policies benefit various sectors, contributing to more robust and sustainable economic growth for the municipality and region.

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Tenebrio molitor and its applications in Biological Control

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ABSTRACT

The growth of the world's population increases the demand for food and natural resources such as water, energy, and land use. The requisition and consequent use of natural resources in an unbridled and unsupervised way generates environmental degradation.

Intensive agriculture to feed billions of people leads to the conversion of forests and other natural ecosystems to farmland, resulting in deforestation, biodiversity loss, and soil degradation.

The need for new sources of protein, more sustainable and that collaborate with the well-being of the ecosystem, generates the process of studying the existing viabilities, even if remote or unknown, and, in this perspective, are the studies on the feasibility of insects as environmentally friendly and alternative sources of protein.

Tenebrio molitor has been the target of many studies because it has characteristics that highlight it as a promising, sustainable, economically viable and ecologically friendly option, within the context of the New Food Frontier, since *Tenebrio molitor* farming contributes to global food security, and requires less costs, less water and land resources, compared to conventional animal husbandry. In addition to their use as food for humans and animals, the use of by-products and in Biological Control has drawn the attention of scholars in the defense of the environment.

Biological control is a sustainable management method that uses natural enemies, such as insects, parasites, pathogens, and predators, to regulate the population of unwanted organisms, presenting an environmentally safe alternative to chemical pesticides (Roberto et al., 2002). This method helps to reduce dependence on chemical products, which, although effective, pose risks to the environment and human health, in addition to promoting the emergence of resistant and secondary pests, and negatively affecting beneficial insects (Bueno et al., 2017).

Tenebrio molitor, known as the flour beetle, has been used as a host, prey and predator in biological control programs, presenting promising and effective characteristics. This insect can host parasitoids such as *Trichospilus diatraeae*, *Tetrastichus howardi*, *Palmistichus elaeisis*, used to control agricultural pests such as the screwworm (*Spodoptera frugiperda*), fruit flies, palm moths and brown caterpillar (*Thyrinteina arnobia*) (Favero et al., 2014); (Tiago et al., 2019); (Zanuncio et al., 2008).

In addition to being used in the breeding of parasitoids, *Tenebrio molitor* has a fundamental role as prey in the breeding of predatory insects such as *Podisus maculiventris*, *Podisus nigrispinus*, *Pristhesancus plagipennis* (De Clercq et al., 1998).

The use of *Tenebrio molitor* in Biological Control has benefits for agriculture, by allowing pest control in a more sustainable way and reducing dependence on chemicals harmful to the environment, however there are also challenges such as the risk of negative impact when larvae are released into natural environments, without adequate control. More research is needed to fully understand the effects of this species on the ecosystem and ensure that its use is done in a sustainable way.

Keywords: Biological Control, *Tenebrio molitor*, Environmental Degradation, Intensive Agriculture.

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INTRODUCTION

DEFINITION: BIOLOGICAL CONTROL

Biological control, according to Roberto et al. (2002), is a natural phenomenon that consists of the regulation of the number of plants and animals by natural enemies, which constitute agents of biotic mortality. Thus, all species of plants and animals have natural enemies attacking their various life stages. That is, it is when an organism controls another organism.

It is a method used for the management of unwanted organisms in the environment, using biological agents, such as insects, parasites, pathogens, and predators, to control the population of the target organism. This method is considered a more sustainable and environmentally safe alternative to chemical pesticides.

With the rise of conventional agriculture, the use of chemicals has been adopted as the main method of controlling pests and diseases, although efficient they pose several risks to the environment and human health. The irrational use of insecticides causes the emergence of resistant and secondary pests and reduces the activity of beneficial insects (Bueno et al., 2017). In this way, the importance of developing productive agricultural practices, but in a sustainable way, controlling and even eliminating agricultural pests without leaving residues or causing damage to plants and the environment is increasingly debated.

APPLICATIONS IN BIOLOGICAL CONTROL

Tenebrio molitor can be used as an agent used in biological control because it can serve as a host for other parasites and is a natural predator that feeds on other insects, including fly larvae, moths and cockroaches. It has been used as an effective tool in the biological control of pests, especially with regard to the handling of insects harmful to agriculture.

Biological control programs rely on the mass breeding of parasitoids, and the lack of artificial diets makes it necessary to use preferred or alternative hosts to produce natural enemies (Pratissoli et al., 2007). These hosts should have low production costs without reducing the efficiency of the parasitoids.

The use of parasitoids in most biological control programs requires that the parasitoids meet some requirements, such as high-quality and low-cost techniques for breeding these insects (Colinet et al., 2011); (Leite et al., 2013).

BIOLOGICAL CONTROL OF THE BOLLWORM WITH TRICHOSPILUS DIATRAEAE

In biological control, *T. molitor* is used in the rearing of natural enemies, being an excellent alternative host for the rearing of parasitoids, such as *Trichospilus diatraeae* (Favero et al., 2014), *Tetrastichus howardi* (Tiago et al., 2019) and *Palmistichus elaeisis* (Zanuncio et al., 2008).

Trichospilus diatraeae is a parasitoid that can be used in the biological control of infestation by screwworm (*Spodoptera frugiperda*) (Figure 31) in corn, cotton, and other grains, fruits, and vegetables.

Figure 31



Source: <https://summit-agro.com/ar/en/2020/12/18/oruga-militar-tardia/>

Favero et al. (2014) [61] highlighted that the flour beetle is a viable and suitable option for breeding *Trichospilus diatraeae*. The results of this research showed that the survival of the parasite, when it was in the pupae of *Tenebrio molitor* was 92.65%. This means that *Tenebrio* in the pupal stage, may be a suitable option to create and provide an environment conducive to the development of the parasite *Trichospilus diatraeae*.

For information, I find it interesting to detail the procedure of using parasites created in the laboratory, in biological control, so we note where the participation of *Tenebrio molitor* in this process comes in.

How to use *Trichospilus diatraeae* in biological control:

1. Target pest identification: Before using *Trichospilus diatraeae*, it is important to correctly identify the target pest. Make sure you're dealing with the fall armyworm.
2. *Trichospilus diatraeae* supply and maintenance: Contact a reliable *Trichospilus diatraeae* supplier to obtain the adult parasitoids. They are usually made available in packs containing parasitized pupae. Follow the vendor's guidelines for proper storage and maintenance.
3. Release of parasitoids: Adult parasitoids should be released into the field when the population of stray caterpillars reaches an acceptable level of infestation. Follow the supplier's instructions to determine the proper release rate, which can vary depending on the size of the growing area and the stage of development of the pest.
2. Monitoring and evaluation: After the release of *Trichospilus diatraeae*, regularly monitor the field to assess the effectiveness of biological control. Observe the level of infestation of screwworms and check for the presence of parasitized pupae of *Trichospilus diatraeae*.

3. Complementary measures: Biological control with *Trichospilus diatraeae* can be complemented with other integrated pest management techniques, such as the use of resistant plants, crop rotation, and cultural management practices. Consult a biological control specialist or agronomist for personalized guidance based on your crop characteristics.

BIOLOGICAL CONTROL OF FRUIT FLIES WITH *TETRASTICHUS HOWARDI*.

Tetrastichus howardi (Figure 32) is a parasitoid insect that is widely used in biological pest control, specifically for fruit fly control (Figure 33).

Figure 32



Source: <https://www.cabidigitallibrary.org/doi/10.1079/cabicompendum.53369>

Figure 33



Source: <https://www.ecycle.com.br/mosca-das-frutas/>

Females of *Tetrastichus howardi* lay their eggs inside fruit fly larvae in the fruits, and parasitoid larvae develop inside these larvae, eventually killing them. In this way, *Tetrastichus howardi* helps to significantly reduce the population of fruit flies in agricultural crops.

Tiago et al., (2019) concluded that *Tenebrio molitor* is a suitable host for the breeding of *Tetrastichus howardi*, which is an important parasitoid of agricultural pests. The pupae of *Tetrastichus howardi* can be stored in pupae of *Tenebrio molitor* for 10, 20, 30, 60 and 90 days at 10.3 C and their emerged adults used in biological control programs, preferably pupae after 10 days of storage, without deleterious effects for the population of this parasitoid.

These results contribute to overcome one of the difficulties encountered in the mass production of parasitoids, which is to obtain a large number of suitable hosts when necessary. Therefore, the possibility of conserving *Tenebrio molitor* pupae for *Tetrastichus howardi* breeding will be useful for the use of this natural enemy in biological pest control programs.

Biological control with *Tetrastichus howardi* is an alternative to traditional pest control methods, such as the use of insecticides. It is a more sustainable and more environmentally friendly option, since it does not cause harm to non-target organisms and does not leave chemical residues in the crops.

BIOLOGICAL CONTROL OF PALM MOTHS AND BROWN CATERPILLAR WITH *PALMISTICHUS ELAEISIS*

Palmistichus elaeisis (Figure 36) is a parasitoid insect used in the biological control of agricultural pests, such as palm moths (*Rhynchophorus*) (Figure 34) and brown caterpillar *Thyrinteina arnobia* (Figure 35). These pests are responsible for causing significant damage to palm and eucalyptus plantations, harming cultivation and production.

Figure 34



Source: <https://www.phosphorland.pt/escaravelho-da-palmeira/>

Figure 35



Source: https://www.agrolink.com.br/problemas/lagarta-dos-eucalipotos_1481.html

P. elaeisis (Figure 36) is a parasitoid that attacks the larvae of palm moths and the brown caterpillar, laying its eggs on them. The larvae of the parasitoid develop by feeding on the interior of the larvae of the caterpillars' moths, resulting in their death. Thus, the use of this parasitoid insect helps in the effective control of the palm moth population, providing a sustainable and environmental alternative.

Figure 36



Source: https://www.researchgate.net/figure/Females-of-Palmistichus-elaeisis-Hymenoptera-Eulophidae-parasitizing-pupae-of-A_fig1_261796931

Palmistichus elaeisis showed good reproductive performance (adequate parasitism, emergence, offspring by pupa, and body size, in addition to more longevity of males and females and sex assess) when reared on pupae of the alternative host *T. molitor*. In addition, the low cost to rear this alternative host indicates it could easily be used to rear mass the parasitoid *P. elaeisis* for biological control program *Palmistichus elaeisis* showed good reproductive performance (adequate parasitism, emergence, offspring by pupa, and body size, in addition to more longevity of males and females and sex evaluate) when reared on pupae of the alternative host *T. molitor*. In addition, the low cost for rear hosting this alternative indicates it could easily be used to rear mass the parasitoid *P. elaeisis* for biological control programs

According to Zanutto et al., (2008), *Palmistichus elaeisis* showed adequate parasitism when reared on pupae of *Tenebrio molitor* (host). Due to the low cost and high adequacy index, the use of *Tenebrio molitor* as a host alternative for *Palmistichus elaeisis* is fully feasible to be used en masse in biological control programs.

BIOLOGICAL PEST CONTROL WITH *PODISUS MACULIVENTRIS*

In addition to being used in the breeding of parasitoids, *T. molitor* plays a fundamental role in the breeding of predatory insects. It is cultivated as prey for predators such as *Podisus maculiventris*, *Podisus nigrispinus*, *Pristhesancus plagipennis*, and *Supputius cincticeps*.

Studies have shown that *T. molitor* larvae have a capacity for predation, serving as prey in the breeding of predatory insects, such as: *Podisus maculiventris*, *Pristhesancus plagipennis*, among others.

Podisus maculiventris (Figure 37), also known as the predatory stink bug or black predator stink bug, is often used as a biological control agent in integrated pest management programs.

Figure 37



Cast Iron: <https://anatisbioprotection.com/en/produit/podisus-maculiventris/?region=ca>

The role of this predatory insect is to feed mainly on agricultural pests, such as caterpillars of various species of insects and aphids. By consuming these pests, *Podisus maculiventris* helps to reduce its population, thus decreasing the damage caused to crops (Figure 38).

Figure 38



Source: https://www.researchgate.net/figure/Dorsal-view-of-an-adult-spined-soldier-bug-Podisus-maculiventris-Say-feeding-on-a_fig1_237565622

This predatory stink bug is considered an effective biological control option because it is able to adapt to different agricultural crops and has a broad spectrum of prey. In addition, it is capable of reproducing itself in the laboratory, which facilitates its large-scale creation for commercial use. Precisely in this sense, there is the possibility of using *Tenebrio molitor* as food provided to the predatory bug.

Gyawaly (2011), conducted a study to investigate the feeding behavior of *Podisus maculiventris* using the yellow mealworm, *Tenebrio molitor* (Coleoptera: *Tenebrionidae*), at different life stages, which it could potentially feed on, in a mass rearing system, with the aim of determining food preferences.

It was concluded that *Podisus maculiventris* prefers to feed on large larvae against small larvae of *T. molitor*. Secondly, the study was carried out to investigate the feeding preference and feeding capacity of *Podisus maculiventris* in different types of larvae. Using smooth, hairy, coleoptera larvae, feeding preferences were determined. Third instar, fifth instar and adults of *P. maculiventris* significantly preferred to feed on smooth larvae. Hairy larvae were the least preferred. *P. maculiventris* showed the highest ability to feed on smooth larval species, followed by beetle and hairy larvae. The findings of this thesis have important implications for successful biological control using *P. aculiventris* and *T. molitor*.

In the study by De Clercq et al., (1998) whose objective was to discuss the practical value of different foods for the mass rearing of *Podisus maculiventris*, it was concluded that female predators raised with artificial diets had fecundity similar to that of females fed with larvae or pupae of *T. molitor*.

BIOLOGICAL CONTROL OF THE FLOWER LEAFHOPPER WITH *PRISTHESANCUS PLAGIPENNIS*

Pristhesancus plagipennis (Figure 39), known as the leafhopper wasp, plays an important role in biological pest control. This wasp parasitizes the nymphs of the flowerhopper (*Mahanarva fimbriolata*) (Figure 39), which is considered one of the most destructive pests for sugarcane crops.

Figure 39



Source: <https://www.biodiversity4all.org/taxa/450938-Pristhesancus-plagipennis>

Figure 40



Source: <https://biofaces.com/post/97968/mahanarva-fimbriolata>

When the spittlebug wasp lays its eggs on the nymphs, the larvae of *Pristhesancus plagipennis* develop inside the body of the host insect, feeding on it. This leads to the death of the spittlebug and reduces the population of this pest in sugarcane plantations.

Therefore, the role of *Pristhesancus plagipennis* in biological control is to regulate the population of spittlebugs, contributing to the sustainable management of agricultural pests. This makes it possible to reduce the need to use chemical pesticides, minimizing crop damage and environmental impact.

Pristhesancus plagipennis is also a larval and nymph predator of many pestiferous insects for which natural enemies are not commercially available. Grundy et al., (2000), describes a method of mass rearing in containers for *P. plagipennis* using dead larvae of *Tenebrio molitor* (L.) and *Helicoverpa armigera* (Hübner) in hot water. The larvae of the yellow flour larvae, *T. molitor*, were the most suitable prey to minimize nymphal development time and mortality, while producing insects with higher body weight.

BENEFITS AND CHALLENGES

Tenebrio molitor plays a crucial role in biological control, both as a host for parasitoids and as prey for predatory insects. Its use in the creation of these natural enemies benefits agriculture, allowing pest control in a more sustainable way and reducing dependence on chemicals that are harmful to the environment.

The use of *Tenebrio molitor* in biological control has some significant benefits. First of all, the larvae are easy to reproduce and maintain, which makes their cultivation an economically viable activity. In addition, these larvae have a minimal risk of becoming a pest themselves, as their feeding habits are primarily directed toward grains, bran, and other organic debris.

However, there are also challenges associated with the use of *Tenebrio molitor* in biological control. One of them is the risk of negative environmental impact when larvae are released into natural environments, without adequate control. In addition, more research is needed to fully understand the effects of this species on the ecosystem and ensure that its use is done sustainably.

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Seed and foliar inoculation with *Azospirillum brasilense* associated with nitrogen topdressing rates in wheat crop

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ABSTRACT

The wheat crop (*Triticum aestivum*) is of great importance in human and animal food, being the second largest grain production in the world. However, it is necessary to develop new technologies that increase productivity in a sustainable way, reducing the cost of implementation and operation. Thus, inoculation with growth-promoting bacteria, such as *Azospirillum brasilense*, appears as a viable alternative, but still requires studies for better positioning. The objective of this study was to evaluate the agronomic performance of wheat as a function of the application of *Azospirillum brasilense* via seed and foliar, alone and together, associated with applications of different doses of nitrogen in topdressing. The experiment was conducted in the field at the Federal Institute of Education, Science and Technology of Rio Grande do Sul, Ibirubá campus, in 2020. The experimental design was a randomized block design (DBC) with five replications per treatment, in a two-factor model, with the inoculation factors of *Azospirillum brasilense* (No inoculation; Seed inoculation; Inoculation via foliar and Inoculation via seed + inoculation via foliar) and nitrogen topdressing doses (0, 40, 80 and 120 kg.ha⁻¹) using the wheat cultivar TBIO Ponteiro. The results obtained indicate that inoculation with *Azospirillum brasilense* via seed and foliar, alone and together, did not present significant effects on the variables evaluated, not generating results that make its use feasible, regardless of the form of inoculation, only in the variable number of ears per square meter, which showed an increase with foliar and seed + foliar inoculation. On the other hand, the highest nitrogen doses (80 and 120 kg.ha⁻¹) showed the best results.

Keywords: *Triticum aestivum*, Seed inoculation, Biological nitrogen fixation.

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INTRODUCTION

Wheat (*Triticum aestivum*) is a winter annual plant belonging to the Poaceae family, subfamily Pooideae and the genus *Triticum*. Its origin is believed to be from wild grasses that developed on the banks of the Tigris and Euphrates rivers around 12,000 years BC, after several years of natural and artificial selection the characteristics of the culture that are known today were reached (SCHEEREN et al., 2015).

This cereal has economic importance worldwide, widely used in human food, through flour, bread, pasta, among others. For animal feed it also has its importance, as it is used in various diets in cattle, pigs, poultry, among others. In addition to being one of the main sources of income in winter crops, it provides an important role in crop rotation, and with the straw left on the soil surface, it also contributes to weed control, erosion reduction and improvement of chemical, physical and biological attributes of the soil.

The wheat crop has a great need for nitrogen fertilization to achieve higher yields. According to Prando et al. (2013), nitrogen (N) is the most absorbed nutrient and also the most exported by wheat plants, with a great influence on crop productivity. The most used source of nitrogen fertilization is urea (approximately 45 % of N). However, this nutrient represents a large part of the production cost of wheat crops, because to obtain urea it is necessary to carry out some complex industrial processes (LUDWIG, 2015). Also, this nitrogen source presents an unfavorable characteristic in relation to N loss by volatilization, when applied mainly by haul, without incorporation. The loss can be accentuated the greater the amount of straw and the lack of rain for its incorporation (CANTARELLA et al., 2008).

Knowing the high economic and environmental cost of mineral nitrogen fertilization, alternatives are sought to meet the N demand of the crop, in this context, plant growth-promoting bacteria (BPCP) stand out. These bacteria have the ability to stimulate plant growth in several ways, including: increased nitrate reductase activity when they grow endofitically in plants (CASSÁN et al., 2008), biological N fixation capacity (HUERGO et al., 2008), phosphate solubilization (RODRIGUEZ et al., 2004), and production of phytohormones that induce root growth, improving the absorption of water and nutrients by plants (DOORNBOS et al., 2012). In general, BPCP are capable of stimulating plant growth and development through direct and/or indirect mechanisms, coexisting in an associated way on root surfaces, the rhizosphere and phyllosphere, and also in the internal tissues of plants of different species (HUNGARY et al. 2010).

Among the diazotrophic bacteria, bacteria of the genus *Azospirillum* stand out, which can fix N₂ to the plant and thus produce auxins, the main one being indoleacetic acid (IAA), and gibberellins, which stimulate plant growth of the roots, increasing the absorption of water and nutrients (BASHAN et al., 2004). According to Barassi et al. (2008), with the inoculation of

Azospirillum there is an improvement in photosynthetic parameters of the leaves, chlorophyll content, stomatal conductance, increase in the proline content in the roots and shoots, greater biomass production, greater plant height, greater elasticity of the cell wall, improvement in water potential and increase in the water content in the apoplast.

In studies carried out over 20 years, Okon and Labandera-Gonzales (1994) concluded that 60% to 70% of the trials had an increase in production through inoculation, with statistical increases of 5% to 30%. Another study in Argentina, with 273 trials with inoculation of *A. brasilense* in wheat, showed an increase in yield of 256 Kg.ha⁻¹ in 76% of the cases (DÍAZ-ZORITA and FERNANDEZ CANIGIA, 2008). The vast majority of experiments carried out in Brazil and Argentina reported benefits, such as plant growth and/or increased productivity, with the inoculation of *Azospirillum* (CÁSSAN and GARCIA DE SALAMONE, 2008).

According to Döbereiner (1989), in relation to BNF, there is a difference between grass genotypes, thus making it possible to further explore their potential through plant breeding. The lack of response to inoculation of diazotrophic bacteria in grasses, in the vast majority, may be due to the use of inappropriate strains (ROSÁRIO, 2013). Reis et al. (2000), state that the genotype of the plant is essential to achieve BNF benefits, as well as the selection of efficient strains. Competitiveness with other native strains or with the soil microbiota can prevent root colonization by bacteria used as inoculant, which is important for the success of inoculation (REIS, 2007).

Antunes et al. (2017) performing seed inoculation with *Azospirillum brasilense* in maize crop, concluded that it is possible to reduce nitrogen fertilization doses by at least 25% without compromising plant development. In grasses, the transfer of fixed N to the plant occurs slowly and only a small part becomes available to the plant, so the BNF process by these bacteria in association with grasses can only partially supply the plants' nitrogen needs (HUNGARY et al., 2011).

The most commonly used form of inoculation of *A. brasilense* is via seed, although it has the disadvantage that incompatibility with fungicide and insecticide used in seed treatment may occur (HUNGARY et. al., 2007). As an advantage, it has optimization in operationality, since a new application is not necessary, not generating more costs to the producer. Foliar inoculation emerges as an alternative, as it does not present risks with the incompatibility of products in seed treatment, since it is applied later and individually (KAPPES et. al., 2017).

Inoculation via seed requires some care, and must be carried out uniformly, do not leave the seeds exposed to the sun, store in a dry place, sow soon after inoculation or at most in 24 hours, otherwise it is recommended to redo the inoculation. If the seeds are treated with insecticide and/or fungicide, the inoculant should be placed last and be aware of the compatibility of the insecticides and fungicides used in seed treatment (HUNGARY, 2011).

In order to improve operability in the field, the foliar application of the inoculant made by spraying in the vegetative stages of the crop, appears as an option, and has proven to be more practical and efficient, because with the application of inoculant via foliar there is not one of the biggest problems that occurs in inoculation in the seed, which is the incompatibility with insecticides, fungicides and herbicides that can have harmful effects (MOREIRA and SIQUEIRA, 2006).

The present study aims to evaluate the agronomic performance of wheat associated with inoculation of *Azospirillum brasilense* via seed and foliar, isolated and together, with different doses of nitrogen fertilization in topdressing.

MATERIAL AND METHODS

The study was carried out in the experimental area of the Federal Institute of Education, Science and Technology of Rio Grande do Sul (IFRS), Ibirubá campus - RS, with geographic coordinates 28°38'57" S and 53°06'23" W and 452 meters of elevation. The soil is classified as a typical Dystrophic Red Latosol, according to the Brazilian Soil Classification System (SiBCS) (EMBRAPA 2018). According to the Köppen climate classification, the study area is located in a region with a humid subtropical "Cfa" climate, with an average temperature of 19°C and an average annual rainfall of 1826 mm (MORENO, 1961). According to data from the INMET experimental station located at the IFRS Campus Ibirubá, during the sowing period until the harvest of the experiment there was a rainfall of 798.8 mm of rain and the average temperature was 15.5°C. According to Westphalem (1983) the minimum water requirement for wheat cultivation is 312 mm.

The experimental design used was a randomized block design (DBC) with five replications per treatment involving a two-factor model (4 x 4) with the inoculation factors of *Azospirillum brasilense* (No inoculation; Seed inoculation; Inoculation via foliar and Inoculation via seed + inoculation via foliar) and nitrogen doses in topdressing (0, 40, 80 and 120 kg.ha⁻¹), totaling 80 experimental units. The wheat cultivar used was TBIO Ponteiro, with a final population of 330 plants m⁻². The experimental units consisted of 9 rows of 3 m in length, with a spacing of 0.17 m between rows, totaling an area of 4.59 m², as shown in Figure 1.

The cropping system used was no-tillage, with soil mobilization only in the sowing row, without future soil disturbance. Soil sampling for further analysis was carried out in the previous crop with soybean crop, considering wheat as the second crop for correction purposes, the yield expectation was 4.5 t.ha⁻¹ and according to the Soil Chemistry and Fertility Commission (2016) the recommended amount of fertilization was 300 Kg.ha⁻¹ of fertilizer of the formula 5-20-20 and there was no need for liming. The recommended N dose was 15 kg.ha⁻¹ at base and 55 kg.ha⁻¹ topdressing, divided into two applications.

In order to eliminate the weeds present in the area and avoid competition for water, light and nutrients with the crop to be implanted, desiccation was carried out using the herbicides Cletodim at a dose of 450 mL.ha⁻¹ b.w., 2,4-D at a dose of 1.5 L.ha⁻¹ b.w. and 0.5 L.ha⁻¹ mineral oil. Sowing took place on June 20, 2020, in a mechanized way, with uniform distribution of seeds in the sowing furrow, at a depth of approximately two cm.

For the treatments with seed inoculation, this was performed before sowing, adding 5 mL.kg⁻¹ of liquid inoculant seed composed of a culture of *Azospirillum brasilense* bacteria, of the AbV5 and AbV6 strains, at a concentration of 2.0×10^8 UFC.mL⁻¹. For the treatments with foliar inoculant applications, this occurred at the beginning of tillering, corresponding to stage 2 of the Feekes-Large scale, with an electric knapsack sprayer with a flow rate regulated to 365 L.ha⁻¹, considering favorable climatic conditions such as temperature below 20°C, relative humidity above 55-60%, wind speed above 3 km.h⁻¹ and less than 10 km.h⁻¹, seeking to avoid problems with drift, which is the movement of a product in the air during or after application to a different location than planned, and the loss of product efficiency, was using 0.5 L.ha⁻¹ of the same liquid inoculant used via seed.

Nitrogen topdressing was divided into two applications, the first at the beginning of tillering (approximately 40 DAS) and the second at the beginning of stem elongation (approximately 70 DAS), corresponding to stages 2 and 6 of the Feekes-Large scale, respectively. The fertilizer used was urea (45 % nitrogen) and the application was carried out manually, on the surface. The other cultural treatments, such as weed, disease and pest management were carried out according to the Technical Information for wheat and triticale (EMBRAPA 2018), when necessary.

The variables evaluated were emergence (stage 1 of the Feekes-Large scale), and the plants emerged in two linear meters of each experimental unit were counted to estimate the initial stand of the area. When the crop was starting to elongate the stem (stage 6 Feekes-Large scale), the number of tillers per plant was counted in two linear meters per experimental unit and to estimate the number of ears per square meter, the ears of two linear meters of each experimental unit were counted, when all ears were out of the sheaths (stage 10.5 Feekes-Large scale).

In addition, the relative chlorophyll content in the leaves at the beginning of flowering period of the crop (stage 10.5.1 of the Feekes-Large phenological scale) was evaluated, and the relative chlorophyll contents in the adaxial face and central portion of the flag leaf of ten plants per experimental unit were determined, using an electronic chlorophyll content meter (CLOROFILOG CFL1030). At stage 11 of the phenological scale, which corresponds to milky grains, plant height was determined by measuring 10 plants randomly in the experimental unit, with the aid of a graduated tape.

At the moment when the crop reached the physiological maturation stage (stage 11.4 of the Feekes-Large scale), 10 plants per experimental unit (including tillers) were randomly collected, cut

at the height of the soil surface. Then, the spikelets of each plant (mother's ear + children's ear) were counted.

After the maturation of the crop, the useful area of 2 meters long by 0.85 meters wide (5 rows), totaling 1.7 m², was harvested manually, which was threshed in a tractor threshing machine. After cleaning, the mass of the sample was determined on a digital scale with a precision of 0.01 gram, and the sample moisture (U%) was measured using an electronic determiner. From the grain mass obtained in the useful area of the plot, the productivity was obtained, expressed in kg.ha⁻¹, correcting the weight to 13% of moisture and extrapolating the productivity of the plot to hectare.

Regressions were also performed to adjust the degree of polynomial in order to establish the maximum technical and economic efficiency of the productivity variable. Through the equation of degree 2 ($y = a \pm bx \pm cx^2$) the mathematical model $y = -b/2b$ was used, in the estimation of the maximum technical efficiency (MET), for the calculation of the maximum productivity the formula $ax^2 + bx + c$ and the formula $[(t/w) - b]/2b^2$ were used to obtain the maximum economic efficiency (MEE). The t is the value of the input (urea) and w the value of the product (wheat) (DA SILVA et al., 2015), which in this period, the kilogram of urea corresponded to the cost of R\$ 3.26 and the amount paid to the producer for the bag of wheat to R\$ 81.00.

Through the grain mass used to determine the yield, it was determined on a hectoliteric scale with a capacity of 0.25 L, and then converted to kilograms per hectolitre with the aid of a conversion table that accompanies the equipment. It was also determined by the manual counting of eight replicates of 100 grains weighed on an analytical scale with a precision of 0.001g and after calculating the variance, standard deviation and coefficient of variation.

The collected data were submitted to analysis of variance according to the model of the experimental design and the causes of variation that presented significance by the F test ($p \leq 0.05$) were submitted to complementary procedures according to the responses obtained by the interactions and main effects. For qualitative factors, the Scott-Knott test was used, and for quantitative factors, regression. The software used was Sisvar (FERREIRA, 2019).

RESULTS AND DISCUSSIONS

The average number of emerged plants was 327.9 plants per m², presenting a satisfactory result, since the seeder was adjusted to distribute 330 plants per m². Regarding the number of tillers per plant, there was no significant difference between the forms of inoculation (Table 1). Munareto (2016) in his work found an increase in the number of tillers, in two varieties, when the seed was inoculated, while in the other variety there was a decrease in the number of tillers when the seed was inoculated. Barzotto et al. (2018) working with barley, concluded that the number of tillers emitted was higher in the treatments inoculated in the absence of nitrogen fertilization and in the highest

dose, which was 120 kg.ha⁻¹. The environmental, nutritional and genetic conditions directly affect the emission of tillers and during this work, the temperatures were raised for tillering. According to Monteiro et al. (2012), the genotype influences the microbial community present in the roots by the difference in the signaling between root and bacteria.

According to table 1, the variable chlorophyll content, a photosynthetic parameter of the leaves, also did not present a statistical difference between the forms of inoculation, unlike the results found by Offeman (2015) and Barassi et al. (2008) who observed increases in chlorophyll content when the seeds were inoculated with *A. brasilense*.

The variable ears per m² showed a statistical difference, where leaf inoculation and seed + leaf inoculation were more efficient in relation to the other forms. On the other hand, even though there was no statistical difference for the number of tillers per plant for the different forms of inoculation, the variable ear per m² presented a higher result for two variables, which can be explained by the fact that these two forms of inoculation had a higher number of viable tillers and were able to generate ears. Unlike Ferreira et al. (2017) and Ferreira et al. (2014) who did not observe a significant difference for this variable when evaluating foliar inoculation in wheat in the Cerrado region.

The number of spikelets per plant was not influenced by the different forms of inoculation, which corroborates the results found by the authors Galindo et al. (2015) and Munareto (2016), who did not observe a statistical difference in the application of *A. brasilense* in wheat for this variable. On the other hand, Munareto (2016), in the experiment in 2015, observed that the association of the forms of inoculation, seed + foliar, presented superior results to the other forms. The joint application of the inoculant has greater potential, due to chemical fertilization not being able to meet the plant's needs in relation to the amount and time of application, unlike the bacterium, where the needs are met continuously until the reproductive phase, which is where the plant most needs N accumulation to change the number of spikelets and the number of grains per ear.

Table 1. tillers per plant, chlorophyll content, number of ears per m² and spikelets per wheat plant in different forms of inoculation of *A. brasilense* in wheat crop. Ibirubá-RS, 2021.

Form of inoculation	Variable evaluated							
	Children		Content of		Ears		Spikelets	
	(Plant)		chlorophyll		(m ²)		(Plant)	
No inoculation	2,2	**ns	46,2	ns	411,5	*b	33,4	ns
Seed inoculation	2,2		47,8		417,4	b	34,3	
Foliar inoculation	2,1		47,6		447,2	a	33,1	
Inoc. Seed + foliar	2,2		49,1		454,0	a	34,9	
Average	2,2		47,7		432,5		33,91	
CV (%)	12,48		7,83		7,5		12,82	

*Means not followed by the same letter in the column differ from each other, by the Scott-Knott test at the 5% level. **ns Not significant by the F test at the 5% level.

It can be seen in table 2 that the yield did not differ between the forms of inoculation, as well as the other characteristics evaluated, plant height, hectolitre weight and weight of one thousand grains. It is pertinent to discuss the variability of responses obtained when working with different genotypes, especially regarding the inoculation of *Azospirillum brasilense*.

Several studies have shown differences in the response of wheat cultivars when inoculated (LEMOS et al., 2013; SALA et al., 2007; SALA et al., 2005). One factor that can interfere with the association is the affinity between bacteria and the plant. Bacteria are attracted to the rhizosphere by the exudates released by plant roots, and use it as an energy source promoting growth (BABALOLA et al., 2010). However, the interaction will depend on factors such as the composition of the exudates (BIANCHET et al., 2013), biotic and abiotic factors of the rhizosphere region (DUTTA; PODILE, 2010) and the competition of *Azospirillum* with native soil diazotrophic bacteria (DIDONET et al., 2000).

In the study carried out by Hungria et al. (2010), significant increases in wheat grain yield of up to 31% were found when they inoculated the seeds with different strains of *A. brasilense*, differently from what was obtained in the present study. For Ferreira (2017), the results in the parameters, hectolitre weight, weight of a thousand grains and productivity did not differ, which corroborates with the results obtained, he also reported that they are due to the fact that the nutrient contents in the soil, especially macronutrients, are in satisfactory conditions, also inferring that the N content could also be adequate by the application of base fertilization and subsequent top fertilization in predecessor crops may have interfered, thus, there were no significant differences between treatments.

Another factor that may have contributed to the lack of difference is that the cultivar used may not have such a positive response in relation to inoculation, since using other cultivars can have more satisfactory results.

Table 2. Plant height, yield, hectolitre weight (PH) and thousand-grain weight (MMG) of wheat in different forms of inoculation of *A. brasilense* in wheat crop. Ibirubá-RS, 2021.

Form of inoculation	Variable evaluated							
	Stature		Productivity		PH		GP	
	(cm)		(Kg.Ha-1)		(Kg.HL ⁻¹)		(g)	
No inoculation	71,7	*ns	3580,1	ns	77,5	ns	33,1	ns
Seed inoculation	73,1		3416,1		77,5		32,7	
Foliar inoculation	72,1		3467,2		77,7		33,0	
Inoc. Seed + foliar	73,5		3646,1		77,8		33,1	
Average	72,6		3527,4		77,6		33,0	
CV (%)	4,0		11,87		1,06		5,3	

*ns Not significant by the F-test at the 5% level.

Regarding N doses, there was a significant difference for all the variables evaluated, tillers per plant, chlorophyll content, ears per meter² and spikelets per plant, height, productivity, PH, MMG, (Tables 3 and 4).

Table 3. tillers per plant, chlorophyll content, number of ears per m² and spikelets per wheat plant at different doses of nitrogen topdressing fertilization in wheat crop. Ibirubá-RS, 2021.

Dose de N - (Kg ha ⁻¹)	Variable evaluated							
	Children		Chlorophyll Content		Spikes		Spikelets	
	(Plant)				(m ²)		(Plant)	
0	1,8	c*	44,4	b	384,1	c	29,4	b
40	2,1	b	48,8	a	422,1	b	33,7	a
80	2,3	b	48,7	a	454,4	a	35,5	a
120	2,5	a	48,9	a	469,4	a	37,1	a
Average	2,2		47,7		432,5		33,9	
CV (%)	12,5		7,8		7,5		12,8	

*Means not followed by the same letter in the column differ from each other, by the Scott-Knott test at the 5% level.

Table 4. Plant height, yield, hectolitre weight (PH) and thousand-grain weight (MMG) of wheat at different doses of nitrogen topdressing fertilization in wheat. Ibirubá-RS, 2021.

Dose de N - (Kg.ha ⁻¹)	Variable evaluated							
	Stature		Productivity		PH		GP	
	(cm)		(Kg.Ha-1)		(Kg.HL ⁻¹)		(g)	
0	66,1	c*	2831,3	c	78,0	a	33,9	a
40	73,2	b	3595,0	b	78,0	a	33,8	a
80	74,9	a	3704,0	b	77,8	a	33,1	a
120	76,1	a	3979,2	a	76,8	b	31,2	b
Average	72,6		3527,4		77,6		33,0	
CV (%)	4,0		11,87		1,06		5,3	

*Means not followed by the same letter in the column differ from each other, by the Scott-Knott test at the 5% level.

The equations of the N doses mentioned in the sequence obtained significance in the ANOVA to perform the regression analysis. The tillers per plant showed superior results with the increase in N rates (Figure 2A), where the doses of 40 and 80 kg.ha⁻¹ already showed good results, 2.1 and 2.3 tillers per plant, respectively, and the dose of 120 kg.ha⁻¹, presented the highest number of tillers, 2.5 per plant. This can be explained by the fact that this variable is determined by the availability of N in the early stages of crop development (MALAVOLTA, 2006). The results found by Ludwig (2015) corroborate this study, where with higher doses of N a greater number of children was reached. For Barzotto et al. (2018), the dose that provided the highest number of tillers in the barley crop was 62 kg.ha⁻¹ of N for non-inoculated seeds and 43 kg.ha⁻¹ of N for inoculated seeds. Applications of N between emergence and emission of the 3rd leaf allow greater tiller emission and applications on the 7th leaf reduce mortality and postpone tiller senescence, increasing the number of fertile stalks and wheat yield (BREDEMEIER; MUNDSTOCK, 2001).

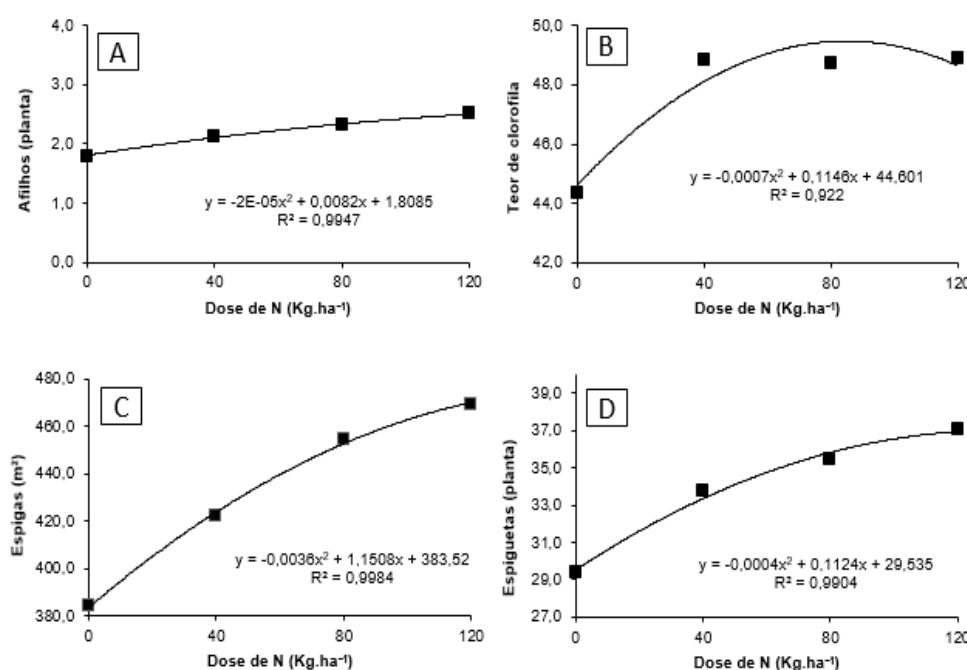
The chlorophyll content showed superior results with the increase in N doses (Figure 2B), the doses 40, 80 and 120 kg.ha⁻¹, with values of 48.8, 48.7 and 48.9 respectively, were higher than the control, which was 44.4. In this sense, Offemann (2015) in his work also concluded that with higher doses of N, leaves with higher chlorophyll levels were obtained. The determination of the chlorophyll content in the leaves shows how the nitrogen nutrition of the plants is, since the main symptom of N deficiency is the yellowing of the leaves (ARGENTA et al. 2001).

Regarding the number of ears, following the trend of tillers, there was an increase in the number of ears as the N dose increased, up to the dose of 80 kg.ha⁻¹, which did not differ from the dose of 120 kg.ha⁻¹ (Figure 2C), with 454.4 and 469.4 ears per m², respectively. This result corroborates that of Marchetti et al. (2001), who obtained an increase in the number of ears with the increase in the doses of N. Barzotto et al. (2018) also concluded that with doses of 80 and 120 kg.ha⁻¹ of N they obtained a higher number of ears in the barley crop.

The number of spikelets per plant showed superior results with the application of N, regardless of the dose (Figure 2D). However, Teixeira Filho et al. (2008) did not observe a significant effect of N doses (0, 30, 60, 90, 120 and 150 kg.ha⁻¹) for the variables number of spikes and number of spikelets per plant.

The variables tiller per plant, ears per m² and spikelets per plant are yield components directly or indirectly determined by the availability of N in the soil, since these enable the accumulation of amino acids, enzymes and proteins in the tissues, which are distributed in the plant, allowing the development of new tissues and accumulated preferentially in the grains (MALAVOLTA, 2006).

Figure 2. A – Number of tillers per plant; B – chlorophyll content; C – number of ears per m²; D – number of spikelets per plant at different doses of nitrogen top dressing fertilization in wheat crop. Ibirubá-RS, 2021



For the variable height (Figure 3A), the doses of 80 and 120 Kg.ha⁻¹ of N were the ones with the highest height. A similar result was obtained by Zagonel et. al. (2002) who observed that according to the increase in N doses, there is also an increase in plant height. Ferreira et al. (2017) also found an increase in the height of wheat plants, since the supply of nitrogen promotes stem elongation and an increase in the number of leaves and tillers. On the other hand, attention should be paid to some cultivars, the greater the height of the plant, the greater the possibility of lodging, a fact that was not observed in the experiment.

Regarding productivity (Figure 3B), the dose of 120 Kg.ha⁻¹ of N was the one that presented the highest productivity. This result is similar to that found by Teixeira Filho (2008), who achieved the maximum productivity of wheat with N doses of 120 Kg.ha⁻¹. On the other hand, Pettinelli Neto et. al. (2002) did not observe an effect of N application on yield increase, due to the supply of N by the predecessor crop, soybean, for several years. The largest increments are obtained in the first 40 kg applied, where the difference for the control without application was 763.8 kg.ha⁻¹, thus highlighting how limiting this element is for the crop (WIETHÖLTER, 2011). For the dose of 40 kg of N ha⁻¹, the increase was 19.1 kg of grains for each kg⁻¹ of N applied, when compared to the dose of 0 N. For the doses of 80 and 120 kg of N ha⁻¹, the increase was only 2.7 and 6.9 kg of grains for each kg⁻¹ of N, respectively.

Calculating the maximum technical efficiency, it was obtained values that with 118.2 Kg.ha⁻¹ of N the maximum productivity was reached, which was 3938.7 Kg.ha⁻¹. But calculating the maximum economic efficiency, it was obtained that to be economically viable 117.96 Kg.ha⁻¹ of N should be applied to achieve greater profit.

The PH value is used as a measure of wheat commercialization, and indirectly expresses the quality of grains. It is known that the higher the PH value, the greater the acceptance and appreciation of the product in the market (MAZZUCO et al., 2002). The value of 78 kg.hL⁻¹ is used as a reference, that is, PH equal to or above this value, wheat with the highest commercial value is considered. In the determination of the PH, several characteristics of the grain are associated, such as shape, texture of the seed coat, size, mass, and also the presence of impurities (straw, soil). Very low PH values may indicate the occurrence of problems in the crop, which affect the filling and quality of the grain (GUARIENTI, 1993), such as excessive rainfall, for example.

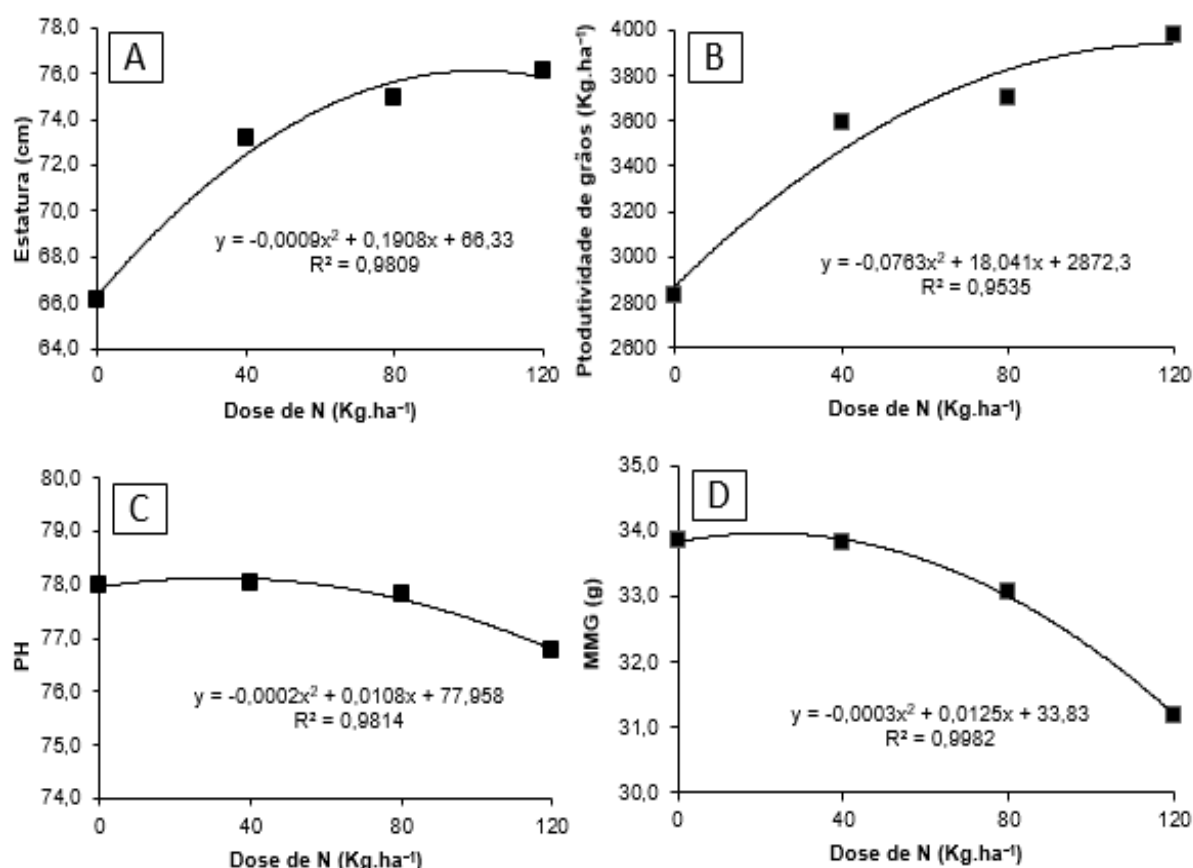
The hectolitre weight had a decreasing value with the increase in N doses (Figure 3C), therefore having a higher value when the N doses were lower or zero (0, 40 and 80 Kg.ha⁻¹) and a lower value with the highest dose (120 Kg.ha⁻¹) as well as Trindade et. al. (2006) and Frizzzone et al. (1996), who observed this decrease in hectolitre weight with the increase in nitrogen fertilization. One hypothesis for this reduction is the increase in photoassimilate competition that occurs in grains where high doses of N are applied, also reducing the PH. Sangoi et al. (2007) observed an inverse

relationship between protein content in grains at the time of harvest and grain yield, where the most productive cultivar was the one with the lowest protein content, and the cultivar with the highest protein content was the one with the lowest yield. This is due to the greater energy expenditure that the plant has to form protein, which can compromise the accumulation of carbohydrates (SOUZA et al., 2004).

The weight of one thousand grains also showed decreasing values with the increase of N doses (Figure 3D), so the doses 0, 40 and 80 Kg.ha⁻¹ were more efficient in relation to the dose of 120 Kg.ha⁻¹ for this variable, which can be explained according to the results obtained by Teixeira Filho (2008) where he observed that with the increase in the number of grains per ear, increased the competition of photoassimilates within the ear and nutrients, thus reducing the mass of the grains. On the other hand, Barzotto et al. (2018) analyzing the mass of one hundred grains in the barley crop, found results different from those of this work, they concluded that, in inoculated seeds, with the increase in N doses there was an increase in the mass of 100 grains.

The higher doses of N had more tillers per plant and also more ears (fertile tillers), normally the grains from tillers receive less photoassimilated at the time of partitioning and end up filling less. So, having more grains from tillers at a dose of 120 Kg.ha⁻¹ of N, the mass of a thousand grains can be reduced. This result corroborates with Barbieri et al. (2013), who observed that plant tillering is a determining factor for the mass of a thousand grains, that is, plants that develop more tillers have greater intraspecific competition, resulting in a lower mass of one thousand grains. Thus, a plant with a smaller number of tillers is better able to increase the mass of a thousand grains, which can be seen in this work.

Figure 3. A - Plant height; B – grain productivity; C – hectolitre weight (PH); D - weight of one thousand grains (MMG) of wheat at different doses of nitrogen fertilization in wheat crop. Ibirubá-RS, 2021.



CONCLUSIONS

The forms of application of *Azospirillum brasilense* via seed and foliar, isolated and together, did not influence the variables analyzed. Only for the variable ears per m² there were increments when inoculating via foliar and seed + foliar in relation to the other application options, this result was superior in two forms of inoculation, which can be explained by the fact that these two variables had the highest number of viable tillers and generated ears.

For the cultivar used, the inoculation with *A. brasilense* did not present results that justify and enable its use, regardless of the form of inoculation, and there were no scenarios that brought good yield increases, corresponding to the amounts invested in the use of bacteria of the genus *Azospirillum*.

In the application of nitrogen in the form of urea, mainly in large doses (80 and 120 kg.ha⁻¹) there was an increase in productivity, height, relative chlorophyll content in the leaves, tillers per plant, ears per m² and spikelets per plant, the higher the dose used, the higher the level of productivity obtained as a response of the plant, where they presented more tillers per plant and also more ears (fertile tillers).

The MMG and PH variables obtained reductions due to the increase in N doses, in the case of MMG the present work presented decreasing results, which can be explained by the increase in



the number of grains per ear, which caused an increase in the competition of photoassimilates within the ear and nutrients, thus reducing the grain mass. In the fact of PH, the hypothesis for this reduction is the increase in the competition of photoassimilates that occurs in grains where high doses of N are applied, also reducing the PH, which can be seen in this work.

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Evaluation of the tolerance of canafistula (*Peltophorum dubium*) under different nitrogen doses

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ABSTRACT

The species *Peltophorum dubium* is widely recognized in Rio Grande do Sul with the common name Canafistula belonging to the Fabaceae family. If there is a deficiency of mineral elements in the soil, the species may experience a decreased response to growth, resulting in slower development. In view of the above, it is intended to evaluate the growth of the Canafistula species in response to different nitrogen dosages. In this way, we sought to determine the plant's response to varying levels of this element. The variables analyzed were: stem diameter, number of leaves, shoot height, shoot mass, root length, root mass and dry mass of both shoots and roots. First, sowing was carried out. On March 20, the seedlings were transplanted to the pots. A randomized block design was used with five replications for each treatment. A total of 20 vessels were subdivided into 4 treatments, T1, T2, T3 and T4 of N doses (0, 40, 80, 120 kg ha⁻¹ respectively). The harvest was carried out on June 19, removing them from the pots. It was left in an open air circulation kiln. The results of the analysis of variance showed a significant effect of the nitrogen doses applied to the Canafistula seedlings for all the variables evaluated except the root dry mass. In all variables, the adjusted regression curve was quadratic and thus the point of maximum technical efficiency for each response variable was determined. The best treatment was T2, which was the critical dose. The T4 that obtained the highest N dose was observed to exceed the critical dose because the culture presented nitrogen toxicity resulting in senescence of the treatment, having as the most severe treatment for the culture. With the results obtained in this research, it was evident that nitrogen plays an extremely relevant role in the production of Canafistula, since it was demonstrated by the results of the analysis of variance a significant effect for all variables except root dry mass.

Keywords: Varied Levels, Fertilization, Growth, Critical Dose, *Peltophorum dubium* seedlings.

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INTRODUCTION

The species *Peltophorum dubium* belonging to the Fabaceae family is widely recognized in Rio Grande do Sul with the common name Canafístula, although it is also known by other denominations, such as Angico-bravo in São Paulo. The etymology of its scientific name *Peltophorum* refers to the meaning "what drives the disc", referring to the stigma of the flower. In addition, in the Tupi-Guarani language, this tree is called ibira-puita-guassú, which translates as "big-redwood" (LONGHI, 1995).

The wood produced by this species has a significant economic value, which is attributed both to its versatility of use and to the quality of its wood. Therefore, it is extremely important to promote a vigorous growth of this plant, considering its economic potential. Understanding the relevance of macronutrients in plant nutrition becomes fundamental in this context, since they are essential chemical elements for vigorous plant development.

In cases of deficiency of these mineral elements in the soil, the species may experience a decreased response to growth, resulting in slower development even in the case of a crop belonging to the legume category (a group known for its ability to fix atmospheric nitrogen through symbiosis with bacteria). Therefore, maintaining proper macronutrient levels in the soil is essential to ensure robust and healthy growth of this plant, which is critical to its economic viability.

Initially, when choosing the object of this research, a certain degree of difficulty was obtained to find relevant scientific literature on the subject in question. However, as the experiment progressed and after a few weeks of research, some scientific articles were identified and reviewed that addressed the influence of fertilization on the species under study. According to Carvalho (2002), most of these scientific studies corroborated the hypothesis that this crop has a substantial demand for fertilization, particularly when it comes to macronutrients.

The objective of this research is to evaluate the growth of Canafístula in the face of different doses of nitrogen, in order to understand the response of this plant to different amounts of this element and to establish parameters to optimize the nutritional management of the species in cultivation environments.

THEORETICAL FRAMEWORK

Canafístula is part of the legume family Fabaceae and is a native tree species that can be called by several popular names such as Angico-bravo for example (CARVALHO, 2002). As for the characteristics, it prefers moist clay soils with great depth of riverbanks, occurring in dense primary forest as well as in secondary formations. Its dispersion is vast and rich, especially in the regions closest to the great river (LORENZI, 2008).

According to Corrêa (1931), its wood has greater durability in dry places and has several uses, being intended for sleepers, bodywork, cooperage, clotheslines, lathes, saddles, civil construction, carpentry and dyeing. Its roots, fruits, and leaves can be used as medicinal properties. Canafistula also enables urban reforestation and property dividing fences. Its fruiting is abundant and develops mainly in the red and clayey soils of the river banks.

Canafistula is among the 15 most important forest species aimed at the sawmill market in the South region (RUSCHEL, 2003) with large-scale capacity for wood production in the Center-South of Brazil (CARVALHO, 1998). On the wood, it has a light pinkish-pink sapwood color, an irregular heartwood that alternates between pinkish-brownish and dark pinkish beige, medium-coarse texture and indistinct flavor (CARVALHO, 2002).

Between the months of March-April the fruits ripen, however the small pods remain viable on the tree for several months. To obtain the seeds, it is recommended that the fruits (pods) of the tree be harvested when they reach the paleaceous color. Sowing can be done with the pods as if they were seeds, however this can result in the formation of crooked or defective seedlings. That said, when possible, you should extract the seeds from the pods. For an easier operation, they can be left in the sun to dry and after that use manual or mechanical friction (LORENZI, 2008).

Its flowering occurs between the months of December and February, starting its production process between 8 and 12 years old with the maturation of the seeds from April to June. Its dispersion occurs autochorically, with barochoric being the main one, by gravity, and anemochoric, when dispersion occurs by wind. Its seeds can be found in the soil seed bank (CARVALHO, 2002).

According to Marchiori & Alves (2012), more specifically in the state of Rio Grande do Sul under analysis, Canafistula is geographically distributed in the Upper Uruguay Seasonal Forest, being one of the most representative, surrounding the riparian forest of the great river up to the municipality of Barra do Quaraí, reaching the Uruguayan department of Artigas and the northeast of the Argentine province of Entre Rios. The Canafistula attracts the eyes of the beholder because it is able to make an ornamentation between the yellow of its numerous flowering that contrasts with the green of the other trees in the canopy, an event that occurs between the months of December and April.

According to Mattei & Rosenthal (2002), in the state of Rio Grande do Sul, the territorial surface cover in relation to forests has been successively decreasing more and more, remaining less than 1/3 of the total area, being restricted only to preservation areas, parks, reserves, small percentages in areas of difficult access and in rural properties represented by small remnants that are generally partially exploited. This resulted in the threat of extinction of several species of high value and economic interest, one of them being the Canafistula.

MACRONUTRIENTS

Macronutrients are a group of essential nutrients needed in large quantities for plant growth and development. They perform distinctive functions in the life of the plant, although in some cases it is possible to replace them with other elements. Thus, macronutrients perform three main functions, acting as structural components, constituting enzymes or playing the role of enzymatic activators (MALAVOLTA, 2006).

Macronutrients, namely nitrogen (N), phosphorus (P) and potassium (K), are the mineral elements that, in many cases, play a decisive role in the development of agricultural crops. This is due to its high quantitative demand (in the case of N and K) or its tendency to become insoluble in the soil (as is the case with phosphorus, P). It is worth mentioning that, with the exception of legumes that have the ability to fix atmospheric nitrogen in symbiosis with bacteria, as is the case of *Canafistula*, the three nutrients can be supplied through fertilization, whether organic or mineral, in most crops and soil types (BISSANI et al., 2008).

In its structural form, the element participates in the molecule of one or more organic compounds, such as amino acids and proteins composed of N; pectate formed by Ca, which is known to be a polygalacturonic acid salt of the middle lamella of the cell wall; the center of the tetrapyrrolic nucleus of chlorophyll occupied by Mg. The enzyme constituent is an individual case of the previous one, it is related to elements, usually metals or transition elements, for example Mo, which is within the prosthetic group of enzymes and which are essential for their activity, such as Cu, Fe, Mn, Mo, Ni, Zn. Finally, the enzymatic activator that does not participate in the prosthetic group of the element, dissociable from the protein portion of the enzyme (apoenzyme), is useful for its activity, such as Na⁺, K⁺, Rb⁺, Cs⁺, among others (MALAVOLTA, 2006).

NITROGEN

Nitrogen (N) is considered an essential element for plants due to its presence in nucleic acids and proteins, molecules crucial for all biological processes. Being a fundamental constituent, nitrogen is the nutrient that plants demand in greater quantity. An essential element is characterized as one that plays an intrinsic role in the structure or metabolism of a plant, the lack of which results in severe abnormalities in plant growth, development, reproduction, or may even prevent the plant from completing its life cycle (TAIZ et al., 2017).

According to Raij (1981), nitrogen is found in the soil mainly in its organic form, being a mobile element. The surplus, which is a small, highly variable part of the total content, is present in the inorganic forms of ammonium, and especially nitrate. In cases of adequate aeration and not too acidic pH, ammonium is transformed into nitrate quickly. Its absorption occurs through the roots of plants, in the form of nitrate, known to be a free form not adsorbed to the soil that basically enters the

plant along with water, so the mass flow almost entirely meets the requirements of crops. The same occurs with sulfur, consumed in the form of sulfate.

Nitrogen makes up 5% of the organic matter in the soil. In organic form, it represents approximately 98% and only 2% in mineral form (MALAVOLTA, 2006). Appropriate nitrogen fertilization consequently improves the leaf contents of this and other nutrients, especially P, which results in an increase in growth and productivity (BONNEAU et al., 1993).

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the Agronomy course of the Federal University of Pampa - Unipampa - Itaqui Campus, with latitude 29°09'50"S and longitude 56°33'09"W. The area is located in the municipality of Itaqui, on the western border of Rio Grande do Sul, with a Cfa climate, according to the Koppen climate classification, meaning that there is no defined dry season with a humid subtropical climate with hot summers (WREGGE et al., 2012). It should be noted that the soil is characterized as a Dystrophic Clay Plintosol (EMBRAPA, 2018).

Initially, sowing took place between January 16 and 17, using 72-cell trays. Three seeds were placed in each cell, in a mixture of commercial substrate and sieved soil, with a ratio of 1:1. During the initial phase of plant development, the seedlings were kept under the protection of a shade cover, with 50% shading. On March 20, the seedlings were transplanted to pots with a volume of 2,000,000 dm³.

A randomized block design was used with four treatments and five replications for each treatment. For cultivation in pots, the soil of the experimental area was used as substrate. The 4 treatments, T1, T2, T3 and T4 consisted of N doses (0, 40, 80 and 120 kg.ha⁻¹, respectively), with five replicates for each treatment, totaling 20 experimental units. To calculate fertilization, the Manual of Fertilization and Liming for the States of Rio Grande do Sul and Santa Catarina (SBCS, 2016) was used, and the Black Wattle was used as a reference because it is within the same family. For the Black Acacia crop, the recommended dose according to the manual and according to the soil analysis of the experimental area is 40 kg.ha⁻¹. The N doses were deposited in the form of urea, using SFT for phosphorus and potassium chloride fertilization, and mixed together with the soil in the pots. For the SFT dose, 351 kg ha⁻¹ was supplied, equivalent to 2.33 g vase, and for the potassium chloride proportions, 206 kg ha⁻¹ was supplied, being 1.37 g vase⁻¹.

The thinning of the plants was carried out 14 days before the time of harvest, when there were two. On June 19, the harvest was carried out, removing them from the pots, classifying them according to the treatment, washing the roots in running water and taking them to the soil laboratory for evaluations. For the evaluations, a caliper, a tape measure and a precision scale were used. Stem diameter, shoot height, root length, shoot green mass and root green mass were evaluated. To

measure the dry mass of the shoot and root, the seedlings were left in paper bags to deposit them in an oven with open air circulation at 65 °C for about 3 days.

The records obtained were submitted to an analysis of variance, and the statistical software R was used to conduct the statistical analysis. For statistical analysis, the data were evaluated for normality and homoscedasticity.

RESULTS AND DISCUSSION

The results of the analysis of variance showed a significant effect of the nitrogen doses applied to the Canafistula seedlings for all variables evaluated except root dry mass (MSR). In all the variables analyzed, the adjusted regression curves showed a quadratic behavior, allowing the determination of the point of maximum technical efficiency for each response variable.

Table 1. ANOVA board.

QM								
FV	DC	NF	APA	MPA	CR	MR	MSPA	MSR
Kicked	2,5*	289,9*	2310,9*	3094,8*	2265,5*	98,1*	495,9*	12,53**
Residue	1,3*	21,2*	333,6*	4877,8*	450,6*	153,8*	630,9*	21,83**
CV	46,5*	17,7*	25,3*	88,1*	29,4*	92,4*	83,6*	101,08**

Source: Prepared by the authors (2023)

*Significant at 5% ($p < 0.05$) according to the Barlett test;

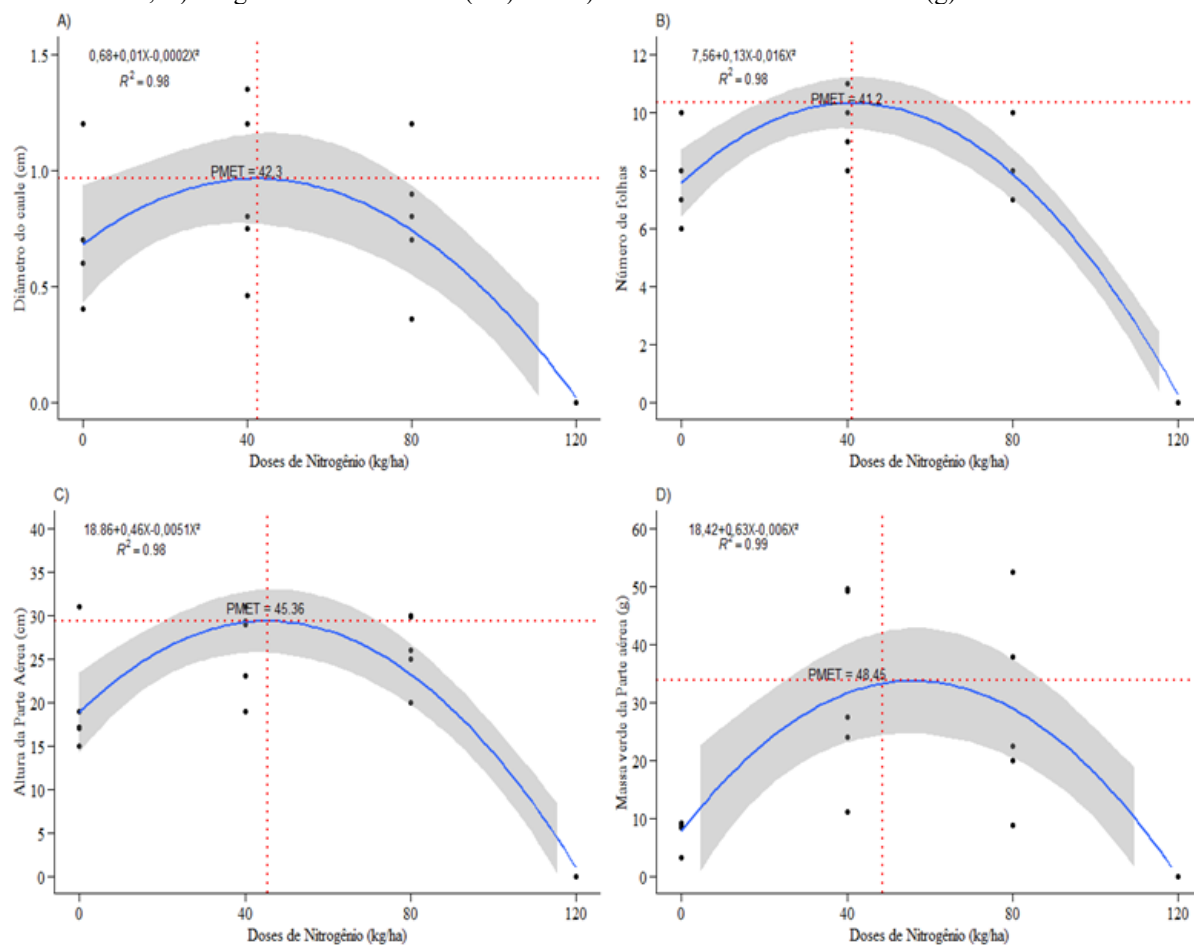
**Not significant at 5% ($p < 0.05$) according to the Barlett test.

QM: Mean square; FV: Sources of variation; Treatment: Treatment; CV: Coefficient of variation; DC: Neck diameter; NF: Number of sheets; APA: Height of the aerial part; MPA: Mass of the aerial part; CR: Root length; MR: Green mass of the root; MSPA: Shoot dry mass; MSR: Dry root mass.

The maximum technical efficiency of a crop designates how much is the upper limit of production, depending on nutrient doses. This point is the maximum increase of the variable studied as a function of the increase in the availability of nutrients for the crop (ORTIGARA et al., 2012). In this context, it is crucial to identify the point of maximum technical efficiency, since this allows determining the most effective treatment and assessing whether the dose applied was adequate. In this way, both excessive application, which would lead to fertilizer waste, and insufficiency, which would require larger doses, is avoided, ensuring a more precise and efficient use of resources.

Figure 1 shows the results of the study on the growth of Canafistula seedlings (scientific name: *Peltophorum dubium*) under controlled conditions, where different doses of nitrogen were applied.

Figure 1: Growth of *Canafistula* seedlings, grown in pots with different doses of nitrogen. A) Stem Diameter (cm); B) Number of Sheets; C) Height of the Aerial Part (cm) and D) Green Mass of the Aerial Part (g)



Source: Prepared by the authors (2023)

In graph A, the diameter of the stem is observed under different doses of nitrogen, as can be seen in the dose 40 kg.ha⁻¹ the diameter of the stem was larger compared to treatment 1 and treatment 3 because if the percentage difference in values of treatments 1, 2 and 3 is calculated (Appendix 1) there are lower values in treatments 1 and 3, where we will have 23.25% and 13.15% less production respectively, with higher percentages of production in treatment 2 demonstrating the behavior of the curve. The analysis of this graph allowed us to estimate the dose corresponding to the PMET of 42.3 kg ha⁻¹ of nitrogen for plant height.

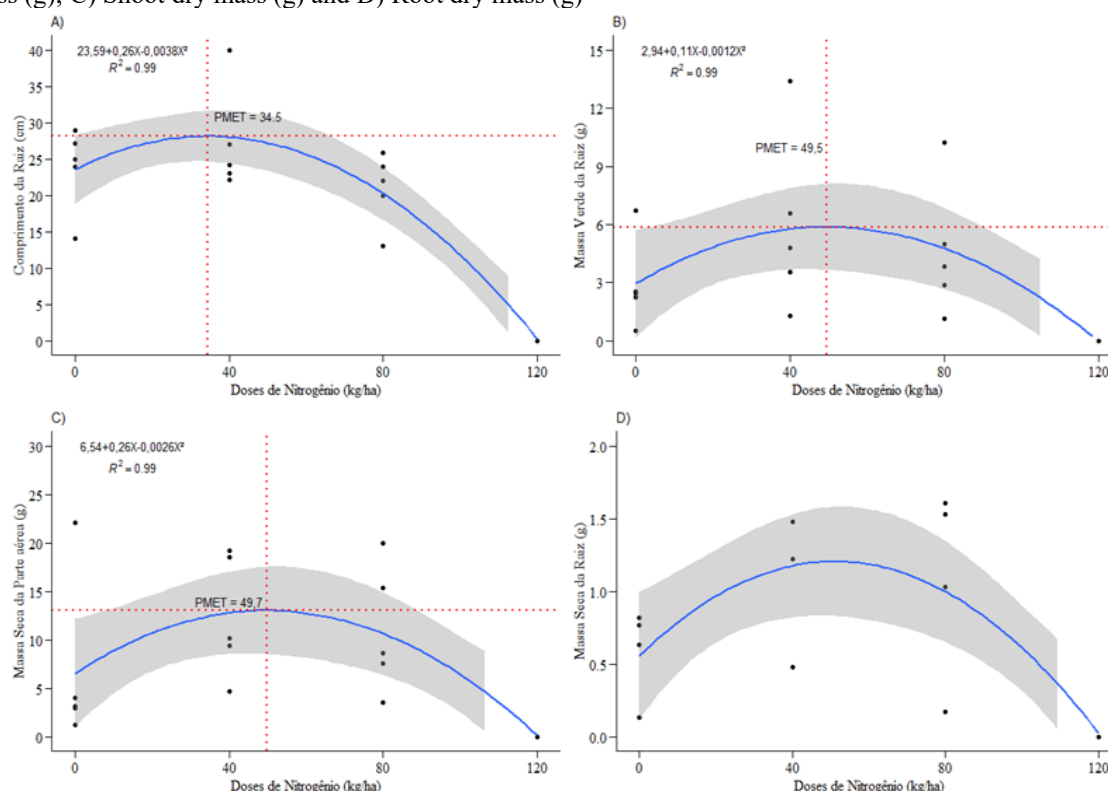
In relation to graph B, we have the number of leaves at different doses of N, observing that at the dose 40 kg ha⁻¹ the number of leaves is higher compared to treatments 1, 3 and 4 with the MET point being 41.2 kg ha⁻¹ of nitrogen.

In Graph C, the height of the aerial part was identified, with a greater increase in the dose of 40 kg ha⁻¹. In treatments 1 and 3, there are lower averages in these treatments, with percentage differences of 24.45% and 0.38% of production less, and a higher average in treatment 2, as shown in graph C. The MET point is 45.36 kg ha⁻¹ of nitrogen.

As for graph D, which refers to the green mass of the shoot, we have a low green mass of the shoot in treatments 1, 3 and 4 and a high green mass of the shoot in treatment 2, resulting in a higher yield at the dose 40 kg ha⁻¹. The MET point is 48.45 kg ha⁻¹.

Figure 2 presents the results for the variables Root Length (in centimeters), Green Root Mass, Shoot Dry Mass and Root Dry Mass (all masses are in grams). These parameters are indicators of the effect of nitrogen on both root and shoot growth, providing a holistic approach to species performance in varied fertilization contexts.

Figure 2: Growth of *Canafistula* seedlings, grown in pots with different doses of nitrogen. A) Root length (cm); B) Green root mass (g); C) Shoot dry mass (g) and D) Root dry mass (g)



Source: Prepared by the authors (2023)

Specifically in the T1 treatment, there was no maximum expression of the culture due to the fact that there was no application of nitrogen, phosphorus and potassium. In this way, *Canafistula* obtained a low development, resulting in low height of the aerial part, a smaller number of leaves as well as a smaller diameter of the stem and lower dry mass and green mass of the root and aerial part.

In the T2 treatment, although it was not the highest dose, it was possible to observe a more vigorous development of *Canafistula*, with successive progress each week. It should be noted that *Canafistula* can take advantage of almost or all the full dose observed by the PMET in figures 1 and 2. For a better understanding, the dose used in this treatment was 40 kg.ha⁻¹, however in some variables it was observed that the plant would better use a dose above 40 kg.ha⁻¹, which is the case of the green mass of the root (Figure 2, B). However, the opposite occurred, where *Canafistula* would

better use a dose below 40 kg.ha⁻¹, which is the example of root length (Figure 2, A). This value is of great value because it is possible to measure a dose more accurately without wasting nitrogen application.

In the T3 treatment, where the highest dose was applied, it was observed that Canafistula absorbed excess N and unbalanced the metabolism resulting in a lower growth, as it was a high dose, which resulted in waste, therefore not recommended. As an example, there was a gradual decrease in the nitrogen dose of 80 kg.ha⁻¹. A valid hypothesis for this treatment would be to divide the dose in two, avoiding the imbalance of the plant's metabolism.

In the T4 treatment, it was considered as zero since it was not possible for the culture to remain until the end of the experiment, in other words, there was plant toxicity due to the high dose of nitrogen, which resulted in Senescence of the Canafistula. For this reason, the chart shows the lowest growth.

Cruz et al. (2011) who analyzed the growth and quality of Fedegoso seedlings grown in a red-yellow latosol in response to macronutrients also found low growth averages in all the attributes examined, in the treatment without added nutrients, which shows that the macronutrient contents preliminarily present in the soil used as substrate to produce Fedegoso seedlings are low. Even with small plant growth averages, which can be explained by Liebig's Minimum law, where plant development is limited by the nutrient that has the least availability in the soil, even if the others are at higher levels for plants. Thus explaining the reason why treatment 1 was not the best since there was no application of any of the nutrients limiting its development. It should also be remembered that the lower value found in the PMET in root length that obtained a non-significant result in root dry mass (Figure 2), it is concluded that this is due to the vessels that limit root growth and can influence the variable in relation to nitrogen doses.

In relation to Treatment 4, which obtained the highest dose of N, it was observed that it exceeded the critical dose because the crop presented nitrogen toxicity resulting in senescence of the treatment, it was concluded that this treatment was the most severe for the crop because it presented burning of edges and tips of leaves, wilting of them, among others. The critical dose for a certain nutrient is defined by some authors as that recommended to be applied to the substrate and below in which the production of a certain species is significantly limited (Cruz, 2007). In view of this result, we can assess that Treatment 2 would be the critical dose for the species, since it was the dose of nitrogen where the species was able to receive, being the recommended dose to be applied to the substrate and below the dose where the plant is sensibly limited. If we use the dose of treatment 3 for the purpose of seedling production, it would be a waste of nitrogen because the growth decreased due to the fact that the excess of N interfered in the physiology of the plant resulting in lower growth, a

fact observed by the PMET that demonstrated that treatment 2 that there was no application in excess of N resulting in growth without interference in the physiology of the plant.

The absence of nitrogen verified by Venturin et al. (1999), who cultivated seedlings of *Peltophorum dubium* (Angico-amarelo) in a Red Yellow Latosol with low nutrient availability, promoted a development deficit in height and diameter, as well as a deficit in the production of dry matter of shoots and root system. It was also concluded by the same authors that the species used indicates high nutritional requirement for N. This confirms the values of the PMET in figures 1 and 2 when referring to the diameter of the stem and height of the aerial part, being one of the lowest values, behind only the length of the root and the number of leaves. On the other hand, Braga et al. (1995) analyzed that seedlings of *Aspidosperma polyneuron* (peroba rosa) cultivated with the absence of nitrogen did not obtain influenced height development, a result that differs from that observed in Angico-amarelo in relation to this same growth trait. It was also highlighted that peroba rosa did not exhibit high nutritional requirement in nitrogen.

According to Massad et. al (2021) in its production of baru seedlings under different volumes of tubes and doses of osmocote that coincidentally are also part of the Fabaceae family where the height of the aerial part, the diameter of the stem, the dry mass of the aerial part, the dry mass of the root and total dry mass were evaluated, it was observed that there was a significant effect between the factors evaluated, in this case, tube volumes and osmocote doses, for the variables height, shoot dry mass, root dry mass, total dry mass and Dickson Quality Index (DQI) of baru seedlings at 120 days of age. In the same work there was a point of maximum technical efficiency where the response was quadratic for the variables height, shoot dry mass, root dry mass, total dry mass and DQI. Proving that in seedlings of the same family there are satisfactory responses regarding development, when the maximum level of technical efficiency is not exceeded. When exceeded, it is perceived that there may be a reduction in the means of the variables, as reported in the higher doses of Osmocote in the aforementioned study and as occurred in the experiment with Canafístula.

Therefore, high or low doses of nitrogen are avoided, or even any other fertilizer used, as they result in a nutritional imbalance of the plant, which can harm or even make it impossible for them to grow in pots or in the case of nurseries, influencing their survival later in the field, after planting. Highlighting the importance of more specific studies in order to improve plant development and improve the use of the fertilization technique, as well as efficient use without economic losses to users, facilitating access to information and making a more standardized recommendation or at least with a scientific basis.

FINAL CONSIDERATIONS

From the results obtained in this research, the effect of different nitrogen doses on *Canafistula* growth was determined, including variables such as stem diameter, number of leaves, shoot height, shoot mass, root length and root mass. Thus, it was perceived that a plant was highly responsive to nitrogen availability, since the results obtained from the analysis of variance had a significant effect for all variables except root dry mass.

The point of maximum technical efficiency for each of the response variables was identified, understanding the ideal behavior of the plant in relation to nitrogen fertilization, realizing that the best treatment according to the MET point is at the dose 40 kg.ha⁻¹. In the other treatments, as in the case of T1, there was a low response of the plant due to the non-application of nutrients. On the other hand, excessive N applications, which was the case of T3, resulted in a nutritional imbalance of the plant, resulting in lower growth. Applications above 80 kg.ha⁻¹ plant senescence was perceived referring to T4.

The use of this nutrient was optimized and the critical dose of nitrogen that *Canafistula* can receive without limitations was established, being then T2 because it is the recommended dose in which the plant was able to receive. However, in a future study it would be interesting to carry out an experiment increasing the number of treatments and decreasing the amount between doses, applying 5 treatments, such as 0, 20, 40, 60 and 80 kg.ha⁻¹.

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Artificial Intelligence in Agricultural Management: Use of Random Forest Models for the Prediction of Seed Production and Reservation in Brazil

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ABSTRACT

This study addresses the application of Artificial Intelligence (AI) models, more specifically random forest, for the prediction of seed production and reserve in Brazilian agriculture. The main objective is to contribute to the advancement of resource management and planning, a critical action to increase the efficiency and sustainability of the sector. The work is highlighted by the importance of understanding the role of AI in optimizing agricultural practices, providing a framework for future research at the intersection between AI technologies and agriculture. Methodologically, the study implemented a rigorous data collection and processing process provided by the Ministry of Agriculture and Livestock of Brazil, covering the harvests from 2016/2017 to 2023/2024. Data cleansing preceded the transformation of categorical variables through one-hot coding and subsequent splitting of the dataset into 80% for training and 20% for testing. Using the scikit-learn library, a random forest model was configured and evaluated, employing validation techniques such as training/test split and cross-validation, in addition to mean square error (MSE) and coefficient of determination (R^2) metrics to measure the accuracy and effectiveness of the model. The results indicate a moderate to strong positive correlation between the variables of time and number of seeds reserved for both growing periods, Safra and Safrinha. However, the analyses pointed to annual variability and differentiated confidence in predictions between periods, suggesting the influence of additional factors and the need for adaptive models. The concentration of production in a few cultures was identified as a potential risk, suggesting that diversification is key to the resilience of the sector. The generalizability of the model was evaluated, and the phenomenon of overfitting was considered a possibility given the variations in accuracy between the training and test data. This study reinforces the transformative potential that AI models, such as the random forest, possess for agricultural prediction and management, opening doors for future improvements and providing valuable subsidies for data-driven strategic decisions in the agricultural sector.

Keywords: Artificial Intelligence in Agriculture, Random Forest Models, Seed Production Prediction, Sustainable Agricultural Management, Agricultural Data Analysis.

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INTRODUCTION

Agriculture is facing increasing challenges due to demands for efficiency and sustainability. This study addresses the importance of Artificial Intelligence (AI) in the prediction of seed production, crucial for planning and resource management in the agricultural sector. We focused on the development and evaluation of an AI model based on random forest, with the aim of improving decision-making practices and operational efficiency in agriculture.

The growing need for optimization in agricultural production and resource management has driven the adoption of advanced technologies, such as Artificial Intelligence (AI). In this context, seed production prediction emerges as a vital field of study, offering valuable insights for agricultural planning and the sustainability of the sector. The present work explores the application of AI models, specifically random forest algorithms, to forecast seed production, in order to improve resource control and management in agriculture.

The scientific importance of this study lies in its contribution to the understanding of how AI models can be applied to improve agricultural efficiency and productivity, as well as providing a framework for future research at the intersection between AI and agriculture. The integration of AI in agriculture, especially for seed production prediction, has the potential to transform resource management and decision-making in the sector. This study demonstrates the feasibility and value of using random forest models for this purpose, highlighting the importance of such approaches for future advances in sustainable and efficient agriculture.

This study has the general objective of developing and evaluating an Artificial Intelligence model based on random forest techniques, aimed at predicting seed production and reserve in the agricultural context. We aspire to contribute significantly to the improvement of resource management and planning in the sector, a prevailing need for increasing agricultural efficiency and sustainability. The study aims not only to improve strategic planning and effectiveness in resource management, but also to boost accuracy and sustainability in agriculture, providing fundamental guidelines for the development of advanced management and planning strategies in the agricultural sector.

In specific terms, the study seeks to: (1) employ a multifaceted analysis of seed production and reserve patterns in Brazilian agriculture using statistical techniques, including timeline plots, Pareto plots, scatter plots, linear regression, and analytical tables; (2) to investigate the applicability and effectiveness of the random forest algorithm, used in this work, for the modeling and prediction of seed production, to evaluate the performance of the model in terms of accuracy, efficiency and generalizability, and to examine the extent to which predictions based on Artificial Intelligence contribute to optimize planning and resource control in agriculture.

These objectives seek to synthesize the practical and theoretical relevance of Artificial Intelligence models, with emphasis on random forests, in the analysis and interpretation of seed production and reserve patterns, highlighting their applicability to elucidate trends, identify variations and discern critical factors that influence these dynamics.

THEORETICAL FRAMEWORK

The literature review contemplates a series of previous research that explores the application of Artificial Intelligence (AI) in agriculture, particularly emphasizing the use of machine learning methods, such as random forests, in the context of production prediction. This review synthesizes both the significant contributions to technological advancement in the sector and specific studies demonstrating the effectiveness of these techniques.

In the field of technological contributions and advances, Vieira Filho and Silveira (2012) discuss innovation in agriculture, underlining the complexity of the sector and the cruciality of technological knowledge and learning for its development. They argue that innovation is an essential catalyst for improving agricultural practices and for the sustainability of production. Adama Brazil (2024) and Climate FieldView (2023) expand on this discussion by addressing the fundamental importance of AI in the modernization of agriculture. These sources illuminate specific applications of AI, such as remote sensing and the analysis of large volumes of data in real time, which have transformed the ability to monitor and manage agriculture. Rehagro (2022) complements this vision, highlighting the virtues of AI in the monitoring and optimization of agriculture, emphasizing its role in promoting sustainable practices and in increasing operational efficiency in the field.

In terms of specific studies, research carried out by Mourtzinis et al. (2021), Saleem, Potgieter, and Arif (2021), and Gadotti et al. (2022) shows the applicability and efficiency of machine learning techniques in the agricultural sector. These studies provide robust evidence of the superiority of methods such as random forests and deep learning in performing specific predictive tasks, pointing to markedly superior performance compared to more traditional statistical modelling techniques. They emphasize the relevance of AI-based approaches as highly competent predictive tools, capable of handling the complexity of agricultural data and producing accurate predictions, which are critical for planning and informed decision-making in the sector.

Therefore, the literature reviewed underscores the steady progression and potential impact of AI on agriculture, indicating a promising horizon for the continued integration of these advanced technologies into contemporary agricultural practices. These advances not only corroborate the position of AI as an essential pillar in agricultural modernization, but also endorse the need for continued research to fully explore the capabilities and benefits of random forests and machine learning in agricultural prediction.

METHODOLOGY

The methodology used to create a "random forest" model aims to estimate the amount of seeds that will be produced and reserved in agriculture. It is a method that uses computing and statistics to analyze data on past agricultural production, in order to make reliable predictions about the amount of seed reserve that will be generated in the future. This process helps farmers and managers to better plan their activities, anticipating the need for seeds and optimizing resources for more efficient and sustainable production. Using data provided by the Ministry of Agriculture and Livestock of Brazil, this study implements a rigorous approach, from data collection to processing, culminating in the development of a robust model for predictive analytics.

This study takes a quantitative approach, using historical seed production data to develop a random forest model. The effectiveness of the model is evaluated using statistical metrics, including mean square error (MSE) and coefficient of determination (R^2).

STUDY DESIGN

The study was designed to apply the random forest model, known for its ability to process large data sets and avoid overfitting. The objective was to evaluate the effectiveness of this model in predicting seed production, incorporating variables such as period, region, seed species, and planted area.

DATA COLLECTION

The data was obtained from the Inspection Management System of the Ministry of Agriculture and Livestock of Brazil, covering detailed information from the 2016/2017 harvest to 2023/2024. The exclusion of data prior to 2016/2017 was necessary due to identified inconsistencies.

DATA PREPARATION

The preparation included cleaning and transforming the data, adopting techniques such as one-hot coding for categorical variables. The division of the data into training and test sets followed the standard 80/20 ratio.

DEVELOPMENT OF THE MODEL

The random forest model was implemented in Python, using the scikit-learn library. The selection of hyperparameters was based on standard practices, considering the balance between performance and compute time.

IMPLEMENTATION AND EVALUATION OF THE RANDOM FOREST MODEL

The methodology used in the implementation and evaluation of the random forest model is detailed, reflecting the various stages necessary for the prediction analysis of seed production in agriculture. This methodology is structured to allow for a detailed and judicious future analysis of the model's results.

In the training phase, critical procedures were carried out, starting with the initial preparation of the data, where coding techniques were applied to adapt the categorical variables to the numerical format required by the model:

```
from sklearn.preprocessing import OneHotEncoder
# One-Hot coding of categorical variables
encoder = OneHotEncoder(sparse=False)
X_encoded = encoder.fit_transform(X[['UF', 'Seed Species']])
```

The data were then divided into training and test sets, with 80% going to training and 20% to testing, essential for subsequent evaluation of the model's ability to generalize to new data:

```
from sklearn.model_selection import train_test_split
# Splitting the data into training and testing
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

With the data prepared, the construction of the random forest model was carried out using the scikit-learn library, configuring hyperparameters such as the number of trees in the model:

```
from sklearn.ensemble import RandomForestRegressor
# Random forest model construction
model = RandomForestRegressor(n_estimators=100, random_state=42)
model.fit(X_train, y_train)
```

To ensure the reliability of the model's predictions, a rigorous validation strategy was implemented, using not only the training/test split but also cross-validation to provide a more robust evaluation:

```
from sklearn.model_selection import cross_val_score
# Cross-validation application
scores = cross_val_score(model, X, y, cv=5)
```

The evaluation criteria included metrics such as the Mean Square Error (MSE) and the Coefficient of Determination (R^2), fundamental to measure the effectiveness and accuracy of the model:

```
from sklearn.metrics import mean_squared_error, r2_score
# Evaluating the model in the test data
y_pred = model.predict(X_test)
mse = mean_squared_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)
```

These methodological steps ensure that the model is well adjusted to the data, making it possible to make reliable and accurate predictions. The generalizability of the model was evaluated through the performance comparison between the training and test sets, crucial to detect overfit or underfit.

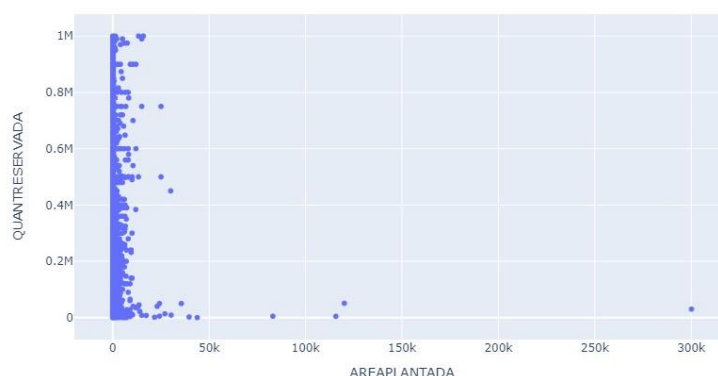
RESULTS AND DISCUSSIONS

ANALYSIS AND INTERPRETATION OF SEED PRODUCTION AND RESERVE PATTERNS

We will examine the patterns of seed production and reserve in Brazilian agriculture, using a random forest model to interpret complex and multifaceted data. The analysis of two different phases of cultivation - the Safra and the Safrinha - and the comparison of the performance of the model in each one are highlighted. The interpretation of graphs and tables provides deep insights into the dynamics of the sector, crucial for the development of effective strategies in agricultural management.

Graph 1 below shows the complex relationship between the area planted and the amount of seeds reserved, not demonstrating a clear direct correlation. Table 1 complements this analysis, detailing the distribution of reserved seeds among the main agricultural crops, indicating a significant concentration in a few species.

Graph 1 - Relationship between Planted Area and Reserved Quantity



Source: The author.

Figure 1 provides an analysis of the relationship between 'Planted Area' and 'Reserved Quantity' in the context of reserved seed production in Brazil, based on SIGEF data. Research focuses on discerning the overall trend, identifying patterns, and highlighting outliers. It is noted that

the graph does not reveal an obvious linear correlation between 'Planted Area' and 'Reserved Quantity', with most of the data grouped at the lower end of 'Planted Area', without demonstrating a proportional increase in 'Reserved Quantity' as 'Planted Area' increases. Such an arrangement suggests the absence of a direct and robust relationship between these variables.

In addition, the analysis highlights the presence of outliers, particularly where the 'Reserved Amount' remains elevated regardless of the 'Planted Area', pointing out possible exceptions that could be attributed to factors such as high productivity per area or external variables not captured by the graph. The Pearson correlation, close to 0.0973, indicates a very weak, almost negligible association, corroborating the lack of a strong connection between the variables analyzed.

This study concludes that the 'Planted Area' does not serve as a reliable predictor of the 'Reserved Quantity', inferring that other variables not considered here, such as efficiency in seed production, soil conditions, agronomic and climatic practices, may exert more significant influences. The low correlation reinforces the need for a more integrated and multifactorial approach to understanding the dynamics of seed production, implying that future analyses must incorporate a wider range of data and analytical methodologies to capture the complexity of the seed sector in Brazil.

Table 1: Percentage Analysis of Seeds Reserved for Major Agricultural Species in Brazil

SPECIES	HOW MUCH RESERVED	%	% Accumulated
<i>Glycine max</i> (L.) Merr. (SOJA)	3749435500,4430	66,2562	66,2562
<i>Triticum aestivum</i> L. (TRIGO)	877409998,2770	15,5047	81,7608
<i>Solanum tuberosum</i> L. (BATATA)	779113570,3830	13,7677	95,5285

Source: Prepared by the authors

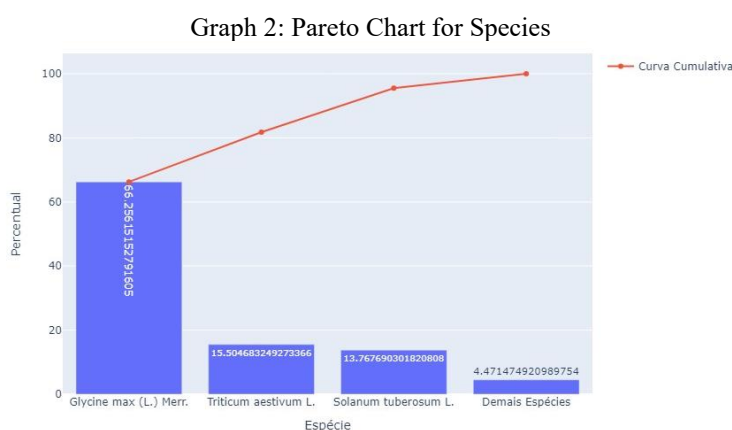
Table 1 provides a quantitative analysis of the seed reserve of three main crops in Brazilian agribusiness, highlighting the predominance of soybeans, wheat and potatoes in the national agricultural spectrum. Specifically, soybeans, *Glycine max* (L.) Merr., stand out significantly, comprising more than two-thirds of the total reserves, emphasizing its central position in Brazil's agricultural and economic structure. The relevance of wheat, *Triticum aestivum* L., and potato, *Solanum tuberosum* L., is also remarkable, underlining their essential contributions to food security and agricultural diversification.

These data point to a concentration of agricultural activity in a few cultures, which, although economically beneficial, introduce risks associated with dependence and lack of variety, emphasizing the importance of diversification strategies. The expressive productive concentration in these species, responsible for more than 95% of the total seeds reserved, shows a duality between economic strength and potential vulnerability to adversities, such as market fluctuations or adverse climatic events.

From this perspective, Table 1 goes beyond the mere presentation of data, functioning as a critical instrument for reflection on agricultural policies. The analysis underscores the urgent need to incentivize crop diversification and adopt sustainable agricultural practices, aiming not only at economic robustness but also at Brazil's resilience and food security. Thus, the study of these data becomes essential for the development of policies that balance production, sustainability and food security in the Brazilian agricultural context.

COMPARATIVE ANALYSIS: SAFRA VS. SAFRINHA

Comparing "Data_Safra" and "Data_Safrinha" reveals marked differences in model performance. "Graph 2: Pareto Graph for Species" and "Graph 3: Sum of Reserved Amount of Seeds by Period" illustrate these variations, showing how seed production responds to different factors and conditions in each crop cycle.

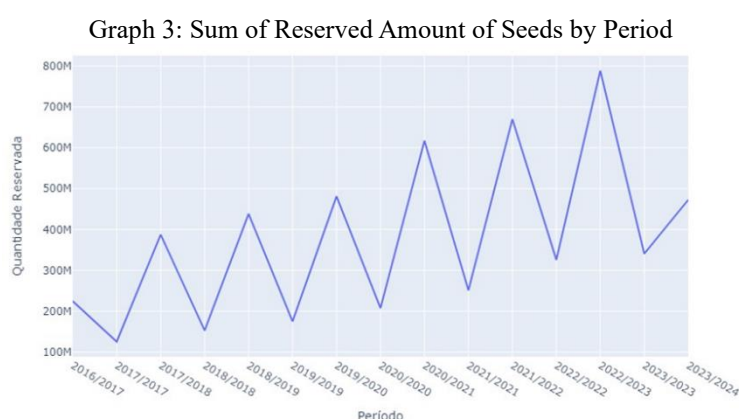


Source: The authors.

In the presentation of the results presented in Table 1, the use of the Pareto graph emerges as an outstanding analytical strategy to elucidate the distribution of seeds among the main agricultural crops in Brazil. This graph is recognized for its ability to visually represent the predominance of certain factors, in this context, specific crop varieties, in contributing significantly to a comprehensive outcome, here being the aggregate of the reserved seeds. The use of this graph is based on its ability to demonstrate the Pareto Principle, or 80/20 rule, elucidating that a smaller segment of causes tends to be responsible for most of the observed results.

The Pareto Chart, identified as Figure 2, is established as an essential visual mechanism to analyze and discuss the allocation and repercussions of the seed reserve in the Brazilian agricultural sector. This instrument facilitates the recognition of areas that demand priority attention for future interventions and research, seeking a detailed understanding of the current configuration of the seed reserve in the country's agriculture, in addition to clarifying market forces and potentials for advances in the domain.

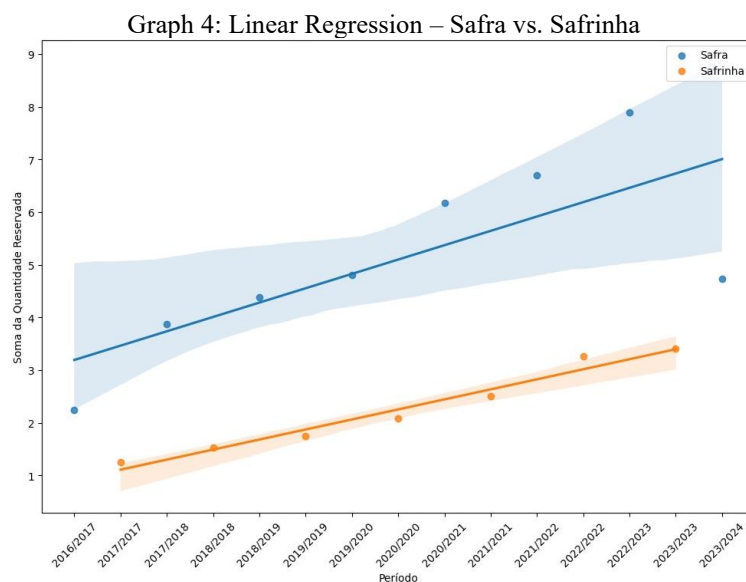
Specifically, the Pareto Chart highlights the preeminent role of crops such as soybeans, wheat, and potatoes in the Brazilian seed production landscape, bringing substantial implications for agricultural policymaking, strategy delineation, and sustainability-oriented ventures. This analysis indicates the importance of adopting a balanced approach that not only enhances the efficient and organic production of these key cultures but also encourages agronomic diversification to strengthen the resilience and adaptability of the sector. The emphasis on soybeans, which represents a significant portion of production according to the data, suggests that policy measures could be directed to expand this culture, investing in areas such as research, genetic improvement and logistics infrastructure, having a positive impact on national agricultural development.



Source: Prepared by the authors

Figure 3 provides a longitudinal analysis of seed stock in Brazilian agriculture from 2016 to 2024, revealing a pattern of significant fluctuations that reflect the dynamics of the agricultural sector. There is no uniform trend of growth or decline in reserves over the years studied; Instead, annual changes point to a response by the sector to a diversified set of influences, including environmental, economic, and market factors. Periods such as 2019/2020 and 2022/2023 are distinguished by peaks in seed stock, possibly indicating years of abundance or response to increases in demand. In contrast, the decline observed in 2023/2024 may denote adversities faced by the sector.

The study also differentiates the "Safrá" and "Safrinha" crop cycles, highlighting the influence of climatic conditions and planting strategies on production. Safrá, the main growing period, benefits from ideal climatic conditions and has high productivity, while Safrinha, despite less favourable conditions and traditionally lower productivity, represents a crucial stage for the sustainability and continuity of agricultural production. These observations underscore the adaptation capacity and resilience of the Brazilian agricultural sector to intermittent variables, providing a basis for an in-depth understanding of management and decision-making strategies in the context of domestic seed production.



Source: Prepared by the authors

Figure 4 illustrates the temporal relationship between the growing seasons, Safra and Safrinha, and the sum of the reserved quantities of seeds in the context of Brazilian agriculture. The blue line, representing the Safra, and the orange line, representing the Safrinha, are the results of a linear regression that seeks to estimate the central trend of the data for each period. The shaded areas correspond to the confidence intervals for each regression, which indicate the degree of uncertainty associated with the model's predictions.

The wider shaded area around the Safra regression line suggests greater variability and less confidence in seed reserve predictions for this period. This implies that additional factors, potentially not captured by the model, may be influencing seed stocks beyond time, such as climatic variations, agricultural policies, or economic changes. Meanwhile, the narrower shaded area around the Safrinha regression line implies greater accuracy in predictions, suggesting that the amount of seeds reserved may be more consistently predicted based on time for that period.

The presence of points above or below the regression lines indicates the variability of the data in relation to the modeled trend, and those points can be considered outliers if they are outside the confidence interval. For example, if a data point is above the shaded area of the Safra, this may indicate a year when the seed stock was exceptionally high, possibly due to a particularly bumper harvest or policies to stimulate the seed stock.

Pearson's coefficient for each dataset quantifies the strength of the linear relationship between time and seed stocks. A Pearson coefficient of about 0.755 for Safra and about 0.983 for Safrinha indicates a strong positive correlation for both periods, with Safrinha showing a near-perfect relationship. However, the interpretation of the coefficient must consider the specific context and potential confounding factors that may affect seed stocks.

These statistical analyses provide fundamental insights into the dynamics of seed production and reserve, evidencing continuous growth in both phases, but with greater predictability and stability during Safrinha. Particular attention is paid to the anomalous behavior of the data in 2023/2024, which highlights the need for additional research to understand unexpected variations and their implications for farm management. The methodology employed reveals critical patterns and provides a solid foundation for strategic planning and informed decision-making in the agricultural sector.

Therefore, the statistical analysis in Figure 4 demonstrates the usefulness of quantitative methods such as linear regression and calculation of confidence intervals to understand the dynamics of agricultural production and to inform strategic decisions in the sector. The analysis suggests that, while there is a positive trend in the volume of seeds reserved over time for both growing periods, annual variability and confidence in predictions may differ substantially between Safra and Safrinha.

MODEL PERFORMANCE ANALYSIS

This chapter is dedicated to evaluating the effectiveness of the randomized forest model developed to predict seed production in Brazilian agriculture. This analysis is structured in three distinct subchapters, each focusing on different datasets and contexts to provide a comprehensive view of model performance.

In the first subchapter, "Seed Production Prediction: A Study on Data_Safra", we examine the model's performance using the specific data of the main crop, focusing on the accuracy of the predictions and the model's ability to conform to the historical data of this critical period.

The second subchapter, "Seed Production Prediction: A Study on Data_Safrinha", discusses the model's predictions for safrinha, a secondary but equally significant growing period, highlighting the peculiarities and specific modeling challenges for this crop cycle.

Finally, in the third subchapter, "Seed Production Predictions: An Analysis between 'Data_Safra' and 'Data_Safrinha'", we made a direct comparison of the model's performance between the two growing periods. This comparison seeks to understand the variations and consistency of the model in different agricultural contexts, contributing to a deeper understanding of the effectiveness of Artificial Intelligence techniques in predicting variable dynamics in the agricultural sector.

Each subchapter contributes to a detailed understanding of how the random forest model adapts and responds to the complexities of seed production, providing valuable insights for future applications and improvements in the field of precision agriculture.

Seed Production Prediction: A Study on 'data_safra'

The analysis of the regression model using the 'data_safra' subset of data, drawn from a larger set, provides a quantitative and qualitative view of the effectiveness of seed production predictions. The metrics obtained — Mean Square Error (MSE) and Coefficient of Determination (R^2) — are essential to evaluate the random forest model adopted in this research.

The Mean Square Error (MSE) metric for the overall and test sets is significant, indicating a noticeable discrepancy between the predicted and actual values. The model's accuracy for new data is therefore lower, as illustrated by the MSE of about 2,833,804,168.5. This high number shows the limitations of the model in predicting new events, a critical aspect in predictive modeling.

On the other hand, the MSE for the training set shows a more promising performance, with a substantially lower value of 1,653,458,753.5. This difference highlights a greater accuracy of the model under the conditions under which it was trained, an expected result and indicative of an appropriate fit to the training data.

As for the Coefficient of Determination (R^2), the values for the test and training sets reveal a significant disparity. For the test set, the R^2 of 0.4149566274957277 implies that only about 41.5% of the variance is explained by the model. Although it indicates a predictive capacity, it also suggests that factors not contemplated in the model have a significant role. For the training set, the R^2 is 0.6544389740961896, revealing that the model manages to explain approximately 65.44% of the variance, demonstrating a reasonable fit to the data used for training.

This variation between the training and test sets, particularly a test success rate of 63.41%, suggests a phenomenon known as overfitting. This occurs when the model learns the particularities of the training data to such an extent that it fails to generalize its predictions to new data, limiting its practical usefulness. This finding suggests the need for a more refined balance between the fit of the model and its generalizability.

Seed Production Prediction: A Study on 'data_safrinha'

The study in question uses the 'data_safrinha' subset of a larger DataFrame to model and evaluate predictions about seed production, using a random forest model. The metrics resulting from the analysis, Mean Square Error (MSE) and Coefficient of Determination (R^2), are vital tools for the performance of the predictive model.

The Mean Square Error (MSE) arises as an indicator of the mean of the squared errors, that is, the differences between the model's predictions and the actual values observed. A high MSE, such as the one obtained for both the general and test sets, with a value around 3,113,846,766.768054, indicates a considerable magnitude of error in the predictions for the new data, pointing to an area of attention and potential improvement in the accuracy of the model. However, the MSE obtained for

the training set is substantially lower, evidencing a more accurate performance in the predictions with a value of 1,386,346,989.5445054.

When analyzing the Coefficient of Determination (R^2 Score), which reflects the proportion of variance in the dependent variable that is explained by the independent variables in the model, we notice a marked distinction between the test and training sets. An R^2 of 0.7183833224143992 for the test set indicates that approximately 71.84% of the variance is captured by the model, a considerable value that attests to the model's effectiveness in explaining the data. This percentage increases for the training set, where the R^2 achieves a robust 0.8676384019256064, suggesting that the model fits well with the training data.

However, the difference between the training and test metrics reveals that, although the model shows efficiency in learning the patterns in the training data, as indicated by a relatively high training R^2 , it does not maintain the same level of accuracy when applied to new data, a discrepancy that signals the presence of overfitting.

These results, together with the Percentage of Success of the Test in Relation to Training of 82.80%, highlight the need for further research and fine-tuning of the model to improve its generalization and predictive capacity. Despite the areas for improvement, the random forest model is presented as a robust and promising approach to address the complexity of data in agriculture, with the potential to significantly improve the accuracy and effectiveness of agricultural resource planning and management.

Seed Production Predictions: An Analysis Between 'data_safra' and 'data_safrinha'

The data reveal that the performance of the model varies between the two periods, with a Coefficient of Determination (R^2) of 0.4149566274957277 for the "data_safra" and a considerably higher R^2 of 0.7183833224143992 for the "data_safrinha". The latter suggests that the random forest model manages to explain about 71.84% of the variability of the data for the safrinha period, a notable contrast with the lower percentage of about 41.5% for the safra period.

When analyzing the Mean Square Error (MSE), we notice that although the values are high for both datasets, the MSE of the "data_safrinha" is slightly higher, which could suggest a greater discrepancy in the predictions for this period. However, it is essential to consider this data together with R^2 , which tells us a different story, indicating a better predictive capacity for safrinha.

More notable is the discrepancy between the training and test results for each dataset. The "data_safra" shows a more significant difference, an indicator that can signal an overfit of the model to the training data, reducing its effectiveness in generalizing to unseen data. On the other hand, the "data_safrinha" shows a smaller discrepancy between the training and test results, reflecting a better

generalization and a strong linear correlation between the variables, as indicated by the high Pearson coefficient of 0.9829378120964237.

This strong correlation for the "data_safrinha" reaffirms the ability of the random forest model to capture data trends, allowing accurate and reliable predictions for this period. The model not only achieves superior performance in predicting safrinha data, but also reveals the ability of AI algorithms to adapt and learn efficiently from consistent and strongly linear patterns.

The comparative data from the "data_safrinha" and "data_safrinha" sets illustrate that success in predictive modelling depends significantly on the nature and quality of the input data. The differences between the two periods reinforce the importance of adjusting predictive models according to the specific characteristics of each seed production cycle. The analysis underlines the need for a careful and contextualized approach in the application of modelling techniques, with the aim of maximising the effectiveness of predictions, essential for agricultural planning and management.

CONCLUSIONS OF THE STUDY

This detailed study, articulating the use of random forest models, outlines a detailed picture of the dynamics of seed production and reserve in the Brazilian agricultural context, offering a solid basis for future decision-making strategies in the sector. The research underscores the intrinsic complexity of agricultural practices in the country, illuminating the variations between distinct crop cycles and diversified regions. With an analytical and statistical perspective, the study maps the interaction between a myriad of determining factors, emphasizing their interconnectivity and mutual influence.

The implementation of the random forest model proved its analytical capabilities, efficiently managing the wide range of industry data and extracting patterns that lead to reliable predictions. Although the variations in the accuracy of the predictions between the Safra and Safrinha cycles have been significant, the application of the model highlighted the adaptability needed to accommodate these fluctuations, a key aspect for predictive modelling in agriculture.

The concentration of production in a limited number of crops emerges as a double facet, representing both an economic strength and a point of vulnerability to market fluctuations and climate changes. The study therefore highlights the critical importance of promoting diversification as a pillar to strengthen the resilience and sustainability of the sector. Agricultural management strategies based on robust data are identified as essential to respond effectively to the dynamics described, implying the need for judicious adjustments in cultivation practices and harvest planning.

The work also points to the need for more incisive future research, which can reveal even more deeply the relationships between the variables that affect agricultural production and refine the

predictive models used. The research opens up perspectives for the integration of climate, economic and agronomic data in a multidisciplinary approach, with the aim of improving the predictive capacity and management of the sector.

By providing valuable contributions to both the scientific literature and agricultural practice, the study supports farmers, managers and policymakers in making informed and evidence-supported decisions. In sum, the present study has not only clarified the complex seed production configurations in Brazil, but has also ratified the relevance and effectiveness of random forest models, representing a notable advance at the intersection between data science and agriculture.

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Pathogenic microorganisms present in contaminated water

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ABSTRACT

Millions of people in the world live without access to good quality water. According to UNICEF (United Nations Children's Fund), less than half of the world's population has access to drinking water. UNICEF data reveal that 35% of the world's population does not have good quality water and 1 (one) in 3 (three) people does not have access to drinking water. The inequality of access to water, the lack of investments in basic sanitation and the lack of hygiene conditions result in millions of deaths in the world from waterborne diseases. In Brazil, according to an estimate by the WHO (World Health Organization) is that 15 thousand people die per year from diseases related to the precariousness of basic sanitation (UNICEF, 2019). In view of the context of mortality due to diseases caused by contaminated water, this work aims to present the pathogenic microorganisms present in contaminated water and, through a literature review, describe the diseases, how they manifest themselves from contamination.

Keywords: Sanitation, Contaminated water, Pathogens.

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INTRODUCTION

The relationship between water quality and public health has been a topic of research for decades. Polluted waters are potential environments for the transmission of diseases due to toxic substances accompanied by pathogens. It is inferred that all contaminated water is polluted, but not all polluted water is contaminated (SANTOS, 2023). However, it is essential to differentiate the terms pollution and contamination when discussing water quality.

In the world, more than 1 billion people have problems with access to drinking water and 2.4 billion do not have basic sanitation. Lack of access to good quality water and sanitation results in hundreds of millions of cases of waterborne diseases and more than five million deaths each year. It is estimated that between 10,000 and 20,000 children die from waterborne diseases (IETC 2001; UNESCO, 2003)

Water quality is defined by a conglomerate of factors and indicators that serve to describe its physical and chemical properties, and biological systems, not to mention its main chemical constituents, which compose it (JOÃO, 2020). According to Toledo *et al.* (2002, FLORENTINO 2021 apud; RIOS, 2021), the use of these indicators consists of the use of variables that correlate with the changes that occur in the microbasin, whether of anthropogenic or natural origins. The concept of water quality is relative, since it is based on the objectivity of the user, or the purpose for which the water is intended (PAULOS, 2008, p.28).

Porto (2012, p. 159) considers that the main impacts that interfere with water quality are related to changes in land use and occupation, which has a strong interference in the silting of rivers, deterioration of water quality and waterborne diseases.

The water used in irrigation usually comes from rivers, streams, lakes or wells adjacent to cultivated areas, and the use of public water supply is rare, mainly due to its high cost. As this water collected does not undergo prior treatment, it can become a potential source of contamination for the vegetable to be irrigated (MDLULI; THAMAGA-CHITJA; SCHMIDT, 2013).

Researchers play a crucial role in identifying the pathogenic microorganisms found in contaminated water. Therefore, it is correct to say that his findings are of great importance for the diagnosis and treatment of diseases associated with contaminated water.

THEORETICAL FOUNDATION

Water contamination by microbiological agents represents a significant concern for public health worldwide, including *enterobacteria*, which are found in the human gastrointestinal tract, animal kingdom, water, soil and plants. Its presence in waters contaminated by urban sewage is pointed out as a bioindicator of fecal contamination. Biological indicators are specific to certain types of impact, as numerous species are proven to be sensitive to one type of pollutant but tolerant

to others. However, no indicator is effectively perfect, taking into account a series of factors such as the class of water bodies, water characteristics (fresh, saline water), climate (temperate, tropical) and the economic factor (DUARTE, 2011).

Schistosomiasis mansoni is a waterborne disease transmitted by snails of the genus *Biomphalaria* that are contaminated by *Schistosoma mansoni* larvae when people infected by the parasite throw their waste containing worm eggs into aquatic environments inhabited by these mollusks (BRASIL, 2024).

Viruses and bacteria have very high resistance in the soil and especially in water, they can cause epidemics if they actually reach the underground waterway. According to the World Health Organization – WHO (1998), the typical organisms present in the underground aquifer that cause diseases are *micrococcaceae*, *streptococc*, *bacilli* and *enterobacteria*.

Cemeteries can cause environmental pollution in the underground aquifers and soil of the region not only due to the toxicity of *the necroleachate* and the pathogenic microorganisms present (WHO, 1998). The waters affected by *the necroleachate* present microbiological contamination by *heterotrophic bacteria*, *proteolytic bacteria*, *sulfite-reducing clostridia*, *enterovirus* and *adenovirus*. There is also a large consumption of oxygen, due to biological decomposition and chemical transformations, especially of products with nitrogen, phosphorus, sulfur and others. The graves cause an increase in the amount of mineral salts, increasing the electrical conductivity of these waters. There seems to be an increase in the concentration of the major ions bicarbonate, chloride, sodium and calcium, and of the metals iron, aluminum, lead and zinc and other metals, there is also the presence of *very toxic diamines* that are made up of *putrescine*, *butanediamine*, *cadaverine*, *pentanediamine*, potent poisons for which no efficient antidotes are available. (MATOS, 2001)

The highly relevant research on groundwater contamination by cemeteries in Brazil was conducted by PACHECO *et al.* (1991), which investigated three cemeteries in the cities of São Paulo and Santos. The study found the presence of microorganisms in the water table, including *total coliforms*, *fecal coliforms*, *fecal streptococci*, *clostridia*, *reducing sulfite clostridia*, among others, originating from the decomposition of bodies buried in the soil. The risk of microbiological contamination associated with the construction of cemeteries in urban areas is considerable. Groundwater is particularly vulnerable to contamination by *viruses* and *bacteria*. Natural springs and shallow wells connected to contaminated aquifers can spread waterborne diseases such as tetanus, gas gangrene, foodborne toxiiinfection, tuberculosis, typhoid, paratyphoid fever, *hepatitis A*, among others. The presence of viral contaminant vectors was found in the water table miles away from the cemeteries (LOPES, 2001).

Contamination by petroleum products in groundwater is currently a large-scale problem, which causes impacts on the environment and the health of living beings, especially humans

(RODRÍGUEZ-MARTÍNEZ et. al, 2006). The growing need for spaces suitable for human occupation in densely urbanized areas requires technological advances in remediation processes to obtain effective results for minimizing environmental impacts. When properly applied, bioremediation is highly viable in aquifers in tropical environments. In soil and groundwater, a wide range of bacteria and fungi (*hydrocarbonclastic*) can use *hydrocarbons* as a carbon source for growth or other metabolic functions, producing carbon dioxide and water. In the environment, these microorganisms are the primary agents of the degradation of these organic compounds and the manipulation of the efficiency of this process is the basic principle of effective bioremediation projects, in these processes the bacteria *Pseudomonas stutzeri* are identified. *Brevundimonas* sp. and *Pseudomonas* sp. (LIN, 1996).

PATHOGENIC MICROORGANISMS

Coliforms - *Thermotolerant coliforms* are microorganisms capable of fermenting *lactose*, being represented mainly by *Escherichia coli*, and other bacteria. *E. coli* is exclusively of fecal origin, being present in high densities in human, mammalian and bird feces. All coliform bacteria are stained, gram-negative, non-sporulated stems that are associated with the feces of warm-blooded animals and with the soil (CETESB, 2022). Fecal coliforms, when found in water, confirm the discharge of domestic sewage without disinfection (NEITZEL; LINDNER, 2013). According to Derisio (2012), bacteria of the coliform group, such as *E. coli*, have been the main indicator when talking about contamination of fecal origin, however, their presence does not bring certainty as to the existence of pathogenic organisms, since they will only depend on the feces coming from beings carrying waterborne pathologies, which makes it an indicator of potential contamination. The presence of thermotolerant coliforms in the water is an indicator of pollution with feces of endothermic animals (VALIM, 2006). Among the risks of contamination, there is contact with recreation areas, where a mixture of pathogenic and non-pathogenic microorganisms is found (ALVES, 2007). The indicators generally used include total coliforms, fecal coliforms, *Escherichia coli* and *Enterococci* sp., as expressed by Tebaldi et al. (2018, apud SHIBATA, 2004).

Cyanobacteria - are also known as blue-green algae due to the combination of characteristics common to bacteria and algae, in addition, they are also photosynthetic prokaryotic. Most *cyanobacteria* are aerobic photoautotrophic microorganisms, that is, they need water, carbon dioxide, inorganic substances and light for their survival, performing photosynthesis and thus obtaining energy for their own metabolism (NASCIMENTO, 2010).

Regarding *cyanobacterial* blooms, these are the result of interactions between physical, chemical and biotic factors, which lead to an explosive characterization of growth, self-limiting and short-lived microorganisms of one or a few species. In this way, it often produces visible colorations

in water bodies, overcoming a barrier that prevents the penetration of light and, consequently, limits the reproduction and life of other living beings present in that place (GUIMARÃES et al., 2018).

The presence of several genera of *cyanobacteria* that form blooms and produce toxins, known as *cyanotoxins*, is noteworthy, representing a significant source of toxic products of natural origin. Although the exact causes of their production are not yet fully understood, the proliferation of these bacteria, often related to excess nutrients, results in the release of these toxins, which are potentially harmful to health, including as promoters of tumors. Cyanobacterial blooms also cause social, economic, and environmental impacts, affecting the aesthetics of water, its odor, and taste, especially when intended for public supply. In addition, specific genera of *cyanobacteria*, such as *Anabaena*, *Microcystis* and *Planktothrix*, with relevance to health and water contamination, are highlighted. In parallel, certain *sporogenic bacteria*, such as *Clostridium* and *Bacillus*, are highlighted as important human pathogens, including species such as *C. botulinum*, *C. perfringens* and *B. anthracis*, the latter feared for its potential as a biological weapon (FIGUEIREDO FILHO et al., 2008).

Viruses - It should be noted that the current legislation (BRASIL, 2004) indicates the inclusion of research on pathogenic organisms, *enteroviruses* and *Cryptosporidium* sp, as a complement to the analytical routines. Studies point out that viruses in particular can already be found in a large number of groundwater samples and that they are associated with reports of health problems in the community that uses these waters. Therefore, it is considered necessary to routinely evaluate these pathogens, to take fundamental measures for the health of the population, to control these occurrences and also to mitigate the respective compromise of groundwater reserves. (PIRANHA, PACHECO, 2004).

Protozoa - It is one of the several pathogenic microorganisms existing in water, with the possibility of contamination. Contamination of water resources by *pathogenic protozoa* has occurred all over the world (NETO et al., 2011).

Human contamination occurs when people use or come into contact with contaminated water. The process of water degradation is continuous and increasing due to the discharge of untreated or inadequately treated sewage, feces of wild or farmed animals and industrial effluents. Waterborne diseases, especially those caused by intestinal protozoa, have emerged as one of the main public health challenges (FRANCO, 2007).

Among the *protozoa*, *Giardia lamblia*, also known as *Giardia duodenalis* or *Giardia intestinalis*, a *flagellated protozoan* found throughout the world and commonly identified in fecal examinations, stands out. *Cryptosporidium parvum* also has a major impact on public health, being recognized as one of the leading causes of waterborne diseases in the United States according to the Division of Waterborne and Foodborne Diseases (DDTHA). The transmission of these *protozoa* occurs mainly by ingestion of contaminated water and by contact with aquatic environments

contaminated by feces of infected animals and/or humans. In addition, *Entamoeba histolytica*, responsible for *amoebiasis*, is another *relevant protozoan*, predominantly found in humans and primates (DDTHA, 2023).

Some of the major diseases that can be caused by contaminated standing water or untreated sewage water include:

Hepatitis A - is a disease caused by the *virus* of the *Picornavirus* family and can be transmitted through the ingestion of water, food and objects contaminated by the *virus*. This disease is highly contagious characterized by inflammation of the liver and, although it is usually mild, in some cases it can evolve in a severe form and be fatal when left untreated. The symptoms of *hepatitis A* usually appear about 4 weeks after contamination by the virus, with the main indications of *hepatitis A* being dark urine, pale stools, yellowing of the skin and mucous membranes, fever, chills, feeling weak, nausea, loss of appetite and fatigue. (PEREIRA, GONÇALVES, 2003).

Giardiasis - is an infection of the digestive system caused by the parasite *Giardia lamblia* whose transmission is made through the consumption of food or water contaminated by feces containing cysts of the parasite, being an infectious disease that can be transmitted between people. The main symptoms indicative of *giardiasis* are abdominal pain, diarrhea, fever, nausea, weakness, and weight loss. (BRAZIL 2024).

Amebiasis - or *amoebic dysentery* is an infection caused by the *protozoan Entamoeba histolytica*, which settles in the intestine and prevents the absorption of important nutrients for the body. Transmission happens through the consumption of food or water contaminated by feces containing *mature amoebic cysts*. The main symptoms are abdominal pain, diarrhea, fever and chills, in addition to bloody or mucus feces, in some more severe cases, the disease can develop the invasive form, in which other organs such as the liver, respiratory tract and even brain are infected (CORDEIRO, MACEDO, 2007).

Leptospirosis - is a disease caused by a bacterium that can be present in the urine of sewer rats, or other infected animals such as dogs and cats, which penetrates the body through the contact of the excrement of these animals or contaminated water with injured skin or mucous membranes, such as eyes, nose. The main symptoms of are high fever, headache, body ache, loss of appetite, vomiting, diarrhea and chills. (SANTOS, ASSIS, SILVA, ANGELIS, 2012).

Cholera - is an intestinal infection caused by the bacterium *Vibrio cholerae* that can contaminate water and food. The main symptoms include severe diarrhea and vomiting, which can lead to severe dehydration (OJEDA RODRIGUEZ and KAHWAJI, 2021).

Ascariasis (roundworm) - is a worm caused by the parasite *Ascaris lumbricoides*, develops and multiplies in the intestine. It is transmitted through ingestion of water or food contaminated with

parasite eggs. The main symptoms of ascariasis are abdominal pain, nausea, difficulty in defecating and loss of appetite (INNOCENT, OLIVEIRA and GEHRKE, 2009).

Typhoid Fever - is an infectious disease caused by the bacterium *Salmonella typhi*, and its transmission is through the consumption of water and food contaminated with the parasite. Main symptoms are high fever, vomiting, belly pain, constipation, diarrhea, headache, loss of appetite, weight loss, or red spots on the skin (BRASIL, 2024).

MATERIALS AND METHODS

It is a basic research with a qualitative approach, carried out through bibliographic research in scientific sources in the area addressed in the theme such as books and scientific articles available on digital platforms Google Scholar, CAPES/MEC Journals.

As pointed out by Brizola and Fantin (2017), literature review is the "junction of ideas from different authors on a given topic". Therefore, the literature review is a fundamental instrument to consolidate concepts about pathogenic microorganisms present in contaminated water.

A search was carried out in the CAPES/MEC Periodicals Portal database, with a view to verifying the scientific production on the subject, using the descriptor "contaminated water", "pollution", "microorganism", "diseases" and "Water Resources". For the selection of scientific articles, the following criteria were established: to present information from the article on Viruses, contamination, diseases, microorganisms, and to report the effectiveness of the study regarding the presence of microorganisms in contaminated waters. The procedures were organized as follows: in the first stage of the research, a survey of the articles found with the terms proposed in the previously mentioned database was carried out. Next, the selection of articles published between the years 2019 and 2023 was carried out, in order to ensure the reach of the most recent publications on the subject. Subsequently, a thorough reading of the articles was carried out and a database was composed.

At this time, data from all studies were tabulated with the intention of classifying the variables important for the study, such as the journal of publication and date. Subsequently, the systematization and analysis of the articles was carried out. At this time, the following exclusion criteria were used: 1) duplicate articles; 2) articles that were not available for download; 3) articles that were not directly represented with the research. The results are available in Table 1.

Table 1 - Results of the Literature Analysis

Articles reported by the search on the platform	30
Duplicate articles	1
Articles not available for reading	1
Articles did not present a study on pathogenic microorganisms present in contaminated water	1
Articles that do not have direct representation for the search	1
Total valid articles for analysis	26

Source: Author 2024

RESULTS AND DISCUSSIONS

In this last stage, tabulated data on the results of the researched articles were consolidated, thus structuring pathogenic microorganisms present in contaminated water, between the years 2019 and 2023. Thus, Table 2 presents the major infectious agents found in contaminated water worldwide and demonstrates the quantity researched.

Table 2 - Contributions by journal

BACTERIUM	AS.
<i>Campylobacter jejuni</i>	01
<i>Escherichia coli</i>	19
<i>Salmonella sorotipo Typhimurium</i>	10
<i>Shigella flexneri</i>	1
<i>Vibrio cholera</i>	2
<i>Yersinia enterocolitica</i>	2
<i>Klebsiella spp</i>	4
<i>Enterococcus spp</i>	3
<i>Staphylococcus aureus</i>	3
<i>Streptococcus spp</i>	3
<i>Legionella pneumophila</i>	3
<i>Clostridium</i>	4
<i>Bacillus</i>	1
HELMINTHS	AS.
<i>Ascaris lumbricoides</i>	1
<i>Strongyloides</i>	1
<i>Taenia</i>	1
PROTOZOA	AS.
<i>Giardia lamblia</i>	6
<i>Cryptosporidium spp</i>	3
VIRUS	AS.
<i>Adenovirus</i>	0
<i>Enteroviroses</i>	0
<i>Hepatitis A</i>	0
<i>Rotavirus</i>	0

Source: the author

These 18 microorganisms highlighted in the studies encompass only a part of the broader panorama of the research, which also includes other pathogens not mentioned in the table. The fact that *Escherichia coli* was mentioned in 19 of the 26 articles surveyed suggests that it is one of the microorganisms most frequently found in contaminated or polluted waters. The high prevalence of *E. coli* is worrisome, as it is an indicator bacterium of fecal contamination and its presence in water bodies can be an indication of risk to public health. It is important to emphasize that these studies were conducted globally, covering a variety of environments investigated. Among the sites studied are supply wells in rural and urban areas, fountains used for recreation and ornamentation, facilities in the food industry, dental offices, as well as natural water bodies, such as lakes and streams. This diversity of supply sources analyzed reflects the importance of a comprehensive approach in assessing water quality and identifying potential public health risks. Importantly, although the reviewed studies did not record the presence of *viruses*, this absence should not be underestimated.

The lack of virus detection is relevant and may indicate the need for further investigations or the implementation of preventive measures to prevent the spread of these pathogens, given their importance in public health and the environment.

CONCLUSION

This study conducted a literature review from 2019 to 2024 seeking the most recent contributions regarding pathogenic microorganisms present in water. In this context, a search was carried out on the CAPES/MEC Journal Portal, and 26 studies were identified, after inclusion and exclusion procedures were established. Overall, this research highlights the important role of researchers in advancing scientific knowledge about the microorganisms found in water. The results indicate that the contamination, for the most part, is the result of population growth and land occupation, which exert a significant influence on the degradation of the quality of both surface and groundwater. Considering the various routes of transmission of diseases related to contaminated water, it is essential to adopt simple measures to prevent contagion, as emphasized by Santos (2023). These include practices such as washing hands and food thoroughly, consuming only filtered or boiled water, avoiding the use of inappropriate places for the disposal of bodily waste, keeping containers that can accumulate water covered, ensuring proper sealing of the water tank, avoiding the disposal of garbage in aquatic environments and inappropriate places, as well as avoiding the consumption of water from floods and places whose water quality is not known. Such measures are within everyone's reach, regardless of government intervention, as is the case with basic sanitation.

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Response of babassu coconut shell and açai biochar on soil attributes and gas emission

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ABSTRACT

Biochar from waste produced by pyrolysis benefits soil fertility, increases water and nutrient retention and reduces greenhouse gas emissions, promoting more sustainable agricultural practices. Thus, the objective of this study was to investigate the benefits of biochar produced from babassu and açai coconut shells on the physical, chemical and biological attributes of the soil, as well as on the mitigation of greenhouse gas emissions. A comprehensive literature review was carried out, exploring articles and books in scientific databases. The results showed that the biochar of babassu coconut shells and açai have significant impacts on the soil. In terms of soil attributes, an increase in water retention capacity, improvement in soil structure and an increase in the availability of essential nutrients for plants were observed. In addition, there was a reduction in the emission of gases such as carbon dioxide-CO₂, methane-CH₄ and nitrous oxide-N₂O, important greenhouse gases, indicating the potential of biochar in mitigating climate change when incorporated into agricultural practices.

Keywords: Biochar, Waste, Pyrolysis, Greenhouse effect, Soil quality.

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INTRODUCTION

The emission of gases began to be a concern for the scientific community around 1988, as there was a drastic and rapid change in climatic conditions, with fossil fuels being the main responsible for the increase in the concentration of greenhouse gases (Hansen *et al.*, 1988; Rezende, 2011; WMO, 2020).

Fossil fuels are the main source of primary energy in the world, accounting for more than 85% of the total energy supply (Rezende, 2011). The rest of the energy supply is composed of nuclear, hydroelectric, and renewable sources, such as biofuels, wind, geothermal, and solar energy (IEA, 2020; Rezende, 2011; WEC, 2019).

Given the large amount of gases emitted into the atmosphere, biochar emerges as a fast, economical, and effective solution to store carbon in the soil and improve its quality. Biochar, also known as biochar, is produced by burning plant biomass at a high temperature, with a reduced and controlled amount of oxygen (Jeffery *et al.*, 2011; Lehmann; Joseph, 2009; Lehmann *et al.*, 2011; Maia, 2011).

In addition, biochar has a heterogeneous structure composed of aromatic carbon and minerals from ashes, resulting from the pyrolysis process of biomass obtained in a sustainable way, using clean technologies and under controlled conditions (Maia, 2011; SSSA, 2024). The biomass used can be made up of materials of plant origin, including waste such as babassu coconut shells and açai almonds (Loo, 2008).

Throughout history, biochar production originated among indigenous peoples, who traditionally used the technique of burying plant and animal waste. This method resulted in the decomposition of these materials, which contributed significantly to improving soil quality and increasing soil fertility (Glaser *et al.*, 2001; IBI, 2024; Souza, 2023). These ancestral management practices played a crucial role in the transformation of Amazonian soils, making them more fertile and conducive to subsistence agriculture (Lehmann *et al.*, 2006; Souza, 2023).

Biochar, a modern product derived from these traditional practices, offers several benefits, such as reducing nutrient leaching into the soil, optimizing fertilizer use, and positive environmental contributions, including capturing carbon dioxide from the atmosphere and reducing greenhouse gas emissions (EMBRAPA, 2022).

In the Amazon region, where babassu and açai coconut palms are abundant, the shells and fruits of these native species have significant potential to be used in the production of biochar. This practice not only reduces agriculture's dependence on chemical fertilizers, but also provides substantial economic and environmental benefits (EMBRAPA, 2024; Glaser *et al.*, 2001).

In this context, this literature review aimed to investigate and learn about the benefits of biochar produced from babassu and açai coconut shells in the physical, chemical and biological attributes of the soil, as well as in the mitigation of greenhouse gas emissions.

DEVELOPMENT

BIOCHAR FROM BABASSU COCONUT SHELLS AND AÇAÍ

The babassu coconut palm is native to Brazil and found mainly in the Amazon region, where it grows naturally in transition areas between the cerrado, the Amazon rainforest and the semi-arid region of northeastern Brazil (Chaves; Axe; Antoniassi, 2006).

In the North and Northeast regions of Brazil, there are extensive areas for the collection of babassu coconuts, which are essential for the subsistence of several communities, however, due to the low value of the product, there is no significant incentive to increase its exploitation (Chaves; Axe; Antoniassi, 2006). Thus, the production of biochar emerges as a sustainable alternative for extractive families who, when they break the fruit, can sell the endocarp, and use the waste to sell or transform it into by-products to supplement their income.

The açai tree is another palm tree native to the Amazon, whose local economy largely depends on the sale of the fruit's pulp (Nascimento, 2008). With this, the production of biochar for agricultural purposes would increase the income of these communities through the sale of seeds after pulping.

In the soils of the Cerrado, it is common to find small pieces of charcoal, known as C-pyr or black carbon, resulting from natural fires or human interventions (Petter, 2010). These materials are often found in the Terras Pretas de Índio in the Amazon, compounds that persist in the soil for centuries and are fundamental to their fertility (Neves *et al.*, 2003).

Understanding the degradation of C-pyr in the soil is fundamental for its use, aiming at capturing carbon from the atmosphere (Petter *et al.*, 2016). The long-term stability of C-pyr in soil, without significant changes in its composition, may contribute to the reduction of CO₂ emissions in the short term (Petter *et al.*, 2016). The ability of biochar to retain carbon in the soil is related to its chemical stability (Lehmann; Joseph, 2009).

Thus, the production of biochar from the waste from the processing of açai can be an effective solution to deal with the improper disposal of this waste, transforming it into a resource that improves soil properties and reduces the risks of environmental contamination.

However, it is essential to conduct additional tests and studies to adjust the production conditions of biochar, ensuring that its environmental and agronomic properties are optimized according to the best available practices (Sato, 2019).

EFFECT OF BABASSU COCONUT SHELL BIOCHAR ON SOIL ATTRIBUTES

Biochar, obtained through the pyrolysis of biomass, has stood out as a sustainable alternative for the improvement of agricultural soils. This process involves the thermochemical degradation of biomass under anaerobic conditions or with low oxygen concentration and high temperatures (Lehmann; Joseph, 2009; Schmidt, 2002).

The babassu coconut shell (*Orbignya phalerata*) presents itself as a viable option, especially in the Northeast region of Brazil, where it is found in great abundance. Babassu is a palm tree native to Brazil, predominant in the Northeast and in the state of Maranhão, widely exploited both for oil extraction and for the use of its fibers and bark (Pereira; Luiz, 2013; Silva; Rodrigues, 2011; Teixeira; Costa, 2016)

The fruit of the babassu fruit has a fibrous layer called epicarp, which represents 11% of the total weight of the fruit and surrounds a central layer, the mesocarp or pulp, which is rich in starch and fiber, corresponding to 23% of the fruit (Lorenzi, 2004; Saints; Silva; Oliveira, 2008; Silva; Filho, 2007). Further inward, there is the endocarp, a very resistant layer, with a thickness of 2 to 3 centimeters, which constitutes 58% of the fruit. This layer is essential for the production of charcoal, having a higher calorific value than mineral coal (Andrade; Birth; Silva, 2005; Lorenzi, 2004). In the core of the fruit are almonds, which represent 8.7% of the total weight of babassu and are the source for oil extraction (Gomes, 2017; Brook; Olive tree; Lima, 2020; Pear tree; Silva; Oliveira, 2016).

Traditionally considered an agro-industrial waste, the babassu coconut shell has great potential when transformed into biochar, thanks to its favorable physicochemical properties. The use of biochar derived from babassu coconut shells in agriculture aims not only to improve soil quality, but also to offer a sustainable solution for reducing greenhouse gases (GHG), contributing significantly to the mitigation of global warming (Almeida; Martins; Ribeiro, 2019; Nunes; Souza; Silva, 2018; Saints; Olive tree; Carvalho, 2019).

Biochar offers a solution that integrates energy and food production, while promoting increased soil nutrition and fertility, as well as contributing to carbon sequestration (Wolf *et al.*, 2010). This makes biochar one of the few technologies available with the potential to address challenges related to soil degradation, food and fertilizer scarcity, competition for biomass, and reduced greenhouse gas emissions (Lehmann; Joseph, 2015).

According to Asai *et al.* (2009), the use of biochar provides a series of environmental and agronomic benefits. Among them are decreasing nitrogen leaching, neutralizing soil pH, reducing the amount of available aluminum, decreasing soil density, increasing saturated hydraulic conductivity, and improving soil water permeability (Asai *et al.*, 2009)). In addition, biochar contributes to greater phosphorus availability for plants, which strengthens soil and crop health (Kammann *et al.*, 2010; Lag *et al.*, 2017; Spokas; Koskella; Baker, 2009).

Thus, the application of biochar in agriculture is a promising practice for the improvement of soil physical and chemical properties, especially in tropical regions where organic matter plays a crucial role in maintaining cation exchange capacity (CEC) (Lehmann; Joseph, 2015; Glaser; Lehmann; Zech, 2002).

Although the chemical structure of biochar and its particulate nature, together with its porous structure (Figure 1), influence properties such as cation exchange capacity, water retention, and nutrient retention and availability (Uchimiya *et al.*, 2010), the effects of biochar on soil are still the subject of debate. Some studies have demonstrated the beneficial effects of biochar on the physical, chemical and biological attributes of the soil (Liang *et al.*, 2006; Steiner *et al.*, 2007; Ouyang *et al.*, 2013).

Figure 1. Representation of biochar particles.



Source: Author (2024).

Other studies have shown that the application of biochar had no significant effect on the physical and chemical properties of the soil (Carvalho, 2015; Reed *et al.*, 2017). In addition, some research indicates that biochar may even reduce the water-holding capacity of the soil (Krull *et al.*, 2010; Tammeorg *et al.*, 2014).

In this context, it is essential to explore and understand the effects of babassu coconut biochar on soil attributes, evaluating its implications for agricultural productivity and environmental sustainability.

EFFECTS OF AÇAÍ BIOCHAR ON SOIL ATTRIBUTES

Sato (2018) states that biochar derived from residues from açaí processing has shown potential to serve as a conditioner in Amazonian soils. However, the control of pyrolysis conditions, particularly temperature, is essential to determine the characteristics and efficacy of the biochar obtained from these residues (Galinato *et al.*, 2011; Oliveira *et al.*, 2017).

At lower temperatures (300 and 400 °C), biochar exhibits a higher yield, but with a strongly hydrophobic tendency (Zhang *et al.*, 2016; Kuzyakov; Bogomolova; Glaser., 2014). On the other

hand, when produced at higher temperatures (600 and 700 °C), the material has higher pH values, greater recalcitrance and greater water retention capacity (Li *et al.*, 2016; Mukherjee; Lal, 2013).

Considering the advantages of biochar produced at low and high temperatures, the intermediate temperature (500 °C) and a longer residence time (3 hours) are considered ideal for the production of biochar from açai seeds. This approach incorporates a set of beneficial characteristics for these soils, without presenting significant limitations of use Mukherjee; Lal, 2013; Fernandes *et al.*, 2017).

Because of these properties, in recent years, several studies have emphasized the positive effects of biochar on various physicochemical characteristics of the soil, including decreased density, increased pH in acidic soils, increased cation exchange capacity (CEC), and contribution as a source of increased organic carbon in the soil (Yan *et al.*, 2021; Chintala *et al.*, 2014; Liu *et al.*, 2012).

Thanks to the predominance of long-lived carbon, biochar emerges as an effective alternative for carbon capture, contributing to the reduction of greenhouse gas emissions and to the increase of organic matter levels in the soil (Woolf *et al.*, 2018).

The extensive surface and pores of biochar can favor the retention of nutrients in the soil, since positive and negative ions can be retained on its surface through adsorption. (Yan *et al.*, 2021; Xu *et al.*, 2014).

The temperature during pyrolysis directly affects the physical properties of biochar (Trompowsky *et al.*, 2005). During the burning of organic matter, volatile compounds are released, including "cell juice", hemicellulose, cellulose, and lignin, forming carbonized compounds (Petter *et al.*, 2016).

These compounds decompose, creating pores of different sizes that increase the specific surface area of the biochar. Typically, this area increases with temperature to some extent, 500 to 700 °C (Petter *et al.*, 2016). However, at high temperatures (>1000 °C), the carbonized compounds undergo fusion due to the degradation of the aromatic compounds, resulting in the loss of carbon and desirable physical characteristics, such as porosity (Petter *et al.*, 2016).

The use of biochar derived from açai seeds has resulted in improvements in soil physical properties, including increased aeration porosity and improved soil aggregation. In addition, in soils of different textures, biochar had positive effects on water retention and availability for plants.

These effects were more evident in soils with a sandy texture and increased with the amount of biochar applied. The addition of biochar to the soil improved the mesopores fraction in all soil types, resulting in a higher saturated hydraulic conductivity (Sato *et al.*, 2020).

Biochar can also be used as an improver to increase the effectiveness of nitrogen (N) fixation in the soil and mitigate its volatilization, consequently improving soil fertility and promoting plant growth and development (Xu; Tan; Gai, 2016).

Additionally, mineral nutrients such as phosphorus (P) are captured by biochar during the pyrolysis process, and, therefore, several studies suggest that biochar can be effective in increasing the availability of this element in the soil (Costa, 2021).

Similar to organic matter, the addition of biochar to the soil also promotes an increase in the number of pH-dependent loads due to the presence of functional groups with predominantly negative residual load. This is influenced by the increase in pH caused by the carbonates present in the biochar ash.

As a result, the cation exchange capacity (CEC) increases, as there are more negative charges at the exchange sites, reducing the competition of cations with H^+ ions for these sites and, consequently, decreasing the leaching of the bases along the soil profile (Gul *et al.*, 2015). These advantages are especially relevant when considering tropical soils, in which the intense weathering process accelerates the degradation of organic matter and the constant leaching of basic nutrients (Sato, 2018).

As observed by Malavolta (2006), the low fertility present in acidic soils is mainly linked to the scarcity of exchangeable bases and the excess of aluminum and manganese. Therefore, the inclusion of biochar in these soils could reduce nutrient losses, especially of bases, by leaching, resulting in a more efficient use of the nutrients present in the soil (Sato *et al.*, 2020).

Sheng and Zhu (2018) found that the addition of biochar in acidic soils resulted in a substantial increase in soil pH and a significant modification in the composition of the microbial community. There were notable increases in Bacteroides and Gemmatimonadetes, while Acidobacteria decreased significantly.

The regulation of soil pH by biochar has been identified as the main factor responsible for this change in the structure of the soil microbial community (Gorovtsov *et al.*, 2020). All due to the alkaline properties which have the ability to raise the pH of the soil, especially in acidic soils (Chan; Xu, 2009).

In addition, Palansooriya *et al.* (2019) found that biochar increases soil pH, exerting a positive effect on the metabolic activity of soil microorganisms and their community structure. Biochar reduces the bulk density of the soil, increases its water and moisture holding capacity, modifies soil nitrogen dioxide (N_2O) emissions, and has effects on nitrifying and denitrifying bacterial communities present in the soil (Huang *et al.*, 2023). Where through the increase of CEC through the application of biochar can result in an increase in the population of nitrogen-fixing bacteria, rhizobacteria and nitrifying and denitrifying bacteria in the soil, promoting plant growth and reinforcing their ability to face environmental stresses (Glaser; Lehmann; Zech, 2002).

Thus, in recent decades, several studies have highlighted the benefits of biochar in various physicochemical properties of the soil (Costa, 2021). In addition to being seen as an ecologically

viable substance, it can be used in the soil to stimulate the retention and availability of nutrients in soils with low fertility or with disadvantageous properties for adequate plant growth (Chandra; Medha; Bhattacharya, 2020).

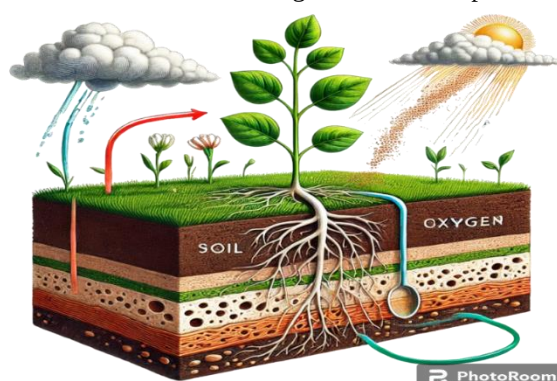
POTENTIAL OF BIOCHAR IN SOIL GAS MITIGATION

Biochar is a biomass carbonized through the pyrolysis process, which means that it is rich in carbon and results from the heating of organic matter in an environment with low oxygen presence (Mendonça, 2019).

According to Yakuwa (2021), the characteristics of biochar vary according to several factors, including the type of biomass used and the temperature of the pyrolysis process. It has a resistant internal structure, comparable to graphite, and a reactive outer layer, due to the existence of several chemical groups capable of joining organic compounds, water and chemical elements that serve as nutrients for plants (Downie; Crosky; Munroe, 2009)

The emission of greenhouse gases is a problem for the survival of the biodiversity of planet earth. According to the National Emissions Registry System (SIRENE), in 2023, the average annual CO₂ emission was 0.0385 tons per megawatt-hour, equivalent to 38.5 kg of emission per megawatt-hour. This situation is likely to persist until the end of the century (IPCC, 2021) (Figure 2).

Figure 2. Climate action on the emission of gases in the soil-plant-atmosphere system.



Source: Author (2024).

The use of these carbonized materials in agricultural soils may represent an important process of carbon capture and waste management (Lehmann, 2007).

In addition, the use of carbonized materials in the soil or as raw material for the manufacture of granular mineral, organic or organomineral fertilizers, which release nutrients in a controlled or gradual manner, can bring other benefits, such as: changes in soil microbial communities, with increased biological diversity; increased agricultural productivity; reduced emissions of methane and nitrous oxides; decreased need for fertilizers; reduced runoff nutrients and, mainly, the improvement

of the agronomic efficiency of fertilizers (Jeffery *et al.*, 2011; Kammann *et al.*, 2012; Spokas; Reicosky, 2009).

Carbonized materials contain condensed aromatic groups that contribute to their resistance to decomposition in the soil, thus making them an effective option for carbon storage, especially considering that soil represents the largest surface deposit of this element (Glaser; Lehmann; Zech, 2002).

Thus, in addition to the immediate economic gains, it is also crucial to consider the environmental benefits, especially with regard to global climate change (carbon storage and reduction of emissions of other greenhouse gases) and greater energy efficiency in agriculture, resulting from increased productivity, reduced use of fertilizers and lower nutrient losses (Cerri *et al.*, 2009; Steiner *et al.*, 2004).

FINAL CONSIDERATIONS

Biochar has a strong link with the recovery and improvement of soil quality, helping to reduce the effects of climate change and increase plant productivity. In addition, the use of biochar promotes better soil aggregation, favoring greater water and nutrient retention.

Therefore, biochar can be widely used in the face of current climate change, as it has significance in reducing greenhouse gases, which makes it an important ally in the search for sustainability on the planet. Thus, biochar has potential as a mitigator of polluting gases, and can be pointed out as an effective resource to improve sustainable soil quality.

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Lycopersicon esculentum 'Indigo Rose': A new horizon in tomato farming <https://doi.org/10.56238/sevened2024.023-009>

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ABSTRACT

The tomato variety *Lycopersicon esculentum* 'Indigo Rose', recognized for its distinctive purple coloration and high anthocyanin content. Developed to improve disease resistance and increase nutritional benefits, this tomato variety stands out for both its aesthetics and its health benefits.

In this context, the present study aimed to address the botanical and genetic characteristics of 'Indigo Rose', which led to its creation. Agronomic aspects are presented, including recommendations on cultivation practices, from soil preparation to harvesting. Resistance to pests and diseases, along with adaptability to different climatic conditions, is highlighted as a key factor for success in growing this variety.

The nutritional benefits of 'Indigo Rose' are widely discussed, with an emphasis on anthocyanins and their antioxidant effects, furthermore, it presents the economic and market impact of this variety, underscoring the growing demand for functional and visually appealing foods among health-conscious consumers.

Keywords: Pink indigo tomato, Nutritional composition of pink indigo, Botanical characteristics, Market prospecting Modified tomato.

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INTRODUCTION

Tomato farming has a long history, rooted in farming practices that date back thousands of years. Within this vast field of study and cultivation, *Lycopersicon esculentum* 'Indigo Rose' stands out as a particularly interesting strain. This chapter aims to explore the unique characteristics, genetics, and nutritional benefits of this peculiarly colored tomato, bioactive compounds, agricultural activities, toxicological safety, and market (Balashova; Pinchuk, 2019).

The 'Indigo Rose' variety is notable not only for its deep purple coloration, but also for the bioactive compounds that give it this hue. Developed through selective crossbreeding, this strain was created to improve resistance to diseases and increase the content of anthocyanins, powerful antioxidants beneficial to human health. Anthocyanins are responsible for the characteristic coloration and have been associated with reduced risk of cardiovascular disease, diabetes, and certain cancers (He et al., 2023).

In addition to the nutritional aspects, 'Indigo Rose' has a number of agronomic characteristics that make it attractive to growers. Its resistance to pests and diseases, coupled with its ability to adapt to different climatic conditions, makes it a robust choice for sustainable agriculture, its way of cultivation, and the economic and market impacts of 'Indigo Rose' (Zhi et al., 2020).

'Indigo Rose' is not only a functional food but also an attractive aesthetic option for chefs and consumers who value the visual appearance of the food they consume (Vu et al., 2019).

By exploring the *Lycopersicon esculentum* 'Indigo Rose', the present work aims to provide a holistic understanding of its potential and challenges, highlighting its contribution to modern agriculture and human nutrition.

BOTANICAL CHARACTERISTICS

The tomato (*Solanum lycopersicum*) belongs to the order Tubiflorae and is a member of the *Solanaceae* family, being a Dicotyledonous plant (Maureira et al., 2022). It stands out among the most cultivated vegetables in the world, due to its high nutritional content and economic potential (Perez-Robles et al., 2023).

The tomato (*S. lycopersicum*) is one of the most appreciated vegetables in the world due to its flavor and its wide variety of shapes and colors. It is a widely cultivated and used vegetable, due to its versatile characteristics, it can be consumed fresh, cooked, or processed (Amr, 2022). Tomatoes are a rich source of functional compounds, ranging from vitamins, minerals, dietary fiber, proteins, and essential amino acids such as carotenoids, chlorophylls, and polyphenols (De Corato, 2020).

The tomato plant has different genetic varieties, allowing the selection of genotypes that are better adapted to the region of interest and that efficiently reproduce its genetic potential. And this directly interferes with the quality of the fruit, such as soluble solids content, titratable acidity, pH,

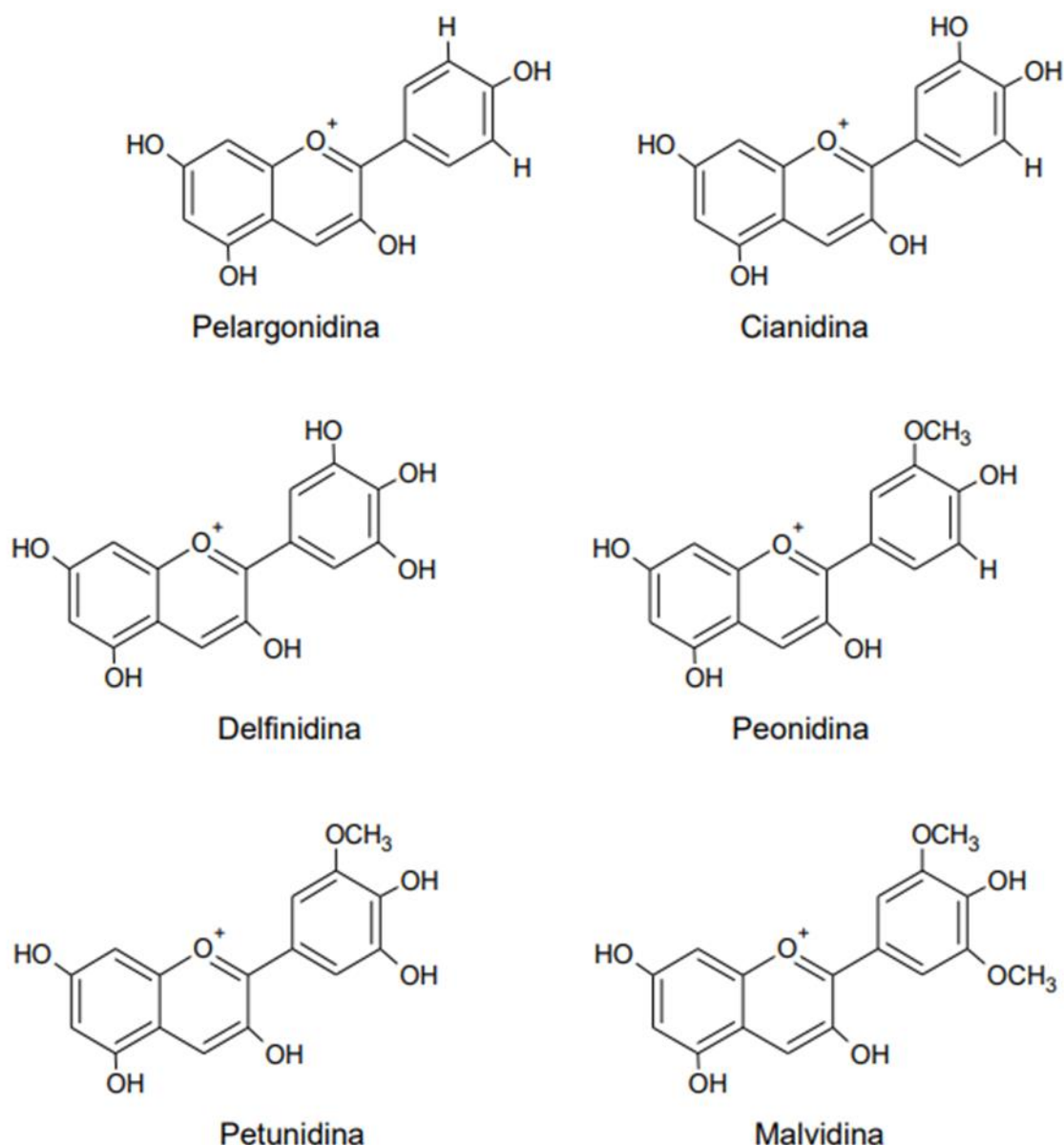
vitamin C, fruit mass and size, among other traits, is fundamental in the choice of superior genotypes (Mohamed et al., 2012).

In recent years, the tomato cultivar 'Indigo Rose' has gained attention due to its purple-skinned fruits being rich in anthocyanins with antioxidant action (Kang et al., 2018). Indigo Rose was created from wild tomato species through gene transfer from the anthocyanin fruit (Aft gene) of *Solanum chilense* and the locus atrovioleum (Atv gene) of *Solanum cheesmaniae* in cultivated tomatoes (Mes et al., 2008).

The genetic variability linked to the pigments of the tomato fruit has allowed the diversification of the fruit composition and eventually properties related to its nutritional value. The tomato fruit is a berry that can take on different shapes and colors. The color of the fruit progressively changes from green to yellow, orange, and red, when different carotenoids and flavonoids are synthesized, and lycopene, the main carotenoid in ripe red fruits, is finally accumulated. Tomatoes are climacteric fruits, and the production of high levels of ethylene is observed early in their ripening (Naeem et al., 2023; Amr, 2022).

Tomato fruits are rich in pigments such as lycopene and carotenoids, but they contain only small amounts of other flavonoids. Anthocyanins, in turn, are an important class of flavonoids that represent a large group of secondary metabolites in plants. Anthocyanins are composed of glycosylated polyphenolics with a range of colors ranging from orange, red, and purple to blue in flowers, seeds, fruits, and vegetative tissues, among the most common we have pelargonidin, cyanidin, delphinidin, peonidin, petunidin, and malvidin (Fig. 1), they can be synthesized, differing in the substituent groups in the structural rings (Cappellini et al., 2021). Anthocyanins are known for their health-protective function in a daily diet, as they are able to activate antioxidant defenses. Therefore, strategies such as genetic engineering and breeding programs have recently been carried out to increase the anthocyanin content in tomatoes (Gonzali & Perata, 2021).

Figure 1: Structure of the main known anthocyanins.



Source: ChemSketch elaborated.

The Aft gene encodes an R2R3 MYB transcription factor called AN2-like, which upregulates anthocyanin biosynthesis in a light-dependent manner (Sun et al., 2020). Thus, the dominant allele of the Atv gene encodes an R3 repressor MYB MYBATV that downregulates anthocyanin biosynthesis, while the recessive Atv allele in Indigo Rose encodes a non-functional version. In the case of Indigo Rose tomatoes, the anthocyanin content is mainly restricted to the skins (Yan et al, 2020; Liu et al., 2020). Thus, the Indigo Rose tomato cultivar is relatively new to the tomato plantation (Teo et al., 2022).

ANTHOCYANIN CONCENTRATION AND COMPOSITION OF INDIGO ROSE TOMATOES

Anthocyanins are natural pigments with diverse physiological functions and protective effects, but most tomatoes produce little anthocyanins (Jian et al. 2023). Solanaceous fruit vegetables, which mainly include tomatoes (*S. lycopersicum*), exhibit natural variations of anthocyanin pigments in terms of specific tissue types, contents, and patterns. Breeding anthocyanin-rich varieties is the predominant avenue to improve the quality of this vegetable, as anthocyanin-enriched tomatoes have been obtained employing breeding or transgenic approaches (Li et al., 2022; Teo et al. 2022).

Anthocyanins in the tomato fruit (*S. lycopersicum*) are biosynthesized in a light-dependent manner. It can be found in the form of nine structures of anthocyanins, such as petunidine-3-(trans - p-cumaroyl)-rutinoside-5-glycoside, which is the main anthocyanin present in tomato, (delfinidine-3-(caffeoyl)-rutinoside-5-glycoside, delfinidine-3-(trans -cumaroyl)-rutinoside-5-glycoside, delfinidine-3-(feruloyl)-rutinoside-5-glycoside, petunidin-3-(trans -cumaroyl)-rutinoside-5-glycoside, petunidin-3-(feruloyl)-rutinoside-5-glycoside, malvidin-3-(p-cumaroyl)-rutinoside-5-glycoside, malvidin-3-(feruloyl)-rutinoside-5-glycoside, petunidin-3-(caffeoyl)-rutinoside-5-glycoside and delfinidine 3-(caffeoyl)-rutinoside-5-glycoside (Wang et al. 2020)

The anthocyanins in Indigo Rose tomatoes, which are responsible for their purple and black color, have additional health benefits beyond those normally associated with tomatoes, such as antioxidant action and support cardiovascular health. The anthocyanin content in Indigo Rose fruits is mostly restricted to the skins of their fruits. Through the studies carried out by Teo et al. (2022), the author points out that the accumulation of anthocyanin occurred mainly in the peels of the fruits instead of the pulp, regardless of the stage of development or the growth conditions of the fruit. Since the fruit skin only accounts for about 5% of the total fruit mass, the total anthocyanin content is about 300 µg per g of fresh weight (Liu et al. 2020).

However, Mes et al., (2008) point out that the fruit loci genes anthocyanin (Aft) and atrovioleacea (atv), are responsible for conditioning the intense purple color in tomatoes, in which the concentration of anthocyanin in the skin of their fruits reached more than 100mg per 100g of fresh fruit. Furthermore, (Liu et al. (2020) further revealed that Aft cooperates with Atv to form a feedback loop to adjust anthocyanin biosynthesis.

Using a mass chromatogram and ultraviolet (UV) absorption, Wang et al. (2020) analyzed the anthocyanins present in the skin and pulp of the Indigo Rose fruit, where they were able to identify 12 anthocyanin structures. Based on the structure, the author identified that petunidin-3-(trans-p-coumaroyl)-rutinoside-5-glucoside is the main anthocyanin in the peel of fruits. The total anthocyanin content present in the peel was higher than the anthocyanin concentration in the pulp, reaching 3977.93 mg/kg in the peel and 88.44 mg/kg in the pulp. These results indicate that

anthocyanins are enriched in the bark of Indigo rose. Petunidin-3-(trans-p-coumaroyl)-rutinoside-5-glucoside and malvidin-3-(trans-p-coumaroyl)-rutinoside-5-glucoside were the two main anthocyanins in the peel, making up approximately 68.7% and 14.2% of the total anthocyanin content, respectively. In the future, tomatoes could be developed as a pharmacological source of antioxidant compounds through anthocyanin improvement, as well as being one of the most popular fruits in the world.

Organic acids are important components that strongly affect the taste and nutritional value of fruits. A total of six organic acids (citric acid, quinic acid, malic acid, tartaric acid, fumaric acid, and oxalic acid) have been reported to have been identified in tomato fruit (Jian et al. 2023). The content and composition of sugars play important roles in assessing the nutritional value of fruits, as they are largely responsible for their sweetness and flavor. Jian et al. (2023) obtained fructose, glucose, and sucrose results in tomatoes ranging from 4.67–9.50 mg.g⁻¹, 3.59–8.30 mg.g⁻¹, and 0.68–1.90 mg.g⁻¹, respectively. The fructose and glucose content in both the purple tomato showed a gradual increasing trend as the fruit matured, while the sucrose content decreased.

Finally, it can be said that the nutritional composition of the Indigo rose tomato is similar to the traditional tomato, and may present small variations due to factors such as growing conditions and specific cultivars. Indigo Rose tomatoes contain essential vitamins and minerals, including vitamin C, vitamin A, vitamin K, potassium, and folate. These nutrients play crucial roles in immune function, vision, blood clotting, and overall well-being.

CULTIVO E MANEJO *L. ESCULENTUM* 'INDIGO ROSE'

During tomato cultivation, it is necessary to carry out soil preparation, including the stages of liming and fertilization, choice of variety and crop during development and growth. In this way, the tomato crop ends up adapting to different types of soil, from acidic, sandy, heavy and slightly alkaline soils (Peixoto et al., 2017).

Some factors can contribute to low yield during tomato cultivation, such as planting in unfavorable seasons, low quality seeds, irrigation and fertilization problems, injuries and indirects caused by pests and diseases, and inadequate water with the amount of dissolved salts in the production market. In this way, they seek tools that are essential for minimizing adverse effects on the climate, increasing the quality of the raw material and in a sustainable way (Silva et al., 2020). soil (Pereira et al., 2020).

The tomato is considered a species widely used in genetic research, regarding the development of fruits resistant to diseases. Modern genetics and genetic improvement methods have not only contributed to the understanding of the genetic control of agronomic traits, but also contribute to the development of thousands of new cultivars (Lamichhane, Thapa, 2022). The main

objectives of tomato breeding are high productivity, tolerance to biotic and abiotic stresses, capable of ensuring the management of genetic resources and their diversity (Celik, et al., 2023).

This Indigo Rose tomato cultivar was developed by Oregon State University (USA), where many biotechnological strategies were explored, leading to significant enrichment in lycopene, anthocyanins, and other flavonoids (Teo et al., 2022; Bassolino et al., 2022).

The breeding or engineering of tomatoes with a high anthocyanin content has aroused great interest, as the antioxidant capacity in purple tomato fruits is higher than in common tomatoes (Lu et al., 2021). The healthy properties of anthocyanin-enriched tomatoes, may be based on the ability to act as scavengers of reactive chemical species and inhibitors of cancer cell proliferation, results have been demonstrated in in vitro and in vivo studies, potential health benefits in humans (Gonzali & Perata, 2020).

In this way, the introduction of 'Indigo Rose' to the market reflects a growing trend in agriculture and consumption, where there is a search for foods that not only satisfy basic nutritional needs, but also offer additional health benefits. This cultivar not only contributes to the diversification of products available on the market, but also exemplifies the role of biotechnology and genetic improvement in promoting sustainable agricultural practices and improving the nutritional quality of food. Thus, the 'Indigo Rose' tomato cultivar represents a significant step forward in the advancement of agricultural science and in responding to the demands of consumers who are increasingly aware of the nutritional impacts of food.

TOXICOLOGICAL SAFETY ASPECTS OF MODIFIED CROPS ASSOCIATED WITH THE USE OF PESTICIDES

There are many questions under debate about the robustness of the data and methodologies used in GM (Genetically Modified) crops, and the 'Indigo Rose' fruit fits into this classification (Gilbert, N. 2013), and future studies are needed to better clarify these questions. Concerns about biodiversity and pest resistance also need to be clarified (Klümperç Qaim, 2014), since there is a dependence on patented seeds, which cause concern regarding food security. (Stone, 2012).

The genetically modified (GM) seed industry has faced several problems related to human health and insect resistance, in addition to inadequate communication by seed companies, the lack of comprehensive studies on safety in relation to (GM) have contributed to the amplification of these issues (Raman R, 2017).

The concern about GM foods revolves around the possibility that they may have harmful effects on human health. There are fears that the consumption of these genetically modified foods could contribute to the emergence of antibiotic-resistant diseases. In addition, as these are relatively new products, there is still significant uncertainty about their long-term effects on the human body

(Bawa; Anilakumar, 2013). The health risks associated with genetically modified foods involve toxins, allergens, and genetic risks.

Consumer acceptance is influenced by the perceived risk of incorporating processed foods with technologies they understand little about. A study conducted in Spain showed that the introduction of GM foods into agri-food markets must be accompanied by appropriate policies to ensure consumer protection (Martinez et al., 2009). Within this context, the purple tomato of the 'indigo Rose' type *S. lycopersicum* was an alternative strategy to develop anthocyanin-rich tomatoes using genetic improvement, taking advantage of wild species of *Solanum* that produce anthocyanins under appropriate conditions (Gonzali; Mazzucato; Perata, 2009). However, studies on toxicological aspects are not reported in the literature for the purple tomato species.

TECHNOLOGICAL PROSPECTING AND FUTURE MARKET PROSPECTS

A patent study was conducted in July 2024 on the Espacenet database to analyze the market and future prospects for *L. esculentum* 'Indigo Rose'.

Espacenet is the database of the European Patent Office (EPO), which provides free online access to millions of invention patent documents and technical developments from around the world. The monitoring of patent data is done in different ways (e.g., bibliographic data, reproduction images, and full text), ensuring accurate and up-to-date information. Espacenet also provides documents filed with the National Institute of Industrial Property (INPI) and in several American offices. (EPO, 2023a).

The patents filed were collected by combining the keywords "Lycopersicon esculentum Indigo Rose" in the advanced search field. No specific time frame was made for the search, so that more documents could be obtained and also to observe its annual evolution in general regarding deposits.

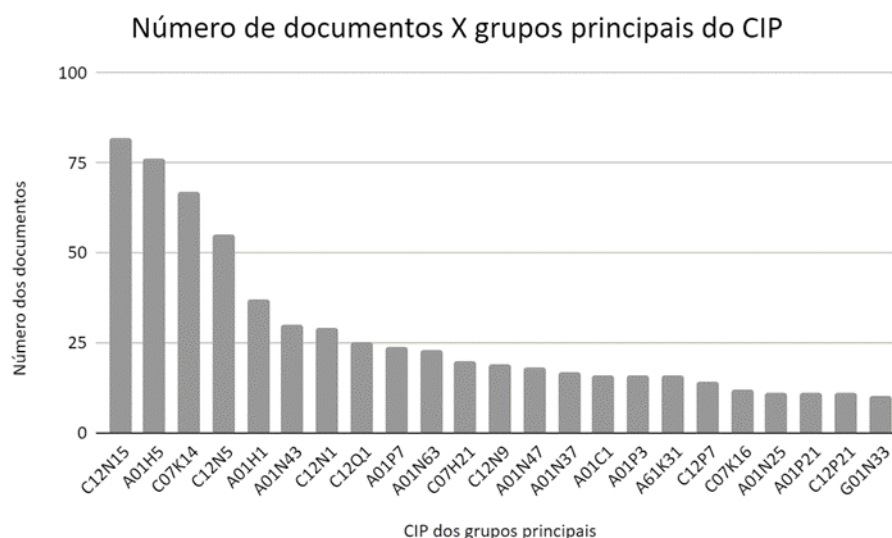
After performing the word search as described above, 604 publications were found that meet the keywords, of which 147 were available for access. The documents available for analysis were exported to the Microsoft Office Excel program, with the objective of analyzing the patent information and generating the images that we will see in this study.

The main International Patent Codes (CIP) found in the research are illustrated below (Figure 2). Among them is the code C12N15/00, which refers to "mutation or genetic engineering; DNA or RNA relating to genetic engineering, vectors, and plasmids, or their isolation, preparation or purification; use of hosts for them (mutants or genetically modified microorganisms)", which is consistent with the fact that the plant researched is the result of genetic engineering.

The second most cited code was CIPA01HS, which names the class described as "angiosperms, that is, flowering plants, characterized by their plant parts; angiosperms characterized in a way other than by their botanical taxonomy", which is also related to the plant in question.

After analyzing the other CIPs described in the figure, we can say that most of the main codes found are related to the areas of Chemistry and Agriculture, which is expected, since we are searching for a vegetable, and, therefore, fits into both areas.

Figure 2. Main patents filed, broken down by International Classification Code.



Source: prepared with data from EPO (2024b).

The annual evolution of the filing of patent documents shows that the first registration was carried out by the University of North Carolina, in the United States, and filed in 1993, with registration number CA2112999A1 and entitled "Transgenic plants resistant to pathogens" and describes characteristics of certain plants with genetically modified genes, which become more resistant.

Figure 3. Annual evolution of patent documents filed in the period between 1995 and 2021.



Source: prepared with data from EPO (2024b).

It was observed in Figure 3 that from the year 2000 onwards, there was a trend of increase in the number of patents filed, however, it was from 2011 onwards that, in fact, there was an increasingly progressive increase in the filing of documents referring to *L. esculentum* 'Indigo Rose'. The years 2018 and 2019 had the highest number of filings (13). Few patents were filed in 2021, which can be explained by the period of secrecy, after the filing of these patents, until they can be available for public consultation. Three patents were published in 2021: one from the United States (US2023270073A1), and two with the registration codes WO2023230428A1 and WO2023152723A1.

The letters "WO" show that the patent was published by the World Intellectual Property Organization (WIPO), in compliance with the Patent Cooperation Treaty (PCT). The PCT is an international agreement that favors the protection of inventions through patents in several countries. Patents registered using the PCT have their acronym beginning with WO.

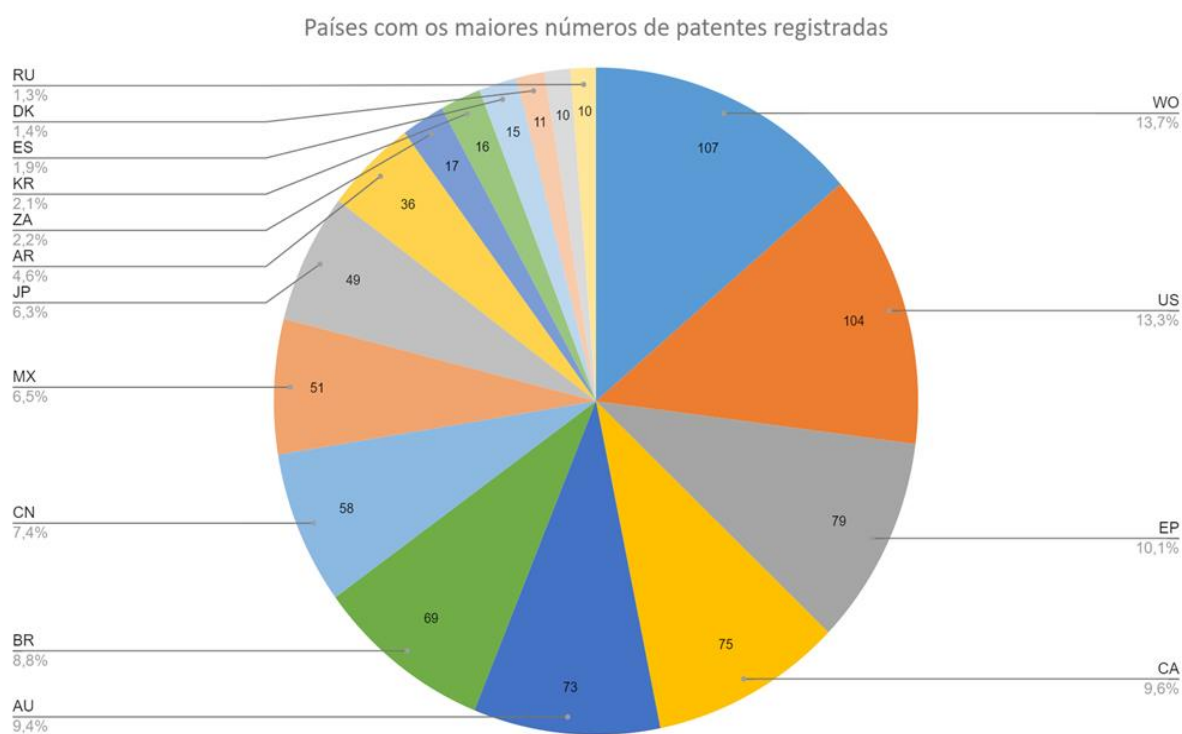
Among the main patent applicants, those published by the WO are the ones with the highest number, with 107 (13.7%) deposits on *L. esculentum* 'Indigo Rose', as shown in Figure 3. The acronym WO represents that the registration is at an international stage and indicates an international publication within the scope of the PCT, which allows the inventor to seek patent protection in different countries using a single application.

Soon after, the second largest applicant is the United States (13.3%), followed by the European Patent Organization (10.1%), followed by Canada (9.6%), followed by Australia (9.4%) and also by Brazil (8.8%). It is also noted the presence of countries such as China, Mexico, Japan, Argentina, South Africa, the Republic of Korea, Spain, Denmark and Russia, which shows, in general, that the interest in the plant is global and independent of the level of social development of the countries.

One of the most consumed vegetables in the world is tomatoes, with an average annual consumption of 20.9 kg per person, reaching more than 50 kg per person in some Mediterranean countries. The world's largest producer is China, but the largest exporter is Mexico (FAO, 2020). In recent decades, tomatoes have shown a continuous increase in productivity and also in global production, expanding their importance in human food (Fernie and Yan, 2019).

Figure 3 represents the patent registrations made by the main applicant countries, which are those that have more than 10 registrations on the subject and among them we can verify the presence of the largest producer and exporter of tomatoes, which is consistent with the interest of these regions in the subject.

Figure 4. Main applicants of patents on *L. esculentum* 'Indigo Rose': WO, World Intellectual Property Organization; US, United States of America; EP, European Patent Organization; CA, Canada; AU, Australia; BR, Brazil; CN, China; MX, Mexico; JP, Japan; AR, Argentina; ZA, South Africa; KR, Republic of Korea; ES, Spain; DK, Denmark and UK, Russia.



Source: prepared with data from EPO (2023b).

The technological prospecting studied shows that the number of patents on the subject has been increasing in recent years, which demonstrates an interest in the subject. According to the FAO report, the global market for tomatoes, as well as other agricultural products, faces several challenges. Projections for the next decade indicate a continued growth in global agricultural production, driven by the advance of plant breeding, such as *L. esculentum* 'Indigo Rose', and the transition to more intensive production systems.

CONCLUSION

Through research, we have discovered that *L. esculentum* 'Indigo Rose' has important and essential components for health with emphasis on the importance of the anthocyanins present, which not only give a vibrant purple color, but also offer antioxidant properties that contribute to health promotion. These compounds have been linked to reduced risk of various diseases, making 'Indigo Rose' a nutritionally rich and valuable option.

Its combination of health benefits, ease of cultivation, and visual appeal suggests a promising future. This variety is expected to continue to gain popularity, contributing to more sustainable agriculture and a healthier diet for consumers worldwide.

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Development, chemical and technological characterization of dry pasta noodles with wheat flour added to acerola pomace flour

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ABSTRACT

Considering that acerola residues are not used as a nutritional source for human consumption and that there is still a lack of knowledge on the part of the scientific community about these residues, it was necessary to prepare the flour from acerola residues. The objective of this work was to develop pasta containing flour from acerola residues, as well as the physicochemical and technological characterization of the prepared pastas. Acerola pomace flour was specifically incorporated at concentrations of 0%, 3%, 5%, 7% and 10% in relation to wheat flour, and the quality of the developed pasta was evaluated through baking tests (cooking time, water absorption, mass increase after cooking), total acidity and pH. The pasta was prepared in the Bakery Laboratory and the chemical and technological analyses were carried out in the Chemistry Laboratory of IFMA São Luís - Maracanã Campus. The whole and dehydrated seeds of the acerola were crushed with the help of a domestic blender and sifted through a 40 mesh sieve to obtain the flour. The production process of the "dry pasta" type was developed according to the following steps: preparation, mixing, kneading, rolling, cutting, drying, packaging, and cooking. The data obtained in the chemical and technological analyses showed that the developed food masses are within the legislation, which indicates an adequate food mass. According

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to the results obtained, it is concluded that acerola pomace flour can be added to the formulation of pasta, as it is an alternative in the elaboration of new products and use of acerola fruit residue.

Keywords: Acerola pomace flour, Pasta, Chemical and technological analysis.

INTRODUCTION

Waste disposal is a global concern both in terms of the environment and the waste of parts of food with high nutritional content. It must be disposed of correctly and away from the processing unit, as they have several compounds with high organic value that can be used as a source of nutrients for microorganisms. Therefore, finding another destination for waste other than disposal has been the focus of study for many researchers, using as the main alternative the elaboration of fruit and vegetable flours and the application in food products from various areas, especially in the bakery industry, always aiming at the nutritional enrichment of commercial food formulations.

Acerola processing waste represents 40% of the production volume. These residues are generally discarded when they could be used as alternative sources of nutrients, with the aim of increasing the nutritional value of the diet of needy populations, as well as solving dietary deficiencies (ABUD & NARAIN, 2009). Considering that acerola residues are not used as a nutritional source for human consumption and that there is still a lack of knowledge on the part of the scientific community (nutritionists, food technologists and/or technicians and food engineers) about these residues, it was necessary to prepare the flour from acerola residues. The flour produced from acerola pomace partially inhibits several digestive enzymes, reducing the digestion of carbohydrates and fats, preventing their absorption by the intestine, helping to control postprandial hyperglycemia (AQUINO, 2009).

Pasta is a food that is indisputably part of the table of the Brazilian people, with a high rate of acceptability, regardless of the social class to which it belongs. Brazil is the third world market in consumption of this paste, behind only Italy and the United States, which highlights the socioeconomic importance of this food, because in addition to being a source of some important nutrients for the diet, it generates employment and income for the population. Because it is basically made up mostly of wheat flour, this food can be considered energetic, however, it is deficient in vitamins and minerals and its proteins are deficient in essential amino acids, like most proteins of vegetable origin (ABIMAPI, 2019). Due to its nutritional importance and because it is part of the basic food basket, pasta, along with bread, beans and rice, is one of the most used products in daily consumption, which makes it ideal to be a vehicle to incorporate important ingredients into the diet. Another important factor that justifies the choice of pasta is the shelf life, much longer than other wheat flour derivatives.

In view of the importance of the use of fruit residues in order to reduce the deposition of these residues and the increase of the nutritional value of food formulations, this work aimed to obtain acerola pomace flour and to develop dry pasta type pasta formulated with acerola pomace flour in partial replacement of wheat flour, evaluate their chemical and technological quality.

MATERIAL AND METHODS

OBTAINING AND PREPARING THE RAW MATERIAL

The residues used in the present study were obtained from acerola (*Malpighia glabra L.*) The fruits were purchased at a local fair in São José de Ribamar - MA, and three collections were obtained. These collections were used for the elaboration and chemical characterization for the purpose of producing acerola pomace flour for the preparation of "dry pasta" type pasta.

To prepare the residues, all fruits were washed in running water to remove the largest dirt present in the peels, then they were immersed in sodium hypochlorite solution at 200 ppm for 15 minutes and then washed in running water to remove excess chlorine, according to Resolution of the Health Surveillance Agency – RDC No. 216/2004 (BRAZIL, 2004)

After cleaning, the fruits were pulped and their residues were dried.

Figure 2- Dehydrated acerola residue



Source: The authors

FLOUR PRODUCTION

The whole and dehydrated seeds were crushed with the aid of a domestic blender and sifted in a 40 mesh sieve to obtain the flours. These were packed in plastic containers with lids and stored at room temperature until the time of the analyses. After processing, the flour was packed in plastic bags and stored until it was used.

Figure 3- Flour from acerola residue



Source: The authors

PREPARATION OF DRY PASTA FORMULATION

A standard formulation of noodles was adopted for all test conditions performed in this work. The noodles were prepared in the bakery laboratory of the Federal Institute of Education, Science and Technology of Maranhão - IFMA São Luís Maracanã.

Five formulations of pasta enriched with acerola pomace flour were elaborated, with the ingredients and their proportions described in (Table 1), it is worth mentioning that the amount of eggs and water in all formulations were constant.

Table 1 - Ingredients of the preparations (g) and quantity (net weight)

Ingredients: Acerola pomace flour, wheat, egg, water			
M1	0g	100g	50g 10ml
M2	3g	97g	50g 10ml
M3	5g	95g	50g 10ml
M4	7g	93g	50g 10ml
M5	10g	90g	50g 10ml

Source: The authors (2019)

The production process of the noodle-type dry pasta followed the following steps: preparation, mixing, kneading, rolling, cutting, drying, packaging, and cooking.

Preparation

From the standard formulation, noodles were produced by applying different levels of unleavened wheat flour with acerola pomace flour. The percentages of acerola pomace flour were 0%, 3%, 5%, 7%, 10% in relation to wheat flour.

Mixing and kneading

An important step in the process, the dry ingredients were mixed in a bowl, then the liquid ingredients were added until a homogeneous dough with the desired consistency was formed, letting the dough rest for approximately 10 minutes. Soon after, they were modeled in a manual cylinder and cut.

Lamination/Cutting

For rolling, the dough passed through the cylinder numerous times until it obtained the appropriate thickness. After rolling, the dough was cut and the thickness of the shaped rolling depended on the desired final product. This procedure was repeated several times until it presented a smooth, uniform and brittle appearance. Then the dough was molded into the shape of noodles and cut by hand so that they acquired the desired length.

Figure 4- Cutting/Laminating



Source: The authors

Drying of the dough

The doughs have undergone a total drying process, in order to eliminate the water added in the production phase. After drying, the dough must have a maximum moisture content of 35% according to current legislation (BRASIL, 2005). At this stage, the fresh pasta was packed in a tray to provide ventilation and surface drying.

Figure 5 - Drying



Source: The authors

Packaging/Storage

The function of packaging is to keep the product free of contamination and protect it from damage caused during transport and storage (EL-DASH; GERMANI, 1994). The pasta was packaged in polyethylene plastic bags in quantities of 100 grams each, and closed in a manual sealer. They were then stored under refrigeration and sent for analysis, preparation (cooking in water) and physical-chemical tests.

Cooking

The pasta was cooked in boiling water. Cooking was carried out in stainless steel pans, where enough time was used for the white part to disappear from the center of each of the doughs.

CHEMICAL CHARACTERIZATIONS OF THE PREPARED PASTA:

The chemical and physicochemical characterizations of the prepared noodles were carried out at the Food Laboratory of the Federal Institute of Education, Science and Technology of Maranhão – IFMA São Luís Campus Maracanã.

Humidity

The moisture content was determined according to the analytical standards of the Adolfo Lutz Institute (2008), which is based on the removal of water by heating.

Figure 6 - Humidity



Source: The authors

Ashes

To determine the ash content, the empty crucible was placed in the oven at 105°C for 1 hour, then it was removed and placed in the desiccator for 30 minutes, after the time, it was weighed, soon after 2g of each sample was weighed in the previously desiccated crucibles, placed in the muffle furnace first at 50°C and gradually increased until it reached a temperature of 250°C, staying at this temperature for 2 hours, after the time, he withdrew and placed himself in the desiccator for 30 minutes, after that he was weighed again and the calculation made.

Figure 7- Cinzas



Source: The authors

Acidity (in ml NaOH solution/100g mass)

For this determination, a chemical analysis was performed, where 10 g of the sample was diluted in 40 ml of distilled water, filtered immediately afterwards, and titration with a 0.1mol NaOH solution was immediately carried out. L, using phenolphthalein as an indicator.

Figure 8 - Acidity



Source: own author

pH

To determine the pH, a physical-chemical analysis was performed, where 15 g of the sample were diluted in 15 mL of distilled water, previously boiled and homogenized. pH measurements were performed by reading in a digital pH-meter calibrated with buffer solution. The pH was determined by direct immersion of the electrode in the samples.

Figura 9 - pH



Source: own author

Cooking time

The quality parameter of the pasta is observed during cooking, as it is what matters to the consumer. To determine the cooking time, the physicochemical analysis was performed by cooking 10g of sample in 140 mL of boiling distilled water, until reaching the appropriate visual quality as a result of the starch gelatinization in the entire pasta section. This point was determined by compressing samples of the baked product every 1 minute, until the white core of the center of the dough disappeared.

Figure 10 – Cooked pasta samples



Source: The authors

Fat absorption (GA)

According to the method of Dench, Rivas & Caygill (1981) the absorption of fat from pasta was determined, 0.5 g of sample was weighed in a centrifuge tube and 3 mL of soybean oil was added. The contents were mixed for 30 seconds and left to rest for 30 min. Then, the sample was centrifuged at 3,000 rpm for 25 min. The excess oil was drained and the tube inverted for 30 min. Fat absorption was expressed as g of retained oil relative to 100g of sample

Increased mass of the cooked product

For mass increase, the sample was weighed before and after cooking, using the ideal cooking time for each sample. The mass increase value is the ratio of the cooked pasta mass to the raw pasta mass expressed as a percentage (%).

STATISTICAL ANALYSIS

The data were evaluated using the Excel version 2010 program (Microsoft Corporation). Analyses to compare the means between the sample points were used.

RESULTS AND DISCUSSION

DEVELOPMENT OF PASTA

In the development of the samples, the color difference between all samples was evident (Figures 11, 12, 13, 14 and 15).

Figure 11- Pasta dough 1



Figure 12- Pasta dough 2



Figure 13- Pasta dough 3



Figure 14- Pasta dough 4



Figure 15 - Pasta dough 5



Figure 11 showed the conventional pasta dough prepared with a mixture of 100% wheat, a 50g egg and 10 ml of water, while Figure 12 revealed the pasta dough made with 3% acerola pomace flour, 97% wheat flour, a 50g egg and 10 ml of water. This noodle had a darker color due to the color of the added flour. Figure 13 showed the pasta dough made with 5% acerola pomace flour, 95% wheat, an egg and 10 ml of water, in the same way, this pasta presented a darker color, as the portion of acerola pomace flour added was increased. Figure 14 showed the pasta dough made with 7% acerola bagasse, 93% wheat, one egg and 10 ml of water, with a darker colored dough, due to the percentage of flour used. Figure 15 showed the pasta dough made with 10% of acerola pomace flour, 90% wheat, an egg and 10 ml of water, the latter presented a darker color than the others, due to the portion of acerola pomace flour added being the largest. Color is the consumer's first contact with the

product, it is usually with the visual presentation where color and appearance stand out, these characteristics are associated with personal reactions of acceptance, indifference or rejection. Such factors are generally associated with culture, religiosity, among others (NOGUEIRA et al., 2002).

PHYSICOCHEMICAL CHARACTERISTICS OF PASTA

The addition of eggs to the formulation of pasta is one of the ways to improve the quality of the product by giving color, improving elasticity, reducing the amount of residues in the water and increasing its nutritional value (ORMENESE et al. 2004). Table 2 presents the results of the analyses of the physicochemical characteristics of pasta.

Table 2. Results of the analysis of the physicochemical characteristics of pasta.

Analysis	Humidity (%)	ph	Titrateable acidity	Ash(%)
Mass 1 (m1)	11,64	6	4,10	1,57
Mass 2 (m2)	11,52	6	3,84	1,63
Mass 3 (M3)	12,01	5,5	3,40	1,53
Mass 4 (M4)	12,03	5	2,51	1,50
Mass 5 (M5)	12,82	5	2,81	1,86

Source: Autor Himself (2019)

The determination of moisture is one of the most important and used measures in food analysis, as it is related to its stability, quality and composition and can affect aspects related to storage, product packaging and even processing. The moisture content is determined with the objective of verifying the efficiency of the drying process and verifying good storage conditions for the product (CASAGRANDE et al., 1999). However, all the pasta analyzed is similar with approximate values. Thus, it was observed that the values obtained in the pasta are within the parameters recommended by ANVISA's RDC No. 93/00, which are up to 35% for wet pasta and up to 13% for dry pasta.

In the determination of pH, all the pasta analyzed presented results equal to or less than 6. The values obtained showed that the pasta is within the standard, because according to RDC n° 90/2000 the maximum pH value should be equal to or close to 6.00 for pasta prepared with wheat flour. pH is a factor of great importance in limiting the ability of microorganisms to develop in food and contributes to defining technological procedures for conservation (SOUZA et al., 2008).

Acidity represents the state of conservation of flours, involving both chemical and microbiological aspects. The study of the acidity of wheat flour, as well as the products manufactured from it, is of great importance, not only in the economic aspect, through losses due to the reduction of shelf life, but also due to the reduction of the acceptability of these products by consumers through

changes in color and flavor (ORTOLAN et al., 2008). Titratable acidity, according to the determination of ANVISA (2000), dry and wet pasta must have a content of 5 ml NaOH N/100g of acidity, and a variation beyond, if this limit is exceeded, it is important to observe the limit, as it can be considered as a warning sign. Thus, it was observed that none of the pasta presented values higher than those allowed by legislation.

Ashes are mineral salts present in flour, mainly iron, sodium, potassium, magnesium and phosphorus, which are obtained by burning the organic matter in the flour, by heating it to temperatures close to 550-5700C. The highest concentration of these minerals is found on the outside of the grain, that is, in the bran; From this it can be concluded that the greater the amount or contamination of bran in the flour, the higher the resulting ash content. According to Normative Instruction No. 8 of June 2, 2005, flour can be classified according to the ash content, with a maximum content of 2.5% for flours. The values obtained in the analysis of the samples showed that the referred fresh pasta is within the legislation, which indicates an adequate food mass. High levels of ash in flours may indicate high extraction, with the inclusion of bran, which is undesirable due to the fact that it provides a darker color, lower cooking and interferes with the continuity of the gluten network (COSTA et al., 2008).

TECHNOLOGICAL CHARACTERISTICS OF PASTA

The results obtained for the specific cooking analyses of the noodles are presented in Table 3.

Table 3 - Technological properties obtained in the specific analyses of pasta containing acerola residue flour

Samples	Cooking time (min.)	Fat absorption (%)	Weight Gain (%)
M 1	3,05	0,51	1,96
M 2	4,23	0,53	1,80
M 3	4,29	0,70	1,65
M 4	4,40	0,75	1,48
M 5	4,45	0,78	1,45

Source: Own Author (2019).

The baking test serves to indicate how a product behaves during its cooking and to determine the ideal cooking time of the dough, the increase in weight, and the loss of soluble solids in the water of this dough, as the final quality parameter of the cooking of this dough is of great importance to the consumer.

It was found that the averages obtained in the cooking time for the five samples of pasta analyzed ranged from 3 to 4 minutes. The small variations in the cooking time of the analyzed noodles may be due to the shape, size of the pasta and the time and temperature of these samples

during drying. A different result in the cooking time of the control sample (100% wheat flour) of fresh spaghetti pasta was found by Spanholi and Oliveira (2009), who obtained a time of 7 minutes and also verified an increase in the cooking time with the replacement of 20% of wheat flour by the same amount of passion fruit albedo flour.

The fat absorption index in the analyzed pasta samples ranged from 0.51% (M1) to 0.78% (M5). The index increases as the amount of acerola pomace in the prepared pasta also increases. According to Cheftel et al. (1989), high values of fat absorption are desirable in products such as pasta, aiming to improve their mouthfeel (texture). Thus, acerola pomace flour is a recommended raw material to be used in the preparation of pasta, when considering the fat absorption parameter.

The weight increase of the cooked product of the pasta analyzed ranged from 1.96% (M1) to 1.45% (M5). It is noted that as there was an increase in the concentration of acerola pomace flour in the pasta analyzed, the weight gain of these pasta decreased. According to Costa (2001), weight gain is related to the capacity of water adsorption in pasta and also depends on the shape and size of the pasta analyzed.

CONCLUSION

The data found in the chemical and technological analyses showed that the food masses developed are within the legislation, which indicates an adequate food mass. According to the results obtained, it is concluded that acerola pomace flour (*Malpighia glabra L*) can be added to the formulation of pasta, as it is an alternative in the elaboration of a new product and use of acerola fruit residue.

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Advanced extraction of bioactive compounds from mamacadela: An approach for efficient and sustainable process

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ABSTRACT

The Cerrado biome has numerous species of fruits little known and exploited, both by the population and the industry, and can be an alternative source of natural active compounds. This study aimed to optimize the process of extraction of antioxidants for mamacadela fruit (*Brosimum Gaudichaudii* Trécul) using the response surface methodology. The variables were: temperature (30 - 60 °C), time (30 - 60 min), water or ethanol, and use or not of ultrasonic bath equipment. The quantification of antioxidant capacity was using the methods: ABTS, DPPH, FRAP, and total phenolic content. In the optimization of the extraction it was possible to identify that the extract with greater antioxidant capacity was with the use of water as solvent at 60°C and with the shortest extraction time of 30 minutes, and without the utilization of an ultrasound bath. Thus, it is important to conduct more studies on the antioxidant potential of mamacadela fruit, seeking agroindustrial exploitation, besides adding value to food products.

Keywords: Antioxidants, Bioactive compounds, Experimental design.

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INTRODUCTION

The native fruits of the Brazilian Cerrado are widely used by the local population, especially in natural form, they occupy a prominent place in the Cerrado ecosystem, being marketed in regional fairs and with great popular acceptance. The characterization of bioactive compounds in fruits of the Cerrado is of great relevance for the search for alternative sources and that can group desirable attributes (antioxidant, antimicrobial, anticarcinogenic, antidegenerative and aging retardant properties). One of the market trends today is the consumer's search for products with sensory and nutritional qualities that provide healthiness and well-being, which made the food industries adapt to these market segments, seeking new formulations and innovative food products [1–5].

Mamacadela (*Brosimum Gaudichaudii* Trécul) is a fruit otherwise known as “mamacadela”, “mamica-de-cadela” or “inharé”, found in the cerrado, little known, and belongs to the family Moraceae. This family has 53 genera and about 1,500 species identified, with tropical prevalence, with more than 50% of the genera present in the Neotropical region, mainly in South America. Moraceae species are found in or near humid forests. Artocarpus, Brosimum, Ficus and Morus are among the best-known genera, which correspond to the widely known and consumed fruit plants of great nutritional and economic importance, such as Jaqueira, walnut, fig and blackberry [6,7].

Mamacadela leaves, bark and roots have ethnopharmacological uses in the treatment of various autoimmune skin diseases, especially vitiligo [8,9]. Root bark tea is used in baths, and ground root juice is used as an added component in ointments and lotions [10]. Even if the leaves and roots are already used, there is little information about the pulp extraction, about presence and antioxidant capacity of the bioactive compounds of this fruit, thus the present work is innovative evaluating by the first time the use of an advanced extraction process for mamacadela pulp. It is worth highlighting that the extraction yield depends on the type of solvent, with variable polarity, extraction time, extraction temperature and sample-solvent ratio. So, the MSR (response surface methodology) is also useful for reducing the number of experimental trials and determining the effects of interaction between variables. Defining optimal conditions in the extraction process is essential to increase the effectiveness of the extraction of bioactive compounds [11–13]. Thus, this work aims to optimize the antioxidants extraction process from mamacadela pulp.

MATERIALS AND METHODS

EXTRACTS AND EXPERIMENTAL DESIGN

Fruits (approximately 5 kg) were collected in the rural area, in the farm Felicidade, in Jussara-Goiás - Brazil, with the following geographic coordinates Longitude: 50 52' 9" West. After washed, sanitized, and seed separation, the pulp was frozen (-18 °C) and transported to the State University of Maringá, where it remained frozen until the moment of analysis.

For the antioxidant extraction, the frozen pulp was subjected to drying at 50 °C in an oven with air circulation. For optimization, 10 g of dry sample was weighed and 25 mL of ethanol (+1) or distilled water (-1) was added during 30 (-1) or 60 (+1) minutes at a temperature of 30 (-1) or 60 (+1) (°C) under light, in a Dubnoff bath (-1) (Model TE-053 25 5 rpm) or with the use of ultrasonic bath (+1) (Unique model USC-1600^a, 100 W, 40 KHz). After the above procedures, each extract was filtered in 80G qualitative paper filter, 90 mm diameter and 90 mm Chiarotti porcelain funnel and then the supernatant was stored in an amber bottle and stored under freezing in a light shelter for further analysis. The extracts were submitted to antioxidant capacity analysis, and analyzed in triplicates. The independent variables tested (Table 1) were extraction temperature, extraction time, solvent (ethanol concentration in aqueous solution) and use of ultrasonic bath equipment. The dependent variables were: the antioxidant capacity quantified by the methods of DPPH radical sequestration, ABTS and FRAP and the content of phenolic compounds.

Table 1. Real and coded levels of variables.

Level	-1	+1
Extraction temperature (°C)	30	60
Extraction time (min)	30	60
Solvent	Water	Ethanol
Using the ultrasonic bath	Not	Yes

ANTIOXIDANT CAPACITY AND PHENOLIC COMPOUNDS

ABTS: An aliquot of 30 µl of extract was added to the tubes, along with 3 mL of already diluted ABTS•+ reagent [14]. The samples were incubated for 6 min, protected from light at room temperature and the reading was made at a wavelength of 734 nm in FEMTO spectrophotometer (Cirrus 80MB). The antioxidant capacity of the mamacadela extract was determined from the Trolox standard curve (2 mol/L) and expressed in mg Trolox/g of sample. The extract was diluted at a concentration of 200 mg/mL so that the ABTS values were within the standard curve ($y = -0.0003x + 0.6603$ / $R^2 = 0.9953$).

DPPH: An aliquot of 150 µl of the samples were added to 2.85 mL of a methanolic solution of DPPH, homogenized and maintained for 1 hour under shelter of light. Then, the absorbance values were measured at the wavelength of 515 nm in the FEMTO spectrophotometer (Cirrus 80 MB), the solvent methanol was used as white [15]. The analytical curve was prepared from ethanolic solutions of Trolox at concentrations ranging from 0 µmol/L to 900 µmol/L . The response was expressed in mg Trolox equivalents per gram of sample. The results were calculated using the standard curve of Trolox and expressed in mg Trolox/g of sample ($y = 0.1140x - 0.1125$ / $R^2 = 0.9991$).

FRAP: The FRAP reagent was prepared using the 0.3 mol/L acetate buffer solution TPTZ 10 mol/L ferric chloride 20 mol/L in the ratio 10:1:1 (v:v). The 300 mol/L sodium acetate buffer solution was performed by adding 3.1 g of anhydrous sodium acetate in 16 mL glacial acetic acid

supplementing with distilled water to a volume of 1000 mL. The preparation of 10 mol/L TPTZ solution (2, 4, 6 tripiridyl-s-triazine solution) was performed by adding the mass of 0.312 g of TPTZ in 5 mL of HCl (hydrochloric acid) 40 mol/L. Following the preparation of the iron chloride solution at 20 mol/L [16]. The new working solution was prepared by mixing 25 mL of acetate buffer, 2.5 mL of TPTZ solution and 2.5 mL of 20 mol/L iron chloride solution. An aliquot of 90 μ l of sample extract, with 270 μ l of distilled water and 2.7 mL of FRAP solution by incubation of 30 min sheltered light at a temperature of 37 °C. The FRAP reagent was used as white, the readings were at 595 nm in FEMTO Cirrus 80MB spectrophotometer. The Trolox standard was used for the development of the calibration curve (0-700 μ mol/L; $y = 0.0013x + 0.0059$ / $R^2 = 0.9995$), the results were expressed in mg of Trolox/g of sample.

Phenolic compounds: The content of total phenolic compounds was determined by using the Folin-Ciocalteu method [17]. In light-proof test tubes, 125 μ l of extract was placed and 125 μ l of Folin 50% was pipetted. Then 2250 μ l of sodium carbonate was added. For the white, the same process was used, only replacing the sample with distilled water. The solutions were incubated in the dark for 30 minutes for complete reaction of the reagent and readings at 725 nm, analysis was performed in triplicate. Gallic acid was used for the development of the calibration curve (0-300 μ mol/L), the results were expressed in mg gallic acid equivalent per 100 g sample on dry basis (mg EAG.100 g⁻¹ dry basis). For this analysis of phenolic compounds content, the extracts were diluted at a concentration of 200 mg/mL ($y = 0.0018x - 0.0182$ / $R^2 = 0.998$).

All results were submitted to the analysis of variance and Tukey's test for minimum significant difference ($p < 0.05$) between means using the statistical program Sisvar 5.6.

RESULTS AND DISCUSSION

Table 2 presents the results of DPPH, FRAP, ABTS, and phenolic compounds for mamacadela.

Table 2. DPPH, FRAP, ABTS analyses expressed in (μg Trolox/g sample) and phenolic compounds content (mg EAG/g sample) for mamacadena.

Treatment	Extraction parameters				Antioxidant capacity			
	T ($^{\circ}\text{C}$)	Time (min)	Solv.	USD	DPPH	FRAP	ABTS	PC
1	30	30	Water	Not	1,77 ^c $\pm$ 0,14	3,04 ^{de} $\pm$ 0,17	38,51 ^c $\pm$ 1,58	0,69 ^{ef} $\pm$ 0,08
2	60	30	Water	Not	2,87 ^{ab} $\pm$ 0,20	5,00 ^c $\pm$ 0,18	43,93 ^b $\pm$ 0,60	0,44 ^f $\pm$ 0,23
3	60	60	Water	Not	2,47 ^b $\pm$ 0,04	6,61 ^b $\pm$ 0,25	11,56 ^{ef} $\pm$ 0,00	0,71 ^{ef} $\pm$ 0,02
4	60	60	Ethanol	Not	0,95 ^{de} $\pm$ 0,03	3,63 ^d $\pm$ 0,06	18,31 ^d $\pm$ 0,65	0,43 ^f $\pm$ 0,03
5	60	60	Ethanol	Yes	0,55 ^{efg} $\pm$ 0,05	2,12 ^{ef} $\pm$ 0,09	13,77 ^e $\pm$ 0,46	2,40 ^d $\pm$ 0,06
6	60	60	Water	Yes	0,98 ^d $\pm$ 0,05	2,00 ^{gh} $\pm$ 0,03	13,33 ^h $\pm$ 1,34	0,53 ^{ef} $\pm$ 0,22
7	60	30	Ethanol	Yes	0,52 ^{efg} $\pm$ 0,02	0,81 ^{gh} $\pm$ 0,04	8,90 ^f $\pm$ 0,18	2,45 ^d $\pm$ 0,07
8	30	60	Ethanol	Yes	0,26 ^{fg} $\pm$ 0,03	0,41 ^h $\pm$ 0,15	0,79 ^h $\pm$ 0,20	3,44 ^b $\pm$ 0,12
9	30	60	Ethanol	Not	0,22 ^{fg} $\pm$ 0,01	0,38 ^h $\pm$ 0,02	1,90 ^h $\pm$ 0,60	3,46 ^b $\pm$ 0,08
10	30	30	Water	Yes	0,56 ^{efg} $\pm$ 0,02	1,11 ^{gh} $\pm$ 0,05	4,60 ^h $\pm$ 0,90	0,53 ^{ef} $\pm$ 0,26
11	30	30	Ethanol	Not	0,24 ^{fg} $\pm$ 0,01	0,95 ^{gh} $\pm$ 1,09	6,83 ^{fg} $\pm$ 0,36	2,99 ^c $\pm$ 0,10
12	30	60	Water	Not	0,82 ^{de} $\pm$ 0,06	2,20 ^{gh} $\pm$ 0,03	21,73 ^{gh} $\pm$ 0,19	0,78 ^{ef} $\pm$ 0,10
13	30	60	Water	Yes	1,01 ^d $\pm$ 0,03	2,61 ^{fg} $\pm$ 0,06	18,83 ^{gh} $\pm$ 0,67	0,92 ^e $\pm$ 0,21
14	60	30	Ethanol	Not	0,64 ^{def} $\pm$ 0,03	1,22 ^{gh} $\pm$ 0,19	4,80 ^h $\pm$ 0,38	4,27 ^a $\pm$ 0,13
15	60	30	Water	Yes	3,09 ^a $\pm$ 0,20	9,00 ^a $\pm$ 0,83	52,63 ^a $\pm$ 1,79	0,55 ^{ef} $\pm$ 0,04
16	30	30	Ethanol	Yes	0,23 ^g $\pm$ 0,03	0,58 ^{gh} $\pm$ 0,02	8,78 ^f $\pm$ 0,54	3,52 ^b $\pm$ 0,20

* Letters in the same column indicate that there is a significant difference ($p < 0.05$). The values are the mean standard deviation of 3 repetitions. T: temperature ($^{\circ}\text{C}$); Solv: solvent; USD: ultrasound bath; PC: phenolic compounds.

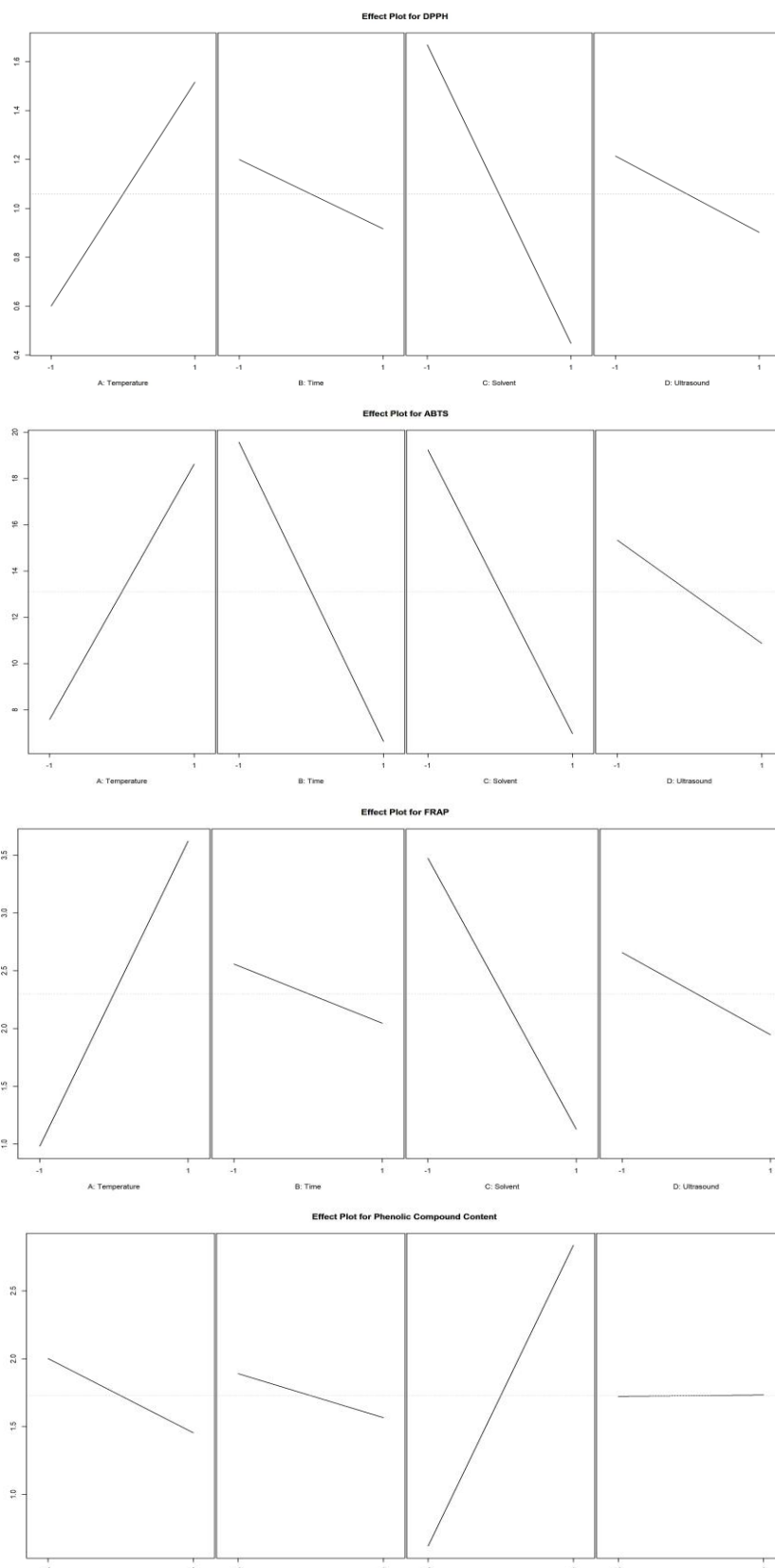
The highest values found for antioxidant capacity were for treatment 15, which uses a higher temperature (60°C), shorter time (30 minutes), water as a solvent, and ultrasound. However, for phenolic compound extraction, the highest values were for treatment 14, which uses a higher temperature (60°C), shorter time (30 minutes), ethanol as a solvent, and without ultrasound uses.

The antioxidant capacity found for mamacadena (Table 2) can be influenced by factors such as maturity, species, cultivation practices, geographical origin, growth stage, cultivation conditions, and storage process, as well as a preservation method and type of carrier agent [18–20]. Water as a solvent, higher temperatures, and the use of an ultrasonic bath were previously cited as great parameters for extracting antioxidant compounds from fruits [11,21–23].

Figure 1 shows the effects of extraction parameters for quantification of DPPH, ABTS, FRAP, and phenolic compound content. The data obtained show various interferences during the

extraction process. While the temperature had a positive effect, the use of ethanol had an inverse effect on the antioxidant extraction of mamacadela, for all methods used for quantification.

Figure 1. Effects of extraction parameters for quantification of DPPH, ABTS, FRAP and phenolic compound content. Temperature -1 = 30°C and +1 = 60°C; Time -1 = 30 min and +1 = 60 min; Solvent -1 = water and +1 = ethanol; Ultrasound -1 = not; +1 = yes.



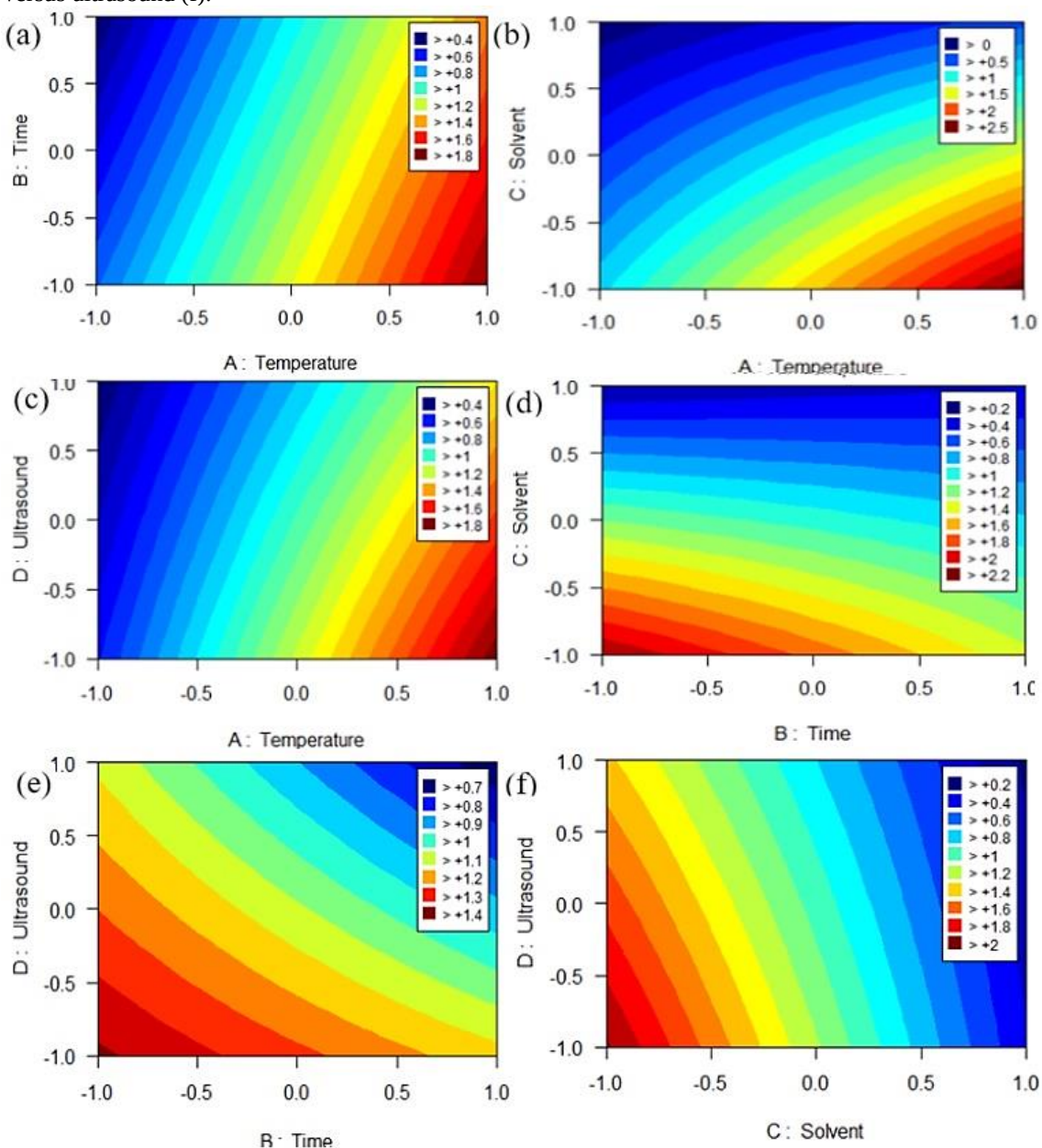
The time factor had a negative effect on the extraction of phenolic compounds and antioxidants. For the solvent type factor, water was the one that extracted the highest amount of antioxidant compounds. However, for the content of phenolic compounds ethanol presented better results.

In the DPPH analysis, the parameter that most interfered with quantifying the response variable was the use or not of ethanol, where the use of water showed the highest result. Therefore, mamacadela antioxidant compounds could be extracted using a sustainable green solvent, facilitating its extraction and reducing the cost of being a cheap solvent and easy availability.

For the ABTS methodology, the interaction between time and water as solvent showed greater significance, the increase in extraction time resulted in a decrease in antioxidant compounds present in the extracts. The FRAP analysis showed a positive relationship between the increase in extraction temperature and the increase in antioxidant compounds.

Figure 2 shows the response surface methodology of DPPH analysis, representing all other analyses that showed similar results. Double interactions were analyzed: temperature versus time, temperature versus solvent, temperature versus ultrasound, time versus solvent, time versus ultrasound, and solvent versus ultrasound.

Figure 2. Response surface for the analysis of DPPH in mamacadela fruits. Interaction of temperature versus time (a), temperature versus solvent (b), temperature versus ultrasound (c), time versus solvent (d), time versus ultrasound (e) and solvent versus ultrasound (f).



In all antioxidant analyses, the maximum temperature showed more significant results (Figure 1 and 2) This result may be related to the increase in diffusion rates and solubility of analytes, and a decrease in viscosity and surface tension of solvents. However, in some cases, a decrease in the extraction yield can be observed, since some compounds, such as phenolics, can be degraded when subjected to high temperatures [24–27].

The chemical composition and phytochemical compounds contained in plant materials have different solubility properties in different solvents, the ideal solvent for extraction will depend on the specific plant materials and the compounds that must be isolated [24,28]. In addition, the use of ultrasound is a promising technology for the extraction process [24,29–31].

CONCLUSION

It was possible to extract a representative amount of antioxidants from mamacadela fruits prioritizing a more sustainable process, using water as solvent. Overall, the conditions that maximized the extraction of antioxidants from the mamacadela fruit were using water as a solvent, at 60 °C, with the shortest extraction time (30 min). Finally, we emphasize the importance of conducting more studies on the antioxidant potential of mamacadela fruit, to seek to add value to these species and encourage their cultivation and genetic improvement, thus enabling the commercialization of these fruits to other Brazilian regions, increasing income for family farming and strengthening food and nutritional security of Brazilians.

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Genetic conservation of breeding populations: Literature review from the perspective of species of the cerrado biome

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ABSTRACT

This work addresses the Genetic Conservation of Breeding Populations, focusing specifically on the species of the Cerrado biome. Using a qualitative approach and drawing on theoretical references, the research examined key concepts related to forest genetic conservation, genetic variability, conservation methods and the challenges faced in this context. The methodology employed involved a detailed bibliographic review and a critical analysis of the information collected in recent years. The efforts and cases of genetic conservation of some species of the cerrado were highlighted, despite the scarcity of studies in this field. The discussion raised the urgent need for more research and actions aimed at the conservation and improvement of the species of the cerrado biome, given their importance for biodiversity and their relevance for the maintenance of natural ecosystems. The study also addressed the advantages and disadvantages of different methods of genetic conservation, as well as future trends in this area. In short, the work offers a comprehensive view of the genetic conservation of cerrado species, highlighting the importance of their preservation for environmental sustainability and food security.

Keywords: Agroforestry, Biomarkers, Cerrado, Genetic Improvement.

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INTRODUCTION

Brazil is one of the world leaders in the biodiversity of tree species, standing out for its heritage of approximately 15 to 20% of all species in the world (BRASIL, 2022; ASSIS, DOBROVOLSKI AND BORGES, 2021).

However, as Peixoto and Vilella (2018) put it, in view of the socioeconomic and environmental challenges faced by Brazilian forest species, the use of biotechnology for the conservation and genetic improvement of tree species populations is indispensable and modern, as it contributes to the maintenance and improvement of species. Mainly, due to the fact that Brazil is a signatory to the Convention on Biological Diversity (CBD), in which it is responsible for preserving and sustainably using the genetic heritage of biological species existing in the national environment (SÁ AND NAVES, 2023; BALLESTEROS-MEJIA, LIMA AND COLLEVATTI, 2020).

Thus, the future of the populations of tree species in Brazilian biomes has been the object of study in the conservation of genetic resources, given the environmental, economic and social challenges, which directly influence the genetic conservation of the various species of the various Brazilian biomes, in particular, the cerrado (PEIXOTO and VILELLA, 2018; ASSIS, DOBROVOLSKI AND BORGES, 2021).

In this regard, according to the authors Assis, Dobrovolski and Borges (2021), the cerrado biome has suffered devastation with numerous socioeconomic and environmental factors, that is, climate change, expansion of livestock and agriculture, which puts native biodiversity at risk, especially endemic tree species, causing the risk of extinction, of decrease in the populations of forest species in this biome, which represents approximately 5% of the species in the world biome.

Given this scenario, it is questioned, as a result of the increase in deforestation in the Cerrado, a risk factor for the existence of native species, whether the forest diversity of the Cerrado has been prioritized by the genetic conservation of forest improvement populations?

The present study aims to carry out a literature review on the theoretical aspects regarding the genetic conservation of forest breeding populations, focusing on forest species of the cerrado biome.

Throughout the literature review, we seek to understand the theoretical aspects of genetic conservation, reviewing the current concepts. In addition, a theoretical overview will be carried out on breeding population, genetic variability, selective pressures and genetic drift, theoretical institutes used in genetic conservation. In addition, it will seek to understand the main methods used in genetic conservation, analyzing their advantages and disadvantages. Finally, to discuss the challenges and trends in genetic conservation, in an interdisciplinary way with the species of the cerrado biome.

MATERIAL AND METHODS

In the research on genetic conservation of forest breeding populations, with a focus on cerrado species, the methodological procedures were based on literature review, with a focus on bibliographic research, through relevant research in scientific articles, books, magazines, and academic websites (MATTAR AND RAMOS, 2021).

In the same regard, Mattar and Ramos (2021) state that the literature review is a crucial step in scientific research, as it provides a more comprehensive and up-to-date analysis of existing knowledge on the respective topic. Therefore, in the last five years, the approaches and methods for conducting literature reviews have evolved, reflecting advances in information and communication technologies, as well as changes in the genetic conservation practices of native forest populations of the cerrado. In this study, the most relevant materials and methods used in recent literature reviews were addressed.

Corroborating, Marconi and Lakatos (2017) state that with the advancement of the internet, sources of information have become more accessible and diverse. In addition to traditional academic databases, such as Scopus, online platforms, institutional repositories, and academic social networks play a significant role in articles, theses, and other relevant documents.

In this sense, the search for the research was carried out through the digital platforms Portal periodicals of Capes, Google Scholar and others, as the search tools were aided with advances and access to the internet, such as Google Scholar, both were widely used to find scientific articles, while reference management tools, such as EndNote and Zotero, assist in the organization and selection of relevant materials (MATTAR AND RAMOS, 2021).

In summary, the material and methods of this literature review were based on the last five years, where they reflect an adaptation to emerging technologies, emphasizing the importance of a systematic approach, diversification of sources and efficient use of digital tools. This evolution continues to promote the quality and relevance of literature reviews as a basis for the advancement of scientific knowledge.

THEORETICAL ASPECTS OF GENETIC CONSERVATION

FOREST GENETIC CONSERVATION

Environmental changes resulting from natural phenomena, as well as anthropogenic actions, have caused concern among scientists and scholars about the preservation and conservation of the genetics of forest species. But what would Genetic Conservation be? In the words of Costa (2018), genetic conservation is the branch of science that produces knowledge with the objective of preserving species capable of genetic adaptation to environmental phenomena, with the use of systematized genetic methods and techniques, in order to minimize the possibility of extinction. This

is because species have genetic variability among populations and subpopulations (SILVA, et al., 2023).

In this sense, it is clear that forest genetic conservation aims to preserve the genetic material of species with potential for forest improvement and for the use of biotechnology, using existing conservation methods, whether *in situ* or *ex situ* (SILVA, et al., 2023).

For Sá and Naves (2023), genetic conservation is in its essence a global strategy and concern to ensure the conservation of the genetic bank of species, in order to preserve and maintain species lost in their natural habitats and centers of diversity.

In this way, genetic conservation is a salutary mechanism for the preservation of forest species, especially in the cerrado biome, which has been the target of anthropogenic actions that have put at risk the diversity of tree species essential for the life of diversity in this biome.

BREEDING POPULATIONS AND THEIR IMPORTANCE

The genetic conservation of populations is the scientific area that requires an object of research in a systematized way. In this regard, research on genetic conservation requires working with a base germplasm, with wide genetic variability, so it requires a breeding population (DE RESENDE AND ALVES, 2021).

According to the authors De Resende and Alves (2021), breeding population is the set of individuals, subpopulation, of a forest species that represents an effective number of individuals, so that they maintain the genetic variability of the original population, aiming at conservation and improvement (SALGOGRA AND CHAUHAN, 2023).

The breeding population is healthy, as it is through it that long-term improvement is sought, that is, over time there is a continuous increase in the presence of beneficial alleles, based on selective cycles, which can result in the gain and maintenance of the adequate population size (DE RESENDE AND ALVES, 2021).

GENETIC VARIABILITY, SELECTIVE PRESSURES, AND GENETIC DRIFT

The genetic variability of forest species plays a crucial role in adapting to and maintaining biological diversity, as well as being vital for the sustainability of ecosystems and human well-being. Therefore, their conservation is of paramount importance to ensure the resilience and health of forest ecosystems (JULLIEN et al., 2019). Also according to the author, gene flow is an evolutionary force that allows the exchange of alleles, thus increasing genetic diversity.

The reproductive system plays an important role in genetic diversity, as self-fertilization limits pollen and seed dispersal and the potential for recombination between alleles of different individuals, unlike crossbreeding. As a result, crossbred species are expected to preserve more

genetic diversity than autogamous species (JULLIEN et al., 2019; SALGOGRA AND CHAUHAN, 2023).

Heterozygosity is one of the parameters of genetic diversity. While gene flow increases genetic diversity by allowing the exchange of alleles between populations (SMITH et al., 2020), self-fertilization can lead to the loss of genetic variability over time, as there is no mixing of genes between different individuals. This makes populations more susceptible to disease, environmental stresses, and changing environmental conditions. In addition, it can lead to the accumulation of deleterious mutations and the expression of harmful recessive traits.

Furthermore, with regard to selective pressures and genetic drift, it is verified that they result from genetic mutation and recombination among members of a population, which results in the acquisition or suppression of characteristics that lead the species to adapt to ecological conditions and to survive environmental changes. Thus, genetic drift can occur due to the reduction or disappearance of existing genetic material in individuals that cease to exist (SMITH et al., 2020; SALGOGRA AND CHAUHAN, 2023).

Therefore, such concepts should be used in the analysis of genetic alterations of forest species existing in the Cerrado, since with the fragmentation of the biome, many rare alleles existing in certain individuals may cease to exist, compromising the conservation of native species of the Cerrado.

METHODS OF GENETIC CONSERVATION

TRADITIONAL METHODS OF GENETIC CONSERVATION

The conservation of the genetic diversity of plants and animals is a key aspect to ensure the resilience and sustainability of ecosystems over time. In this regard, over the years, a number of traditional methods have been developed to preserve this genetic diversity, ranging from seed storage to the protection of natural habitats (SALGOGRA AND CHAUHAN, 2023). This article explores some of these methods and their importance in maintaining biodiversity and providing valuable genetic resources for various areas, such as agriculture, medicine, and scientific research.

Among the methods discussed are seed and germplasm banks, *ex situ* collections, creation of natural reserves, genetic improvement programs, and *in situ* conservation (MOLONEY et al. 2023). Understanding and applying these strategies play a crucial role in preserving biological diversity and ensuring a sustainable future for generations to come.

The seed bank under the tree canopy was made up of diversified species of life form and dispersal syndrome, being determinant for successional dynamics (MORAES et al. 2020). In addition, it is considered the set of all viable seeds in the soil and can be composed of seeds of

species present in the local vegetation, as well as species that are present in neighboring areas, which arrive through seed rain (CAPELLESSO et al. 2015, OLIVEIRA et al. 2018).

The conservation situation of the species applies due to climate change and anthropogenic actions that have been causing strong genetic erosion of the species in their dispersion zones, which justifies the prospection and collection of germplasm for the introduction of new accessions in germplasm banks and the establishment of work collections (CORADIN et al. 2022). *Ex situ* conservation is a biodiversity preservation strategy that involves maintaining and caring for living organisms outside their natural habitats. This approach is essential to protect endangered species, as well as to preserve the genetic diversity of plants and animals (DINIZ-FILHO, 2020).

Thus, the conservation of plant variability in *ex situ* conservation chambers thus acquires relevance not only as a basis for breeding programs, which seek high performance and greater productivity, but also constitutes a matter of food security and ensuring the continuous use of the most important plant species for human consumption (SANTONIERI et al. 2016; SALGOGRA AND CHAUHAN, 2023).

The idea of nature conservation, for the creation of nature reserves, has required thinking about the maintenance of natural areas with little or no anthropogenic alteration (BRANDÃO et al. 2021). One of the alternatives for conservation was the creation of Conservation Units (UC), or legally protected territorial areas, in order to safeguard biodiversity and natural resources (GALVÃO, 2018).

The importance of nature conservation through the creation of nature reserves and Conservation Units (CUs), as strategies to protect and propagate biodiversity, conserving genetic material and natural resources. It is critical to recognize that maintaining areas with little or no human interference is crucial to preserving healthy and functional ecosystems. The UCs play a crucial role in protecting flora and fauna, as well as promoting awareness about the importance of environmental conservation. However, it is important not only to establish these protected areas, but also to ensure effective and sustainable management to ensure their long-term effectiveness (BALLESTEROS-MEJIA, LIMA AND COLLEVATTI, 2020).

The development of Brazilian agribusiness has brought major transformations and advances in the productive and technological structure, promoting a process of innovation in part of the country (OLIVEIRA; RODRIGUES, 2020; SANTOS et al., 2017). For example, the improvement of cashew (*A. occidentale* L.) solved the case of plant height and productivity, short stature helps in orchard management: pruning, pest control and harvesting, generating a substantial increase in nut production in CE, PI and RN (QUEIROZ et al., 2012). Overall, genetic improvement plays a crucial role in promoting food security, adapting to environmental changes, and sustaining agriculture, ensuring that plants can thrive and provide food.

In situ conservation, on the other hand , refers to the conservation of species and habitats in their natural environment, that is, where they are found in nature (ESLABÃO et al., 2022). This term is often used in contrast to "*ex situ* conservation," which involves removing specimens from their natural environment to be kept and protected in controlled facilities such as a zoo, botanical gardens, or germplasm banks. The *in situ conservation method* aims to protect entire ecosystems, wild populations, and natural habitats, ensuring that they continue to exist in their original environment. This can involve a variety of strategies, such as the creation and management of protected areas, the implementation of regulations to protect endangered species and their habitats, the sustainable management of natural resources, and the involvement of local communities in conservation.

It is clear that traditional methods are viable means to be applied in the genetic conservation of the populations of the Brazilian cerrado, as a way to ensure preservation. However, it is observed that other methods are currently being applied in the conservation of forest species.

MODERN TECHNIQUE METHODS: GERMPLASM BANKS, *IN SITU*, *EX SITU* AND *ON FARM CONSERVATION*

The genetic conservation of forest species has sought, through scientific studies, methods that ensure the existence of species, in view of natural phenomena and anthropogenic actions that threaten the existence of species in the Brazilian environment, including the Cerrado biome (SALGOGRA AND CHAUHAN, 2023). In this sense, some methods stand out in the process of species conservation.

According to Moloney et al (2023), the germplasm bank is a technique within the *ex situ method*, in which organic specimens are kept and conserved in an artificial environment, but under the control and supervision of man, seeking in this process to control the humidity of the environment and its temperature, giving greater viability to the seeds, for a long period. Through the germplasm bank, scholars have access to the genetic variety of several species, being able to conserve their hereditary set or carry out research on genetic modification and improvement, in order to make them more resistant to environmental changes. (SALGOGRA AND CHAUHAN, 2023)

Regarding the *in situ* conservation method, according to Moloney (2023) it can be said that it is the form of genetic conservation of certain tree species in their natural habitat, so that the conservation of the genetic chain is conserved naturally, in an environment that provides contact with land, water, and existing biological diversity (SALGOGRA AND CHAUHAN, 2023).

In this way, *in situ* conservation is carried out through protection strategies and policies, among which are legally protected areas, that is, Conservation Units, as provided for in the Law of the National System of Conservation Units - SNUC (HOBAN, et al., 2020).

Last but not least, there is the on-farm method, which according to Salgogra and Chauhan (2023) is the traditional method in which farmers or producers conserve species or seeds on their properties, it has a unique role in species conservation, since they conserve and maintain species in their habitat and in contact with biodiversity. *On-farm* conservation helps in the genetic conservation of species, contributing to the preservation of species, and contributing to the genetic perpetuation of species and ensuring a natural heritage for future generations.

CHALLENGES AND TRENDS IN THE GENETIC CONSERVATION OF CERRADO SPECIES

STUDIES WITH NATIVE SPECIES OF THE CERRADO

The genetic conservation of forest species is one of the alternatives to try to minimize the loss of hereditary content of tree species (LEMES, DE ANDRADE AND LOYOLA, 2020). However, in the Cerrado, with the advance of agriculture and livestock, society demands sustainable development, which makes it difficult to introduce more effective environmental policies in the economic system, because it is not enough just to create legislation, because without public policies of applicability, as well as the lack of projects from the private sector for the preservation of species, the problem of population fragmentation and genetic loss tends to increase (COSTA AND MELO, 2020).

According to Medeiros et al (2022), it is verified that the conservation study focused on the cerrado and its species were developed by a few groups, restricting it to *the cerrado stricto sensu* and riparian forests. In addition, it points out that plant species of the cerrado biome in conservation and restoration projects are neglected, being disregarded the original characteristics, growth, in short, there is no systematized method to evaluate results.

Corroborating Ballesteros-Mejia, Lima and Collevatti (2020) state that the Brazilian cerrado biome, due to inadequate land use, presents a depression of habitat fragmentation, reaching 39% of its cover, due to the growth of agriculture and livestock. Thus, this can cause the genetic loss of several species useful for conservation and genetic improvement. Therefore, the lack of scientific studies of the genetics and ecology of the cerrado strengthens the evidence to describe patterns in the study of the genetic diversity of the cerrado.

Furthermore, despite the little study on the genetic conservation of species in the cerrado, the university has stood out in research on the genetic conservation of species in this Brazilian biome, which despite being the second largest Brazilian biome, is threatened by the advances of human anthropic actions. (ASSIS, DOBROVOLSKI AND BORGES, 2021).

Among the few studies on the genetic conservation of cerrado species, Chave (2018) states that research carried out by the Federal University of Goiás stands out, for the formation of genetic

banks, aiming at the improvement and genetic preservation of species such as: Baru, Cagaita and Jatobá-do-Cerrado.

In addition, studies have been developed with the aim of conserving and improving Cerrado species, since the genetic variability of the Cerrado species is essential for survival and adaptation to environmental and socioeconomic changes that threaten the biome (RIBEIRO AND RODRIGUES, 2006; COLLI, VIEIRA AND DIANESE, 2020). Among the studies, the following stand out: Study with Araticum (*Annona crassiflora* Mart.) which was developed with a view to its conservation and improvement, as it has potential for ornamentation and medicinal value. Another species studied is the Baru (*Ipteryx alba* Vog.) that has been researched because it has its value in food and in the pharmaceutical industry. Another species studied is the Cajuí (*Anacardium* spp.), a fruit widely used in the feeding of the species of the cerrado and the population, with enormous industrial potential. (GOMES et al, 2021). Cagaita (*E. Dysenterica*) was studied due to its genetic population structure, as well as its potential in agricultural production. The Ipê-Roxo (*Tabebuia Impetiginosa*) had a study for genomic analysis aiming at preservation and sustainable management. The Cerrado Jatobá (*H. stigonocarpa*) was studied due to its food potential and the quality of its wood, which provides important information for conservation programs. Jenipapo (*G. americana*) was studied for analysis of heterozygosity levels and the reproductive process. The Pequi (*Caryica brasiliense* Camb.) was studied with a view to its genetic improvement due to being an important fruit tree in the diet (RIBEIRO AND RODRIGUES, 2006).

NEW TECHNOLOGIES FOR GENETIC CONSERVATION

In the country, about 50% of family farming establishments are concentrated in the Northeast, with the vast majority located in the region with a semi-arid climate; the remaining percentage corresponds to 19% in the South, 16% in the Southeast, 10% in the North, and 5% in the Midwest (MASSRUHÁ et al. 2020). According to Silva et al. (2019), the agricultural sector in the Northeast does not behave in a homogeneous way, that is, farmers located in the semi-arid region are faced with different geographical, cultural, and socioeconomic conditions, which must be taken into account regarding the productivity characteristics of each species and its technological efficiency.

The adaptability of common bean genotypes, for example, is specific to each region, brings a series of benefits to the farmer, since not all cultivars respond well, in all regions, due to local environmental conditions, such as temperature, humidity and especially the photoperiod, which interfere in the development of the crop, significantly reducing its productivity (HIOLANDA et al. 2018).

Thus, all types of plants must be subjected to experiments in crop fields in different regions, in order to identify which are the most suitable and which have the best yield in each location.

Several breeders have adopted molecular marker tools to assist in breeding work, especially for germplasm characterization, assisted selection, identification of accessions with tolerance to biotic and abiotic stresses, in which the results have been a major contributor to the advancement of breeding work on various crops (SANTOS et al. 2013). For Leal et al. (2010), the molecular markers RAPD and SSR are among the most used to determine genetic divergence.

The technique of random amplified DNA polymorphism (RAPD) is low-cost and easy to perform, where it consists of arbitrary primers and does not depend on the previous sequencing of the genome of the species in which it will be applied (DUTRA FILHO et al., 2013). Thus, we realize that the main advantage of this technique is the speed and ease of execution in obtaining the results. For Dutra et al. (2013), the EST'S SSR primers are a functional class of molecular markers based on simple repeated sequences. They are linked to *loci* that determine characteristics of interest, have a co-dominant character, and can differentiate homozygous from heterozygotes, forming highly polymorphic genetic loci (FERREIRA; GRATTAPAGLIA, 1998).

However, the joint use of these two types of markers, each amplifying specific regions in terms of their potential, will contribute to greater genome coverage and also to greater consistency in the results related to interpopulation genetic similarity or divergence (Dutra et al. 2013).

Technology plays a key role in genetic conservation for several reasons. Firstly, it allows for the efficient and long-term storage of genetic material in germplasm banks, preserving genetic diversity and ensuring future food security and biodiversity. In addition, the technology facilitates the selection of desirable traits in plants and animals through the identification and use of genetic markers, accelerating genetic improvement programs and adapting varieties to adverse environmental conditions. Assisted reproductive technologies are essential to conserve and genetically propagate animals and plants of high genetic value or threatened with extinction, contributing to the conservation of species at risk and the recovery of wild populations. To this end, gene editing techniques offer new possibilities, allowing the precise modification of genetic material to correct genetic defects, develop resistance to pests and diseases, or adapt organisms to climate change. Finally, bioinformatics tools and DNA sequencing technologies allow for detailed monitoring of genetic diversity, which is essential to understand the genetic structure of populations and guide conservation strategies (SALGOGRA AND CHAUHAR, 2023).

While genetic enhancement techniques offer numerous advantages, it is important to recognize that they also have significant disadvantages, such as the potential loss of genetic diversity and the homogenization of populations, which can increase vulnerability to pests and diseases (SALGOGRA AND CHAUHAN, 2023).

FINAL CONSIDERATIONS

It is concluded that the genetic conservation of breeding populations is crucial to ensure the genetic diversity and resilience of agricultural and forest crops in the face of environmental challenges, pests and diseases.

In addition, it was found that by preserving and protecting plant varieties adapted to different climatic conditions and environments, we can maintain food security and promote long-term agricultural and forestry sustainability. In addition, genetic conservation is essential to enable future breeding programs, providing a reservoir of valuable genes for the creation of new varieties with desirable traits such as disease resistance, tolerance to environmental stresses, and increased productivity.

Furthermore, it was found that the genetic conservation of forest species in the cerrado has not been a priority for the study of conservation in Brazil, even in the face of 39% of this biome having been consumed by anthropic action, with irreparable forest genetic losses.

Thus, it was clear that specific studies were carried out on some native species of the cerrado. Universities that have led research in the conservation of species in the biome have stood out.

Therefore, the study demonstrated the urgent need for more research and actions aimed at the conservation and improvement of species in the cerrado biome, given their importance for biodiversity and their relevance for the maintenance of natural ecosystems.

Additionally, investing in the genetic conservation of breeding populations is critical to ensuring global food security and promoting agricultural sustainability in an ever-changing world.

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Survey of insects with yellow adhesive traps in environments of the Federal University of Triângulo Mineiro

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ABSTRACT

To evaluate the entomological biodiversity of some sites at the Federal University of Triângulo Mineiro, in Uberaba-MG, a study was carried out with traps arranged in three environments. The objective of this study was to verify both the quantity and the biodiversity of insect species. After the analysis of the material, a high species richness was observed in a room lit with natural and artificial light, with open windows and daily movement of people in the environment. In a room lit with natural and artificial light, with closed windows and daily movement of people, only one specimen of Coleoptera was collected. In a room lit only with artificial light, with closed windows, no movement of people and strict sanitary control, no specimen was sampled. This is a place focused on the area of clinical analysis. It was found that the institution had partial success in the evaluated areas, especially about the cleanliness of the Laboratory.

Keywords: Entomological glue, Insect traps, Biodiversity.

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INTRODUCTION

The entomological collections aim to provide a database for the development of strategic research for ecology, biogeography and conservation. They provide fundamental information for various studies of insects, such as geographic distribution patterns, biodiversity, biological cycles, and pest control (Camargo et al, 2015; Da Costa et al, 2006).

In addition to being harmful pests for crops, several species of insects can also be vectors of the most varied diseases. However, most monitoring is done only on plantations to avoid pests, so monitoring for disease control in places with high circulation of people is most often neglected. In view of the epidemiological importance of the group, such monitoring should be routine (Bertelsmeier, 2021).

In order to have the expected result in the capture of insects, some factors must be taken into account, such as climatic conditions, time of year and correct choice of the type of trap (Camargo et al, 2015).

Depending on the project, collection methods can be active or passive. Active collection involves looking for insects in the environment, while passive collection involves the construction or installation of traps or baits (Gullan; Cranston, 2017).

Numerous studies have proven that yellow sticky traps are the most efficient type of trap for monitoring insects. This efficiency is due to the greater number captured and the greater diversity of species, since yellow is one of the most attractive colors (Teixeira et al. 2009).

Since we wanted to capture different species, we chose this method, as it proved to be the most attractive to most species and therefore the most efficient.

The identification of insects is the main part of almost every entomological study. The most efficient method for correct identification of insects is to find an expert (Gullan; Cranston, 2017).

The objective of this work was to survey the richness and abundance of insects, captured by sticky traps, positioned in different environments of the Federal University of Triângulo Mineiro (UFTM). UFTM's headquarters are located in Uberaba/MG.

MATERIALS AND METHODS

To capture the insects, yellow sticky traps measuring 9 x 3.5 cm were used. In each location, four sticky traps were exposed for a period of seven days, in December 2023. The monitored environments were: room illuminated with natural and artificial light, with closed windows and daily movement of people; room illuminated with natural and artificial light, with open windows and daily movement of people; room lit with artificial light, with closed windows, no movement of people and strict sanitary control in the Clinical Analysis Laboratory of the Federal University of Triângulo Mineiro, in the city of Uberaba, Minas Gerais.

After 7 days, the adhesive traps were removed to identify the captured insects. With the use of a stereoscopic microscope and the aid of a dichotomous taxonomic key, the captured insects were identified and subsequently tabulated.

The identification occurred as recommended by Almeida, et al., 1998; Borror, Delong, 1969; Gallo, 1988; Rafael et al, 2012.

RESULTS

In the experiment, 4 traps were collected for each type of environment. In room A (room lit with natural and artificial light, with closed windows and daily movement of people) only one representative of Coleoptera Linnaeus, 1758 was identified. In environment B (room lit with natural and artificial light, with open windows and daily movement of people) 3 specimens of Psocoptera Shipley, 1904, were collected; 23 of Homoptera Boisduval, 1829; 32 of Nematocera Latreille, 1825; a copy of Psychodidae Newman, 1834; 5 from Cyclorrhapha Sharp, 1894; 8 of Coleoptera Linnaeus, 1758; 7 of Staphylinidae Latreille, 1802 and 2 of Hymenoptera Linnaeus, 1758. In environment C (room lit with artificial light, with closed windows, no movement of people and strict sanitary control in the Clinical Analysis Laboratory of the Federal University of Triângulo Mineiro in Uberaba, MG) no specimens were collected during the period (Table 1).

Table 1. Ectognatha collected in sticky traps exposed for seven days, in December 2023; in three distinct environments: A) room illuminated with natural and artificial light, with closed windows and daily movement of people; B) room lit with natural and artificial light, with open windows and daily movement of people and C) room lit with artificial light, with closed windows, without movement of people; in Uberaba, MG.

	A	A	A	A	B	B	B	B	C	C	C	C
Psocoptera Shipley, 1904								3				
Humptera Vaisduval, 1829					5	8	4	6				
Nematocera Latreille, 1825					20	7	2	3				
Psychodidae Newman, 1834								1				
Cyclorrhapha Sharp, 1894					2	3						
Coleoptera Linnaeus, 1758	1				5			3				
Staphylinidae Latreille, 1802					3	2		2				
Hymenoptera Linnaeus, 1758					1		1					
Wealth	1				36	20	6	18				

DISCUSSION AND CONCLUSION

The Order of *Psocopterans* is composed of animals often found in humid environments, such as leaf litter and bird nests. Some feed on flour and cereals, being considered pests in food storage

places. (Casasola-González; García-Aldrete; Herrera-Fuentes, 2013). The *Psychodidae* family is composed of small insects, with nocturnal habits and unpredictable flight, with larvae that adapt to a wide range of habitats, from areas with stagnant water to semi-desert environments. Both prefer shady and humid places. However, they were found in small quantities and only in environment B, which has open windows and movement of people. A greater number of the Order Homoptera were also found in this place, which comprises terrestrial insects, of varying size, from large and medium to extremely small. One of the damages caused by homoptera can be damage to plant tissues (Merzouki *et al.*, 2014). The sub-order that was most captured by the experiment and still in environment B was *Nematocera*, which correspond to mosquitoes characterized by thin and segmented antennae and aquatic larvae. They are distinguished by their long and articulated antennae (Ribeiro; Mans; Arcà, 2010). In this order, the *Aedes aegypti* species is the most found in the urban environment and is also responsible for the vector of several pathogens, from the female to animals and humans. In this way, as the place has open windows and a vast movement of people during the day, the contact with this insect is great, and can thus transmit arboviruses into the *Campus*.

The suborder *Cyclorrhapha*, the family *Staphylinidae* and the order *Hymenoptera* were collected only in one environment, a room lit with natural and artificial light, with open windows and daily movement of people.

In relation to *Hymenoptera*, such as ants, bees and wasps, they are easy to disperse and infest, and have environments with easy access to food and circulation of people as their habitat (Marques, *et al.*, 2010). *Cyclorrhapha* corresponds to flies, these are important mechanical vectors of several diseases. Faulde *et al.*, 2001; Fotedar *et al.*, 1992; Pelli *et al.*, 2013; Kappel *et al.*, 2013; Pelli *et al.*, 2007; Pelli *et al.*, 2012; Šrámová, 1992.

Unlike the others, the Order *Coleoptera*, which is the order of beetles, was collected in two environments, but in different quantities, the first went to the room lit with natural and artificial light, with open windows and daily movement of people, which had the largest amount of collection and the second was to the room lit with natural and artificial light, with closed windows and daily movement of people.

It is concluded that only one insect of the order *Coleoptera* was captured in environment A, with natural and artificial light, closed windows and daily movement of people, with natural and artificial light. Thus, the success of sanitary control in the clinical analysis laboratory of the Federal University of Triângulo Mineiro is evidenced and that the closed window, even in environments with movement of people, is partially effective in avoiding most urban insects.

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Emergy study applied to permaculture in Barra da Lagoa in Santa Catarina

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ABSTRACT

Permaculture has been presented as part of a complex study that references sustainability. With a holistic view, the study is effectively based on the analysis of the emergy method. From this method, it seeks the formation of the energy flow of a specific property located in Barra da Lagoa, in Florianópolis - Santa Catarina. It aims at the availability of building concrete bases for further studies on the theme of energy, in a specific study of renewable energies. In the end, it is interested in demonstrating the relationship between energy and a complete cycle of activities open to a closed system.

Keywords: Emergy, Energy Flows, Santa Catarina.

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INTRODUCTION

Sustainable energy is one of the important issues in modern society. Local innovations have become a necessity for the transition to new ways of life and in a more sustainable way. Sustainable and renewable energy sources are still little explored around the world, considering the potential of clean sources such as wind and solar.

On the other hand, energy flows are of fundamental importance since they are basic training in the context of Permaculture. Permaculture is an expression originated from the English "**Permanent** Agriculture" and was created by Bill Mollison and David Holmgren in the 70s of the last century. Over the years, it has come to be understood as "**Permanent Culture**", as it has come to cover a wide range of knowledge from various scientific areas, going far beyond agriculture. (NANNI, 2019). It is about understanding the different ecosystems and understanding the energy in permanent flux, as well as the thermodynamic processes.

For the production of more sustainable ways of living, permaculture understands that closing cycles can be useful by intensifying processes on a property. The second principle of permaculture planning (HOLMGREN, 2002), capture and store energy, suggests saving and investing any type of resource consumed and capturing local energy flows – renewable or not – with the intention of making long-term investments (PROMPT, 2021).

Sustainability can be seen as the concept of "sustainable development". The understandings and meanings related to a series of ethical implications and principles, inserted and applied in academic contexts, social segments, development plans and processes (HANAI & ESPÍNDOLA, 2011).

Also, the term "sustainable" appears for the first time in the United Nations report: Our Common Future (World Commission on Environment and Development, 1991), known as the Brundtland report in 1987 (MENDES, 2009). Thus, the initial term of "sustainability" was consolidated in the field of Biological Sciences and Ecology, it refers to the carrying capacity of an ecosystem and its natural elements in the face of anthropogenic modifications, allowing its reproduction or conservation (CAMARGO, 2016).

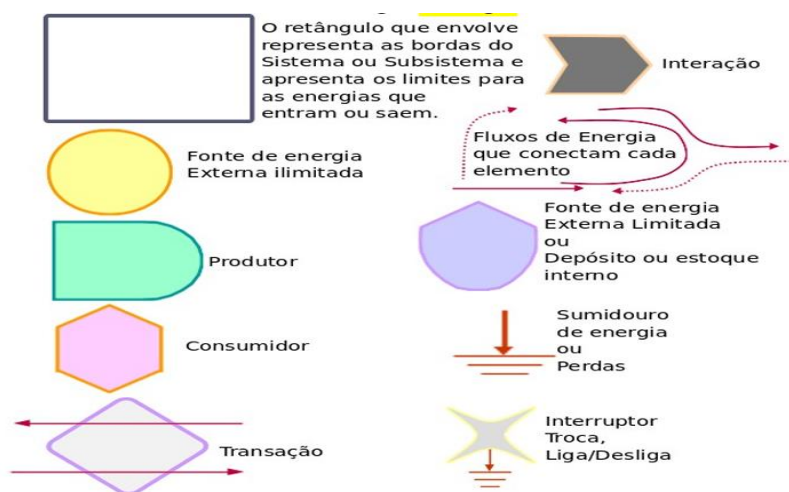
For the study of permaculture and its energy sources, in various types of systems, the emergy can be used as a methodological basis, for studies with application from diagrams. Emergy is considered as a methodology initially developed by Howard Odum. It takes shape in the analysis from environmental management tools, also maximizing economic processes. According to Venturi (2020):

(...) Calculating the emergy of an activity or product would be a methodology to more accurately study all the energy spent in a given "ecological footprint", that is, it is an analysis closer to the actual amount of energy used and accumulated in each system. (Venturi, 2020, pg. 54).

The basis of energy on every planet comes, of course, from the energy of the Sun, measured in Joules. Unlike conventional economics, the study of emergy tends to visualize the system in its entirety. Emergy cost tends to be much more effective and true than a system of environmental costs, where there are only externalities passed on to society, proposed by conventional economics (VENTURI, 2020). It is also characterized by a distinction between environmental economics and ecological economics (BORGES & AGUIRRE, 2023).

Also according to Venturi (2020), emergy, in English, would be the junction of the expression *embodied energy* = *emergy* = energy. To calculate the emergy, one must start by elaborating an emergy systemic diagram. This diagram serves to identify the key inputs of each system and from it the operations of the systems. Renewable resources (R) are considered to be: solar energy, precipitation, air mass movement and evapotranspiration. The non-renewable resources (N) are: eroded soil, phosphorus present in the soil, groundwater used at a rate higher than the recharge. Resources acquired in the market (F) are all those that were obtained outside the limits of the system (ROMANELLI, 2007).

Figure 1. Symbols and their meanings commonly used in energy/emergy flow diagrams. Source: (VENTURI, 2002, pg. 102).



It refers to an overview of the system, combining different sources of information and organizing efforts (CARVALHO-JUNIOR, 2022). Figure 1 proposes a symbology for the realization of energy diagrams.

In a later stage, the emergy indices are calculated, in order to summarize and relate the energy flows of the economy with those of the environment. Thus, at Emergia there is a complex study that "prices" and gives value to each of the energy activities of the property in question, assisting in the analysis of energy indicators. Pricing will not be carried out in this article.

In this way, the emergy is used to identify the total demand of the system and its energy efficiency reflected by the relationship between energy produced and energy employed. There are the

incoming energies and the outgoing energies.

Thus, this project brings the possibility of a permaculture study in the Atlantic Forest of Santa Catarina, specifically in the locality of Barra da Lagoa in Florianópolis, with its special focus on the property of Juliana, a woman born in Juréia - SP, 49 years old, teacher at the Acácio Garibaldi school in Florianópolis, Santa Catarina.

In 2022, while teaching at the Acácio Garibaldi school, I met Juliana. She had fallen ill and asked me to take care of the house during the summer period. This period was important to introduce me to the energy concern of a property and ended up culminating in the beginning of my entry into the specialization in permaculture at UFSC. Helping her in this endeavor presented herself as a good alternative.

Figure 2: Map of the property's situation. Source: Image from Google Earth, edited by the author (2024)



Figure 3: Juliana and her challenges. Source: Image captured by the author (2024)



JUSTIFICATION

The process of staying on the property for three months made me wonder what I could do to make it more sustainable. The property has many deficiencies, including a vegetable garden that does not have its development, lack of sewage treatment, unfinished works and absence of waste recycling processes.

Permaculture processes should emphasize and dynamically internalize appropriate technologies, such as the use and promotion of environmentally coherent and efficient equipment and the potential for closing energy cycles.

The use of emergy as a methodological tool for both analysis and permaculture projects is intended to be applied in order to bring consistency to the situations of the present study, as well as to present itself as a contribution to the theme of permaculture in broader contexts.

DELIMITATION OF THE PROBLEM

The project is then limited to the application of the emergy methodology associated with permaculture tools, up to the stage of consolidation of the emergy diagram. diagnosing and analyzing the energy flows considering the input and output of energies in the 300 m² property located on top of the hill of Prainha da Barra da Lagoa, Florianópolis, SC.

OBJECTIVES

The project also aims to capture and store energy with the possible objective of analysis in the face of the demands of the property and outside it. It also aims to study the climatic problem in the Atlantic Forest space. It focuses on energy efficiency or efficient use that uses little energy and has low impact, in a sustainable way (MARS, 2008).

OBJECTIVE

Analyze and propose design guidelines for a property using emergy diagrams.

SPECIFIC OBJECTIVES

- Describe the property in relation to its history, as well as its physical and environmental characteristics, establishing relationships with Permaculture;
- Develop a diagram of the system with the current emergy flows of the property;
- Propose permaculture strategies aimed at closing the cycles on the property;
- Simulate an emergy diagram that represents the flows from the implementation of these strategies, thus performing a comparative analysis between the two diagrams produced.

METHODOLOGY

Methodological procedures will be carried out from the emergy. permaculture. From there, analyze the property in question from the exploratory research and application of the emergy method: the understanding of the energy flows in the property, as well as the efficiency of the permaculture solutions proposed from the diagnosis will be made based on the flowcharts carried out.

STEP 1: THEORETICAL STUDY:

The theoretical study focuses on the bibliographic review available on Google Scholar, Scopus, Scielo and on specific bibliography, as well, with reference to the state of the art in the theme of permaculture, emphasizing energy flows and the dynamics of counterpoint in renewable energies. It will seek to list specific works on permaculture studies within the scope of the Atlantic Coastal Forest.

STEP 2: DATA COLLECTION:

Data collection, an important work for carrying out analysis and emergy study, aims to obtain data on the context of the property, which may come from preliminary studies and existing open processes. The following techniques will be used for data collection: compilation and analysis of pre-existing documentation provided by the owner, participant observation, photographic survey, semi-structured interviews.

STEP 3: DATA PROCESSING:

The data collected will be processed through mapping, with the help of Google Earth and Google Slides tools. The mapping will be linked to the photographic survey, in order to obtain clarity about important spaces on the property. For terrain analysis, methods belonging to permaculture will be used, considering the use of zones and sectors.

STEP 4: EVALUATION FROM EMERGY:

From the mapping of the existing reality, which will clarify the results obtained with the collection and treatment of data, and the theoretical study, the information will be crossed in order to obtain a map with the energy flows. This will consist of an energy/emergy flow diagram. The symbology will be based on Figure 1, and will undergo adaptations due to the feasibility of the tools used in this work. However, this work will not follow this diagram exactly, because the tools are different. By cross-referencing the data, it will be possible to understand which permaculture strategies can be applied with a focus on the movement of change over time on the property. The

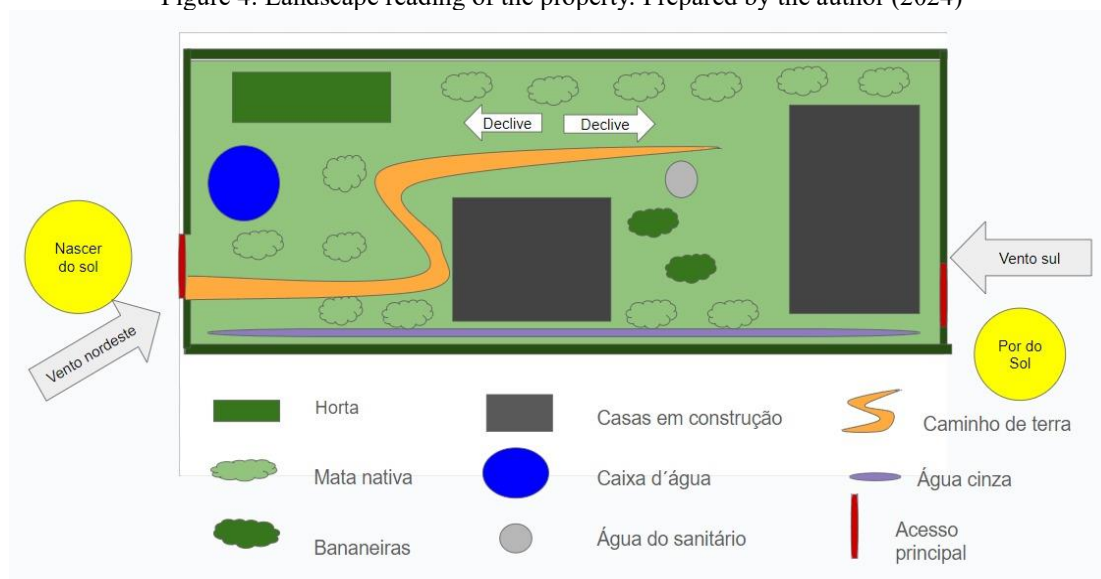
suggested strategies will be compiled in the form of possible guidelines for intervention in similar contexts.

RESULTS

Juliana has lived on the property since 1990. Since then, he has been building his property intuitively, without fundamental and specific repairs. The energies of his property develop in open flows, without great care and in an unsustainable way. Juliana's health problems brought more difficulties to carry out her day-to-day activities. Access is through a steep trail that requires time and resources to carry out activities.

The context of this property is very peculiar, as it is located on the hill of the little beach in Barra da Lagoa. Access is through a trail approximately 400 meters long, on a staircase made of stones without major tracts. Its land is demarcated with an entrance gate, inside a property with a slope at the front and a slope at the back. The land is fenced in front and on the sides.

Figure 4: Landscape reading of the property. Prepared by the author (2024)



There is a large water tank in the front that is supplied by Casan and another, in the back, that is deactivated. The house is supplied by energy from the public grid - Celesc. Still in the front, there are vegetable gardens on small terraces that are currently abandoned.

Figure 5: Currently abandoned vegetable garden. Source: Image captured by the author (2024)



The electricity from the concessionaire is moved to the end of the hill, arriving at his house and supplying the property. The property receives little sunlight and worries when there is rain, contrasting with internal leaks in the house and with the soaked land without water use, accumulating puddles for the proliferation of mosquitoes, among other things. It has two houses without sewage treatment systems. There is an internet connection but poor signal quality.

Figure 6: Front House. Source: Image captured by the author (2024)



Homes do not have a structure for energy conservation. The front house has large openings in the walls, windows covered with plastics. They also have old roofs full of leaks, which makes it difficult to live in times of heavy rains or even worse in extreme rains. In winter the interior of the house is very cold and in summer it is very hot. It is also in the middle of the two slopes of the property, draining the gray water from the kitchen to the slope of the back of the land.

Figure 7: Back house. Source: Image captured by the author (2024)



The back house, under construction, follows one of the slopes of the property. No sewage treatment. All made of wood, with its concrete bases. In this way, the buildings present on the property do not present sustainable forms that can deal with energy flows or develop appropriate functions in relation to extreme weather events.

Also, the idea of building the house at the end of the land aims to serve as an inn in the summer season, providing extra income for the maintenance of the two houses and with the objective of providing improvements to the property. This second house, whose works began six years ago, faces barriers to its completion due to lack of adequate planning and other various reasons.

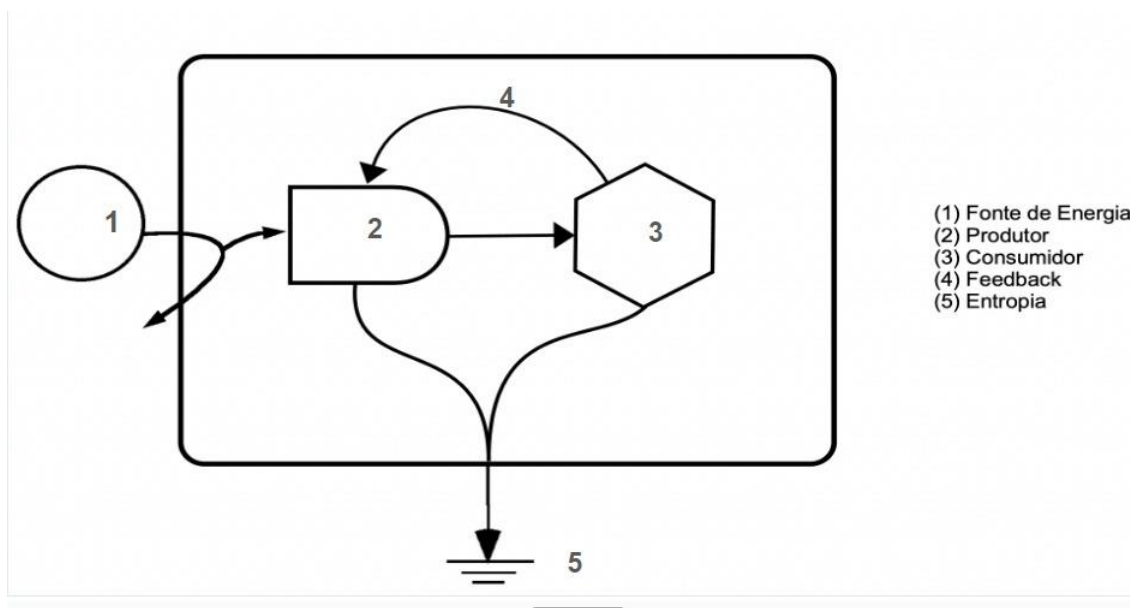
In order to improve the analysis of the terrain and make use of the permaculture zoning method, the following existing zones were identified:

Table 1: Areas of the property. Prepared by the author (2024)

Areas	Existing activities
Zone 0	House 1 (house 2, as it is unfinished, will not be considered as a Zone 0)
Zone 1	Spontaneous vegetable garden
Zone 2	Food plants, herbs for teas, zucchini
Zone 3	Banana
Zone 4	No related activities identified
Zone 5	Unmanaged native forest

For the development of the emergy diagram, the model to be followed is presented, at first, for an analysis of the energy flow and later analysis of the external dependence and environmental analysis from the flowchart. We thus have energy sources, property producers and consumers represented.

Figure 8: Flowchart exercise. Source: Oldemar Carvalho Junior (2024)



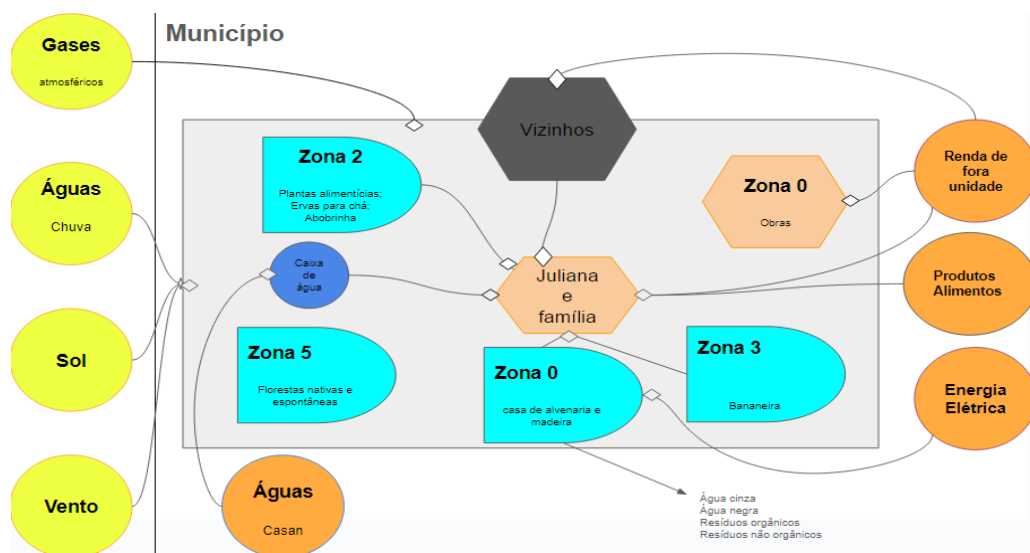
The elements identified in the property in question are represented in Figure 4. Based on the diagram in Figure 8, we can classify them as follows:

Table 1: Property elements. Source: Prepared by the author (2024)

Energy Sources	Producers	Consumers
Sun	Plants	Human
Wind	-	Animals
Rainwater	-	-
Utility water	-	-
Gravity	-	-
Electrical energy		

Producers: Plants (autotrophic organisms) that produce biomass from organic compounds for animals that permeate the property, and serve as food for animals (including people).

For the consolidation of the emergy diagram, the classified elements were distributed with reference to the previously identified permaculture zones.



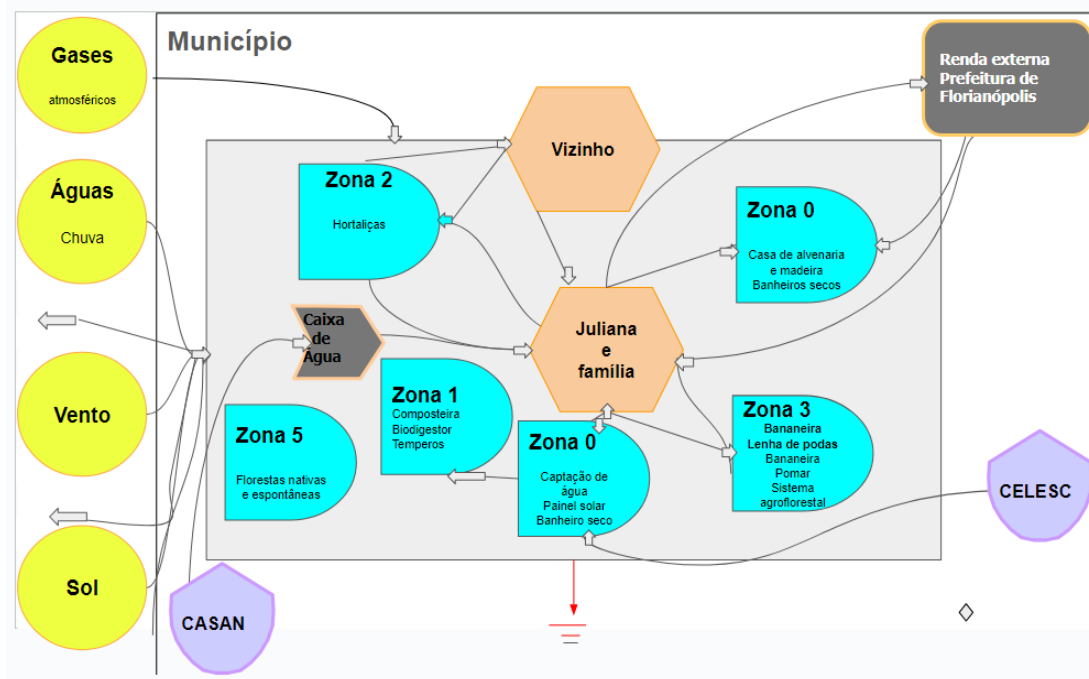
The diagram in Figure 9 shows that there are disconnected energy flows in this property. The activities are centered on Juliana, with whom the problem of the place where she lives is perceived. There are impasses and also findings of (un)sustainability. It is verified that there is a range of energies that enter the property but are not used, generating an escape of solar energy, where part enters the property and another leaves. So it is with the wind. Energy sources are misused in the way that aggravates their situation every day.

There is also a large footprint where activities are carried out with dependence on energy supply from outside the residence. Resilience in the face of property challenges is threatened if there are extreme events. There is a very great dependence on the neighborhood and the municipality for basic activities.

The activities result in the production of gray water, water contaminated with feces, organic and non-organic waste that, in addition to not being reused, returns to the environment without treatment. The lack of sewage treatment is the high point to be solved. Although there is a storage of water from the concessionaire, there is no storage of rainwater or retention systems in the soil, resulting in rapid losses, since the slopes of the land are accentuated. On the other hand, in periods of drought the soil ends up losing moisture, requiring manual irrigation of the plantations with water from the concessionaire.

From the initial diagram, which represents the current reality of the property, a diagram was developed with proposals for new elements that provide the closure of some open cycles detected (Figure 10):

Figure 10: Flowchart of Juliana's property after the application of a permaculture plan. Prepared by the author (2024)



A first step towards closing the flows is the interaction between production and consumption within the property. The use of renewable and unlimited energies in capturing property is of fundamental importance. Also, the lower use of existing sources outside the analysis site is a consequence of the attempt to close the cycle. It is proposed the use of photovoltaic panels to capture solar energy and also the use of water more efficiently, with rainwater capture and storage systems, making less use of water coming from Casan.

It is also proposed to intensify the activities of vegetable gardens and planting with a wider range spread across zones 1, 2 and 3, considered of fundamental importance, as a first step, for self-sufficiency of Juliana and her property. Also allied to the care of small animals (chickens). This aims to alleviate the total dependence on foreign food resources and consequently the sustainability of economic resources.

As the income comes from the municipality, it is recommended that you also interact with the neighbors of the properties next door to maximize the economic utility and diversification of food.

Also, a serious problem of the first order is the absence of sewage treatment. Juliana proposes the construction of a biodigester for the treatment of water contaminated with feces, to later be returned to the soil as fertilizer. An alternative is also sought to try to use gray water in the management of the property, combining the excess of water from Casan for the maintenance of the vegetable garden and the completion of the construction of the back house.

In addition, the back house has been built by neighbors who support Juliana. Its foundations were laid about 10 years ago, but only in recent years has it been one of the priorities. In this way you will use available resources for construction. All these processes reported above are of

importance for the completion of the work, closing the flows in their possibility and less dependence on the municipality in the production of the owner's material life.

It is also necessary to maintain the plants and seasonal pruning, especially in winter. The pruning residue is used as fuel for use in a wood stove to be built later, adapted to the reality of this place. It also seeks to increase interdependence with neighbors in terms of food and material resources throughout the year, proposing an alternative to jointly produce a vegetable garden that supplies the two properties.

FINAL CONSIDERATIONS

The objective of this study was to analyze a property located in Barra da Lagoa. To this end, at first, it was defined that the most appropriate was an analysis that encompassed the problem and its context. According to the visit to this territory, it was found that the processes that existed there were generally (un)sustainable.

Thus, with the exploratory research, a search for a proper methodology for the development of analysis that would be in the transition from one place to another, that would take advantage of the energy flows, began.

In this way, the aspects of the property and its possible development over time were analyzed. We sought to contextualize it in order to understand the processes that surround it. It was also necessary to introduce a model for its configuration.

Of the 12 principles of permaculture, the following were sought to contemplate: capture and store energy; Use and value renewable services and resources; Do not produce waste; Use small, slow solutions; Use and respond to change with creativity. Upon completing the closing of the cycles, it was observed that the structure of the property has a high impact and is (un)sustainable, with future alternatives to deal with its development.

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Sorghum cutting and grazing for hay production

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ABSTRACT

Sorghum hybrids (*Sorghum bicolor* cv. Bicolor) with Sudan grass (*Sorghum bicolor* cv. Sudanense) have been gaining increasing importance in feeding herds, due to their resistance to drought, great speed of establishment and growth, high capacity for tillering and regrowth after cutting or grazing (which allows successive uses), good nutritional value and great capacity for dry matter production. For the crossing of the species, a strain of Sudan grass (*Sorghum sudanense* (Piper) Stapf.) is used as a male and, as a female, a strain of grain sorghum (*Sorghum bicolor* (L.) Moench. Thus, the use of hay from sorghum for cutting and grazing is one of the alternatives to the problem of seasonality of forage plants, allowing the surplus produced, or in exclusive cultivation areas, to be stored and used in animal feed in times of scarcity. The objective of this work was to carry out a review of the narrative literature on sorghum, cutting and grazing for hay production.

Keywords: Haygrass, Composition, Sudan.

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INTRODUCTION

The main limitations for roughage production in Brazil are related to climatic seasonality, with higher production in the summer, due to higher precipitation and high temperatures, and lower production in the winter, due to unfavorable conditions that reduce plant growth and forage digestibility. To maintain animal productivity during periods of scarcity and lower nutritional value of forage, it is crucial to adopt conservation strategies, such as the production of silage, pre-dried, and hay, which ensure the availability of roughage feed throughout the year (FAEP/SENAR-PR, 2020).

Among the species of the genus *Sorghum*, there are cultivars adapted for green use (grazing and cutting), silage and haymaking. Sorghum varieties and hybrids, which have suitable characteristics for silage production and for use in the cutting regime, are generally not recommended for hay production, as they have thick stalks and do not support direct grazing. The cultivars of Sudan grass (*Sorghum bicolor* cv. Sudanense) are suitable for grazing and for the cutting regime, and can produce good quality hay, since they have thin stalks, providing rapid dehydration (Rodrigues, 2000). Sudanese sorghum, also known as Sudanese sorghum or Sudanese grass, is an early-cycle plant that can be harvested every 40 to 50 days. It has medium size, high nutritional value, vigorous tillering, high regrowth power, tolerance to salinity and main aptitude for hay production, it is also suitable for grazing because it can withstand animal trampling well. In addition, it can also be used for silage in due course. (Menezes et al., 2019; Tabosa, 2020).

In this sense, sorghum hybrids (*Sorghum bicolor* cv. Bicolor) with Sudan grass (*Sorghum bicolor* cv. Sudanense) have been gaining increasing importance in feeding herds, as they are resistant to drought, have a high speed of establishment and growth, a high capacity for tillering and regrowth after cutting or grazing (which allows successive uses), good nutritional value and a large capacity for dry matter production (Tomich, 2006).

In the hay production process, forage conservation occurs through dehydration. To properly preserve forage as hay, it is essential to quickly stop plant respiration and protein degradation after harvest. Haymaking involves changes in the structure and chemical composition of the plant due to the removal of water. Understanding these changes is crucial to apply good practices in the production, conservation, and feeding of ruminants, especially to ensure the availability of food during critical periods of the year (FAEP/SENAR-PR, 2020). Therefore, the use of thin-stemmed cultivars is indicated and higher planting density and early harvest are recommended.

Thus, the use of hay from sorghum for cutting and grazing is one of the alternatives to the problem of seasonality of forage plants, allowing the surplus produced, or in exclusive cultivation areas, to be stored and used in animal feed in times of scarcity. The objective of this work was to carry out a review of the narrative literature on the importance of welfare in dairy cattle farming.

ORIGIN AND CHARACTERIZATION OF CUT/GRAZING SORGHUM

The probable origin of sorghum is on the African continent, although there is evidence to suggest the possibility of two independent regions of dispersion: Africa and India. Not being native to the Western Hemisphere, sorghum was introduced more recently to the Americas.

In Brazil, its cultivation is rapidly becoming popular, and the country is already the fifth largest producer in the world, according to recent data from Conab. The 2022/2023 harvest was estimated at approximately 3.528 million tons, reflecting a significant increase in production, whose average productivity was around 2,815 kg/ha (Conab, 2023).

Due to its high resilience to water stress, sorghum has become a crucial crop for arid and semi-arid regions due to its water-use efficiency and its ability to produce biomass in adverse conditions, which favors its expansion in Brazil and other regions with a similar climate (Asadi, Eshghizadeh, 2021).

There are currently three main types of sorghum cultivated: forage sorghum, which produces a higher amount of dry matter compared to grain sorghum, has thick stems, and is widely used in silage production (Rezende et al., 2020; Ribeiro et al., 2017); grain sorghum, which has a moderate productive potential and can be used for pasture, hay production or silage (Ribeiro et al., 2017); and hybrid sorghum with sudangrass, which has thin stems, high tillering capacity, and rapid regeneration after grazing (Bath, 2019).

Forage sorghum for cutting and/or grazing comes from crosses of species of the genus "*Sorghum*", in which a strain of Sudan grass (*Sorghum bicolor* cv. Sudanense) and as a female a grain sorghum strain (*Sorghum bicolor* cv. Bicolor). The hybrid resulting from this cross is a plant of fast vegetative growth, abundant tillering and easy establishment. It has good resistance to water deprivation, presenting great rusticity and little demand regarding soil quality, in addition to ease of management for cutting or direct grazing, good nutritional value and high forage production (Rodrigues, 2000).

Tomich *et al.* (2006) highlighted the high protein content and high digestibility of this forage, being a roughage option of high nutritional value for the period of scarcity of pastures, making sorghum for cutting/grazing a high quality food source for cattle.

HAY PRODUCTION AND CONSERVATION

The forages available in the pastures, during the dry period, do not contain in quantity and quality all the essential nutrients to fully meet the requirements of the grazing animals. Thus, it is of paramount importance to produce high-quality forage for the production of hay of high nutritional value during the summer, resulting in efficient use of this forage resource to overcome the quantitative and qualitative deficiencies observed during the dry season (Reis *et al.*, 2001).

To produce high-quality hay, certain conditions must be observed: good quality forage must be harvested and dried with a minimum of nutrient losses. The basic principle of haymaking is the conservation of the nutritional value of the forage through rapid dehydration, since the respiratory activity of the plants, as well as that of the microorganisms, is paralyzed. Thus, hay quality is associated with factors related to the plants that will be hayed, the climatic conditions occurring during drying and the storage system employed (Reis *et al.*, 2001).

The climate is the main limiting factor in hay production and plays a fundamental role in the process. Temperature, relative humidity (RH), wind speed and solar radiation significantly influence the speed of forage dehydration, thus interfering with hay quality (Evangelista, Lima, 2019).

The water content at cutting for haymaking is about 60 to 75 % for grasses, while the ideal cutting time would be the one in which the forage would be more suitable for haymaking, from a qualitative and quantitative point of view. Therefore, this time cannot be defined only in terms of growth or pre-fixed cut dates, but rather in periods of crop rest, local conditions of the environment and economic aspects. It is therefore worth emphasizing that the quality of the forage at the time of cutting is of primary importance in the quality of the hay (VILELA, 2009).

Forage dehydration is directly related to the loss of nutrients and, consequently, to the nutritional value of the hay. In this phase, a large amount of water evaporates and should be carried out in the shortest possible time (Evangelista, Lima, 2019). The initial drying stage is fast, because in this phase the stomata remain open and the vapor pressure deficit between the forage and the air is high and the water loss can reach 1 g g⁻¹ of DM hour⁻¹ (Reis *et al.*, 2001).

In the first two hours the forage loses water until it reaches 60% moisture, then the loss becomes slow. And for adequate dehydration of the forage to occur, the relative humidity of the air must be a maximum of 65%, otherwise there will not be a sufficient gradient for the evaporation of water from the plant to the environment. It is also necessary that the cut material be turned over every two hours to accelerate this loss of water (Evangelista, Lima, 2019).

During the forage drying process, when the humidity is between 60 and 65%, water loss occurs slowly until it reaches about 45%, at which point the stomata close and water loss starts to occur through the leaf cuticle. From there, moisture continues to decrease through cell plasmolysis until it reaches the optimal level for hay, between 15 and 20%. At the end of dehydration, the forage, despite reduced metabolism, becomes vulnerable to environmental damage such as rewetting, leaching and leaf fall. This phase continues until the forage reaches adequate water content that should not exceed 18 - 20% (Evangelista, Lima, 2019).

Hay is one of the most versatile forage conservation systems, since, as long as it is properly protected during storage, it has the following advantages: it can be stored for long periods with small changes in nutritive value, a large number of forage species can be used in the process, hay can be

produced and used on a large and small scale, it can be harvested, stored and fed to animals manually or in a fully mechanized process, and can meet the nutritional requirements of different categories of animals (Reis *et al.*, 2001).

Thus, it is essential to properly store hay to preserve its quality. The place must be dry, ventilated and protected from sunlight. Bales should be stacked on pallets, allowing air circulation to prevent fermentation and nutritional loss. Regular inspections are necessary to detect excessive moisture or mold. Special constructions are not required, but the environment must guarantee good conservation conditions (Evangelista, Lima, 2019).

FACTORS THAT INTERFERE WITH THE NUTRITIVE VALUE OF HAY

The nutritive value of hay is the result of the interrelationships that occur between numerous factors, the most important of which are those related to plants, processing in the field and storage conditions. Changes in nutritive value occur as a result of the genetic diversity of plants and interactions with the environment and management (Reis *et al.*, 2001).

The leaf is the most nutritious and digestible part of the plant, preferred by animals. A high leaf:stem ratio increases the nutritive value and softness of hay. Forages with more leaves dehydrate faster, reducing the risk of losses due to rain. Thin, soft stems also indicate good quality hay. Therefore, a well-produced hay must have soft stems and a high number of leaves, resulting in a soft and good quality product (Evangelista, Lima, 2019).

It is worth noting that the physical appearance of a hay, even if it seems appropriate, should never be a sole requirement for the decision on the quality or classification of that hay. Thus, a bromatological analysis performed with correct and meaningful sampling protocols can show its nutritional value. Analyses such as crude protein, neutral detergent insoluble fiber, acid detergent insoluble fiber, fibrous fraction-bound nitrogen and mineral concentration must be performed in order to maintain quality control of the food purchased or produced (Domingues, 2009).

According to Reis *et al.* (2001), in addition to these aspects, it is important to report that soil fertility influences the production and nutritive value of forage plants, allowing plants to absorb chemical elements essential to animals and increase the production of high-quality forage by stimulating growth.

However, Lascano *et al.* (2001) reported that the effect of nutrients on the soil has been shown to be of little relevance on forage quality, but with a notable effect on total production and yield of different forage species. The exceptions would be nitrogen, whose effect on crude protein levels is considerable, and the contribution of sulfur and calcium in soils deficient in these minerals, which can improve digestibility and tissue composition. Reis *et al.* (2001) add that, in addition to nitrogen and calcium, phosphorus, potassium and microelements are necessary to ensure high forage

yields and maintain the persistence of desirable plants in the stand for long periods. The periodic evaluation of soil fertility helps to determine the amounts of correctives and fertilizers to be applied, ensuring the economic return on investment.

Lascano *et al.* (2001) identified several environmental factors (droughts, high temperatures, flooding, shading and mineral deficiencies) with a marked influence on the quality of forage and hay produced from it. They concluded that temperature has the most intense effect on the digestibility of forages, due to its effect on the decrease in the leaf/stem ratio, increasing the less digestible fractions.

The stage of development at the time of cutting has a great influence on the quality of the forage. With growth, changes occur, which result in an increase in the levels of structural compounds, such as cellulose, hemicellulose and lignin; at the same time, a decrease in cell content. In addition to these changes, it is important to note that the decrease in the leaf/stem ratio results in changes in the structure of the plants. Thus, it is expected that older plants will have a lower content of potentially digestible nutrients (Reis *et al.*, 2001).

In hay production, several losses can occur throughout the process that begin immediately after cutting, with inevitable biochemical changes, such as respiration and oxidation, occurring during drying. Removing water quickly helps minimize these losses. Other losses include leaching, loss of leaves due to handling, failure to collect, improper storage, high humidity that maintains cellular respiration, and the development of microorganisms. Inadequate production practices can also increase these losses (Evangelista, Lima, 2019).

According to Reis *et al.* (2001), on average, 2.5% of nitrogen (N) is lost due to excessive temperature increase and/or interference by microorganisms. In addition, these conditions promote non-enzymatic reactions, such as Maillard reactions, which result in the loss of carbohydrates and digestible proteins. These reactions often cause darkening of the forage and an unpleasant odor, reducing its palatability.

Losses of minerals such as phosphorus and calcium can occur in small amounts, however prolonged exposure in the field can alter these values. The occurrence of leaching, leaf breakage and other indirect physical processes can lead to the loss of minerals, notably potassium (Reis *et al.*, 2001).

It is important to consider that during drying and as a result of respiratory activity (which results in a decrease in soluble carbohydrate contents), the concentrations of crude protein, neutral detergent fiber, acid detergent fiber, and lignin, which are not affected by respiration, may increase proportionally, since the results are expressed as a percentage of dry matter (Reis *et al.*, 2001).

The main reason for the use of hay in animal feed is to provide energy for maintenance, milk and meat production, work and other functions during dry periods. Hay also provides protein, vitamins and minerals to maintain proper body condition to achieve adequate production levels.



FINAL CONSIDERATIONS

Hay production from sorghum is a strategic alternative to mitigate the effects of seasonality on forage supply, especially in regions where climate variability affects the availability of quality pasture throughout the year. Sudanese sorghum, due to its resilient and nutritional characteristics, proves to be an excellent option for hay production as a roughage feed alternative for ruminants during periods of scarcity.

The use of appropriate techniques in the harvesting and storage of hay is essential to preserve nutritional quality and ensure that hay can meet the requirements of the animals, providing the necessary nutrients to maintain milk and meat production.

Therefore, sorghum hay offers an efficient solution for production systems facing challenges related to climatic seasonality. The adoption of appropriate hay management and conservation practices will allow producers to ensure the availability of quality feed throughout the year, promoting the stability of animal production and food security.

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Evaluation of vermicompost quality: Efficacy in seed germination and reproduction of *Eudrilus eugeniae*

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ABSTRACT

This study aimed to evaluate the quality of vermicompost produced through vermicomposting, using the germination index of two seed species and the reproduction of earthworms as indicators to ensure the absence of toxicity and promote the safe use of vermicompost. The experiment was conducted in 20-liter vermireactors, using 25 adult earthworms of the species *Eudrilus eugeniae* per reactor. Three treatments were applied, varying the proportions of fruit, vegetable, and grass clippings residues. The phytotoxicity of the vermicompost was assessed through the Germination Index (GI%) of lettuce and cucumber seeds. The GI was calculated by comparing the germination and root elongation of seeds treated with vermicompost extracts to the control. Earthworm reproduction was evaluated at the end of the experiment by comparing the initial and final number of earthworms and cocoons to calculate the reproduction rate. The data were analyzed by Analysis of Variance (ANOVA), followed by Tukey's test to identify significant differences between treatments. The results indicated that Treatment T3, which combined different proportions of residues, was the most effective in promoting both the growth and reproduction of earthworms and the germination of seeds, suggesting that the combination of organic residues is crucial for producing high-quality, non-toxic vermicompost. These findings highlight the importance of an integrated approach in treatment formulation to optimize sustainable vermicompost production.

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INTRODUCTION

According to a FAO study, approximately one-third of the food intended for human consumption is wasted globally, amounting to around 1.3 billion tons, raising urgent concerns about the sustainability of food practices (FAO, 2022). This issue becomes even more critical considering that in 2021, between 702 and 828 million people faced food insecurity (FAO, 2022). In Brazil, Amarante et al. (2022) highlight that in 2020, 79 million tons of solid waste were generated, of which 45.3% were organic waste, including food waste.

In response to this wasteful scenario, the United Nations set targets within the Sustainable Development Goals (SDGs), with target 12.3 focused on halving global food waste by 2030 (UN, 2015). This emphasis underscores the need to rethink food practices and waste management on a global scale.

Food waste, divided into animal and plant origins, represents a significant challenge. Dang et al. (2023) emphasize the variety of products derived from the food industry, while Galanakis (2022) points to the diversity of waste from plant sources. This wide range of waste highlights the complexity of adequately managing these materials.

As cities face increasing challenges in generating fruit and vegetable waste, the proper approach to disposing of these materials becomes crucial, as noted by Bhardwaj et al. (2022) and Jun et al. (2022). One of the primary sources of such waste is supermarkets, whose management practices still lack effective collaboration and stringent legislation, as evidenced by Moraes et al. (2022).

Even before the COVID-19 pandemic, the waste of fruits and vegetables had already reached significant levels, with 5.3 million tons associated with fruits and 5.6 million tons with vegetables (ABRAS, 2019). In 2020, supermarkets in Brazil contributed a significant percentage of this waste, highlighting the need for effective actions in this sector (Gustavsson et al., 2011; ABRAS, 2021; Moraes et al., 2022). In light of this wasteful context, the implementation of sustainable waste treatment technologies becomes essential.

Vermicomposting, a low-cost and highly efficient technique, stands out as an environmentally friendly approach. This process involves the degradation of waste by earthworms and microorganisms in a controlled environment, resulting in a high-quality final product known as vermicompost (Lim et al., 2011).

During the maturation phase of vermicomposting, microorganisms such as bacteria, fungi, and actinomycetes play a predominant role, continuing the transformation of the organic compounds digested by earthworms (Lim et al., 2011). As a result, the vermicompost produced contains high levels of organic matter, nutrients, and plant growth-promoting substances produced by the enteric bacteria of the earthworms, making it an excellent fertilizer (Ratnasari et al., 2023).

One of the most commonly used species in the vermicomposting process is the earthworm *Eudrilus eugeniae*, which can reach up to 35 cm in length and is geographically distributed across specific regions of the continent, although it is now found in various parts of the world. This species exhibits distinct anatomical and behavioral characteristics that differentiate it from other species. Its reproductive system is efficient, with specialized organs for producing and depositing cocoons containing fertilized eggs. This process is influenced by environmental factors such as temperature and soil moisture, which play a crucial role in its reproduction and population success (Nattudurai et al., 2014).

Additionally, *Eudrilus eugeniae* is widely used in the biostabilization of organic materials, as highlighted by Santos et al. (2021), and demonstrates a remarkable ability to digest and assimilate organic matter, as evidenced by Khaldoun et al. (2022). Native to the African continent, this species is commonly found in the soils of Nigeria and neighboring countries. Its adaptability to captive environments is particularly notable in tropical regions (Malheiros, Maia, and Campos, 2019).

Vermicompost, a nutrient-rich product, emerges as an invaluable alternative. However, its potential toxicity represents a significant concern, especially due to the possibility of contamination by harmful substances during the process. To ensure the safety of vermicompost intended for food cultivation, phytotoxicity analysis becomes essential, utilizing germination indices and bioassays (Bhat et al., 2017). These tests not only determine the maturity of the vermicompost but also indicate its impact on cultivated plants (Mendes et al., 2021).

Another crucial aspect is the consideration of earthworm reproduction during the vermicomposting process. This biomass, intrinsically related to earthworm reproduction, not only indicates the quality of the vermicomposting system but also contributes to the efficient degradation of waste. Additionally, it plays an important role in pathogen suppression, significantly contributing to the production of a safer, more stable, sanitized, and non-toxic vermicompost (Blouin et al., 2019; Mendes et al., 2021; Oyege et al., 2023). In light of this, the objective of this study is to evaluate the quality of vermicompost produced through vermicomposting, using the germination index of three seed species and earthworm reproduction as indicators, aiming to ensure the absence of toxicity and promote the safe use of this vermicompost.

MATERIALS AND METHODS

VERMICOMPOSTING PROCESS

The residues used in the vermicomposting process were derived from fruits and vegetables donated and collected from a produce market located in the city of Pelotas, Brazil. Fresh green grass was used as a structuring material. The experiment was conducted in experimental units consisting of three treatments, following a 3x2 factorial design, with each treatment replicated twice.

The experiment was carried out in vermireactors, each with a working capacity of 20 liters. In each vermireactor, 25 adult clitellated earthworms of the species *Eudrilus eugeniae*, sourced from the breeding facility of an ecotoxicology laboratory at the Federal University of Pelotas, were introduced. The experimental setup and the proportions of residues and structuring material are detailed in Tables 1 and 2.

Table 1: Vermicomposting Experiment with Three Treatments

Treatment	Number of Earthworms	Species of Earthworm	vermireactor (L)
1	25	<i>Eudrilus eugenia</i>	20
2	25	<i>Eudrilus eugenia</i>	20
3	25	<i>Eudrilus eugenia</i>	20

Table 2: Proportions of Residues and Structuring Material

Treatment	Fruit (%)	Vegetable (%)	Grass Clippings (%)
1	80	-	20
2	-	20	80
3	40	40	20

EARTHWORM REPRODUCTION

After the vermicomposting process, the earthworms were carefully removed manually from each reactor. During this stage, a precise count of the number of earthworms and cocoons in each reactor at the end of the experiment was conducted. A comparison between the initial and final number of earthworms was performed, and the reproduction rate (%) of the earthworms was then calculated using the following equation (2):

$$\text{Reproduction Rate} = (\text{final number of earthworms} / \text{initial number of earthworms}) \times 100 \quad (2)$$

STATISTICAL ANALYSIS

The data were analyzed using Analysis of Variance (ANOVA) to determine significant differences between treatments, with a significance level of 5% ($p < 0.05$). Tukey's multiple comparison test was applied to identify specific differences between treatments, indicated by distinct letters in the graphs.

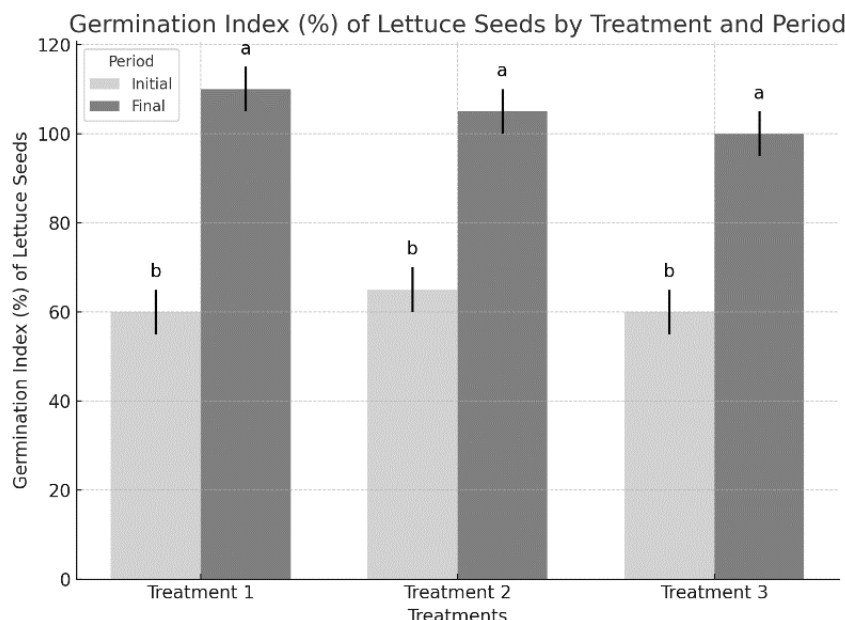
RESULTS AND DISCUSSION

GERMINATION INDEX

Figures 1 and 2 present the Germination Index (GI) results for lettuce and cucumber seeds, respectively. Figure 3 shows the GI% over time for both lettuce and cucumber seeds. In Treatment 1, the GI of lettuce seeds was significantly higher in the final period, reaching about 110%, compared to the initial period, which was around 60%. For Treatment 2, a similar pattern was observed, with the GI in the final period being significantly higher, reaching approximately 105%, compared to the

initial period, which was around 55%. In Treatment 3, the GI in the final period was about 110%, while in the initial period, it was approximately 55%. As in the previous treatments, there was a significant difference between the periods.

Figure 1: Comparison of Lettuce Seed GI (%) Between Treatments Throughout the Experimental Period



Regarding Figure 2, in Treatment 1, a significantly higher GI of cucumber seeds is observed in the final period, reaching approximately 120%, compared to the initial period, which recorded around 60%. In Treatment 2, the GI also significantly increased from the initial to the final period. Initially, the GI was around 55%, while in the final period, it rose to approximately 110%. Treatment 3 follows the same pattern as the other two. In the initial period, the GI was about 55%, and in the final period, it increased to approximately 115%.

Figure 2: Comparison of Cucumber Seed GI (%) Between Treatments Throughout the Experimental Period

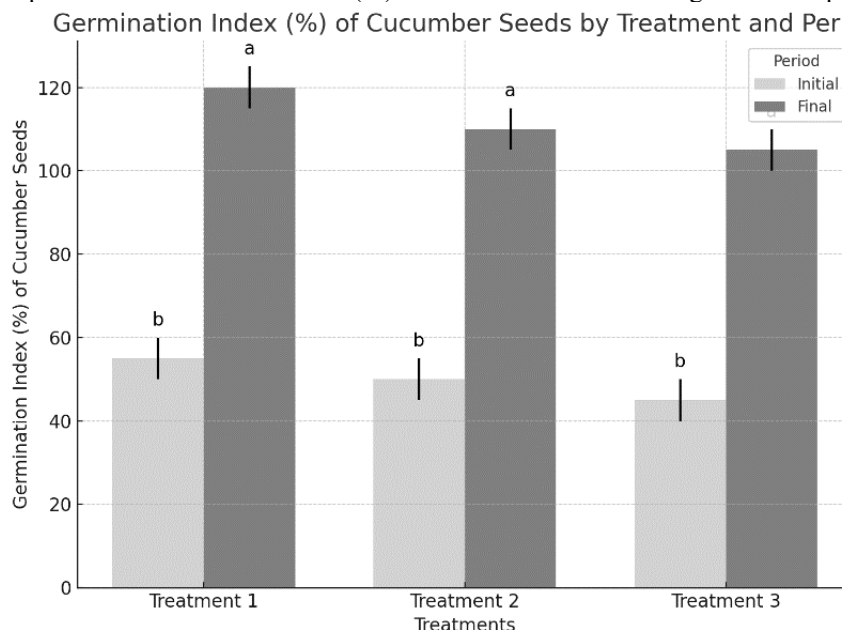


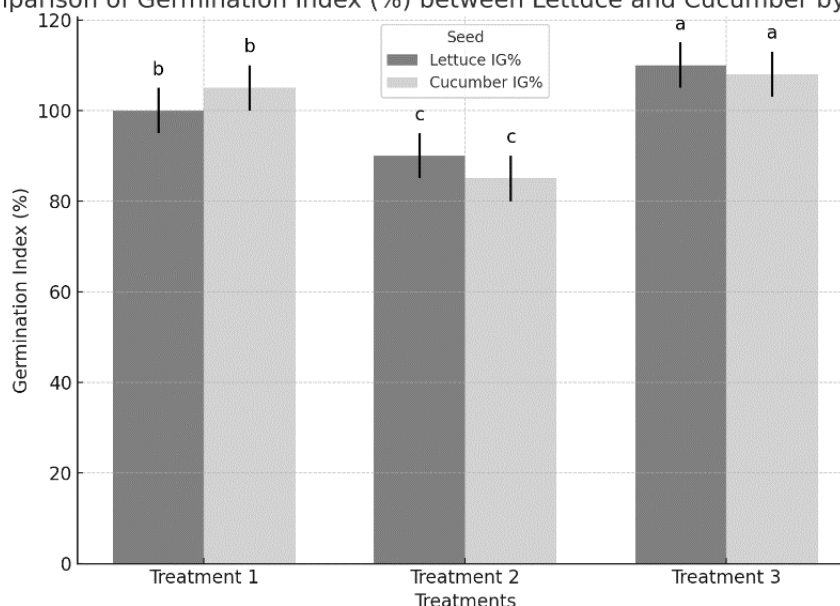
Figure 3 compares the Germination Index (GI) between lettuce and cucumber seeds across three different treatments. The figure highlights the differences in GI between the two seed species within each treatment, indicating statistical significance.

In Treatment 1, both lettuce and cucumber seeds showed similar GIs, around 100%, with no statistically significant differences.

In Treatment 2, there was a significant difference between the GI of lettuce and cucumber seeds. The GI of lettuce seeds was lower, about 90%, while the GI of cucumber seeds was close to 100%. In Treatment 3, the GI was again high for both seeds, with values close to 115% for lettuce and cucumber. There was no statistically significant difference between the two seeds in this treatment.

These results suggest that while Treatments 1 and 3 promoted high and similar levels of germination in both seeds, Treatment 2 was less effective for lettuce seeds, resulting in a significant difference in GI compared to cucumber seeds.

Figure 3: Comparison of Germination Index (GI%) Between Lettuce and Cucumber Seeds by Treatment
Comparison of Germination Index (%) between Lettuce and Cucumber by Treatment



The Germination Index (GI) of seeds is a commonly used biological indicator to determine the phytotoxicity and maturity of compost (Luo et al., 2018). The latest Chinese agricultural industry standard, titled "Technical Specifications for the Composting of Livestock and Poultry Manure," released in 2019, requires the GI of mature compost to be at least 70%. This standard aligns with the recently revised Chinese standard for organic fertilizers (NY525–2021), which also requires a GI $\geq$ 70% (Yang et al., 2021).

The results indicate that the treatments were effective in improving the GI of both lettuce and cucumber, with specific variations depending on the treatment and species. Treatment 2 showed a notable difference between the two species, suggesting that specific factors in this treatment may have been more suitable for cucumber than for lettuce. These factors may include variations in nutrient availability, moisture, or other soil parameters that directly influence the germination process.

The absence of significant differences in GI between lettuce and cucumber in Treatments 1 and 3 suggests that the conditions in these treatments were suitable for both species, resulting in good germination performance. This implies that these treatments may have broader potential for application across different crops, being less dependent on the specific needs of a single species.

Based on the observed results, it is possible to relate the differences in the Germination Index (GI) to the composition of the applied treatments. According to Alromian (2020), nitrogen (N) is an essential component for lettuce plants, integrating into proteins, chloroplasts, and phospholipids, and playing a fundamental role in plant growth and development. In this context, Treatments 1 and 3, which contain fruit residues, may provide more readily assimilable forms of nitrogen, creating more favorable conditions for lettuce seed germination. This superior nitrogen availability may explain the

potentially higher germination rate observed in these treatments compared to Treatment 2, which is composed exclusively of vegetable residues.

The lower availability of nitrogen in readily assimilable forms in Treatment 2 may have limited the initial development of lettuce seeds, resulting in a lower GI. Furthermore, according to Domínguez et al. (2021), the fibrous structure of vegetable residues, such as those used in Treatment 2, tends to cause slower decomposition and gradual nutrient release. This slower decomposition process may have resulted in a lower germination rate for cucumber seeds in this treatment compared to the treatments containing fruit residues, where faster decomposition may have made nutrients available more immediately and efficiently to the seeds. This difference in nutrient release may have contributed to the inferior performance observed in the GI of cucumber seeds in Treatment 2 compared to the other treatments.

These interpretations reinforce the importance of considering the composition of organic residues used in treatments, as they directly influence the availability of essential nutrients for seeds, affecting germination rates. Therefore, the strategic use of organic residues that offer faster decomposition and nutrient release, such as fruit residues, may be more advantageous in promoting effective germination in different types of seeds (Mendes et al., 2021).

EARTHWORM REPRODUCTION

Figure 4 presents the number of earthworms and cocoons per treatment, categorized into cocoons, juveniles, and adult earthworms, with treatments indicated as T1, T2, and T3. The error bars represent the variability within each group. For the "Cocoons" category, treatments T2 and T3 showed similar numbers, while treatment T1 had a significantly lower number ($p < 0.05$). Treatment T3 stood out with the highest number of cocoons, being significantly superior to T1 ($p < 0.05$).

In the "Juveniles" category, treatment T3 again had the highest number, being significantly superior to treatments T1 and T2 ($p < 0.05$). T1 and T2, on the other hand, did not show significant differences between them, both with lower numbers of juveniles ($p > 0.05$). Regarding adult earthworms, treatment T3 presented the highest number, with a significant difference compared to treatments T1 and T2 ($p < 0.05$). Although T2 was superior to T1, it still had a significantly lower number of adult earthworms compared to T3 ($p < 0.05$). Treatment T1 had the lowest number of adult earthworms, significantly lower than T2 and T3 ($p < 0.05$).

As observed by Nweke et al. (2020) in their study with the earthworm *Eudrilus eugeniae*, the results differed from those observed in treatment T2. In the study, the use of a diet composed of vegetable residues proved to be the most effective in promoting earthworm reproduction, evidenced by the increase in the number of survivors, cocoons produced, and biomass weight at the end of the experiment. However, Suthar (2009) found that a combination of residues promotes both growth and

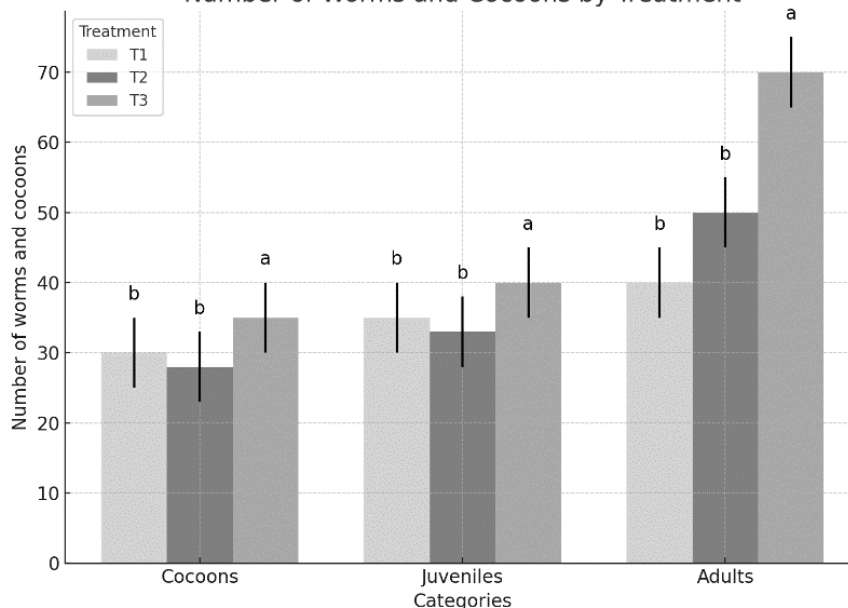
reproduction rates of earthworms, provided they are mixed with bulking materials in appropriate proportions. This possibly explains the satisfactory results observed in treatment T3.

These observations suggest that treatment T3 was the most effective in promoting earthworm reproduction and growth, resulting in higher numbers of cocoons, juveniles, and adult earthworms. Treatment T1, on the other hand, was the least effective, particularly in the production of adult earthworms, which may indicate lower nutrient availability or suboptimal conditions for earthworm growth. Treatment T2 had an intermediate performance, better than T1 but still inferior to T3 in all analyzed categories.

The microbial community plays a fundamental role in the degradation and transformation of organic matter during composting, directly affecting the production of water-soluble substances and influencing seed germination (Wang et al., 2021). The quality of the resulting compost can also impact earthworm reproduction, as they depend on an adequate environment and balanced nutrients to reproduce effectively. This effect was evident in the results obtained in the phytotoxicity analysis and earthworm reproduction in Treatment T3.

These differences may be related to the composition of the materials used in each treatment, directly affecting the reproduction and development of earthworms. Treatment T3 may have offered a more nutritious environment or more favorable conditions for reproduction, resulting in greater reproductive success and a higher number of adult earthworms. These results are crucial for optimizing earthworm cultivation conditions, depending on the experiment's objective, whether to increase the production of cocoons, juveniles, or adults.

Figure 4: Distribution of Earthworms and Cocoons by Categories and Treatments
Number of Worms and Cocoons by Treatment



CONCLUSION

This study highlighted the importance of the composition of organic residues for seed germination and earthworm reproduction. Treatments that combine different organic residues have proven to be more effective in creating favorable conditions for the release of essential nutrients.

The variability in results underscores the need to carefully select the materials used in vermicomposting to maximize the efficiency of the process. An integrated approach that considers the needs of both plants and earthworms is essential for optimizing composting and promoting sustainability in agricultural production.

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Outbreak of edema disease in piglets in the Sertão da Paraíba

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ABSTRACT

Edema disease is a worldwide toxi-infection, which mainly affects recently weaned piglets, and is caused by verotoxigenic strains of *Escherichia coli* bacteria. The epidemiological, clinical and anatomopathological aspects of an outbreak of edema disease in pigs in the hinterland of Paraíba are described. Piglets of both sexes were affected in the post-weaning period. The clinical course was acute, characterized by neurological manifestations and edema. At necropsy, edema of the eyelid, stomach wall, mesocolon and ascites were observed. Histopathology of the nervous system showed an increase in perivascular spaces associated with edema. There were also occasional neurons located in the frontal, temporal and occipital cortices and basal ganglia with cytoplasmic hypereosinophilia and nuclear pyknosis. The diagnosis was established through epidemiology, clinical signs, anatomopathological findings, and microbiological isolation of the agent. Some epidemiological factors are capable of predisposing animals to *E. coli* infections. Thus, it is necessary to implement preventive measures in order to minimize risk factors that are linked to adequate nutritional and sanitary management.

Keywords: Swine disease, Toxi-infection, *E. coli*.

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INTRODUCTION

Edema disease is a worldwide toxi-infection, which mainly affects recently weaned piglets, and is caused by burial-hemorrhagic (EHEC) or verotoxigenic (VTEC) strains of *Escherichia coli* bacteria, which produce *Shiga-like* toxin 2e (verotoxin 2e) and fimbriae F18 (Ribeiro *et al.*, 2016).

Most affected pigs have an acute clinical course, with death within 24 hours (Borowski *et al.*, 2002). Animals that recover usually become refuse and the recurrence of the disease is frequently described in herds (Mello; Lot 2009).

The presumptive diagnosis of the disease can be established based on epidemiological, clinical and necropsy data of the animals. Confirmation of the diagnosis is established through the association of the isolation of the bacterium with the characterization of the gene responsible for the production of the toxin, and the anatomopathological findings (Filippsen *et al.*, 2001). The objective of this work is to describe the main epidemiological, clinical and anatomopathological aspects of an outbreak of edema disease in pigs in the hinterland of Paraíba.

MATERIAL AND METHODS

An outbreak of edema disease in pigs diagnosed at the Animal Pathology Laboratory (LPA) of the University Veterinary Hospital Prof. Ivon Macêdo Tabosa of the Federal University of Campina Grande, Patos Campus, Paraíba, was reviewed. In the clinical and necropsy protocols, information was collected regarding epidemiological data (age, sex, breed, litter size and origin of the animal), clinical signs and anatomopathological findings.

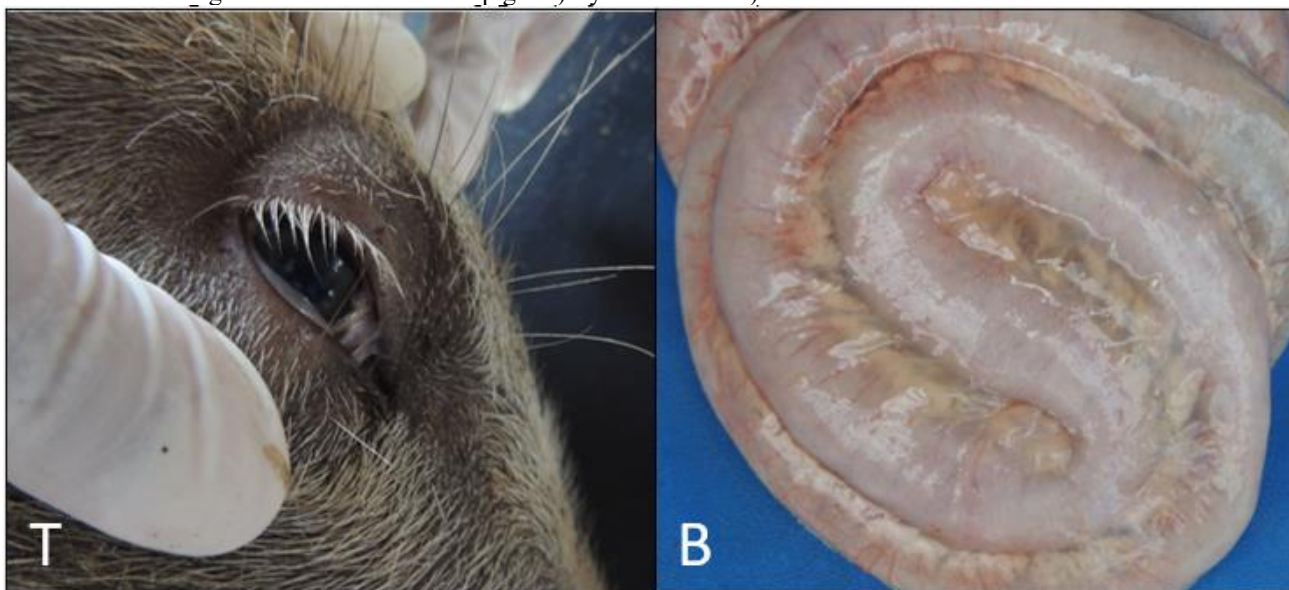
RESULTS AND DISCUSSION

On a property in the rural area of the city of Patos, Paraíba, 18 piglets of both sexes, approximately three months old, were kept in a semi-intensive regime and belonging to two different litters. The animals began to manifest apathy, tremors of intention, ataxia, difficulty in staying in station and lateral decubitus, and 14 animals died in a period of six days. All affected animals were in the post-weaning period. The food consisted of leftover food from restaurants and corn bran. One of the dead animals was sent for an autopsy.

Macroscopically, eyelid edema, ascites, diffuse mesocolon edema (Figure 1) and stomach wall edema were observed. Histopathology of the nervous system showed an increase in perivascular spaces associated with the presence of mildly eosinophilic, proteinaceous, and amorphous material (edema) (Figure 2). There were also occasional neurons located in the frontal, temporal and occipital cortices and basal ganglia with cytoplasmic hypereosinophilia and nuclear pycnosis. In the stomach, the submucosa is marked and diffuse distension due to edema associated with hypereosinophilia and

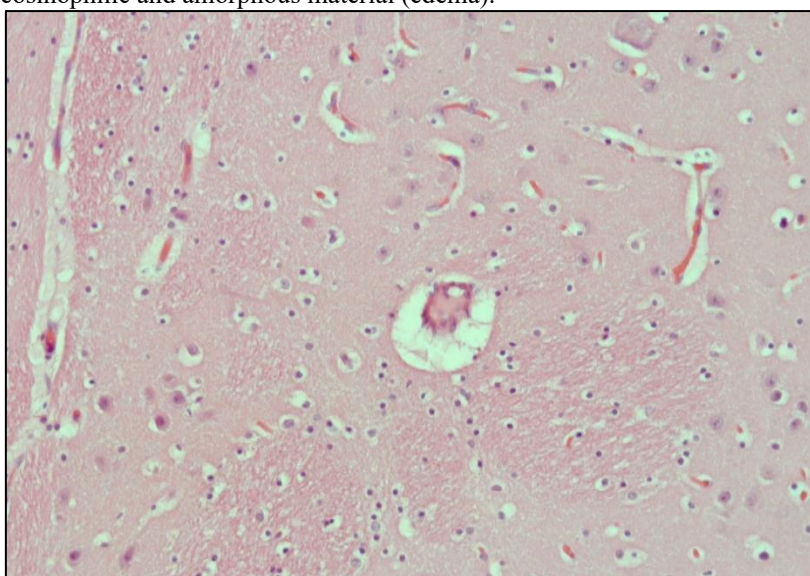
thickening of the media layer of the blood vessels (fibrinoid necrosis), with occasional thrombi in the vascular lumen.

Figure 1: Edema disease in pigs. A) Eyelid edema. B) Diffuse edema of the mesocolon.



Source: LPA-FOCG.

Figure 2: Edema disease in pigs. In the brain, there is an increase in perivascular spaces associated with the presence of mildly proteinaceous, eosinophilic and amorphous material (edema).



Source: LPA-FOCG.

Intestine fragments were submitted to culture and microbiological isolation using *Blood agar*, *MacConkey agar* and *Sabouraud dextrose agar* with chloramphenicol, incubated at 37°C for 24 hours in aerobiosis resulting in the growth of colonies compatible with *Escherichia coli*.

The diagnosis was established by epidemiological and clinical findings, and confirmed by anatomopathological examination and isolation of the agent. The reduction of lactogenic immunity and the increase in stressors related to changes in feeding and management (separation from the

mother, piglet mixing, change of environment), represent a critical time for the establishment of infections. This period was previously the one with the highest incidence of the disease (Brum *et al.*, 2013; Coelho *et al.*, 2017). Food and sanitary management measures were indicated to improve immunity and reduce cases. The main clinical manifestations presented consisted of neurological signs associated with edema. Neurological signs of ataxia, seizures, incoordination, and tremors, along with edema of the face and ventral region of the neck are described as features in the disease (Helke *et al.*, 2015; Santos and Alessi, 2016). The development of neurological alterations is related to circulatory disorders, mainly represented by edema and hypoxia (Fairbrother; Gyles, 2012).

CONCLUSION

The disease of edema has an important frequency, predominantly in the form of outbreaks in piglets in the post-weaning period. Neurological signs followed by facial edema in this period of life are suggestive of the disease. Some factors are capable of predisposing animals to infection by *E. coli*, thus, it is necessary to implement preventive measures in order to minimize risk factors such as sudden change of feed, supply of high-protein diets, piglet stress due to maternal separation, mixture of litters in the same stall, overcrowding, poorly performed disinfection in the facilities, absence of sanitary void between lots, temperature and humidity variations in the stalls.

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Nervous form of listeriosis in cattle

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ABSTRACT

Listeriosis is an infectious disease of bacterial origin, widely distributed in the world, which mainly affects small ruminants. The clinical and pathological aspects of listeriosis in cattle in the Sertão of Paraíba are described. From 2003 to 2023, the Animal Pathology Laboratory of the Federal University of Campina Grande performed 1,272 necropsies of cattle, of which 159 (12.50%) were diagnosed with diseases that affected the central nervous system (CNS) and of these, two cases were attributed to listeriosis (1.25%), being crossbreds, one female (Bovine 1) and one male (Bovine 2), aged 5 years and 18 months respectively. Bovine 1 came from the municipality of Patos, while Bovine 2 was from the municipality of Piancó, both located in the Sertão da Paraíba, raised in a semi-extensive regime. Both animals showed nervous symptoms, Bovine 1 initially receiving the presumptive diagnosis of rabies. Macroscopically, no lesions were observed in the CNS. Microscopically, in Bovine 1, microabscesses were observed characterized by moderate multifocal to coalescent areas of neutrophilic infiltrate without capsular involvement, moderate mononuclear infiltrate with rare neutrophils around vessels (cuffs) and a discrete amount of axonal spheroids in the medulla oblongata region, in addition to discrete lymphoplasmacytic infiltrate in the meninges of the occipital cortex and cerebellum. The microscopic lesions observed in Bovine 2 were similar, varying in intensity and location. The diagnosis was based on epidemiological, clinical and histopathological findings. The nervous form of listeriosis occurs rarely in cattle in the hinterland of Paraíba, and may present nonspecific clinical alterations and be confused with other pathologies of the CNS of cattle.

Keywords: Bovine diseases, Central nervous system, Bacterial diseases, Microabscesses.

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INTRODUCTION

Listeriosis is an infectious disease of bacterial origin, widely distributed in the world, which mainly affects small ruminants (Cruz 2008). The disease is caused by bacteria of the genus *Listeria*, two species of greater importance in veterinary medicine: *L. monocytogenes*, frequently reported in cases of meningoencephalitis in ruminants; and *L. ivanovii*, associated with cases of abortions in sheep and cattle (Schild 2007). Infection in the nervous form is commonly related to the consumption of poor quality silage associated with previous lesions in the oral cavity, in addition to inflammatory processes, such as periodontitis (Schild 2007). The bacterium ascends via sensory axons using retrograde axonal transport to the trigeminal ganglion until it reaches the brain/medulla or via the motor portion of the fifth pair of cranial nerves until it reaches the midbrain and medulla oblongata. Macroscopic lesions are not usually observed in this form of the disease (Rissi *et al.*, 2010). The objective of the present study was to describe cases of the nervous form of listeriosis in cattle, emphasizing its epidemiological, clinical and pathological aspects.

MATERIAL AND METHODS

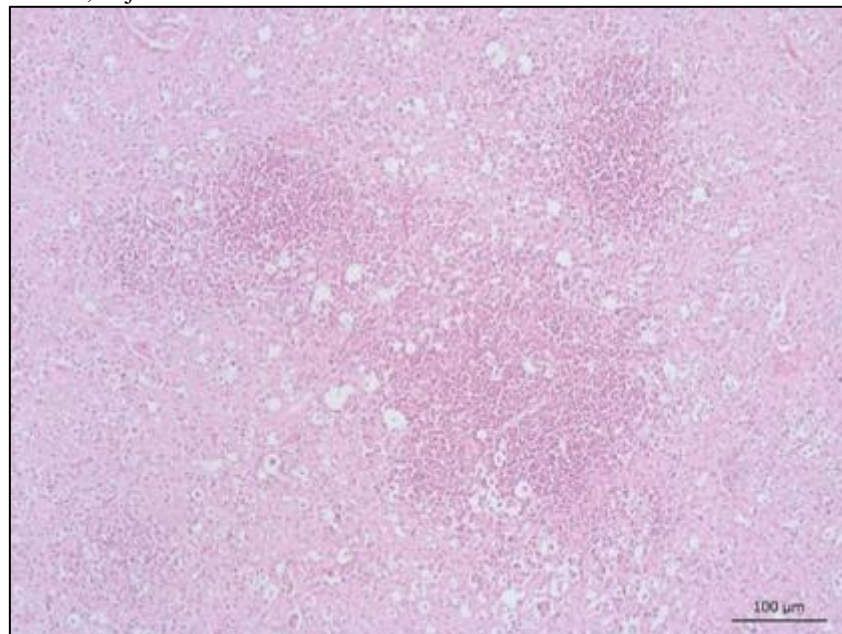
A retrospective study was carried out in search of confirmed or suspected cases of the nervous form of listeriosis in cattle. To this end, epidemiological, clinical, and pathological data were obtained after reviewing the protocols of bovine necropsies performed at the Animal Pathology Laboratory of the Veterinary Hospital of the Center for Rural Health and Technology of the Federal University of Campina Grande (LPA/HV/CSTR/UFCG), from January 2003 to December 2023. Information was obtained regarding the age, sex, breed, time of year and origin of the animal, in addition to clinical signs, macroscopic and histopathological changes. The histological slides were reviewed and, when necessary, new slides were made from the paraffin or formaldehyde material.

RESULT

During the study period, 1,272 cattle were necropsied at the LPA of UFCG, of which 159 (12.50%) were diagnosed with diseases that affected the central nervous system (CNS). Of these, two cases were diagnosed as listeriosis (1.25%). Regarding the epidemiological data, the animals were crossbred, one was female (bovine 1) and the other male (bovine 2), aged 5 years and 18 months respectively. Cattle 1 came from the municipality of Patos and was diagnosed in May 2004. Bovine 2 was from the municipality of Piancó, diagnosed in June 2009, both located in the hinterland of Paraíba. Both were raised in the semi-extensive regime, but did not receive silage. Bovine 1 presented apathy, staggering gait, sternal decubitus, head turned to the flank, nystagmus, strabismus, congested episcleral vessels, lingual paralysis, motor incoordination and tail paralysis, which initially resulted in a presumptive diagnosis of rabies. Bovine 2 presented walking in circles, motor

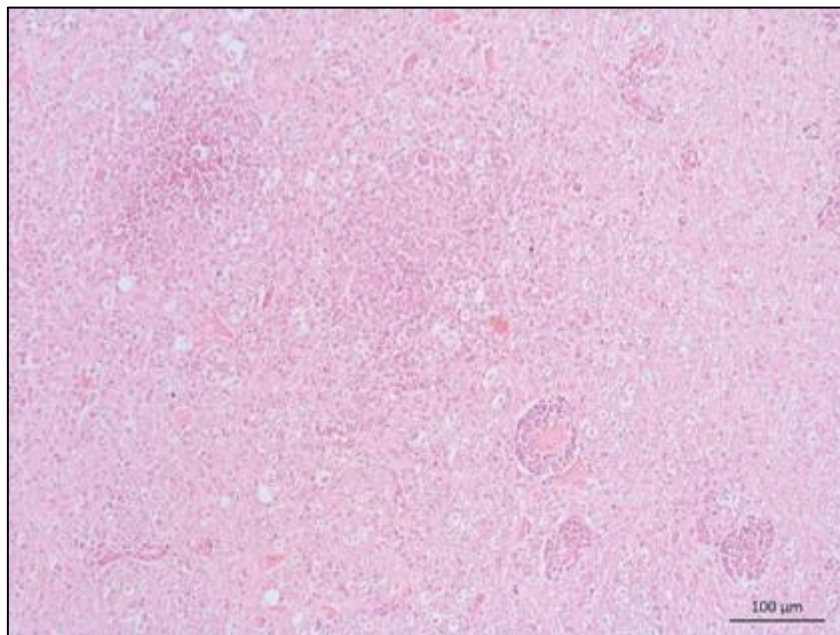
incoordination, salivation, lip ptosis, lateral decubitus and decreased anal reflex. Macroscopically, no lesions were observed in the CNS. Microscopically, in bovine 1, microabscesses were observed characterized by multifocal to coalescent areas of inflammatory infiltrate consisting of intact and degenerated neutrophils (Fig.1), there was also moderate mononuclear infiltrate, with rare neutrophils, around vessels (cuffs) and a discrete amount of axonal spheroids in the region of the medulla oblongata (Fig.2), in addition to a discrete lymphoplasmacytic infiltrate in the meninges of the occipital cortex and cerebellum. The microscopic lesions observed in bovine 2 were similar, varying in intensity and location, which were accentuated and affected the medulla oblongata, with moderate spheroids and meningitis absent.

Figure 1. Bovine, medulla oblongata cross-section at pons level, multifocal to coalescent areas of neutrophilic infiltrate forming microabscesses. HE, obj.5x.



Source: LPA-FOCG.

Figure 2. Bovine, medulla oblongata, mononuclear infiltrate with rare neutrophils around vessels (cuffs) and axonal spheroids. HE, obj.5x.



Source: LPA-FOCG.

DISCUSSION

The diagnosis was based on epidemiological, clinical and histopathological findings. The nervous form of listeriosis in cattle affects animals of varying ages, usually young adults up to 2 years old (Rissi *et al.*, 2006; Konradt *et al.*, 2017). In the present study, one of the animals was 5 years old, however, there are no studies that prove the relevance of the age group for the occurrence of the disease (Morin 2004). In addition, no predisposition by races and genders is observed (Konradt *et al.*, 2017), even though there is no contradiction, the casuistry in this report does not allow us to infer this observation. The animals were raised in a semi-extensive regime, but did not receive silage, which when of poor quality is considered one of the main sources of infection in ruminants, as reported in other countries and in Rio Grande do Sul (Barlow; McGorum 1985; Barros *et al.*, 2006; Rissi *et al.*, 2006; Schild 2007). Thus, an environmental infection is suggested in the two reported cattle. The cases occurred during the rainy season, similar to those observed in other countries during the winter (Barlow; McGorum 1985). The clinical signs observed in the two animals were mainly related to lesions in the brainstem and cranial nerves, which is consistent with the cases described in the literature (Rissi *et al.*, 2006; Oevermann 2010; Rissi *et al.*, 2010; Walland *et al.*, 2015). It is important to emphasize that the clinical symptomatology is not pathognomonic and, therefore, other differential diagnoses such as rabies, polioencephalomalacia, meningitis, coenurosis and otitis should be considered (Schild 2007). No macroscopic lesions were observed in the CNS, which is consistent with the findings of Rissi *et al.* (2006). The diagnosis of cases of the nervous form of listeriosis in this study was based on the histopathological alterations characteristic of the disease, mainly due to the visualization of microabscesses associated with the perivascular cuffs. The microscopic lesions

observed in cases of listeriosis nervosa in cattle are like those observed in sheep and goats, and are often located in the rhombocephalon, especially the medulla oblongata (Konradt *et al.*, 2017).

CONCLUSION

The nervous form of listeriosis occurs rarely in cattle in the hinterland of Paraíba, and is characterized by varied neurological manifestations and microabscesses formations in the brainstem. Depending on the evolution of the disease, clinical changes may be nonspecific and confused with other pathologies of the central nervous system of cattle.

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Retrospective study of dermatophylosis in sheep in the Sertão of Paraíba

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ABSTRACT

The epidemiological, clinical and pathological aspects of dermatophylosis in sheep in the Sertão da Paraíba, Northeast Brazil, are described. From 2003 to 2023, 7 cases of dermatophylosis in sheep were diagnosed at the Animal Pathology Laboratory of the Federal University of Campina Grande. Of the affected animals, four were females and three males. Most of the animals were adults, four of whom were crossbred and three of the Santa Inês breed. The disease was most frequently diagnosed in April, followed by June and November. All the animals came from municipalities belonging to the Sertão region of Paraíba. Clinically, the animals presented multifocal to coalescent areas of alopecia, located in decreasing order of frequency, on the head, back, neck, ears and limbs. In two animals, the lesions were generalized. Macroscopically, the prevalent skin lesions were characterized by thickening of the skin by slightly moist crusts that formed grayish-white plaques. Histologically, multifocal to coalescent areas of epidermal hyperplasia (acanthosis) were observed, associated with marked parakeratotic and/or orthokeratotic hyperkeratosis. In the middle of the epidermis and between the keratin lamellae, multifocal areas of moderate neutrophilic infiltrate associated with cellular debris (intraepidermal pustules and serocellular crusts, respectively) and numerous filamentous, segmented and basophilic structures, compatible with *D. congolensis*, were observed. The diagnosis was established through epidemiological, clinical and anatomopathological findings. The disease occurs sporadically in sheep in the Sertão da Paraíba, affecting adult animals of both sexes, and characterized by alopecic and crusty skin lesions.

Keywords: Sheep disease, Skin diseases, Crusty lesions, Bacterial infection.

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INTRODUCTION

Dermatophylosis is a skin disease caused by *Dermaphilus congolensis*, a bacterium of the class of actinomycetes, Gram positive and filamentous that, although normally present in the skin of animals, acts as an opportunist under favorable conditions that unbalance the immune barrier of skin protection and leads to the proliferation of bacterial zoospores in the integument (Pereira; Meireles 2007; Macêdo *et al.*, 2008). The bacterial invasion is followed by a neutrophil-mediated inflammatory response forming microabscesses in the epidermis that prevent the progression of the bacterium, but allowing its regeneration. This process of bacterial invasion, inflammation and regeneration is responsible for the appearance of pustular crusts characteristic of the disease (Pereira; Meireles 2007; Riet-Correa *et al.*, 2007). The disease can have an acute, subacute or chronic evolution, being described more frequently in cattle, sheep and horses (Cunha *et al.*, 2010). Clinical signs involve alopecia, crusty, well-defined and circumscribed skin rashes. In sheep, the main clinical characteristic is the agglutination of wool forming firm structures, a condition commonly known as sheep's wood wool (Castelo Branco *et al.*, 2012; Vieira *et al.*, 2017). Microscopically, parakeratosis, hyperkeratosis, acanthosis, dermal sclerosis, and neutrophil infiltration of the epidermis are observed (Riet-Correa *et al.*, 2007). The diagnosis can be made through microscopic observation of the bacterium in crusts fixed and stained by methylene blue and can be confirmed through culture of the agent and molecular biology techniques (Hass; Torres 2016). The treatment of sick animals is carried out from therapy with penicillin, streptomycin or oxytetracycline. The control and prophylaxis of the disease are based on the isolation and treatment of the sick, avoiding management errors that can cause skin lesions and can serve as gateways for the agent, as well as providing shelter to the animals in rainy seasons (Hass; Torres 2016). The objective of this study is to describe the main epidemiological, clinical and pathological aspects of cases of dermatophylosis in sheep in the Sertão da Paraíba, Northeast Brazil.

MATERIAL AND METHODS

The biopsy and necropsy records of sheep at the Animal Pathology Laboratory of the Federal University of Campina Grande, from January 2003 to December 2023, were reviewed in search of cases diagnosed as dermatophyllosis. From the clinical and necropsy protocols, information was obtained regarding epidemiological data (gender, race, age and origin), clinical signs and anatomopathological findings. Photographic records were also retrieved to complement the description of macroscopic lesions. For microscopic description, the histological slides of the cases were reviewed and new slides were made from tissue fragments filed in paraffin blocks. All sections were routinely processed and submitted to hematoxylin and eosin (HE) staining.

RESULTS

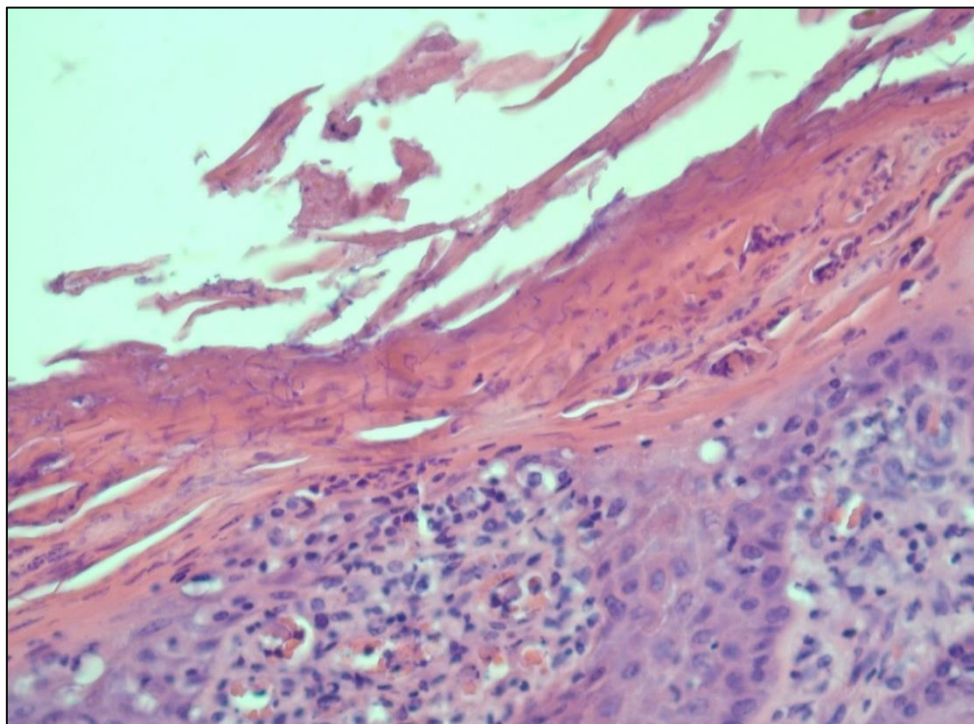
During the study period, 7 cases of dermatophylosis in sheep were diagnosed. Of the affected animals, four were females and three males. Most of the animals were adults (6/7), four of which were crossbred animals and three animals of the Santa Inês breed. The disease was most frequently diagnosed in April (5/7), followed by June (1/7) and November (1/7). All the animals came from municipalities belonging to the Sertão region of Paraíba. Clinically, the animals presented multifocal to coalescent areas of alopecia, located in decreasing order of frequency, on the head (5), back (4), neck (3), ears (2) and limbs (2). In two animals, the lesions were generalized. Macroscopically, the skin lesions were characterized by thickening of the skin by crusty, slightly moist, grayish-white plaques, which were easily detached when manipulated (Fig. 1). The adjacent hairs were rough and agglutinated, easily detached from manipulation; sometimes they contained piosanguinous secretion. Histopathology showed multifocal to coalescent areas of epidermal hyperplasia (acanthosis), associated with marked parakeratotic and/or orthokeratotic hyperkeratosis. In the middle of the epidermis and between the keratin gills, multifocal areas of moderate neutrophilic infiltrate associated with cellular debris (intraepidermal pustules and serocellular crusts, respectively) and numerous filamentous, segmented and basophilic structures, compatible with *D. congolensis*, were observed (Fig. 2). In three cases, direct examination of the crusts was performed, where basophilic, filamentous, transversely and longitudinally septate structures with morphology compatible with *D. congolensis* were observed.

Figure 1: Dermatophylosis in sheep. Crusted and alopecic lesions forming grayish-white plaques.



Source: LPA-FOCG.

Figure 2: Dermatophylosis in sheep. Hyperplasia of the epidermis with numerous basophilic filamentous bacteria. HE, Obj.40x.



Source: LPA-FOCG.

DISCUSSION

The diagnosis of dermatophylosis was established through epidemiological, clinical and anatomopathological findings. The epidemiological characteristics of the reported cases are in agreement with other studies, where dermatophylosis is described with greater incidence after periods of intense rain, affecting animals of both sexes indiscriminately (Riet-Correa 2007; Castelo Branco *et al.*, 2012). It is believed that several stressors, including rainy and hot periods, as observed during the month of April in the region where the cases were studied, promote an imbalance of superficial and nonspecific immune defense barriers, breaking the integrity of the skin and allowing the zoospores of *D. congolensis* to invade the integument and produce bacterial dermatitis (Pereira; Meireles 2007). Clinically, the animals presented crusted and scaly skin rashes, consistent with other studies where the formation of multilaminar pustular crusts clinically characterized the disease (Pereira; Meireles 2007). Hass and Torres (2016) describe that in a typical dermatophylosis lesion, the local lesion appears as an area of matted hairs that can, when detached together with a moist crust, leave an exudative area red. Regarding the location of the lesions described, there was similarity to that described by Castelo Branco *et al.* (2012) and Macêdo *et al.* (2008), where the main sites of disease involvement were the back, head, ears and limbs of the animals. In only two animals, the lesions were distributed in a generalized way and presented a progressive and chronic form. Generalized lesions of dermatophylosis in sheep have been attributed to immunosuppressive factors such as food deficiency, excessive humidity, concomitant diseases and injuries caused by shearing in

these animals (Riet-Correa 2007). The diagnosis of dermatophylosis can be quickly established from the observation of the etiologic agent in the crusts of the lesions. The confirmation of dermatophylosis cases was due to the histological observation of numerous filamentous, segmental and basophilic structures that assume the appearance of a "pile of coins" or in the form of a "tram track", similar to what has been described in the literature, where the agent is described microscopically as being septate with longitudinal and transverse branched filaments, forming divided ribbons of spherical or oval cocus, with 0.5µm diameter (Hass; Torres 2016).

CONCLUSION

Dermatophylosis is a dermatopathy that occurs sporadically in sheep in the Sertão of Paraíba, affecting adult animals of both sexes and characterized by alopecic and crusty skin lesions. Histopathological findings, with intralesional filamentous bacteria, allow the definitive diagnosis of the disease.

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Clinicopathologic characterization of diseases diagnosed in cockatiels (*Nymphicus hollandicus*) in the Sertão da Paraíba

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ABSTRACT

The clinical and pathological aspects of diseases diagnosed in cockatiels (*Nymphicus hollandicus*) in the Sertão da Paraíba, Northeast Brazil, are described. From January 2003 to December 2023, 362 birds were necropsied at the Animal Pathology Laboratory of the Federal University of Campina Grande. Of these, 9 (2.48%) cases were cockatiels, where six were females and three were males, most of the animals were adults and came from the municipality of Patos, Paraíba. The diseases diagnosed were: cloacal prolapse (09/02); dystocia-egg retention (01/09); complete fracture of tibiotarsal bone and fibula (01/09); perforating ulcer and cellulomite (01/09); sepsis associated with scabies (09/01); squamous cell carcinoma (01/09); liver cirrhosis (01/09); and osteopathy due to calcium deficiency (01/09). Changes in the cloaca and oviduct were the most frequent conditions, with the others being seen occasionally. Although they involve different causes, most of the diseases observed are directly or indirectly related to sanitary and nutritional management practices. Highlighting the importance of knowledge about the possible diseases that can affect this species, whether it is raised freely or domiciled.

Keywords: Bird diseases, Cockatiels, Management errors, Psittaciformes.

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INTRODUCTION

Psittacines are birds admired for their ability to interact socially and the variety of sounds they are able to emit. Cockatiels (*Nymphicus hollandicus*) are one of the most popular Psittaciformes species as pets in the world (Zavatta *et al.*, 2024). When raised in captivity or as companion animals, cockatiels often have their habitat and diet modified inappropriately, which can trigger several health problems related to feeding and recurrent management errors (Assis *et al.*, 2018). Commonly, the stress caused by inadequate handling can predispose birds to the development of immunosuppression and greater susceptibility to a variety of infectious and non-infectious diseases (Rocha *et al.*, 2014). Other factors such as chemical irritants and the incidence of solar radiation may also be associated with the emergence of diseases, including neoplastic diseases (Filgueira; Reis, 2009). Thus, the objective of this work is to describe the diseases diagnosed in cockatiels in the Sertão of Paraíba, considering their main clinical and pathological aspects.

MATERIAL AND METHODS

A retrospective study of necropsy cases in birds was carried out at the Animal Pathology Laboratory of the Federal University of Campina Grande, Patos, Paraíba, northeastern Brazil, from January 2003 to December 2023, with the purpose of identifying diseases in cockatiels. The clinical and necropsy protocols were reviewed, and information related to epidemiological data (species, sex, age and origin) was later collected. Photographic records were also retrieved to complement the macroscopic descriptions of the lesions. To describe the microscopic lesions, the histopathological slides were reviewed and, when necessary, new slides were made from the material archived in paraffin blocks, and stained with Hematoxylin and Eosin (HE).

RESULTS

During the study period, 362 birds were necropsied, 9 (2.48%) of which were identified as cockatiels (*Nymphicus hollandicus*). The diseases diagnosed included: cloacal prolapse (02/09); dystocia-egg retention (01/09); complete fracture of tibiotarsal bone and fibula (01/09); perforating ulcer and cellulomite (01/09); sepsis associated with scabies (09/01); squamous cell carcinoma (01/09); liver cirrhosis (01/09); and osteopathy due to calcium deficiency (01/09).

CLOACA PROLAPSE

Two animals were diagnosed with cloacal prolapse (cockatiels 1 and 2), both females, adults, with lean and regular body score, respectively. Cockatiel 1 presented cloacal prolapse with no apparent cause and was referred for a clinical procedure to reduce the prolapse, but presented cardiorespiratory arrest and was referred for anatomopathological evaluation. At necropsy, prolapse

of the final segment of the cloacal was observed, with a reddish-black area covered by crust. Cockatiel 2 presented apathy, greener feces and partial egg retention in the cloaca. The owner tried to assist in the expulsion of the egg, but the procedure ended up culminating in the prolapse of the cloaca. The animal was taken to the veterinarian and sent for surgery to correct the prolapse, but decompensated and died post-surgery. At necropsy, cloacal prolapse with red-blackish edges and a healthy surgical wound measuring approximately 1 cm in diameter were observed (Fig. 1 A). An area of blackish red dilation was also observed in the oviduct region.

EGG RETENTION DYSISTOCIA

An adult female cockatiel from the municipality of Patos, Paraíba, with an increase in volume in the cloacal region, was diagnosed with egg retention. The veterinarian in charge performed a maneuver by pressing the region, observing excretion of caseonecrotic and lumpy exudate. The animal died after 24 hours. At necropsy, several immature eggs were observed in the oviduct. The cloaca was dilated, with diffusely reddish mucosa and a marked amount of caseonecrotic and lumpy exudate (Fig. 1 B).

ÚLCERA PERFURANTE AND COELOMITE

A four-year-old male cockatiel from the municipality of Barro, Ceará, presented apathy and anorexia, evolving to death in approximately five hours. The animal was raised indoors with free access to a cage and fed with fruits and specific commercial feed. At necropsy, an area of transmural ulceration was observed, measuring approximately 0.3 cm in diameter, and surrounded by a reddish halo in the isthmus region. At the opening of the segment, mucosa with a moderate amount of viscous and blackish-red material (digested blood) was observed. Contamination of the coelomatic cavity by contents of the digestive tract was also observed (Fig. 1 C).

TRAUMA

A six-year-old female cockatiel from the city of Patos, Paraíba, was admitted with a history of having been attacked by other birds inside the cage. The animal died and was sent for necropsy. On external examination of the cadaver, a complete fracture of the tibia, fibula and left tarsus was observed, associated with a focally extensive reddish area (hematoma) (Fig. 1 D).

SARNA AND SEPSE

A two-year-old female cockatiel from the municipality of Patos, Paraíba, raised with other contacts in a cage, and fed on seeds, presented a history of apathy, anorexia and scabies for approximately two months, and treatment with Ivermectin and Dolemil was carried out. On external

examination of the cadaver, a thin body state, diffuse desquamation of the pelvic limbs was observed. At the opening of the coelomatic cavity, diffusely reddish air sacs, lungs and kidneys were observed. The liver was diffusely red-black, and some muscle fibers were darker in color. Microscopically, bacterial myriads were observed in the blood vessels and liver, as well as diffuse congestion and leukocytostasis.

SQUAMOUS CELL CARCINOMA

A 15-year-old male cockatiel from the municipality of Patos, Paraíba, presented apathy, diarrhea and irregular mass in the left pelvic limb, which evolved to amputation. The animal died and was sent for necropsy. On external examination of the cadaver, a cachectic body state, absence of feathers in the ventral region, and a multinodular, irregular, yellowish mass with blackish puniform multifocal areas on the right foot were observed. Microscopically, a densely cellular, poorly delimited and expansive neoformation was observed, composed of malignant epithelial cells assuming arrangements in cords and nests, often with areas of central keratinization (corneal pearls), and supported by moderate fibrovascular stroma. Polygonal neoplastic cells with well-defined, eosinophilic cytoplasm ranging from sparse to moderate. Nuclei ranging from round to oval with scant chromatin and sometimes multiple nucleoli evident. Moderate pleomorphism, characterized by anisocytosis and anisocariosis. Not very evident mitoses (0 to 2 per field of highest magnification [400x]). Areas of intratumoral multifocal necrosis permeated by inflammatory infiltrate of heterolymphs and rare macrophages and carcinomatous infiltration of adjacent bone tissue were also observed. Microscopic features compatible with well-differentiated squamous cell carcinoma.

HEPATIC CYRROSIS

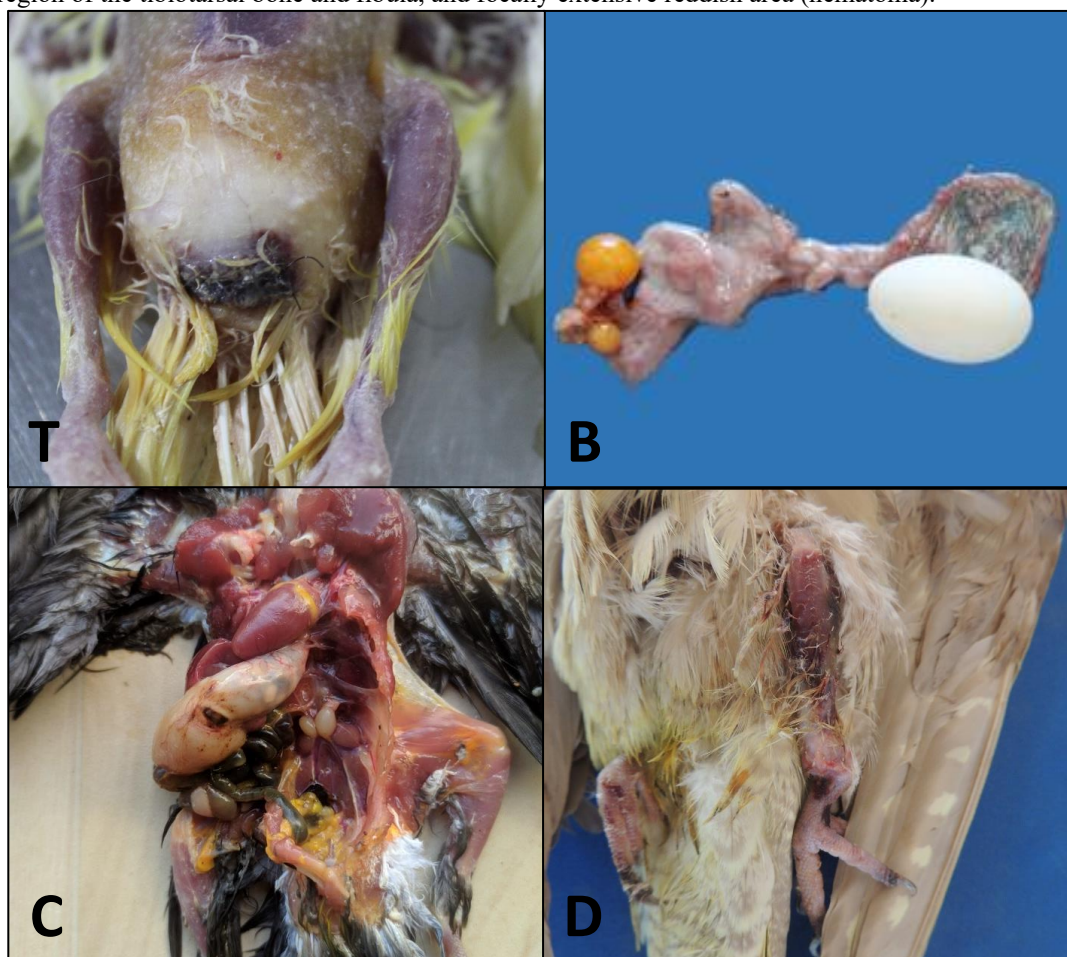
A 17-year-old male cockatiel from the city of Paracuru, Ceará, presented apathy and nausea for three days. Soon after, he appeared dead. Previously, the animal had a respiratory infection that culminated in eye impairment, and loss of vision. It fed on a mixture of seeds (oats, sunflower seeds and birdseed) stored improperly, as well as bread, green corn and cabbage. At necropsy, a small volume of translucent fluid was observed in the opening of the coelomatic cavity. The liver was markedly reduced in size, with a slightly greenish capsular surface, diffusely irregular, with well-defined multifocal nodules measuring approximately 0.1 cm in diameter, which deepened to the parenchyma. Microscopically, it was observed that approximately 70% of the hepatic parenchyma was replaced by extensive trabeculae of mature and immature connective tissue, sometimes associated with a discrete and multifocal inflammatory infiltrate composed of lymphocytes, plasma cells and macrophages, surrounding well-defined islands of hepatocytes (regeneration nodules). Hepatocytes frequently showed macro and microvacuolar degeneration of the cytoplasm, and in

some sections there were focally extensive areas of coagulation necrosis, characterized by pycnosis, karyorexia or nuclear absence, hypereosinophilia or even cytoplasmic rupture.

OSTEOPATHY DUE TO CALCIUM DEFICIENCY

A three-month-old female cockatiel from the municipality of Patos, Paraíba, was diagnosed with osteopathy due to calcium deficiency. The animal had arching of the pelvic limbs and fingers, compatible with calcium deficiency. Microscopically, diffuse replacement of bone tissue from both femurs by fibrous tissue was observed.

Figure 1: Diseases diagnosed in cockatiels (*Nymphicus hollandicus*) in the Sertão of Paraíba. (A) Cloaca prolapse. Surgical wound area with blackened edges. (B) Dystocia-egg retention. Egg in the final portion of the oviduct. (C) Perforating ulcer and cellulomite. Presence of ulcer, digested blood and viscous material. (D) Trauma. Complete fracture in the distal region of the tibiotarsal bone and fibula, and focally extensive reddish area (hematoma).



Source: LPA-FOCG.

DISCUSSION

In the present study, most of the necropsied animals came from the municipality of Patos, Paraíba, where the laboratory where the research was carried out is located. Most of the animals were female, but this fact was not relevant because most of the diseases were not recurred, and it was not possible to compare the sexes. The most frequent disease was cloacal prolapse, which together with

dystocia – egg retention, may be related to nutritional deficiencies such as imbalance in calcium levels, nutritional status, high photoperiod, sexual stimulation by another bird and even egg malformations (Pollock; Orosz 2002; Zavatta *et al.*, 2024). The other diseases had only one case each. Other diagnosed diseases, such as liver cirrhosis and osteopathy due to calcium deficiency, may also be related to nutritional factors, since the diet of these animals is mostly restrictive to commercial rations that do not always meet physiological needs, or in the case of the patient with cirrhosis, who had an inappropriately high-fat diet, overloading the metabolic functions of the liver, which over the years may have contributed to the development of the disease (Assis *et al.*, 2018; Toyama *et al.*, 2022). Regarding the case of trauma, as described in the literature, traumatic accidents in birds are common, whether resulting from collision, being run over, or predation (Andrade *et al.*, 2024). It is possible that the fact that the animal lives in a cage with other animals and has a thin body state may indicate conditions of inadequate handling, increasing stress levels, with consequent changes in behavior and aggressiveness. Regarding the case of sepsis and scabies, it is important to highlight that as described in the literature by Rocha *et al.* (2014), the handling condition of birds directly influences the immunity of these animals, predisposing to the proliferation of opportunistic agents such as bacteria and fungi, developing diseases and potentially leading to death. With regard to the case of squamous cell carcinoma, although it commonly occurs in other species such as felines, canines, cattle, and horses, it has also been described in birds (Zamboni *et al.*, 2020). The changes observed microscopically are compatible with those described in the literature (Souto *et al.*, 2021).

CONCLUSION

Despite the low number of diagnosed cases, it is important to highlight the variety of diseases observed, reinforcing their relevance in the poultry medical clinic. This lower number of cases can also be attributed to underreporting of cases. Another important factor observed was that most of the diseases diagnosed are directly or indirectly related to management errors, either in the environment in which the animal lives or in relation to the diet offered. Thus, the importance of knowing about the proper management of this species is highlighted, as well as about the diseases that they can develop throughout life.

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Effect of temperature on germination of golden grass seeds (*Syngonanthus nitens* (Bong.) Ruhland) originating from the region of Mateiros, Jalapão (Tocantins)

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ABSTRACT

Jalapão is a region rich in natural beauty and is in the east of Tocantins, the population practices handicrafts made with golden grass (*Syngonanthus nitens*) sewn with buriti "silk". Throughout the cerrado, fire is used as part of the management of existing species, for *S. nitens* popular knowledge states that with the proper use of fire its flowering is stimulated. The research was carried out to contribute to the definitions of management of the species. The germination of *S. nitens* seeds from the municipality of Mateiros, exposed naked and in capitula for 10 min at temperatures of 50, 100, 150 and 200 °C, was evaluated. The viability of *S. nitens* seeds submitted in capitula and naked at 50°C for 10 minutes was higher when compared to the other temperatures. The exposure time of the bare seeds and in chapters at 150 and 200 °C made them unviable.

Keywords: Golden grass, Germination, Temperature.

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INTRODUCTION

Jalapão is an area of 34,113 km² to the east of Tocantins, which encompasses 15 municipalities and borders the states of Bahia, Maranhão and Piauí (SEPLAN, 2003). One of the main economic activities is family farming, with farmers and extractivists.

Syngonanthus nitens (Bong.) Ruhland, popularly known as golden grass, is an herb with a short stem, bearing leaves in a basal rosette from which 1 to 10 terminal scapes with capitulum-type inflorescences start. It is characterized by having golden scapes and cream and shiny involucre bracts (Giulietti *et al.* 1996). The species is from the Eriocaulacea family, represented by predominantly tropical species typical of the Cerrado biome, usually in open, swampy or periodically flooded places. They are known as "evergreens" because they maintain the original characteristics of their scapes and inflorescences unchanged after harvest (Giulietti *et al.*, 1996).

The species is quite common in the mountains of the entire Espinhaço Chain with occurrences also in the high-altitude fields of the central portion of South America. The scapes of *S. nitens* are exploited especially in the states of Minas Gerais, Bahia and Goiás (Giulietti *et al.*, 1996). In Tocantins, the "sempre-viva" is also exploited for the making of handicrafts, mainly in Jalapão, but it is also found in other regions of the state, such as the municipalities of Dianópolis, Tocantínia and Caseara.

The artisanal activity with golden grass (*Syngonanthus nitens*) sewn with buriti "silk" has been traditional in the region for about 90 years, but has become economically important since the early 2000s.

Sexual reproduction is of great importance to the population dynamics of the species, and about 40% of recruits may come from seeds (Schmidt *et al.*, 2007). Pollination and seed dispersal can be carried out by wind (Schmidt, 2005; Giulietti & Hensold, 1990).

The seeds are oblong, weigh about 0.033 mg, are around 0.89 mm long and 0.32 mm wide, brown in color and have longitudinal streaks (Schmidt *et al.* 2007). The seed production per chapter is in large number, with a maximum of 237 seeds/chapter and on average it produces 60 seeds/chapter (Schmidt, 2005). Santos (2009) states that each golden grass inflorescence presents, on average, 161 seeds, suffering variation in the number of seeds considering its phenology and the average weight of each seed results in 0.0464mg.

S. nitens has been the target of studies on the development of techniques that indicate the best form of management and allow the sustainable use of the resource, thus avoiding damage to the biodiversity of adjacent paths and phytophysiologicals.

Fire in the Cerrado, as in most savannas, is characterized by being a superficial fire, which mainly consumes herbaceous plants (Miranda *et al.*, 2002). The air temperature during a burn can range from 85°C to 840°C, while in the ground temperatures range from 29°C to 55°C at 1cm depth.

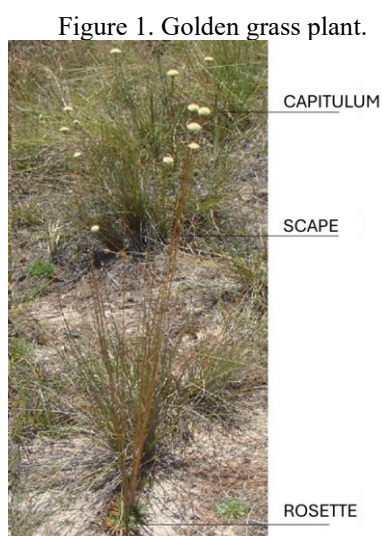
The variation in soil temperature below 5cm depth is almost nil, reaching a maximum of 3°C (Coutinho, 1978; Miranda *et al.*, 1993).

In the region of Jalapão (Tocantins), fire is an important management tool in humid fields, where golden grass occurs. Although traditional knowledge indicates that fire stimulates the flowering of *S. nitens*, little information is available on the effects of temperature on the survival and germination of seeds of this species.

Thus, the present study aimed to evaluate the influence of temperatures 50, 100, 150 and 200°C on the germination of *Syngonanthus nitens*, originating from the municipalities of Mateiros, in the State of Tocantins.

MATERIAL AND METHODS

The golden grass plant (*S. nitens*) is composed of a capitulum, scape and rosette (Figure 1).



A total of 100 golden grass scapes were collected in October 2012, in a humid field (vereda), located in the municipality of Mateiros (geographic coordinate 23 L 0287374), State of Tocantins (Figure 2). This location was chosen because it is a region where there are native populations of golden grass and who use it as raw material in the making of handicrafts.

Figure 2. Collection of golden grass scapes, in the region of Mateiros.



The capitula and scapes after harvest were stored in high-density polyethylene packages because it allows low impermeability to water vapor, in order to maintain the original characteristics until the beginning of the laboratory analyses. For better packaging of the study material, after transporting the paths to the laboratory, the scapes were kept in glass containers.

All laboratory activity was developed in the Seed Laboratory of the Lutheran University Center of Palmas - CEULP/ULBRA, located in the state capital, from January to April 2013. First, the seeds were separated with the aid of binocular stereoscopy magnifying glass and tweezers, as shown in Figure 3.

Figure 3. Golden grass seeds outside their capitula (bare), on filter paper in Petri dishes.



For the experiment, the seeds were placed on filter paper (previously sterilized in an oven at 105°C for 72 hours), in Petri dishes. The seeds were subjected to treatments inside and outside their chapters. Three replications were used, thus 27 plates with 25 seeds each, three for the control.

The seeds were placed in an oven with forced air circulation, with controlled temperature and exposure time. The temperatures used were 50 °C, 100 °C, 150 °C and 200 °C in an exposure time of 10 minutes.

After the treatments, the seeds were submitted to germination test still in Petri dishes, with filter paper soaked in distilled water. The seeds contained in chapters were separated after treatments.

The germination test was conducted in a germination chamber with photoperiod and thermoperiod control. The lighting in this case was by the use of fluorescent lamps with white and cold light, with a controlled light regime (12h/12h). The germination temperature was 28 °C, and the exposure time was 80 days.

Observations were carried out daily to verify the number of germinated seeds. Considering germinated the seed with the emergence of the radicle or cotyledon. The experimental design was completely randomized, in a factorial scheme. The factors were: types of seeds (bare and in capitulum) and exposure temperatures (50, 100, 150 and 200 °C).

For the parameters analyzed, analyses of variance were performed and the means were compared by Tukey's test at 5% significance. The SANEST statistical package was used for the analyses.

RESULTS AND DISCUSSIONS

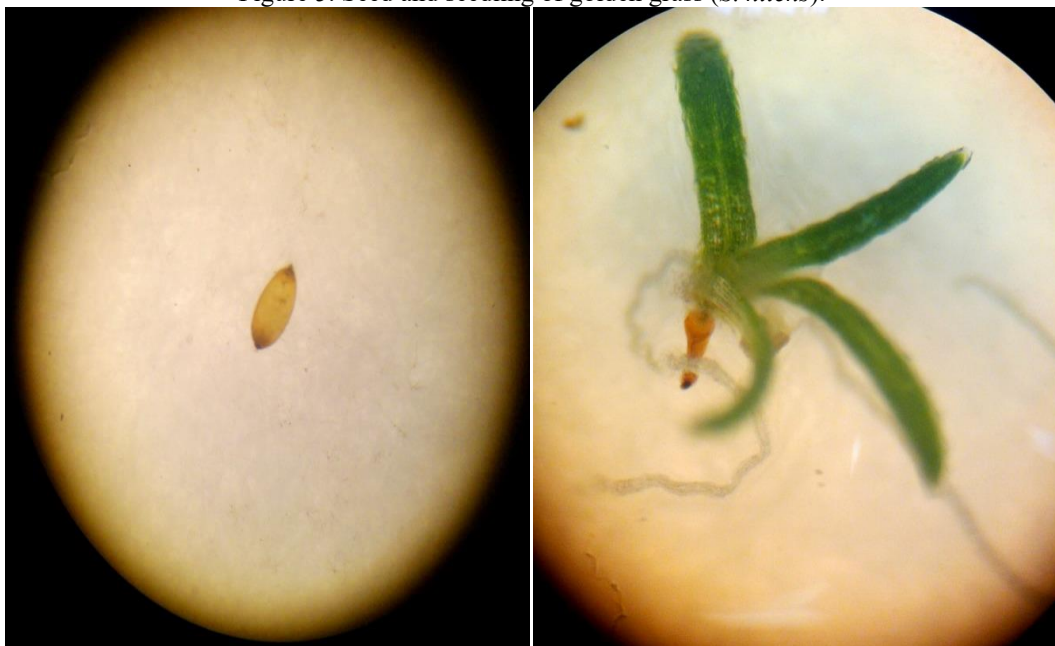
Figure 4 shows the seedlings of *Syngonanthus nitens*. The germination process began from the seventeenth day in the test chamber.

Figure 4. Golden grass (*S. nitens*) seedlings evaluated with the naked eye.



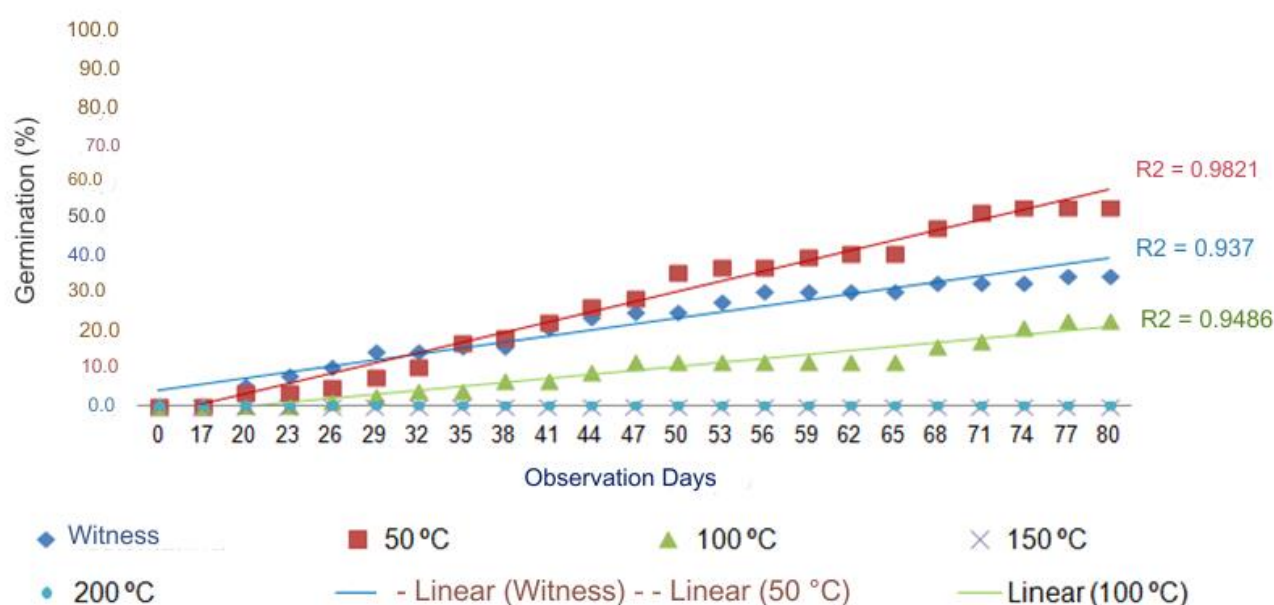
For the best observation, in an attempt to minimize uncertainties, during and close to the end of the test (79th day) all seeds were evaluated through a microscope, as can be seen in Figure 5.

Figure 5. Seed and seedling of golden grass (*S. nitens*).



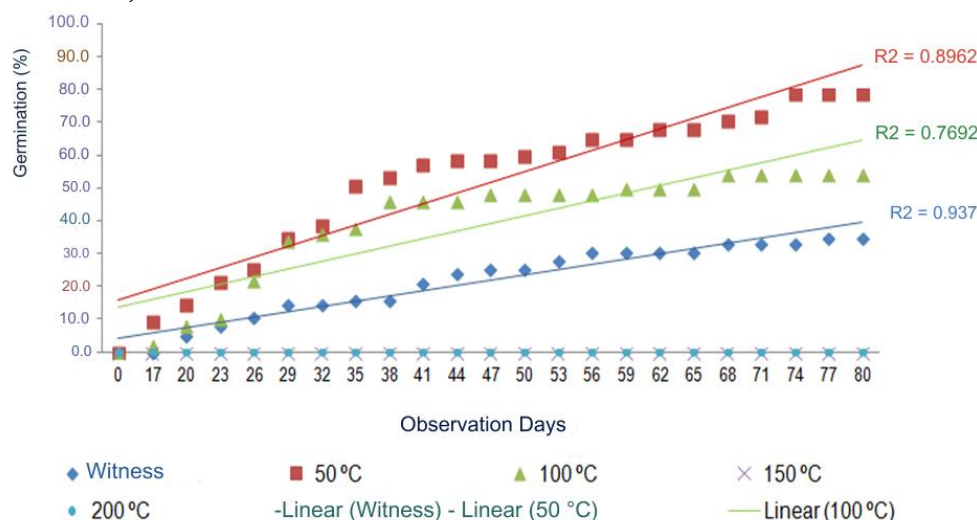
The seeds, when subjected bare to temperature shocks (Figure 6), showed germination difference between them from the twentieth day onwards, but the differentiation was significant after 50 days. These showed a median germination index below ($G < 85\%$). The highest germination index was demonstrated by the seeds submitted to 50°C (53.3%) being higher than the control (34.7%). The temperatures of 150°C and 200°C made it impossible to germinate *S. Nitens* evaluated naked. The values of r^2 (Coefficient of determination), found for the seeds evaluated naked, were 0.98 for the control; 0.93 for 50°C and 0.94 for 100°C ; and reveal a high degree of linear statistical relationship between the variables analyzed.

Figure 6. Germination of *S. nitens* seeds collected in the municipality of Mateiros, subjected to bare temperatures (0 , 50 , 100 , 150 and 200°C).



As shown in Figure 7, the seeds collected in the municipality of Mateiros, when subjected to temperature shocks, presented a median germination index below ($G < 85\%$). The highest germination index was demonstrated by seeds submitted to 50°C (78.7%) followed by exposure to 100°C (54.0%), being higher than the control (34.7%). The temperatures of 150°C and 200°C made it impossible to germinate *S. Nitens* evaluated in chapters.

Figure 7. Germination of *S. nitens* seeds collected in the municipality of Mateiros, submitted in capitula at temperatures (0, 50, 100, 150 and 200°C).



The samples submitted to a temperature of 50°C reacted better when exposed in their capitula, reaching the maximum germination index of the experiment (78.7%). This fact corresponds to a germination rate 25.4% higher than those exposed directly to the same temperature and 44% higher than the control. The viability of *Syngonanthus nitens* seeds submitted in capitulations at 50°C for 10 minutes was higher when compared to temperatures of 100, 150 and 200°C.

Samples subjected to 150 and 200 °C for 10 minutes became unfeasible. The r^2 values found for the seeds submitted in the chapter were 0.89 for the control; 0.76 for 50°C and 0.93 for 100°C; and reveal a high degree of linear statistical relationship between the variables analyzed.

Hanley *et al.* (2003), observed the existence of a relationship between seed size and their resistance to high temperatures. According to these authors, species with small seeds, such as *S. nitens*, are more resistant to high temperatures than species with large seeds.

As small seeds, unlike large ones, remain close to or on the surface of the soil to germinate, their greater resistance to high temperatures, in regions periodically subjected to fire, constitutes an adaptation to this environmental factor. These results are useful and, through the use of this information for the development of management techniques consistent with the relationship of this species and the use of fire, can contribute to the development of recommendations for sustainable management of *S. nitens* from the humid fields of Jalapão and other regions of the Cerrado in which this species has economic importance.

The germination rates after the 100° treatments and the intolerance to temperatures of 150° and 200°C indicate that seeds of *S. nitens* may not survive and not germinate after the passage of the fire for a period of 10 minutes, considered long since experiments in humid fields of Jalapão indicate that the time in which the vegetation remains under high temperatures is short (< 60 seconds) and

that, even during the passage of the fire, the temperatures of some places may not exceed 200°C (SCHMIDT, 2011).

CONCLUSIONS

The golden grass samples submitted to a temperature of 50°C reacted better when exposed in their capitulum, reaching the maximum germination index of the experiment (78.7%), which corresponds to a germination index 25.4% higher than those exposed directly to the same temperature and 44% higher than the control. The viability of *Syngonanthus nitens* seeds submitted in capitula and bare at 50°C for 10 minutes was higher when compared to temperatures of 100, 150 and 200°C. The exposure time of the bare seeds and in chapters at 150 and 200 °C made them unviable.

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Use of lettuce (*Lactuca sativa* L.) As a parameter to prove the application of the landfarming bioremediation technique

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ABSTRACT

The environment has been suffering major problems that affect its quality. The pollution of water reserves, disorderly deforestation, too many fires and the misuse of soils that increasingly lose their essential characteristics for the survival of life on earth. The tailings of the adsorption process are plant biomass with a high content of the fuel adsorbed on its solid structure. This waste discarded in the soil can be removed or mitigated through the bioremediation technique. Bioremediation is a technique for decontaminating contaminated environments that uses living organisms, plants or microorganisms (bacteria and fungi), with the purpose of attenuating or recovering certain contaminants present in the environment. This study aimed to use lettuce (*Lactuca sativa* L.) as a parameter to prove the effectiveness of the Landfarming bioremediation technique in the recovery of soil contaminated with gasoline. An experiment was carried out with lettuce crops, in bioremediated and non-bioremediated soils, simulating a real field situation, with monitoring of the variables temperature, humidity and pH, in the plant growth period (35 days), followed by nutrient analyses on plants cultivated in these two types of soils. It was possible to observe that the plants were maintained throughout their cycle with healthy aspects, demonstrating that the soil had its bioremediation well executed, making it suitable for use in planting. There was no visual difference between the seedlings of the bioremediated soil and those of the soil collected at UEPB. The results of the analyses for macronutrients were within the normal range. However, for heavy metals, the lettuce samples analyzed, both in cultivation in natural soil (UEPB) and in bioremediated soil, presented levels above the standards determined by ANVISA. Therefore, these plants are not recommended for human consumption due to these high levels of existing metals.

Keywords: Contaminated soil, Landfarming bioremediation, Lettuce crop.

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INTRODUCTION

The environment has been suffering major problems that affect its quality. The pollution of water reserves, disorderly deforestation, excessive fires and the misuse of soils, which lose their fertility, compromising their productive capacity, even causing the desertification of large regions and waters, which increasingly lose their essential characteristics for the survival of life on earth. Numerous situations are the cause of these problems. The way natural resources are used, the deficiency in the preservation and monitoring of reserves and the lack of awareness in the applicability of environmental laws are among them. Industrial waste of the most diverse types is disposed of inappropriately, causing the contamination of soils and water sources. In the academic area, research waste also causes concern and the search for technologies that minimize these harmful effects is of great importance not only in academia, but also for the environment.

When mentioning the terminology "solid waste" it refers to an image of domestic waste, or at most, solid state waste, whether commercial or industrial. In fact, the definition of solid waste encompasses much more than these types of "waste". From the definition of the Brazilian Association of Technical Standards (ABNT), the term "solid waste" replaces the word "garbage"; and from the definitions of the National Solid Waste Policy (PNRS) the word "waste" appears to define solid waste that can no longer be reused, reused or reinserted in any way in the production cycle, or in consumption and production activities (BARROS, 2014).

In developed countries, such as the United States, Canada and several European countries, the biochemical technique of remediation has been widely used in works that are based, for example, on the treatment of soils contaminated by petroleum hydrocarbons. However, contrary to what has been observed in these countries, in Brazil, bioremediation projects are still in the field of theory, with few practical cases, although there is a real probability of expansion (ANDRADE et al. 2010).

Bioremediation is a technique for decontaminating contaminated environments that uses living organisms, plants or microorganisms (bacteria and fungi), with the purpose of attenuating or recovering certain contaminants present in the environment. In order to be efficient in this process, some factors become conditioning factors such as temperature, presence of oxygen, nutrients and pH (MORAIS FILHO; CORIOLANO, 2016).

In the field of bioremediation, one of the applications that has been most evident is related to the treatment of soils contaminated by oil and its derivatives. Petroleum hydrocarbons have a natural origin, so that, consequently, many microorganisms have a natural ability to degrade them (MENEZES et al., 2007). The microorganisms present in the soil are capable of degrading contaminants to harmless substances that are not harmful to the environment, such as carbon dioxide (CO₂), water (H₂O) and cellular biomass (MASHI, 2013).

Among the biotechnological options, the Landfarming bioremediation process has a considerable prominence due to the low operating cost and availability of treatment of large volumes of oily waste (SILVA, 2009).

Landfarming is one of the remediation technologies that consists of the application of residue on the soil surface for microbial biodegradation, this technique follows the conditions required for the treatment of soil with contaminated solid waste susceptible to degradation, described by ABNT - 1997 - NBR 13894 Soil Treatment (*Landfarming*). This process has low operating costs for large-scale treatment and does not require much maintenance (ABNT, 1997).

Lettuce (*Lactuca sativa L.*) is one of the most widespread and consumed vegetables in Brazil, having great importance in the country's economy and in the diet of the population (KIEHL, 1999; SMITH and HADLEY, 1989; SOUZA, 2005).

The objective of this work was to use the cultivation of lettuce (*Lactuca sativa L.*) as a parameter to prove the effectiveness of the Landfarming bioremediation technique in the recovery of soil contaminated with gasoline, as there is a need to provide a destination and use to this recovered soil, without causing environmental impacts to the disposal environment.

THEORETICAL FRAMEWORK

REMOVAL OF CONTAMINANTS FROM AQUATIC BODIES AND THE ADSORPTION PROCESS

In recent years, research has been carried out at the Universities, on a laboratory scale, with the objective of using techniques such as adsorption for the purification of water contaminated with petroleum derivatives using native biomass from their study regions. The tailings of the adsorption process are adsorbent biomass with a high contamination index, due to the adsorbed oil retained in its solid structure.

Adsorption is a mass transfer operation from a fluid phase to a solid phase, this phenomenon occurs on the surface of the solid. The larger the contact surface, the more favorable the adsorption process (RUTHVEN, 1984).

The main elements of adsorption are the fluid, the surface (usually a porous solid), and the components retained by the surface. The adsorbent is the solid in which adsorption will occur; the fluid in contact with the adsorbent is called the adsorptive, which can be a gas phase or a liquid solution, and the adsorbate is the phase made up of the components retained by the adsorbent (NASCIMENTO et al., 2019).

The first industrial applications of the adsorption process took place during the wars, in the 1920s, and it was used for the removal of alcohol and benzene from gaseous streams (developed by

Bayer AG, Germany) and for the recovery of ethane and heavy hydrocarbons from natural gas (developed by Union Carbide Corporation, USA) (PUPIM; SCHEER, 2005).

SOIL CONTAMINANTS AND TECHNIQUES FOR REMOVING THESE CONTAMINANTS

According to Rizzo et al. (2007), soil contamination by the introduction of oil into the environment is not new, on the contrary, there are records of this type of pollution since 1754. However, it was from the 1960s onwards that attention turned to this reality and several treatment techniques began to be adopted.

The various activities of the oil industry, such as drilling, production, transportation, processing and distribution, generate considerable amounts of solid waste, containing various classes of hydrocarbons, which can lead to serious environmental problems (FORMIGHIERI; JERÔNIMO, 2017).

According to CONAMA Resolution No. 001/86, environmental impact is defined as the alteration of the physical-chemical and biological properties of the environment. The treatment of this waste is essential to promote sustainable management of exploration and use of mineral resources.

According to Silva (2009), the treatment alternatives for waste contaminated with petroleum products are varied, including physical-chemical and biological processes, with the objective of removing organic pollutants at concentrations that are undetectable or, if detectable, at concentrations below the limits established as safe or acceptable by legislation.

The need to treat the waste generated from the gasoline adsorption process into natural biomass, through the bioremediation technique, arose from the need to reduce or neutralize the possible environmental implications that could be caused by the disposal of this waste in the soil in dumps that still exist in some cities in Brazil and also in landfills.

BIOREMEDIATION AND THE LANDFARMING TECHNIQUE

Bioremediation is a process in which living organisms, usually plants or microorganisms, are technologically used to remove or reduce (remediate) pollutants in the environment. This biotechnological process of remediation has been intensively researched and recommended by the current scientific community as a viable alternative for the treatment of contaminated environments, such as surface water, groundwater and soils, as well as industrial waste and effluents in containment landfills (Gaylard et al., 2005).

Biological processes such as bioremediation vary in terms of the type of treatment, which can be *in situ* when performed on-site and *ex situ* when performed outside the contaminated site (GAYLARDE et al., 2005). Both involve procedures that can be applied in the treatment of the

surface or subsurfaces and depend on several aspects such as the heterogeneous distribution of the tailings, the concentration of the contaminant, the toxicity and persistence of the contaminant at the site, as well as the favorable conditions for the growth of microorganisms (MOREIRA and SIQUEIRA, 2006). After choosing the type of treatment, the most appropriate technique is chosen.

Landfarming is a technique in which oily residue is incorporated into the soil, under controlled conditions, to remove the degradation and immobilization of hazardous contaminants present by the soil microbiota. The residue is applied to the surface of an area and mixed with the soil through conventional equipment, such as tractors equipped with plows and/or harrows (*in situ*). The soil of the site must be contained in a properly impermeable cell, so that there is no contamination of the water table. This technique is appropriate for the treatment of non-recoverable oil containing impregnated absorbent materials (straw, sawdust and peat) and water-in-oil emulsions (CETESB, 2013).

The biological removal of petroleum products through *Landfarming* has been applied commercially on a large scale with relative success. The technology has been widely used due to its simplicity and cost-effectiveness. The dominant mechanisms of pollutant removal involved in *Landfarming* are the volatilization of volatile low molecular weight compounds during the first days of contamination or treatment, biodegradation and adsorption (MAILA; CLOETE, 2004).

According to the United States Environmental Protection Agency (USEPA), the *Landfarming technique* consists of disposing the residue in the reactive layer of the soil, so that the autochthonous microbiota acts as an agent of hydrocarbon biodegradation (TOMASONI et al., 2019).

CULTIVATION OF LETTUCE (*LACTUCA SATIVA L.*) AS A PARAMETER TO PROVE THE LANDFARMING TECHNIQUE

Lettuce is one of the most popular crops, planted and consumed throughout the Brazilian territory. The various cultivars of this vegetable adapt well to our diverse climate. Moisture management throughout the growing period is a critical factor for good quality production. Even in relatively short periods of inadequate moisture, it can affect the crop. During germination, temperatures of 7 to 24 °C are required. Short days are ideal for growing lettuce. Days lasting more than 12 hours cause lettuce blooming (naandanjain.com.br, 2022).

ALMEIDA (2019) used the *Landfarming* technique as a means of reducing or completely removing the granite processing tailings (mud) added to decontaminated soil, and observed the appearance and growth of plants that served as a parameter to prove the effectiveness of bioremediation for possible application in agriculture. In this research, the effects on the growth and development of vegetables were evaluated through observation. The author concluded that it is feasible to use the bioremediation technique to reuse this waste as a complement to soils.

It is important to highlight that germination bioassays with plant seeds are carried out during the first days of their development, in which a series of important physiological processes occur and the presence of a toxic substance can cause adverse effects, resulting in a series of anomalies and even interfere with the survival of this plant (CASTRO, 2013).

METHODOLOGY

LOCATION OF THE EXPERIMENTAL AREA AND ANALYSES

The bioremediation and sowing experiments of the lettuce bed were carried out at the Laboratory of Extension, Teaching and Chemical Technology (LETEQ/CCT/UEPB). The physicochemical analyses of the soil were carried out at the Laboratory of Chemical and Physical Analysis of Soils of Embrapa Cotton, both located in the city of Campina Grande, PB. The lettuce analyses were carried out at the Plant Analysis Laboratory of the Federal University of Paraíba (CCA/UFPB), located in the municipality of Areia, PB.

MATERIAL

The soils used were collected at Embrapa Cotton and in the area next to the Laboratory of Extension, Teaching and Chemical Technology (LETEQ/CCT/UEPB). The lettuce seedlings were acquired from a vegetable grower in the region of Pocinhos, PB, with the ideal size for transplanting in the bioreactors.

BIOREACTORS

For the development of the research, a plastic tray measuring 8x55x35 cm, totaling 15.4 cm³, illustrated in Figure 1, and a glass bioreactor measuring 10x30x20 cm, totaling 6 cm³, were used as a horizontal bioreactor.

Figure 1 - Tray Horizontal Bioreactor



Source: The authors(2022).

The procedure for planting lettuce was developed with bioremediated soil obtained in research developed according to Cavalcante, et al., 2021. Initially, the bioremediated soil was stored in the tray bioreactor, where the lettuce seedlings were later planted, where they remained for a period of 35 days to evaluate the growth. After this time, they were harvested, passed through each green plant and taken to a greenhouse at 65°C for 72 hours. After these 72 hours, the samples were taken from the oven and weighed again on a digital scale with two decimal places to verify the dry weight of each. Only after these steps were carried out were these samples sent for macronutrient and heavy metal analysis at the plant analysis laboratory of the Center for Agrarian Sciences - CCA/UFPB in Areia-PB.

Figure 2 illustrates the glass bioreactor measuring 10x30x20 cm, totaling 6 cm³.

Figure 2 - Landfarming bioreactor in glass



Source: The authors(2022).

In the glass bioreactor, natural soil was used without the application of the Landfarming bioremediation technique, collected from the area located next to the LETEQ/CCT/UEPB. In this bioreactor, four lettuce seedlings were planted to serve as a comparison with those planted in the bioremediated soil contained in the tray bioreactor. The planting and collection procedure was the same used in the tray bioreactor.

Figure 3 – Equipment for measuring temperature, humidity and pH



Source: The authors(2022).

In both bioreactors, the following parameters were monitored and quantified: temperature, humidity and hydrogen potential (pH), so that the soil was favorable to crop growth. The soil was moistened with tap water as the moisture was below 60%. Soil temperature and pH were checked twice a week, always in the same shift. A 3x1 pH meter was used (Figure 3) to measure the parameters mentioned above.

SOIL CHARACTERIZATION

The characterization of the bioremediated soil, used for lettuce planting, was carried out at Embrapa Cotton, Campina Grande, PB. The parameters analyzed were nutrients (N, P, K, Ca, Mg and S), pH and organic matter according to Embrapa's soil analysis methodology.

RESULTS AND DISCUSSION

VEGETATIVE ANALYSIS OF LETTUCE

Figure 4 illustrates the tray bioreactor with the lettuce transplanted for adaptation, observation and evaluation of the research.

Figure 4 - Lettuce transplanted in a tray bioreactor for adaptation, observation and evaluation of initial growth.



Source: The authors(2022).

It was possible to observe from the images of the seedlings (Figure 4) that on the first day after transplanting, they were in perfect physiological and vegetative conditions. They were adequately colored and well healthy, indicating that they had all the characteristics that they would have a normal development. Even though this type of container is not the most suitable for conducting this type of experiment, the amount of bioremediated soil used was satisfactory for the good progress of the experiment and an excellent development of the plants.

Figure 5 illustrates the tray bioreactor with the lettuce after 10 days of transplanting.

Figure 5 – Evolution of lettuce development in a tray bioreactor, 10 days after transplanting.



Source: The authors(2022).

Observing Figure 5, it is possible to state that the container used as a bioreactor, with bioremediated soil, proved to be appropriate for such practice, differently from what was initially thought, and it was possible to observe the appearance of the plants 10 days after their transplantation. And, in this way, it is true to say that from this number of days the plants began to take on new architectural configurations. Natural etiolation was already expected, due to the plants not being in direct contact with the sun, and it can be seen more clearly in Figure 6, with bioremediated and natural soil a few days before the harvest for weighing and analysis. It is worth

noting that the choice of this crop was mainly due to the fact that it has a very short cycle, is easy to handle and has a lot of plant mass in which it would be essential to carry out the analyses proposed in the experiment.

Figure 6 – Development of lettuce in a tray bioreactor, with bioremediated soil and in a glass bioreactor, with natural soil.



Source: The authors(2022).

After 35 days after lettuce transplanting, during the follow-up of the experiment it was possible to observe the evolution of the seedlings of the crop, proving that the bioremediated soil is able to be reused for planting plant species for human consumption. However, only with the results of plant analyses will it be possible to say whether the plants are fit for human consumption or not.

Soil moisture and pH were also controlled twice a week, during the entire period of the 35 days of the experiment, verifying within this interval that soil moisture remained between 60 and 70% and pH was in the range of 6.5 to 7. This is a neutral pH, very conducive to the natural development of plants. With these values, it is possible to highlight that we can further improve the results of soil bioremediation by making few changes in the form of planting and in the total time of the experiment.

CHEMICAL ANALYSIS OF LETTUCE

Table 1 describes the results of the chemical analyses for macronutrients (N, P, K, Ca, Mg) and heavy metals (Cd, Cr, Ni and Pb) of lettuces, carried out 35 days after transplantation to the bioreactors. These analyzes were carried out at the Plant Analysis Laboratory of the Center for Agrarian Sciences of the Federal University of Paraíba in Areia.

Table 1 - Analysis of lettuce after 35 days of transplanting to the bioreactor.

Sample	In the LAB	LETTUCE ANALYSIS								
		N	P	K	Ca	Mg	Ni	Pb	Cd	Cr
Lettuce in natural soil	94521	29,58	1,94	61,28	19,81	4,47	2,23	5,78	0,22	1,29
Lettuce in bioremediated soil	94522	28,53	3,93	34,85	21,98	6,57	1,04	6,57	0,23	1,05

Legend: N, P, K, Ca and Mg: Digestion with H₂O₂ and H₂SO₄; Ni, Pb, Cd and CR: Digestion with HNO₃ and HClO₄

After 35 days of transplanting, the lettuce plants were collected. Then, the green weight was carried out, taken to the greenhouse at 65 °C for 72 h. After this period, the plant material was taken for laboratory analysis to determine the chemical composition (N, P, K, Ca, Mg, Cd, Cr, Ni and Pb), as shown in Table 1.

In Brazil, the National Health Surveillance Agency (ANVISA) is the agency responsible for limiting the concentration of inorganic compounds in food. These limits are stipulated based on studies carried out by these organizations, with the help of foreign bodies, such as the World Health Organization (WHO) itself.

For the element cadmium (Cd), the National Health Surveillance Agency (ANVISA, RDC N° 42 OF AUGUST 29, 2013) has a maximum limit of 0.20 mg.kg⁻¹ for leafy vegetables, in such a way that the lettuce sample grown in natural soil (0.22 mg.kg⁻¹) and in bioremediated soil (0.23 mg.kg⁻¹) did not comply with the standards. It is worth mentioning that plants such as lettuce are cadmium accumulators, being quite tolerant to high concentrations, showing no symptoms of toxicity (MENDES; OLIVEIRA, 2004).

For the element lead (Pb), the National Health Surveillance Agency (ANVISA, RDC No. 42) has a maximum limit of 0.30 mg.kg⁻¹ for leafy vegetables, where both lettuce samples showed a high level for this element.

With these results of heavy metals above those indicated by health agencies, these plants cannot be indicated for human consumption. We cannot say whether these heavy metals were from the soils used or from plants that have already been contaminated from their origin. However, these plants can possibly be indicated as removers of some of these metals from soils.

In the case of macronutrients (N, P, K, Ca, Mg) the results are presented in g.kg⁻¹. The nitrogen (N) values found in the analysis are considered adequate for lettuce, being close to the lower limit, which is 30 to 50 g.kg⁻¹ (TRANI and RAIJ, 1997).

Phosphorus (K) presented levels slightly below the desired for lettuce, as described by TRANI and RAIJ (1997). The concentration was below the lower limit of the range mentioned by these authors, which is 4.0 to 7.0 g.kg⁻¹. However, with lettuces from bioremediated soil, it is possible

to observe a lower potassium content than lettuces from natural, non-bioremediated soil by approximately 50%.

CONCLUSION

Based on the results, it can be said that the application of the *Landfarming* technique can be one of the ways to minimize the effects of degradation of soils contaminated by organic waste.

The preparation of the bioreactor suitable for the favorable conditions for the treatment of the tailings is a fundamental step to facilitate the operations of homogenization, aeration and humidification of the soil.

The daily monitoring of pH, temperature and humidity parameters were essential for them to be corrected at the appropriate time, always maintaining conditions favorable to the efficiency of the system.

The experiment was installed with lettuce seedlings acquired in the region, with bioremediated soil and natural soil, and the results were very satisfactory, with the evolution of the plants within the normality for the environment in which they were installed.

The plants remained throughout their cycle with the appearance of healthy plants, demonstrating that the soil went through the bioremediation process properly, making it suitable for use in planting not only lettuce, but other vegetables as well.

Visually, no differences were detected between the lettuce plants from the bioremediated soil and the plants from the soil collected in the field of the LETEQ/UEPB laboratory.

The results of plant analyses for macronutrients (N, P, K, Ca and Mg) both in natural soil and for bioremediated soil were within the normal range. With few variations between one and the other. However, for heavy metals, in the lettuce samples analyzed, in both soils studied, the levels of Cd, Pb, Cr were above the standards determined by ANVISA. Therefore, these plants are not recommended for human consumption in this situation. They can be used to remove/extract part of these elements from the soils, improving them and, later, making them totally suitable for various crops.

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Typology of conventional and agroecological vegetable production systems in the Campos Gerais region of Paraná, Brazil

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ABSTRACT

In the region of Campos Gerais do Paraná, family farming has a large share in the production of food for direct consumption, such as vegetables. As in the rest of the state and the country, it has been observed that in recent years there has been a distinction between vegetable production systems, especially with the growing stimulus to the consumption of agroecological products. In this context, the objective of this study was to characterize the production systems of conventional and agroecological vegetables, analyzing the typology, in the municipalities of Castro, Palmeira and Ponta Grossa, through multivariate statistical analysis. For this, 29 rural properties were previously selected in the three municipalities mentioned, in which a semi-structured questionnaire was applied. The properties were selected together with technicians from EMATER-PR (regional and local office) and municipal governments, with the basic criteria: having olericulture as their main activity and fitting the profile of family farming. Social, technical-agronomic, economic and financial information was collected. The collected data were tabulated and transformed into numerical values. Subsequently, they were statistically treated using principal component analysis. Of the 29 rural properties interviewed, 19 used the conventional vegetable production system and were mostly located in Ponta Grossa. As for the properties that use the agroecological production system, it can be seen that they were better distributed among the municipalities of Ponta Grossa (4 properties), Palmeira (3 properties) and Castro (3 properties). It was found that the time that the family has lived on the property was not a determining factor for the distinction of the production systems. However, the time they have been in the activity and the area used in the cultivation of vegetables were extremely important variables. It can be observed that the properties in agroecological system are more recent and use a smaller cultivated area. Principal component analysis proved to be a promising tool for this type of study, as it allowed the analysis of technical-agronomic, economic and financial variables, both internal and external to the property, so that it was possible to distinguish differences between conventional and agroecological vegetable production systems. With this, it can be assessed that the complexity between the vegetable production systems in Campos Gerais do Paraná is high. The agroecological system is the one that presents the greatest problems with the control of pests and diseases, even in smaller cultivation areas, which implies lower income for the property, even though producers have a higher frequency of commercialization. For the conventional system, although the cultivation areas are larger, the lack of knowledge of financial management tools, low demand for training and updates are factors that impact the production and sustainability of the property.

Keywords: Organic Agriculture, Rural Economics, Principal Component Analysis.

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INTRODUCTION

Agricultural production of family origin has been the object of study in recent decades, and its representativeness in the world and national scenarios are unquestionable (ALTIERI, 2012; FRANÇA et al., 2009; SCHENEIDER, 2006). Family farmers account for more than 80% of the 500 million family units on farms worldwide (IFAD, 2013).

In family farming, the option of producing vegetables is very common, as there are advantages that attract producers, such as production in small areas, direct sales to consumers (fairs and grocery stores), with the entry of daily, weekly or monthly money, also short crop cycles, among others.

The vegetable market in the State of Paraná moved in 2015 about R\$ 4.03 billion, with a cultivated area of 115.5 thousand hectares and production of 3.03 million tons, being the municipality of São José dos Pinhais with the highest production, accounting with a production of 9.8%, followed by Colombo and Marilândia do Sul (DERAL, 2016).

In recent years, changes in consumption habits have led to the segmentation of the vegetable sector in Brazil, changing its production and marketing mode. The production of vegetables by the conventional system has become a tradition, with the use of similar inputs from the production of monocultures. This often leads producers to use agrochemicals that are not recommended for these crops, either due to lack of knowledge of the producer, or ignorance, or even knowing the product, knows that he cannot use it, but does so contrary to technical recommendations.

In the opposite direction of this production process, there are the so-called organic or agroecological-based producers, breaking paradigms. Produce without the use of agrochemicals, only with natural inputs, often produced on your property.

LITERATURE REVIEW

CHARACTERIZATION AND IMPORTANCE OF FAMILY FARMING

Family farming consists of a means of organizing agricultural, forestry, fishing, pastoral and aquaculture productions that are managed and operated by a family and are predominantly dependent on family labor, both women and men (FAO, 2014).

In the national production, family farming is quite representative, participating with 83% of the national production of cassava, 69.6% of the production of beans, 45.5% of corn, 38% of coffee, 33% of rice, 21% of wheat, 58% of milk (composed of 58% of cow's milk and 67% of goat's milk). In animal production, 59% of the pig herd, 51% of the poultry herd and 30% of the cattle herd reach the rates (IBGE, 2006). According to the legislation on family farming (2016), even though the numbers of Brazilian family farming are expressive, this is still a sector that needs support so that it can reach its potential. Unfortunately, a large proportion of farmers live in conditions of poverty.

Even so, they are responsible for a significant portion of food production in the country, especially in regions such as the Northeast. On the other hand, Buainain (2006) states that family farming is extremely diversified, including both families who live and exploit smallholdings in conditions of extreme poverty, as well as producers inserted in modern agribusiness, who have various incomes, higher than what defines the poverty line.

According to Law No. 11,326, of July 24, 2006, a family farmer or rural family entrepreneur is considered to be one who practices activities in rural areas, meeting the following requirements: I- does not hold an area greater than four fiscal modules; II- predominantly uses labor from the family itself; III- has family income predominantly originated from the establishment or enterprise itself; IV- run your establishment or enterprise with your family (MDA, 2009).

Family farmers are responsible for more than 80% of the food supply consumed in much of the world, contributing significantly to poverty reduction and food security (IFAD, 2013). In Latin America, there are about 17 million peasant units, occupying approximately 60.5 million hectares, or 34.5% of the total cultivated land, with properties averaging 1.8 hectares (Altieri, 2012).

One of the striking situations of family farming is precisely in the fact that it is representative in the economic and social spheres, assuming an important role in issues related to sustainable production. However, it can be considered as unproductive, generating a dichotomy, especially when compared to agribusiness (Tonet, 2015). The contribution of family farming to agricultural production is potentially viable in the supply of food, reduction of unemployment and poverty of the most vulnerable families living in rural areas, but it presents low productivity and insufficient income generation for possible investments and guarantees the permanence of families on their agricultural properties (ECLAC, 2014).

The 2006 Agricultural Census (last Census) identified 4,139,369 establishments that are characterized as family farming (85.2%) of the total, occupying an area of 107.8 million hectares. That is, 30.5% of the total area occupied by Brazilian agricultural establishments and accounts for the generation of R\$ 18.1 billion of the gross value of production (37.9%). Its importance is also reinforced in relation to jobs in rural areas, thus being responsible for the employment of 13.7 million workers. In the southern region of the country alone, 849,977 establishments (90.5%) were identified, and in the state of Paraná there are 302,907 (IBGE, 2006).

According to Faulin and Azevedo (2003), the production of vegetables commercially or for subsistence plays an important role for family farming, as it is a crop without the need for large tracts of land, which does not require great technical knowledge or high investments. Lima and Wilkinson (2002) corroborate by stating that family farming creates opportunities for local work, reduces rural exodus, diversifies production systems, enables economic activity in greater harmony with the environment and contributes to the development of small and medium-sized municipalities.

However, numerous technical and economic challenges must be overcome by producers when they practice this activity with a commercial character (open market, restaurants and small commercial establishments) or are part of specific and institutional programs for the acquisition of their products. As an example, the PAA/CONAB (Food Acquisition Program – National Supply Company), the PNAE (National School Feeding Program-FNDE, National Fund for the Development of Education) and the Green Fair (Ponta Grossa City Hall) in a more commercial activity. For Oliveira et al. (2016), in most cases the precarious infrastructure available and the low access to new technologies have been major repressors of supply, generating difficulties and deficiencies in links of the production chain. Olericulture presents a high risk due to phytosanitary problems, sensitivity to climatic conditions, vulnerability to seasonality of supply, but when it comes to the potential of net income per hectare to the producer, it surpasses other temporary crops (LOURENZANI; SILVA, 2004).

Family farming can have some other names, such as peasantry, small family production, subsistence production, small production enterprises, among others, representing the different interpretations of family farmers within certain different socioeconomic and political contexts (LOURENZANI, 2005). For Ploeg (2014), family farming cannot be defined only by the size of the establishment, but by the way people cultivate and live. That is why it is also considered a way of life.

In recent decades, Brazil has made significant progress in terms of a better understanding of the real meaning of the social group called family farmers, recognizing its economic diversity and social heterogeneity of small landowners, who use their own family's labor force, producing for their subsistence or for commercialization (DELGADO; BERGAMASCO, 2017).

For Bonnal and Kato (2011), the creation of the MDA (Ministry of Agrarian Development) was an important initiative for the implementation of specific public policies for family farming, in addition to the approval of the National Policy on Family Farming and Rural Family Enterprises, which established principles and instruments aimed at the class. Thus, for Miranda and Martins (2015), the creation of agricultural policies driven by the Federal Government in the 1990s and the beginning of the twenty-first century marked the beginning of an era characterized by important initiatives aimed at strengthening small farmers. The creation of PRONAF (National Program for the Strengthening of Family Farming) was a significant leap, which affirmed and recognized the family farmer as an important and essential member of society, who was considered small, and practiced agriculture for subsistence (DELGADO; BERGAMASCO, 2017).

Family farming is articulated in different forms and intensities between the elements: family, land and workforce and thus adapting to different contexts: social, economic and political. According to Guilhoto et al., (2006) the family farming sector is part of the history of Brazil and consequently

of humanity itself. Its interference has been reduced over the centuries due to the technological development of the agricultural sector itself and the other productive sectors of the economy.

Despite its importance, family farming encounters obstacles that limit its development, mainly due to the scarcity of land, lack of technical assistance and insufficient financial resources, so these factors limit the reach of the technological standard necessary to make this segment competitive (SOUZA FILHO; BATALHA, 2005).

Reports show the difficulties encountered in the production process of family farming and especially within the production of conventional and organic vegetables. Since, for example, the seasonality of production causes the supply of production to be discontinuous, making it difficult to commercialize production (ASSIS; ROMEIRO, 2007; SEDIYAMA et al., 2015).

VEGETABLE PRODUCTION SYSTEMS IN FAMILY FARMING

In Brazil, the area cultivated with vegetables is approximately 837 thousand hectares and the production volume is about 63 million tons, covering more than a hundred horticultural species cultivated in all regions (CNA, 2016). In 2015, the area cultivated with vegetables in Paraná was 115.5 thousand hectares, with a production of 3.03 million tons. With a market turnover of approximately R\$ 4.03 billion (DERAL, 2016).

The advantages of vegetable production in family farming are due to the following factors: reduced crop cycle, production in small areas, permission for a great diversity of species, use of family labor, relatively low production costs and the possibility, among other things, of direct marketing with the consumer. For example, in neighborhood markets, street markets and grocery stores. Another advantage that we can highlight is subsistence production, thus ensuring the survival of families in rural areas, since the size of properties with this activity varies from 1 to 3 hectares. According to the last agricultural census, family farming had about 1,169,234 establishments producing vegetables (IBGE, 2006).

The per capita consumption of fruits and vegetables (FV) in Brazil is still very small, about 130 grams (FAO, 2014), although this consumption is gaining a lot of prominence in the media, since the population is looking for the conscious consumption of healthy products that are sources of vitamins, proteins and minerals. This search gains even more importance when talking about organic or agroecological-based production.

Studies by the World Health Organization (WHO) recommend that the daily consumption of 400 grams per capita day of fruits, vegetables and greens (FLV) in Brazil this number is far below the recommended 132 grams per capita day (MS, 2006). This low consumption shows us that the vegetable market can grow up to 3 times to achieve this goal. As a result, the WHO has shown that due to the low consumption of vegetables and fruits are associated: Obesity (43% in adults and 21%

of young people are overweight), heart diseases (31% of ischemic heart diseases); strokes (11% of strokes) and cancer incidence (10% of gastrointestinal cancer cases).

Vegetables in open field production systems require investments of US\$ 1 thousand to US\$ 5 thousand per hectare, and generate more profit for each hectare cultivated when compared to other crops such as grains. Under normal market conditions, it is estimated that vegetables generate income between US\$ 2 thousand and US\$ 20 thousand per hectare, in the open field (SEBRAE, 2017).

Conventional Production System

Conventional vegetable production is characterized by the use of chemical fertilizers at the time of planting and also as a cover crop during the development phases of the crops. The use of fungicides, insecticides and herbicides have also become common practices in this activity.

With the intention of developing modern agriculture and increasing productivity, a profound change in the agricultural production process began in the 1950s in the United States, called the "Green Revolution" (SILVA et al., 2005). At the heart of this modernization was the use of agrochemicals and other inputs of industrial origin. In Brazil, the "Green Revolution" began in the 1960s and strengthened in the mid-1970s with the creation of the National Crop Protection Program (PNDA). This Program, among other purposes, aimed to stimulate the national production and consumption of pesticides to the extent that the granting of rural credit was conditional on the mandatory use of part of this resource with the purchase of pesticides (ALVES FILHO, 2002; SOARES; FRENCH; COUTINHO, 2005). However, policies to encourage the use of **pesticides** were implemented in a context of structural deficiencies and social vulnerabilities, marked by the lack of knowledge of rural producers and the low level of education of rural workers, which was not accompanied by processes of qualification of the farmers involved in production (MOREIRA et al., 2002; SOARES et al., 2005).

In 1987, Brazil was already the largest pesticide market among developing countries and the fifth largest market in the world, after the USA, Japan, France and the Soviet Union. In 2002, Brazil already occupied the fourth place in the *ranking* of pesticide-consuming countries (MOREIRA et al., 2002). According to a study by the German consulting firm Kleffmann Group, Brazil is currently the largest consumer market for pesticides in the world (PACHECO, 2009). Although pesticides are produced to target specific targets, such as fungi, insects, and mites, this selectivity is never achieved: whether we like it or not, the evolutionary history of living beings makes them similar in biochemical and physiological characteristics. Many of the cellular components or metabolic pathways that are targets of the active ingredients of pesticides are similar to those found in humans.

Agroecological production systems

Several aspects are involved in the conversion from conventional systems to organic production systems, especially the economic and political ones that condition the adoption of organic agriculture among different socioeconomic strata of farmers, and that need to be considered when thinking about the large-scale diffusion of this form of production, requiring more expressive support, which considers its specificities, on the part of the State's agricultural policy (ASSIS; ROMEIRO, 2007).

These authors also highlight the existence of costs and difficulties at entry, related to the initial loss of productivity due to the time for soil reconditioning, and the uncertainties generated by the still precarious structure of commercialization, which has discouraged a more effective response from most farmers, even considering the level of prices that consumers are willing to pay.

Historically, the first movements linked to Ecologically-Based agriculture in Brazil were related to the production of vegetables. The so-called fresh FV (fruits, vegetables and greens) segment, mainly vegetables (legumes and greens), was the lever of the pioneering initiatives that emerged in Rio de Janeiro, Brasília, Rio Grande do Sul, São Paulo and Paraná (ASSIS; ROMEIRO, 2007).

With regard to the commercialization of agroecological vegetables, it originated in two main systems: street markets and home delivery of baskets, which, despite their initial success, present difficulties for the expansion of organic olericulture to a large number of farmers (AMARAL, 1996).

In view of this situation, supermarkets increasingly appear as a path to an effective expansion of this market. In Brazil, following a global trend, large supermarket chains show growing interest in these products, which are for many organic farmers an important alternative for marketing their products (MEIRELLES, 1997).

CHARACTERIZATION OF THE CAMPOS GERAIS OF THE CENTRAL EASTERN MESOREGION OF PARANÁ

The Central-Eastern Paraná mesoregion is located in the Second Paraná Plateau, also called Ponta Grossa Plateau, in the Campos Gerais region, and covers an area of 2,178,254.3 hectares, which corresponds to about 11% of the state territory, with 19 municipalities (AMCG, 2017).

In the region, the climate suffers some variations closely linked to its location, such as temperature, precipitation rates, number of hours of insolation, relative humidity and wind direction. However, analyzing more recent data, based on longer series and obtained with more advanced resources, it is possible to identify two climates in the region, within the Köppen Classification (IAPAR 2000):

- (i) Cfa: subtropical climate with average temperature in the coldest month below 18°C (mesothermic) and average temperature in the hottest month above 22°C, with hot summers, infrequent frosts and a tendency to concentrate rainfall in the summer months, with no defined dry season.
- (ii) Cfb: corresponds to the temperate climate, with an average temperature in the coldest month below 18°C (mesothermal) with cool summers, and temperature of the hottest month below 22°C and no defined dry season.

Still in relation to the climate of the Region, it is influenced by other important mechanisms that we can highlight:

- Occurrence of infiltration of cold air masses mainly during the winter;
- Action of humid sea winds influenced by the South Atlantic Anticyclone, causing orographic rains in the Serra do Mar, which can advance and cause rainfall in the plateaus;
- Variations in the position of the Thermal Equator and the South Atlantic Anticyclone, changing the conditions of precipitation, temperatures, relative humidity and winds;
- The "El Nino" and "La Nina" phenomena have also been observed with some frequency, greatly altering the climatic conditions of the Campos Gerais Region.

Temperature variations may occur in the Campos Gerais Region due to the presence of valleys, such as the Tibagi River and its tributaries. Another important factor is latitude, as the region has varied amplitude due to its North-South extension. Considering a shift from the South to the North, the average annual temperatures range from 17-18°C to 20-21°C with a predominance of 18-19°C of annual averages. The average annual rainfall of Campos Gerais is in the range of 1200 mm and 1800 mm, when working with the data of the existing series.

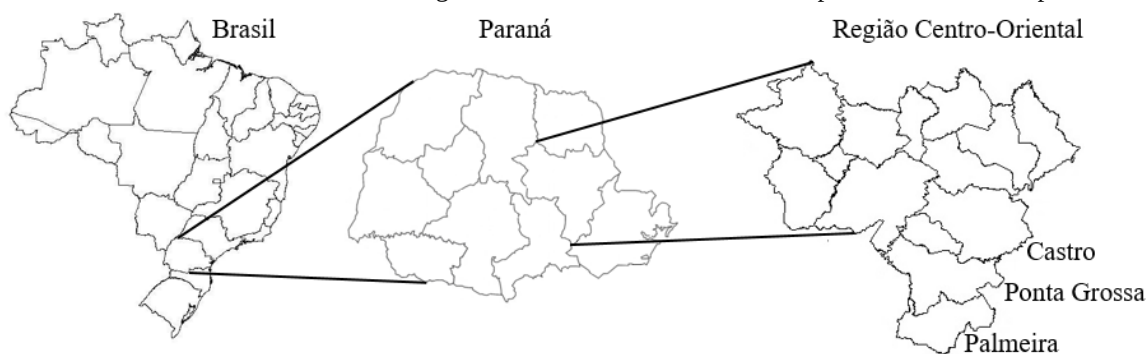
The soils are described as being sandy, shallow and poor, which is shown to be only a partial truth. According to Sá (2007) there are considerable areas formed by silty and/or clayey soils, such as those derived from lithotypes of the Ponta Grossa formation (mainly pelitic rocks) or bodies related to the Serra Geral Magmatism. The main orders of soils in the Campos Gerais Region are: Cambisols - 37%, Latosols - 33%, Ultisols - 10% and Neosols - 17%, with occurrence in sandy rocks of the Furnas formation and the Itararé Group (UEPG, 2003).

MATERIAL AND METHODS

Between June and November 2017, 29 family-based rural properties were visited, in which a semi-structured questionnaire was applied (Appendix 1). These properties are located in the municipalities of Castro, Palmeira and Ponta Grossa, belonging to the Central-Eastern Mesoregion of Paraná (Figure 1). The properties were previously selected, together with technicians from Emater-

PR (regional and local office) and municipal governments, having the following basic criteria: having the activity of olericulture as the main one, fitting the profile of family farming (with up to 4 rural modules, and being in the activity of vegetable production for a minimum period of 5 years). It should be noted that in the municipalities of Castro and Palmeira one rural module is equivalent to 16 hectares, and in Ponta Grossa 12 hectares.

Figure 1. Location of the Central-Eastern Region in the State of Paraná, with emphasis on the municipalities under study.



The Central-Eastern Paraná mesoregion is located in the Second Paraná Plateau (Ponta Grossa plateau), and covers an area of 2,178,254.3 hectares, corresponding to 11% of the state territory. According to Köppen's classification, the climate of the region is humid subtropical (Cfb), with an average temperature in the coldest month below 18 °C and the occurrence of frequent frosts (mesothermic), cool summers, average temperature in the hottest month below 22 °C and no defined dry season. The average annual rainfall is approximately 1,600 mm, with August being the driest and January the wettest (IAPAR, 2009).

The semi-structured questionnaire was composed of 90 questions, which was applied to the producers *in loco*, containing questions that enable analyses regarding the indicators chosen to typify them considering social, economic, technical and environmental aspects, also taking into account the threats, risks and uncertainties, in a comparative way between the systems (conventional and organic) in the production of vegetables. This methodology was based on what was described by Manzini (2003), who describes that it is possible to plan to collect information through a script with questions, which in addition to collecting basic information, serves as a means for the researcher to organize himself for the process of interaction with the informant.

From the analysis of the interviews, the collected data were tabulated and transformed into numerical values. Subsequently, the data were statistically treated, using principal component analysis (PCA). The PCA was performed based on the correlation matrix of the variables. Previously, the variables were standardized to mean zero and variance one (1) (MANLY, 2008). The PCA proposes to form linear combinations of the original variables, in such a way that these new variables form a more summarized set of data (LEITE et al., 2009).

Thus, the purpose of such analysis was to distinguish the production systems of rural properties and to verify the correlations between the variables in order to identify the main risks, threats and uncertainties of the systems. With this, we sought to dissimilar individuals according to their own variances, according to their behavior within a population, that is, "groups" of individuals are formed according to the variations of their own characteristics. Statistical analyses were performed with the aid of the R software, version 3.3.4 (R CORE TEAM, 2018).

RESULTS AND DISCUSSION

CHARACTERIZATION OF VEGETABLE PRODUCTION SYSTEMS IN CAMPOS GERAIS CONSIDERING THE ASPECTS OF RURAL SOCIETY

Of the 29 rural properties interviewed, 19 used the conventional vegetable production system and most of them are located in Ponta Grossa (Table 1). As for the properties that use the agroecological production system, it can be seen that they were better distributed among the municipalities of Ponta Grossa (4 properties), Palmeira (3 properties) and Castro (3 properties) (Table 1).

Table 1. Distribution of properties (number of properties) among the municipalities of Campos Gerais do Paraná between conventional and agroecological vegetable production systems

Distribution Production System	Ponta Grossa	Palm	Castro	Total
Conventional	17	2	0	19
Agroecological	4	3	3	10

Considering the social variables, it can be observed that there is an inversion between the conventional and agroecological production systems regarding the distribution of the population by gender. In this case, in the conventional system, there is a predominance of women in the countryside in relation to men; while in the agroecological system, men are the majority of the population (Table 2).

Regarding the distribution of age groups, in both production systems it was found that the majority of the population is distributed between the age groups of 41 to 60 and 26 to 40 years (Table 2). However, among the properties with an agroecological system, the population between 21 and 25 years old is equal to the population between 26 and 40 years old. As a result, the population of children, adolescents and young people up to 25 years of age in the agroecological system (40.6%) was higher than in the conventional system (24.2%). Also, it can be observed that, in general, the properties with the conventional system are composed of an older population (Table 2), which may be directly related to the resistance to change to the transition of the production system, as well as the education of the producers (MAZZOLENI; NOGUEIRA, 2006).

It was also possible to verify that 33.3% of the producers in the conventional system did not have complete elementary education or were illiterate, a condition not observed for the agroecological system, which in turn had a larger population with complete higher education (Table 2).

Table 2. Social variables, as a percentage of the total population analyzed, of the conventional and agroecological vegetable production systems of Campos Gerais do Paraná

Social variables	Production System	
	Conventional	Agroecological
Family members		
Men	47,8	53,1
Women	52,2	46,9
Age groups		
Up to 10 years	3,0	9,4
Between 11 and 15 years old	4,5	6,3
Between 16 and 20 years old	10,6	6,3
Between 21 and 25 years old	6,1	18,8
Between 26 and 40 years old	27,3	18,8
Between 41 and 60 years old	36,4	34,4
Over 60 years old	12,1	6,3
Schooling		
Illiterate	1,5	0
Incomplete fundamental	31,8	28,1
Complete Fundamental	19,7	18,8
Incomplete high school	13,6	21,9
High School	19,7	18,8
Technical education	3,0	3,1
Incomplete Superior	4,5	0
Complete Superior	6,1	9,4
Activities prior to vegetable production		
Employed or self-employed in the city	15,8	10,0
Employee of other rural properties	26,3	0
General Farming (Owner)	57,9	90,0
Place of residence		
On the farm	89,5	100
Rural area but off the property	5,3	0
Urban area	5,3	0
Workplace		
On the farm	89,5	100
Rural area but off the property	5,3	0
Urban area	5,3	0
Needs or hires labor		
Yes	21,1	10,0
No	78,9	90,0
Satisfaction with the hired workforce		
Yes	0	0
No	100	100
I would like to hire labor		
Yes	75,0	0
No	25,0	100
Vision on family succession		
He didn't think about it	63,2	90,0
It won't happen	0	0
He is thinking of establishing partnerships to continue in the activity	0	0
It will happen naturally	36,8	10,0

Mazzoleni and Nogueira (2006) highlighted two striking factors to overcome the difficult stage of conversion from conventional to agroecological systems: the level of education and experience with other professional activities. In this case, the authors emphasize that these are not indispensable conditions, as farmers with low education and experience only with agriculture can also achieve the conversion and even certification of an organic property, placing themselves positively in the market. However, producers with formal training and market knowledge play a role in bringing new visions and breaking old paradigms, promoting a multiplication effect of agroecological practices.

However, in the present study, it is worth noting that the activity previously performed was not a preponderant factor, because in both systems, but massively in the agroecological system, most producers already came from agricultural activity (Table 2).

For both production systems, the place of residence and work coincided, and most families live and work exclusively on their rural properties (Table 2). However, in the conventional system, one producer (equivalent to 5.3% of the population) lives in the rural area, but outside the property, and another lives in the urban area, both in the city of Ponta Grossa. However, the producer residing in the urban area works exclusively with the production of vegetables, while the producer residing in another property also works in the urban area. In this case, in the agroecological system, it is possible to observe greater satisfaction and comfort of producers, as it is not necessary to search for other sources of income outside the rural property.

There is predominantly no need to hire labor in both production systems. However, in the conventional system, the need to hire labor is higher than in the agroecological system. And, among the labor contractors, in both systems there was total dissatisfaction with the contracted services (Table 2).

Although they do not need labor other than the family, curiously, the vast majority of properties in the conventional system would like to hire the laboratory services of third parties. While in the agroecological system no producer is interested in hiring labor, which may be linked to the fact that the population of this production system is older (Table 3.2) and has a larger area used for cultivation (*see* section 3.5.2). This result was unexpected, as Ecologically-Based agriculture requires a larger contingent of labor per unit area than conventional agriculture (CAMPANHOLA; VALARINI, 2001).

An important aspect to be highlighted is that both in conventional vegetable production systems and in family-based agroecological systems, producers are not concerned with the issue of family succession, because massively producers have not even thought about it (Table 2). This is a serious problem, especially for the agroecological system, because as it was verified, it has a larger young population. However, among those concerned about the future, 36.8% of the conventional

system and 10.0% of the agroecological system, all believe that succession will occur naturally, passing from parents to children (Table 3.2).

Panno and Machado (2016) highlight the young exodus, with intensity in the female gender, causing an increase in the aging and masculinization of the rural population (a condition already observed for the agroecological system). Consequently, hindering the succession process and the prospects for the continuity of agricultural activities. Also, the farmers' perception of their situation, purposes and the future of their property end up directing their decisions and driving the decisions of their descendants.

Thus, it is evident that producers must be concerned with the future of the property and the activity performed, and that they must necessarily involve their children in the production process and in decision-making. Panno and Machado (2016) also focus on the fact that the most influencing and motivating factor for young people to remain on the property, attributed as a fundamental aspect in the decision-making process, is the possibility of financial return that the property can provide. Thus, these young people possibly already have a more incisive role in the family's activities and realize the financial return that the property can offer will hardly be achieved with an activity outside of there.

CHARACTERIZATION OF VEGETABLE PRODUCTION SYSTEMS IN CAMPOS GERAIS CONSIDERING TECHNICAL-AGRONOMIC AND ECONOMIC ASPECTS

Table 3 presents the results of the main technical and economic variables³ raised with the interviews. Succinctly, it was found that the time that the family has lived on the property are not essential factors for the distinction of production systems. However, the time in the activity and the area used in the cultivation of vegetables were extremely important variables. With these, it can be observed that the properties in agroecological system are more recent activities and that they use a smaller cultivated area (Table 3).

Table 3. Technical and economic variables of conventional and agroecological vegetable production systems in Campos Gerais do Paraná.

Technical and economic variables	Production System	
	Conventional	Agroecological
Time on property (years)	23,7 (8,8)	21,7 (7,7)
Property size (ha)	10,4 (13,0)	11,9 (7,3)
Time in activity		
Up to 10 years	15,8	30,0
Between 10 and 20 years old	21,1	30,0
Between 20 and 30 years old	36,8	40,0
Over 30 years old	26,3	0
Area used for growing vegetables (ha)	3,2 (2,4)	1,7 (0,6)
Vegetable production is the main activity (%)		

³ Economic aspects were considered to be those internal to properties, which do not depend on external agents, such as banks, financing agencies, among others.

Yes	63,2	60,0
No	36,8	40,0
Production system (number of properties)	19	10
Interest in agroecological production (%)		
Yes	31,6	100
No	68,4	0
Tillage method (%)		
Partially machined	36,8	70,0
Fully machined	63,2	30,0
Cultivation in beds (%)		
Yes	73,7	30,0
No	26,3	70,0
Carry out some soil conservation practice (%)		
Yes	63,2	80,0
No	36,8	20,0
Fertilization (%)		
It does not perform	10,5	0
Chemistry	10,5	0
Organic (animal waste)	68,4	100
Chemical and organic	10,5	0

Values in parentheses represent the standard deviation.

Table 3. Technical and economic variables of conventional and agroecological vegetable production systems in Campos Gerais do Paraná. Cont.

Technical and economic variables	Production System	
	Conventional	Agroecological
Use of agricultural correctives (%)		
Yes	100	90,0
No	0	10,0
Weed Control Method (%)		
It does not control (coexists with the invaders)	0	0
Capina manual	47,4	60,0
Use herbicides	21,1	0
He seeks to live together and when he controls it he does it manually	31,6	40,0
Pest Control Method (%)		
Does not control	0	0
Chemical	89,5	0
Biological	0	10,0
Alternative	10,5	90,0
Disease Control Method (%)		
Does not control	5,3	0
Chemical	78,9	0
Biological	0	0
Alternative	15,8	100
Crop rotation		
Yes	100	100
No	0	0
Scales up production		
Yes	89,5	100
No	10,5	0
Uses irrigation (%)		
Yes	84,2	90,0
No	15,8	10,0
There are issues with lack of water on the property		
Yes	82,4	80,0
No	17,6	20,0
Conduct training (%)		
Yes	47,4	100
No	52,6	0
Complain about lack of technical assistance (%)		

Yes	52,6	90,0
No	47,4	10,0
Technical assistance officer (%)		
There is no assistance	44,4	50,0
Private assistance	38,9	10,0
Unions or cooperatives	0	0
City Hall or Emater	16,7	40,0
Destination of production (%)		
Government programs (PNAE, PAA, Feira Verde)	10,5	30,0
Free markets	5,3	10,0
Government programs and street markets	84,2	60,0
Frequency of marketing		
Daily	15,8	10,0
Every 2 days	42,1	20,0
Every 3 days	21,1	10,0
Other	21,1	60,0

Table 3. Technical and economic variables of conventional and agroecological vegetable production systems in Campos Gerais do Paraná. Cont.

Technical and economic variables	Production System	
	Conventional	Agroecological
Demand (%)		
Hardwoods	42,1	10,0
Roots	5,3	10,0
Fruits	5,3	0
There is no preference between products	47,4	80,0
Share of vegetable sales in income		
Between 0 and 20 %	0	0
Between 21 and 40 %	10,5	10,0
Between 41 and 60 %	15,8	20,0
Between 61 and 80 %	10,5	20,0
Between 81 and 100 %	63,2	50,0
Monthly gross income (R\$)	4.279 (3.274)	2.045 (1.460)
Difficulties in calculating property costs and revenues		
Yes	21,1	60,0
No	78,9	40,0
Have financing for facilities or equipment (%)		
Yes	57,1	75,0
No	42,9	25,0
Commitment of income from financing (%)		
Between 0 and 5 %	21,1	20,0
Between 6 and 15 %	0	20,0
Between 16 and 25 %	5,3	0
Between 26 and 50 %	10,5	0
Above 50%	5,3	30,0
Don't know	57,9	30,0
Finds it difficult to get credit or financing (%)		
No	50	60,0
Lack of Guidance	0	0
Bureaucracy	33,3	40,0
Interest	0	0
Other	16,7	0
Use credit lines (%)		
No	57,9	33,3
Banks	15,8	0
Credit Unions	5,3	0
Pronaf	21,1	66,7

Values in parentheses represent the standard deviation.

For principal component analysis (PCA), not all the variables presented in Table 3 were used, due to problems of multivariate collinearity (MANLY, 2008). Thus, the variables that circumvented this problem and best explained the variance of the study were selected. This selection was based on the highest correlations of the variables.

After performing the PCA, it was found that six principal components (PC) were needed to explain more than 70% of the total variance (Table 4). However, only the first two PC showed greater relevance, explaining 42.39% of the total variance, since the proportion of explained variance between PC 3 and PC 6 was very similar and much lower than PC 2 (Table 4).

Table 4. Standard deviation, proportion of variance and variance explained by the principal components of the technical-agronomic and economic variables

Main Component (CP)	Standard deviation	Variance Ratio	Cumulative Variance Ratio	Cumulative Variance (%)
CP 1	2,29	0,25	0,25	25,07
CP 2	1,91	0,17	0,42	42,39
CP 3	1,34	0,09	0,51	50,91
CP 4	1,30	0,08	0,59	58,93
CP 5	1,16	0,06	0,65	65,30
CP 6	1,12	0,06	0,71	71,24

PC 1 was represented by both technical and economic aspects (Table 5), mainly related to the production system. In this case, the production system and the practices related to pest and disease control showed positive eigenvalues, while fertilization, vegetable cultivation as the main economic value, monthly gross income and the destination of production were negative values (Table 5). Such results demonstrate the existence of a close relationship between the production system and the control of pests and diseases and that this relationship is contrary. That is, a risk, especially for economic aspects. In this way, CP 1 can be named as "Economic Efficiency Index of the Production System".

In turn, CP 2 was also represented by technical and economic aspects. In this case, the use of irrigation and the problems with the lack of water associated with the cultivation of vegetables as the main economic factor presented negative eigenvalues. While the frequency of marketing was the only variable with a positive eigenvalue (Table 5). Therefore, CP 2 can be named as "Index of water dependence in the cultivation of vegetables for commercialization".

It is worth noting that both in CP1 and CP 2, vegetable cultivation as the main economic crop presented negative eigenvalues, as well as a negative correlation with the scaling of production, which in itself demonstrates that this practice presents a great threat to vegetable production systems (Table 3.5). In this context, Padovan et al. (2017) highlight that the diversification of production, with products distinct from horticulture such as corn and beans, in addition to being a fundamental posture for ecological balance, so important to agricultural systems, is also considered a strategy for

continuous income generation by family farmers throughout the year, due to the seasonality of production of each cultivated species. Thus, the diversity of crops in the production units reduces the risks of frustration resulting from climatic adversities, in addition to making it possible to offer different options to the consumer market.

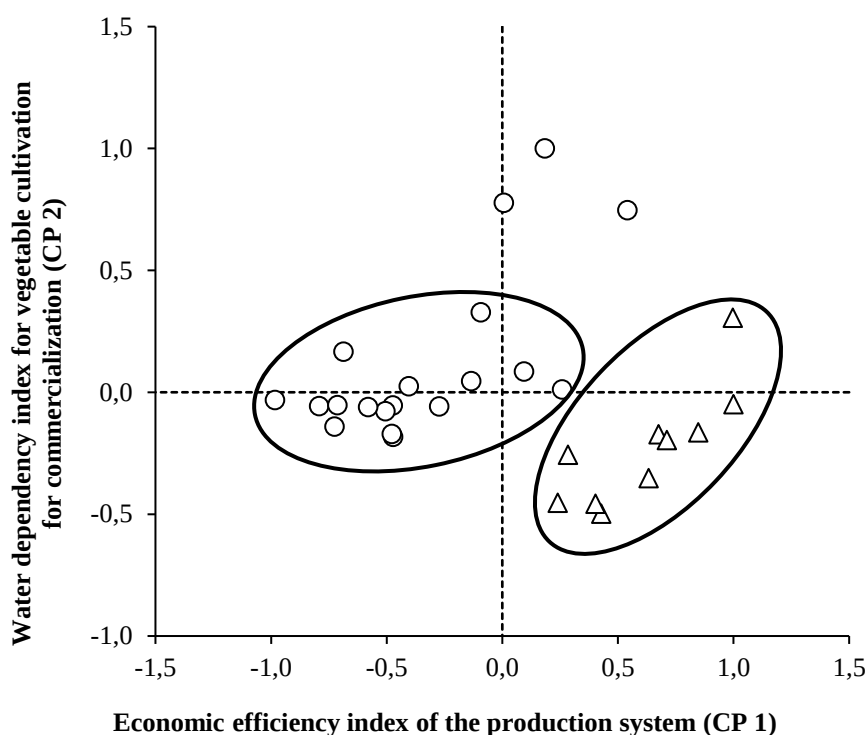
Table 5. Eigenvalues of the variables between the first six principal components (CP) of the technical-agronomic and economic variables

Variables	CP 1	CP 2	CP 3	CP 4	CP 5	CP 6
Planting in beds	-0,19	0,07	0,35*	-0,32*	-0,11	-0,27*
Fertilization	-0,30*	0,03	-0,40*	0,03	-0,22*	-0,02
Use of concealers	-0,06	0,14	-0,05	0,35*	-0,23*	0,48*
Production System	0,34*	-0,25	-0,01	0,02	-0,01	0,04
Interest in agroecology	0,25	-0,27	-0,09	-0,26*	0,14	0,30
Use of irrigation	-0,13	-0,43*	0,01	0,02	-0,12	-0,02
Problems with lack of water	-0,06	-0,44*	0,06	-0,01	-0,19	-0,07
Scaling up production	0,17	0,02	-0,09	0,03	0,49*	-0,01
Weed Control	-0,02	-0,20	0,28	-0,04	-0,17	0,48*
Disease control	0,31*	-0,23	-0,19	-0,03	-0,13	-0,05
Pest control	0,37*	-0,16	-0,01	0,00	-0,09	0,04
Training	0,22	-0,16	0,43*	0,22	0,11	-0,09
Lack of technical assistance	0,24	-0,01	-0,39*	-0,10	0,08	-0,17
Soil conservation practices	0,16	0,15	0,15	0,50*	-0,22*	0,06
Vegetable cultivation as the main economic	-0,24*	-0,31*	-0,24	0,02	0,07	0,08
Time in vegetable production	-0,15	0,04	-0,02	-0,27*	0,19	0,33*
Area used for the production of vegetables	-0,09	-0,13	-0,08	0,46*	0,43*	-0,04
Importance of vegetables for the property's income	-0,18	-0,29	-0,17	0,16	-0,29*	-0,23*
Gross monthly income	-0,26*	-0,08	-0,16	0,15	0,24	0,22
Production destination	-0,23*	-0,18	0,23	-0,17	0,16	0,17
Frequency of marketing	0,21	0,23*	-0,23	-0,19	-0,25*	0,26

*Variables with a weight greater than 70% in relation to the highest eigenvalue, within each principal component.

Relating the PC to the properties interviewed, it is possible to clearly observe the distinction between the properties that work in the agroecological production system and the properties of the conventional cultivation system (Figure 2). It can also be observed that the properties in the conventional system showed greater dispersion, to the point that three properties were completely different from the other properties in the conventional system.

Figure 2. Biplot dispersion (n=29) between the Economic Efficiency Index of the Production System (CP 1) and the Index of Water Dependence in the Cultivation of Vegetables for Commercialization (CP 2) of agricultural properties in the conventional (○) and agroecological (Δ) vegetable production systems in the Campos Gerais region of Paraná.

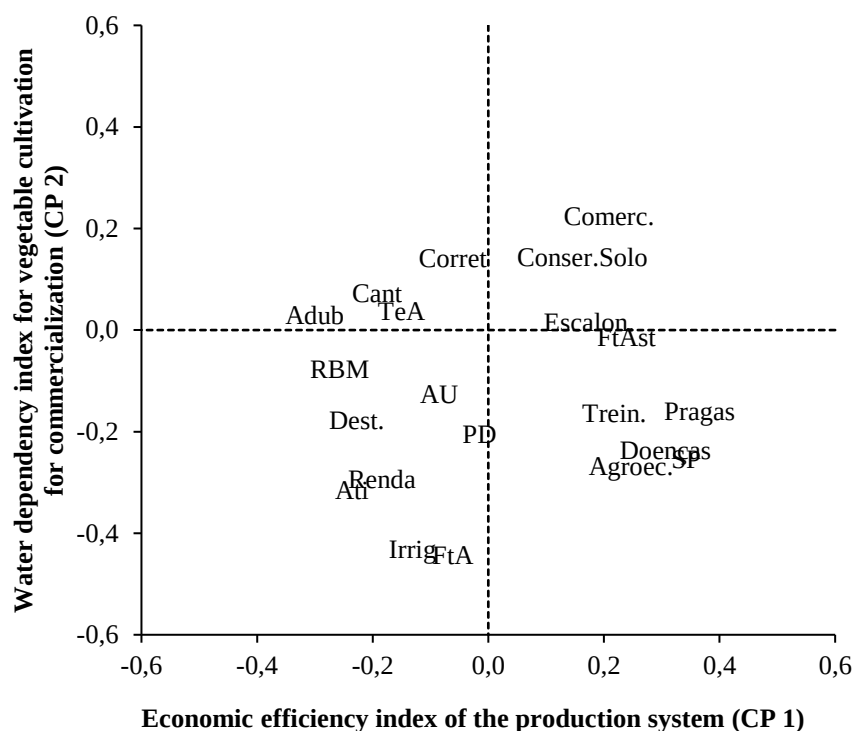


Correlating the variables (Figure 3) with the rural properties (Figure 2), from the point of view of the Economic Efficiency Index of the production system (CP 1), it can be observed that the properties in the agroecological production system are the ones that have the greatest problems with pests and diseases, although they are the most participative in technical training, and that they spend less time in the activity and make fewer investments in fertilization. Such technical conditions end up resulting in lower gross monthly income for the properties (Figure 3).

Such results are due to the fact that in organic cropping systems, pest and disease control should be done only when there is a possibility of considerable damage to production. Prior to such damage, the natural balance of the agroecosystem must be sought, through practices that promote biodiversity, such as intercropping, crop rotation, green manure, windbreaks, and the use of companion plants. As well as seeking to increase the levels of soil organic matter and balanced crop nutrition, in addition to other factors that allow adequate management of the systems (SEDIYAMA et al., 2014).

Therefore, considering the lower investments in fertilization of producers in the agroecological system and the short time they have been in the activity (Figure 3), it is estimated that their production systems are not yet in ecological balance, which ended up restricting their production and profitability.

Figure 3. Multivariate correlations between the variables (n=21) in relation to the Economic Efficiency Index of the Production System (CP 1) and the Water Dependence Index in the Cultivation of Vegetables for Commercialization (CP 2) of agricultural properties in the conventional and agroecological vegetable production systems in the region of Campos Gerais do Paraná. Cant = Planting in beds; Adub = Fertilization; Corret = Use of concealers; SP = Production system; Agroec = Interest in agroecology; Irrig. = Use of irrigation; FtA = Problems with lack of water; Escalation = Production scaling; PD = Weed control; Diseases = Disease control; Pests = Pest control; Train = Training; FtAst = Lack of technical assistance; Conser.Solo = Soil conservation practices; PAt = Vegetable cultivation as the main economic one; TeA = Time in vegetable production; AU = Area used for the production of vegetables; Income = Importance of vegetables for the property's income; RBM = Gross monthly income; Dest = Production destination; Comerc = Frequency of commercialization.



On the other hand, properties in the conventional system are the properties with the longest time of activity, which means that these producers seek less training and are not affected by the lack of technical assistance. These properties are also the ones with the highest monthly gross income, directly related to the larger area used for the cultivation of vegetables, greater investments in fertilization and fewer problems for the control of pests and diseases (Figures 1 and 2). Thus, with these results, the hypothesis that the agroecological systems evaluated are not yet in balance is reinforced.

Similarly, Luz et al. (2007) observed that under protected cultivation conditions, tomato production in the organic cultivation system is inferior to conventional cultivation, but with less seasonality in production. However, the authors did not mention whether the causes of the lower production were aspects related to soil fertility or pest and disease management, although they did evaluate these variables.

Based on the Water Dependence Index in the cultivation of vegetables for commercialization (CP 2), it can be observed that the frequency of commercialization was not influenced by the production system (Figure 3.3). However, it is important to highlight that the frequency of

commercialization showed a strong negative correlation with the area used for the cultivation of vegetables and the destination of production. Demonstrating that the size of the area or to whom the production is intended for the frequency of commercialization does not matter. However, what most affected this variable were the aspects related to the lack of water for production and, consequently, the use of irrigation. In this case, again the farms in the conventional production system were the ones that presented the highest use of irrigation and the greatest problems with lack of water, restricting their frequency of commercialization (Figure 3).

Lima et al. (2009; 2012) found that lettuce and eggplant cultivation, respectively, are affected by water deficit under different soil cover conditions, such as no-tillage, in a conventional production system. Thus, the authors emphasize that irrigation is a necessary practice for the production of the vegetables in question.

In this context, Assis and Romeiro (2007) point out that a factor that limits the conversion from conventional production systems to organic systems is the existence of costs and barriers to entry, related to the initial loss of production due to the time for soil reconditioning, and the uncertainties generated by the still precarious marketing structure, which has discouraged a more effective response from most farmers, even considering the level of prices that consumers are willing to pay.

Another important multivariate correlation to be highlighted was that the lack of technical assistance directly interferes with the scaling of production. Likewise, properties with such problems are the ones that make the least investments in fertilization. As a result, production on these properties becomes limited, which restricts their gross monthly income (Figure 3).

In addition, rural properties that carry out soil conservation practices have a higher frequency of commercialization, consequently have fewer problems with lack of water and make less use of irrigation (Figure 3). These results are important because they reinforce the importance of soil conservation for the sustainability of agricultural production (LIMA et al., 2016; NAREZI, 2018; NUNES et al., 2018).

This importance of soil concern, especially in organic systems, has been highlighted for a long time in the literature. According to Assis and Romeiro (2002), for the success of agroecological systems, the first concern should be, in the implementation, related to the soil, with regard to the recovery and maintenance of its biological balance, as this will influence the efficiency of the system. As a result, in the environmental aspect, organic systems generate little significant impacts. While, in the conventional one, these impacts are more evident, especially regarding the quality of the products produced (ALENCAR et al., 2013).

CHARACTERIZATION OF VEGETABLE PRODUCTION SYSTEMS IN CAMPOS GERAIS CONSIDERING TECHNICAL-AGRONOMIC AND FINANCIAL ASPECTS

Considering the main technical-agronomic aspects (Figure 3) and the financial aspects⁴, the first three PC explained 51.18% of the total variance (Table 3.6). However, it can be observed that the proportion of variance explained by CP 2 to 4 was very similar, ranging from 0.15 to 0.10 (Table 6).

Table 6. Standard deviation, proportion of variance and variance explained by the principal components of the technical-agronomic and financial variables.

Main Component (CP)	Standard deviation	Variance Ratio	Cumulative Variance Ratio	Cumulative Variance (%)
CP 1	1,93	0,25	0,25	24,84
CP 2	1,48	0,15	0,39	39,38
CP 3	1,33	0,12	0,51	51,18
CP 4	1,24	0,10	0,61	61,49
CP 5	1,05	0,07	0,69	68,78
CP 6	1,01	0,07	0,76	75,52

⁴ Financial aspects were those that are external to the property, on which the producer depends on third-party services (bank branches and/or credit unions, for example), such as agricultural credits, financing, among others.

PC 1 was composed of the positive association of the production system with pest and disease control, with the negative association of the destination of production, monthly gross income and difficulties in calculating the costs and revenues of the property (Table 7). Thus, it is possible to verify again the dependence of the destination of production and gross monthly income in relation to the control of pests and diseases among the production systems. Also, the limitation of producers in the financial management of the property was highlighted, as most producers do not know how to calculate their production costs or even their profitability and relation to gross monthly income (Table 3). Thus, it is proposed that the association of these variables composes the "Financial Management Efficiency Index".

Table 7. Eigenvalues of the variables between the first six principal components (CP) of the technical-agronomic and financial variables.

Variables	CP 1	CP 2	CP 3	CP 4	CP 5	CP 6
Production System	0,45*	0,14	0,00	0,03	-0,24	-0,02
Time in vegetable production	-0,21	-0,14	-0,06	0,03	-0,43*	-0,38*
Area used for the production of vegetables	-0,05	0,15	-0,55*	0,25	0,04	-0,35*
Production destination	-0,27*	0,31	0,14	-0,33*	-0,15	0,17
Marketing frequency	0,26	-0,36*	-0,03	-0,01	-0,09	-0,38*
Share of vegetable sales in income	-0,13	0,38*	0,11	0,44*	-0,23	0,04
Gross monthly income	-0,27*	0,19	-0,32	-0,04	0,04	0,11
Difficulties in calculating property costs and revenues	-0,25*	-0,27*	0,26	0,24	-0,07	0,17
Financing	0,05	0,26	-0,39*	-0,37*	0,20*	-0,18
Commitment of income through financing	-0,07	-0,09	-0,08	-0,35*	-0,72*	-0,03
Difficulties in getting credit or financing	0,11	0,21	0,41*	-0,48*	0,15	-0,24
Lack of water	0,02	0,55*	0,15	0,16	-0,20	-0,09
Scaling up production	0,16	-0,08	-0,37*	-0,15	-0,16	0,63*
Disease control	0,44*	0,16	0,03	0,17	-0,05	0,11
Pest control	0,47*	0,04	0,02	0,05	-0,12	0,04

*Variables with a weight greater than 70% in relation to the highest eigenvalue, within each principal component.

In this context, PC 2 was composed of the combination of the problems of lack of water for production with the participation of the commercialization of vegetables in the total income of the property in relation to the frequency of commercialization and the difficulties in calculating the costs and revenues of the property (Table 7). Thus, it can be seen that the arrangement of these variables composes the "Production Valuation Index", as it will influence production, marketing, income and production management.

In turn, for PC 3, it was formed by the association of difficulties in obtaining credit or financing with the area used for the production of vegetables, the scaling of production and financing (Table 7). With this, it was observed the difficulty in obtaining credits being inversely proportional to the size of the cultivated area and the regular production, this directly reflects on the investments of the property made through financing. Thus, CP 3 is the "Index of investments in production".

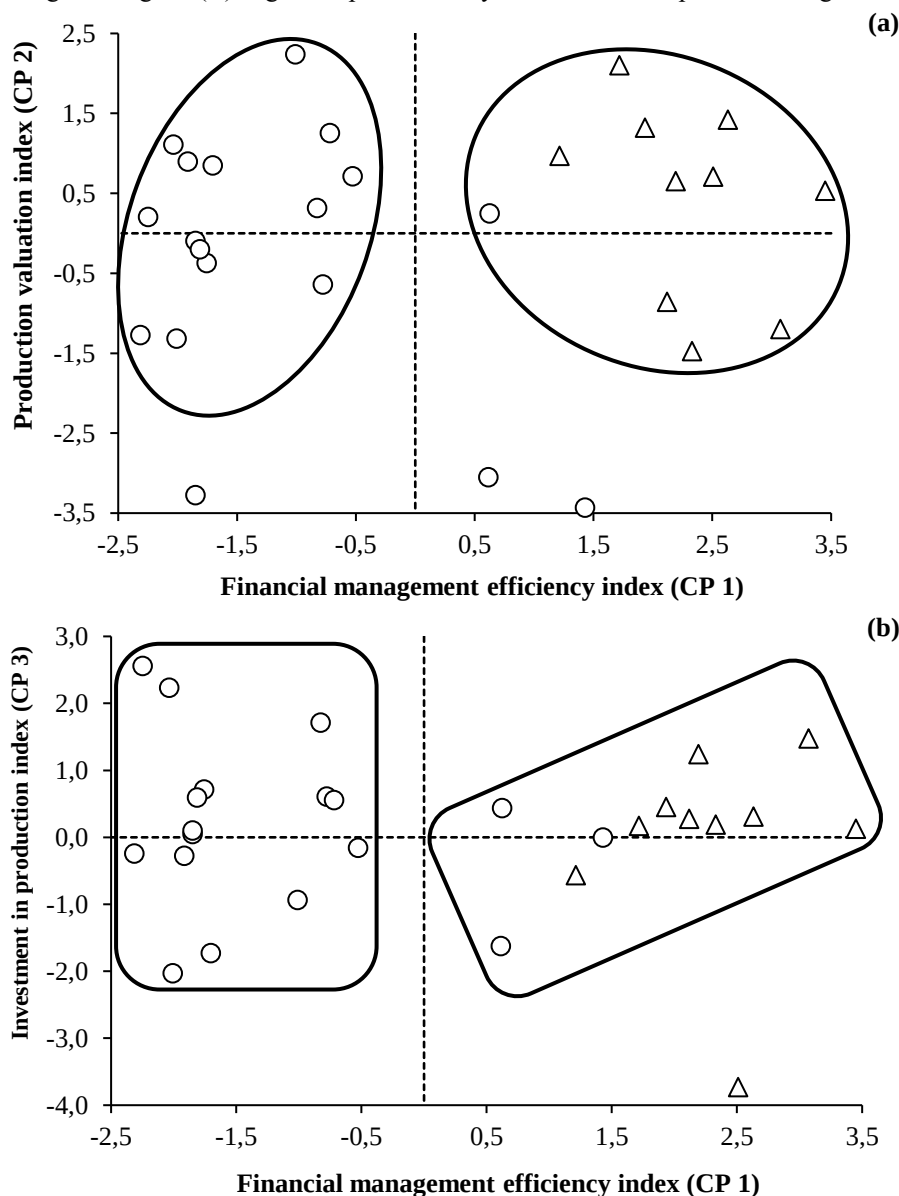
The relationship of the properties interviewed between the Financial Management Efficiency Index and the Production Valuation Index (Figure .4a) clearly highlighted the differences between conventional and agroecological production systems. However, one property of the conventional system showed similar behavior to the agroecological properties, while 3 other properties (the same ones observed in Figure 2) were completely different from the others (Figure 4a).

In turn, the relationship between the Financial Management Efficiency Index and the Production Investment Index (Figure 4b) also distinguishes production systems. However, in this case, three properties of the conventional system resembled the agroecological system and one agroecological property showed high dissimilarity from all the other properties (Figure 4b).

Considering the relationship of the properties (Figure 4) with the variables of these main components (Figure 5), it can be observed that the agroecological properties are the ones with the best financial management, as they demonstrate less difficulties in calculating their production costs

and revenues. However, the valuation of their products is deficient, which can be attributed mainly to the destination of their production, since their commercialization frequency is higher than the properties of the conventional system (Figure 5a).

Figure 4. Biplot dispersion (n=29) between (a) the Financial Management Efficiency Index (CP 1) and the Production Valuation Index (CP 2) and (b) CP 1 and the Index of investments in the production of agricultural properties in the conventional (○) and agroecological (Δ) vegetable production systems in the Campos Gerais region of Paraná.



As highlighted, most producers allocate their production to government programs (Table 3). Although this is an important marketing channel for family farming products, especially in the southern region of Brazil (SARAIVA et al., 2013), there are other possible marketing channels to add value to organic products, such as street markets, supermarkets, restaurants, natural food stores, among others (CAMPANHOLA; VALARINI, 2001).

It is worth noting that in no way is the migration of the producers' marketing channel being encouraged, as government programs are a form of assured purchase for them (SZIWELSKI et al.,

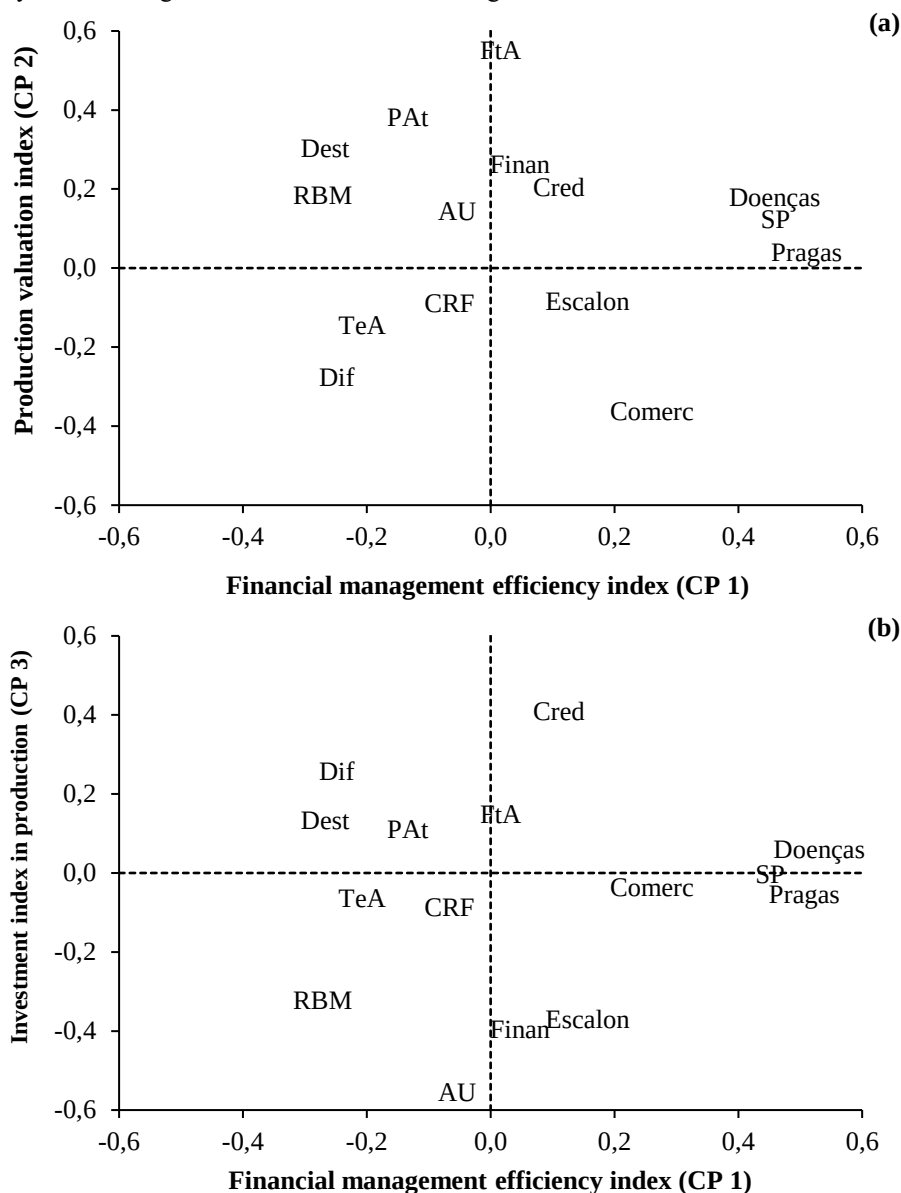
2015). But, yes, the existence of other market possibilities capable of improving the product valuation index is being demonstrated (MALUF, 2004).

Even so, the valuation of the production of the agroecological system is complex. To exemplify, Silva et al. (2005) discuss the existence of some barriers to the dissemination of the consumption of agroecological products in retail (supermarket chains). First, the economic factor is the great complicating factor, as consumers claimed that the high price of organic products makes consumption difficult. But, on the other hand, it is necessary to work better on the display of these products in the store, as previously pointed out by the location of the products in a single section. As well as the regularity of organic products in retail establishments.

When analyzing the financial management efficiency index with the production investment index (Figure 5b), it was observed that agroecological production systems find it more difficult to obtain credit or financing, although they have better notions of managing their property. In this case, the best management may be a direct reflection of the smaller cultivation area, absence of costs in the purchase of phytosanitary products, and absence of labor contraction (ASSIS; ROMEIRO, 2007; LUZ et al., 2007; SOUZA et al., 2008).

In turn, the difficulty in obtaining credit, Assis and Romeiro (2007) have already highlighted for more than a decade the prejudice in relation to the availability of agricultural credit to organic agriculture by state agencies. However, the authors point out that among the producers interviewed by them, among whom they used agricultural credit, the minority that did not observe resistance or faced difficulties were those who used specific lines of credit for organic production.

Figure 5. Multivariate correlations between the variables (n=15) in relation to (a) the Financial Management Efficiency Index (CP 1) and the Production Valuation Index (CP 2) and (b) CP 1 and the Production Investment Index (CP 3) of agricultural properties in the conventional and agroecological vegetable production systems in the Campos Gerais region of Paraná. Cred = Difficulty in getting credit or financing; SP = Production system; FtA = Problems with lack of water; Escalation = Production scaling; Diseases = Disease control; Pests = Pest control; PA = Vegetable cultivation as the main economic one; TeA = Time in vegetable production; AU = Area used for the production of vegetables; Income = Importance of vegetables for the property's income; RBM = Gross monthly income; Dest = Production destination; Comerc = Frequency of marketing; Finan = investment financing; CRF = commitment of income due to financing.



Still analyzing the relationship between the Indices of deficiency of financial management and investments in production, it was found that the difficulty in obtaining credit and financing presented a strong negative correlation with the scaling of production (Figure 5b). Such a correlation makes a lot of sense and points to a serious problem of family farming as a whole, regardless of the production system: lack of planning in cultivation that results in the scaling of production reflects directly on investments in the property.

MAIN RISKS, THREATS AND UNCERTAINTIES IDENTIFIED AMONG PRODUCTION SYSTEMS: SUMMARY OF MULTIVARIATE ANALYSES AND INTERVIEWS

Considering the importance of family farming, regardless of the production system, it is necessary to identify the main risks, threats and uncertainties. In this context, these aspects were analyzed intuitively based on the joint interpretation of the principal component analyses and other variables raised in the interviews (Tables 2 and 3). Thus, the variables were grouped as a risk, threat or uncertainty for both production systems (Table 8).

The main common risks among production systems can be observed, the distinction being that phytosanitary management, especially pest and disease control, is a greater risk to agroecological producers (Table 8). Similarly, for both systems, family succession was the main uncertainty identified. As for the threats, it can be clearly seen that the threat posed by the conventional system is not reflected in the agroecological system (Table 8).

Table 8. Main risks, threats and uncertainties of conventional and agroecological production systems in Campos Gerais do Paraná

Production System	Risks	Threats	Uncertainties
Conventional	Lack of scaling up production. Lack of water for production.	Frequency of commercialization. Lack of property management knowledge. Lack of updating in the production process. Lack of technical assistance	Family succession. Abandonment of the activity
Agroecological	Phytosanitary management. Lack of scaling up production. Lack of water for production.	Valuation of production. Difficulty in getting credit or financing.	Family succession. Abandonment of the activity

CONCLUSIONS

The complexity between vegetable production systems in Campos Gerais do Paraná is great. The agroecological system presents greater problems such as the control of pests and diseases, even in smaller cultivation areas, which has repercussions on lower income on the property, even though these producers have a higher frequency of commercialization. This fact is also due to the destination of production and the valuation of products not occurring satisfactorily.

For the conventional system, although the cultivation areas are larger, the lack of knowledge of financial management tools and low demand for training and updates are factors that have repercussions on the production and sustainability of the property.

Principal component analysis proved to be a promising tool for this type of study. It allowed the analysis of technical-agronomic, economic and financial variables, both internal and external to



the property. It is possible to distinguish between conventional and agroecological vegetable production systems in Campos Gerais do Paraná.

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Contaminant fungi in processed peanuts

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ABSTRACT

Peanuts (*Arachis hypogea* L) are a plant cultivated in many parts of the planet and are considered a relevant food crop, with many minerals and vitamins in their grains, as well as fats and proteins, which are important for human health. In underdeveloped or developing countries, peanuts represent an important source of income for many families, and can be used by the oil and animal feed industries. Despite being a low-cost food source, peanuts can pose risks to human health, as they are subject to contamination by mycotoxin-producing fungi. Mycotoxins are heat-resistant compounds, which are not completely eliminated after heat treatment, meaning that even when roasted or cooked, peanut kernels can cause inconvenience to those who consume them. Cases involving allergies, necrosis of organs such as kidneys and liver, and even carcinogenesis, caused by mycotoxins, are widely recorded in the medical literature. This research work aimed to evaluate the occurrence and diversity of mycotoxin-producing fungi in peanut kernels, sold in closed packages in the city of Inhumas. BDA medium (potato dextrose agar) was used for the isolation of fungi. The sampling consisted of 200 grains, belonging to five different brands. Half of the samples were disinfected with 1% sodium hypochlorite. Morphological characteristics (macroscopic and microscopic) of the colonies were used to identify the genera to which the isolated fungi belong. The results revealed a high rate of fungal contamination in peanut kernels, with *Fusarium* being the predominant fungus. Fungi of the genera *Rhizopus* and *Aspergillus* were also identified in the samples. It is expected that the results obtained will contribute to increase the information on the presence of toxigenic fungi in peanut kernels, helping in the decision-making of regulatory agencies and consumers who use this important food source.

Keywords: *Arachis hypogea*, Mycotoxins, Toxigenic fungi.

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INTRODUCTION

Peanut (*Arachis hypogaea* L) is a species of herbaceous plant, belonging to the Fabaceae family, whose fruits develop in pods (legumes) below the surface of the ground. It was cultivated for the first time, probably in the valleys of Peru (GEETHA *et al.*, 2013), thus having South American origin. It belongs to the genus *Arachis*, which contains more than 82 wild species (ROYAL BOTANIC GARDENS, 2022), 66 of which occur in Brazilian territory (FLORA E FUNGA DO BRASIL, 2022).

Approximately two-thirds of the peanuts produced in the world come from China and India, but their production is spread across a hundred countries, especially in Asia and Africa (CHEN *et al.*, 2019), with an approximate cultivation area of 30 million hectares (NCUBE; MAPHOSA, 2020). In Brazil, the state of São Paulo concentrates most of the production, having been responsible for more than 90% of the peanuts produced in the 2017/2018 harvest (GRIGOLETO *et al.*, 2019).

Peanuts are the fourth main oilseed plant and the 13th most important food crop in the world (ISALAR *et al.*, 2021). It has outstanding nutritional characteristics, constituting an important food source for populations in tropical and semi-arid regions of the planet. Its beans contain high percentages of oil, proteins, carbohydrates, phosphorus, calcium, magnesium, amino acids, polyphenols, and vitamins (SINGH *et al.*, 2021) and can be consumed, raw, roasted, or cooked, as is the case, for example, in the northeast of Brazil.

Currently, there are several products derived from peanut processing, such as candy, confectionery, paste/cream, butter, oil, flour, as can be easily observed in supermarkets, or even on internet sites. Peanuts can also be used for oil extraction (domestic or industrial use) for soap production, in cooking or even for the manufacture of cosmetics (ABDULLA, 2013). In addition, its grains can also be processed into animal feed, and its waste can be turned into fertilizers (ISALAR *et al.*, 2021).

Agricultural products such as peanuts, grown in tropical areas, usually hot and humid, are susceptible to contamination by fungi and bacteria. In addition, the exposure of grains to physical and chemical factors, associated with the absence of good agricultural and manufacturing practices, makes it possible to be attacked by spoilage microorganisms, at any stage of the production chain, (MONYOA *et al.*, 2012; EMBRAPA, 201), among them toxigenic fungi, which produce microtoxins.

Mycotoxins are secondary metabolites, produced by numerous species of filamentous fungi and very dangerous to humans and animals, since such microorganisms can infect and develop in food and feed. Such metabolites are generally characterized by being active in extremely low concentrations and being resistant to degradation (MIRABILE *et al.*, 2021). Once ingested by the consumer, mycotoxins behave in a toxic way, and can cause acute diseases such as skin rashes,

vomiting, diarrhea, headache or chronic diseases such as nephropathies, immunosuppression and carcinogenesis (FREIRE; da ROCHA, 2017).

The mere presence of toxigenic fungi in processed peanut kernels does not necessarily indicate the presence of mycotoxins, but it increases the possibility of their occurrence and points to the low sanitary quality in which the product is found. Thus, the construction of the present work originated from the idea (or intention) of increasing the amount of information on the occurrence of toxigenic fungi in processed peanut samples, aiming to demonstrate to the general public, consumers and regulatory agencies, the state in which the quality of peanuts sold in Inhumas, Goiás, is located. with regard to the presence of these microorganisms.

THEORETICAL FRAMEWORK

PEANUT

Peanuts are a leguminous plant, native to South America, whose cultivation has been occurring in Peru for at least 8,500 years. Portuguese and Spanish explorers, at the time of colonization, would have found Indians growing peanuts in countries such as Mexico, Brazil, Argentina, Paraguay and Bolivia. From these regions, then, peanuts would have been disseminated to Africa, Europe, Asia, the Pacific Islands, and the United States (HAMMONS *et al.*, 2016).

Like many other crops, peanuts have acquired greater relevance in regions far from their origin. Notably, its importance is most evident in Asia, where 64% of all world production comes from. In Africa, peanut production represents 26% of global production (FAOSTAT, 2019) and exceeds the combined amount of all other legume grains produced on that continent (BERTIOLI *et al.*, 2011).

In Brazil, peanut production is basically concentrated in the state of São Paulo, which totals 92% of national production with 890 tons (FOREIGN AGRICULTURAL SERVICE, 2023). Data from the 2018/2019 agricultural cycle inform that the total of grains of this *commodity* produced in Brazil resulted in a revenue that exceeded the mark of R\$ 1 billion, covering all aspects related to the crop, from cultivation to the industrial process (JAMMAL, 2019).

The data mentioned above on production and financial transactions suggest the size of the economic impact of peanut crops, which play an important role in job creation and increased income for families that are directly or indirectly involved in the production of this crop (ALBUQUERQUE; DOS SANTOS; CAVALCANTI, 2010).

It is estimated that approximately 80% of the total population of the African continent depends on agriculture as a means of subsistence (FAO, 2015). As a source of income in periods where drought is predominant, peanuts gain prominence for the generation of jobs in this continent, their manufacture had an estimated growth of 130% between the years 1970 and 2013, with Nigeria

being the main producing country with 39% of international production and 7% of global production, producing 4.9 million tons in an area of approximately 5.4 million hectares (LOZANO, 2016).

PEANUTS: GENERAL ASPECTS

Peanuts are of significant importance in several socioeconomic aspects, especially in underdeveloped nations. It is a crop with a low production cost, due to its resistance to pests and diseases, which can be grown in small areas. In addition, the demand for peanuts is high, both for *fresh consumption* and for the production of processed foods, which creates business opportunities and increases the possibilities for job and income generation (MARTINS; VICENTE, 2010).

Chemical and nutritional characteristics of peanuts add value to its production and commercialization (UNICAMP, 2006), since its grains have great gastronomic versatility, and can be consumed raw, roasted, processed or even as part of the elaboration of products such as peanut butter, peanut butter, paçoca, among others (SALVE *et al.*, 2020). This is because its grains have significant amounts of various nutrients such as proteins, mineral salts, vitamins, fibers and healthy fats (SOARES; SCALLOP; CARVALHO, 2021).

Peanut kernels are also an excellent source of oil, rich in fatty acids beneficial to human health, having important characteristics for use in the food and cosmetics industries. Unlike other oils, peanut oil has high levels of monounsaturated and polyunsaturated fats (SINGH *et al.*, 2021).

The relationship between peanut production and care for the environment is also a relevant topic, as the cultivation of this plant can require a lot of soil care and thus, if there is no proper management, productivity can decrease over time. In addition, the inadequate disposal of production residues can cause land degradation and reduce the potential of local environmental resources (SOUZA *et al.*, 2010), thus requiring appropriate strategies to mitigate possible impacts.

FUNGI

The peanut plant is cultivated in tropical and subtropical regions, with low water availability, at latitudes between 10° and 30° south (BELLETTINI; ENDO, 2001; SILVA *et al.*, 2018). It can measure between 30 and 50 centimeters in height, have alternate leaves, composed of three oval-shaped leaflets, with yellow flowers, which develop at the base of the stems. Its fruits appear below the surface of the soil, and may have an oval shape, with a protective film of reddish-brown color and between three and four grains inside its pods (KRAPOVICKAS; GREGORY, 1994).

Due to the fact that it is a crop that develops entirely in the soil, peanuts are subject to fungal contamination. Fungi are eukaryotic, heterotrophic, diverse, unicellular or multicellular organisms and can be found in practically all environments on the planet, especially in soil and aquatic

environments (TORTORA, 2012). It is rare to find environments free of the presence of these organisms, which use the atmosphere as their main means of survival and can tolerate significant variations in temperature, humidity, pH and oxygen levels. (JUNIOR, 2015).

In general, fungi have spores that appear somewhere in their life cycle. These spores are microscopic reproductive bodies, which commonly enter industrial environments through the contamination of raw materials and can be disseminated through the air, in the form of aerosols or water, and are also carried by animals and insects (BERNARDI; GARCIA; COPETTI, 2019). This is a form adopted by fungi so that they can propagate, colonizing new substrates, thus ensuring their survival (FERRO *et al.*, 2019).

Fungi obtain nutrients through other living beings, such as plants and animals, through the decomposition of the organic matter of these organisms through parasitism. They play an important role in the decomposition of organic matter, in the cycling of nutrients, in addition to having great biotechnological potential, being used by the pharmaceutical industry in the production of medicines, personal hygiene products, in the preparation of food and beverages, and in the production of biofertilizers (DE ABREU *et al.*, 2015).

Some fungi, such as mushrooms and truffles, are prized for their flavor and nutritional value, while others are used in the production of cheeses, wines, and beers (BAIÃO, 2020). Despite being beneficial in many processes, a significant part of fungi is toxigenic, which indicates that in addition to contaminating food inputs, they are poisonous and can produce dangerous toxins, causing numerous health problems in animals and humans (ROCHA *et al.*, 2014).

With regard to peanut fungal contamination, several factors are related, which can occur before, during and after harvest, mainly due to the absence of good practices along the production chain. Thus, inadequate storage conditions, lack of adequate hygiene during harvest, non-conformities during processing and transportation, contaminated soil and irrigation water, and contact with other infected foods represent circumstances that favor the process of contamination of peanut grains by fungi (CAVALCANTE; OLIVEIRA, 2022).

The main genera of fungi frequently found in peanut kernels are *Aspergillus*, *Penicilium*, *Rhizopus* and *Fusarium* (VISOTTO *et al.*, 2008). *Aspergillus* sp. and *Penicilium* sp. are generally associated with poor physiological quality of the grains, involving problems related to size, color, hull integrity, texture, and flavor (SABBADINI *et al.*, 2009).

The genus *Aspergillus* encompasses more than 340 officially accepted species of filamentous fungi (Bennett, 2010). They are organisms recognized for their remarkable reproductive capacity (through the release of conidia) and for their remarkable metabolic versatility. They can thrive easily in environments with low humidity and water activity, spreading across a wide variety of terrestrial habitats (BORGES *et al.*, 2012).

Fungi of the genus *Aspergillus* are the main causes of the deterioration of agricultural products. Its species also produce important mycotoxins, posing a risk to human and animal health, especially *A. Flavus*, *A. Parasiticus*, *A. Niger* and *A. Ochraceus* (KLICH, 2002). However, *A. Flavus*, *A. Niger*, and *A. fumigatus* can cause aspergillosis, which is characterized by lung problems, allergies, and systemic impairment (LIRA, 2022).

Penicillium is a genus of fungus comprising approximately 150 described species. Most of them are spoilage, can decompose food and attack plants and animals in low temperature conditions (HECK *et al.*, 2021). It has very peculiar characteristics when observed under a microscope, making identification quite complex, mainly due to the number of branches of its hyphae and the size and shape of its conidia (CHALFOUN; BATISTA, 2003).

A particularly interesting characteristic in fungi of the genus *Penicillium* is their ability to produce lipases (SILVA, 2022). Lipases extracted from molds, such as *Penicillium*, have several applications in the medical field, in the production of pharmaceuticals, in the cosmetics and food industries, and also in the production of biodiesel (HECK *et al.*, 2021).

The genus *Fusarium* comprises phytopathogenic fungi that attack several species of plants used in human food, causing considerable damage to crops around the world. *Fusarium* sp. are responsible for a disease generically known as fusariosis, which can affect both the shoots and the roots of plants. Its most common species are *Fusarium oxysporum* and *Fusarium solani*, which affect crops such as tomatoes, potatoes, bananas and corn (PINARIA; LIEW; BURGESS, 2010).

Fusarium infection can occur in different ways, including contamination from other infected grains, through the soil, or even from the water used in irrigation (NELSON *et al.*, 1992). To control the growth of these fungi, agronomic techniques such as crop rotation, certified grains, and the use of specific fungicides are usually used. However, integrated management is the best strategy for disease prevention and control (LESLIE; SUMMERELL, 2019).

The genus *Fusarium* produces a variety of mycotoxins, the most important being trichothecenes (vomitoxin and T-2 among others), fumonisins, zearalenone, moniliformin and fusaric acid. In general, *Fusarium* species can produce different mycotoxins, depending on the cultivation conditions (SANTIN *et al.*, 2021).

Rhizopus is one of the main groups of fungi that cause black molds in food (fruits, vegetables, and grains). The fungus *Rhizopus* uses conditions such as temperatures between 20° C and 30° C and places with high humidity to develop (SILVA *et al.*, 2021). However, they are also easy to find in the environment. These microorganisms, in addition to being food spoilage, can cause diseases in humans, the most important of which is cerebral zygomycosis, which mainly affects the lungs, subcutaneous tissue and gastrointestinal tract, reaching even the blood vessels when it is already very widespread (RODRIGUES, 2009).

MYCOTOXINS

Mycotoxins are secondary metabolites produced by filamentous toxigenic fungi that cause toxic reactions when ingested by humans or animals. *Fusarium*, *Aspergillus* and *Penicillium* are the most abundant fungi that contaminate food and produce mycotoxins before, during and after harvest (BINDER *et al.*, 2007).

Mycotoxins can be classified according to the species of fungus that produces, their chemical structure and their mechanism of action. The same species of fungus can produce different mycotoxins, depending on the environmental conditions in which this microorganism develops. On the other hand, a single mycotoxin can be produced by different species of fungi. Although there are numerous fungi capable of producing mycotoxins, the most technically significant genera are *Aspergillus*, *Penicillium* and *Fusarium*. Mycotoxins can take on various structural conformations (HUSSEIN; BRASEL, 2001). Of the approximately

300 substances identified as mycotoxins, the most studied include aflatoxins, trichothecenes, fumonisins, ochratoxin A, rye spur alkaloids and patulin (BANDO *et al.*, 2007).

Mycotoxins can be harmful to human and animal health, and ingestion of contaminated food can cause acute and chronic toxic effects, including liver, kidney and neurological problems. Aflatoxin is considered a human carcinogen and is associated with a higher incidence of liver cancer (COSTA; VERZELETTI; WAGNER, 2014). According to Liu; Wu (2018), aflatoxin may be responsible for inducing hepatocellular carcinoma in a range of 4.6% to 28.2% of cases worldwide.

Numerous studies have shown that the presence of aflatoxin caused by *Aspergillus* sp. in peanuts is a global problem (SANTOS *et al.*, 2018; LIEN, 2019; ARISTIL, 2020; QIN *et al.*, 2020; MASAKA *et al.*, 2022). Alternatively, many studies have demonstrated over the last few years that other mycotoxins can also occur in peanuts, such as ochratoxin A, produced by *Aspergillus niger*, *Aspergillus carbonarius*, (MAGNOLI *et al.*, 2006), *Aspergillus Ochraceus* and *Penicillium* (KRSKA *et al.*, 2012) and zearalenone by *Fusarium* (SANGARE-TIGORI *et al.*, 2006; KRSKA *et al.*, 2012).

In order to minimize mycotoxin contamination in peanuts, it is considerable to implement control measures at all stages of the production chain, from cultivation to processing and storage. Some of these measures include the selection of high-quality grains, the use of appropriate agronomic practices, the control of humidity and temperature during storage and processing, the use of detection and analysis methods to identify the presence of mycotoxins, in addition to good manufacturing practices (SAITA; PANDOLFI, 2019).

PEANUT QUALITY

Ensuring a product with adequate quality for the consumer is a process that involves awareness, commitment and persistence of agents related to the production chain of peanuts and

derivatives. The quality of peanuts can be defined by several factors, including the harvesting process, which is an essential step in the quality of the final product (SCALCO; QUEIROZ; MACHADO, 2008).

Costa *et al.* (2019) emphasize that in production systems, harvesting and post-harvest processes are the basis for obtaining high-quality products. The process of handling peanuts, when not carried out properly, can promote the growth of fungi, lead to undesirable fermentations and produce mycotoxins such as ochratoxin (OTA), which can harm the health of humans (ROCHA *et al.*, 2014).

The post-harvest stages involve processes that must be carried out properly to prevent peanut grains from being contaminated by fungi, such as *Aspergillus*. Contamination can occur primarily in the soil, which is a great indication of poor quality during processing operations (SUASSUNA *et al.*, 2005).

In general, the stages of processing for the quality of the beans involve: harvesting, which must be carried out during the maturation stage of the plant and its pods; followed by drying, which must be carried out as soon as possible. The pods should be placed up, facilitating the absorption of wind and sunlight, minimizing water activity and later humidity. Next, the cleaning stage aims to remove all impurities, which are due to the field (leaves, branches, stones and other materials considered foreign bodies), for this the peanut grains are subjected to processes such as sieving and fans to facilitate the extraction of dirt (ZANUTTO, 2021). After the cleaning process, the peanuts will be submitted to the classification process with different criteria regarding the color, size and quality of the grain, which help to distinguish which are the best lots to sell (SANTOS *et al.*, 2009).

The largest crop of peanuts is harvested during the rainy season, which makes it difficult to dry. As the grain must be bagged with a maximum moisture content of 8%, according to IN No. 32, of August 24, 2016 (BRASIL, 2016), after harvesting, it is recommended that it be immediately subjected to drying to avoid moisture problems, which can be carried out naturally or artificially. It is necessary to avoid rewetting the grain and mitigate the development of fungi and other problems related to peanut quality. Once rewetted during the processing stages, the grains are even more susceptible to attack by fungi (AGROBYTE, 2005). In addition, it is important to eliminate broken pods and grains, as they can affect the conservation of peanuts (SILVA, 2005).

The storage of peanuts should be planned in such a way as to avoid deterioration by moisture and to extend the shelf life of the product. According to Santos (2005), it is recommended that the bags be stacked on wooden pallets, facilitating the circulation of air around the grains, in a place with double-layer walls, smooth flooring, efficient protection, dry and with regular evaluation of the product's humidity, in order to ensure that it is within acceptable standards (CASTRO, 2010). In addition, it is necessary to carry out constant monitoring to identify the presence of pests and rodents,

taking the necessary measures to control them. If possible, it is recommended to store the peanuts at temperatures between 15 and 25°C (COX, 2012) and during transport to make sure that the conditions of the packaging are adequate to avoid damage that compromises the integrity of the grains and cross-contamination (SILVA, 2005).

Peanut kernels, like several other legumes, even after the storage stage, continue with the metabolism process still active. Even with the decreased respiration rate, there are some conditions that can influence this process, such as temperature and relative humidity conditions that can speed up the deterioration of peanuts (NUNES *et al.*, 2021).

SCALCO (2008) emphasizes that quality management in the peanut production chain is of paramount importance, not only to maintain the quality of the product, which is unquestionable, but also to improve the practices and procedures of the activities that make up the entire chain in order to reduce losses, waste and, therefore, cost.

According to SANTOS and FONSECA (2010), the *Codex Alimentarius* highlights the necessary care for food, which in general must have low bacterial contamination, absence of residues of microorganisms and veterinary drugs pathogenic to humans, and minimal contamination of chemical agents or microbial toxins. As peanut kernels develop underground, exposure to attacks by microorganisms becomes greater and, once contaminated, leads to problems related to food safety and the occurrence of aflatoxigenic fungi (ROLLEMBERG *et al.*, 2018). Aflatoxin is the name given to a group of very similar substances, toxic to humans and animals, produced mainly by two subspecies of the *fungus Aspergillus*, called *Aspergillus flavus* and *Aspergillus parasiticus*, when the product's moisture, relative humidity and environmental temperature are favorable (BINDER *et al.*, 2007).

Consumption of aflatoxin products can lead to problems such as kidney damage, liver cirrhosis, fever, and liver cancer. In African and Asian countries, where foods contaminated with aflatoxins are widely consumed, the incidence of liver cancer is approximately 13 cases per 100,000 inhabitants per year (FONSECA, 2004).

From an economic point of view, the presence of this fungus reduces the composition of the prices paid to producers (LASCA, 2004). In 2001, the Brazilian Association of the Chocolate, Cocoa, Peanut, Confectionery and Derivatives Industry (ABICAB) launched a quality brand that not only has a marketing aspect, but is directly linked to the quality of the raw materials acquired by the industry.

The ABICAB seal emerges as a certification tool, ensuring the excellence of the products of the industries. This seal, an indicator of quality and reliability, rewards products eligible according to strict ABICAB standards, covering ingredient quality, manufacturing processes, food safety, regulatory compliance, in addition to ensuring that products are free of mycotoxins. The certification

criteria involve several stages of the production chain, evaluating the origin and quality of ingredients, hygiene, traceability, sanitary standards, socio-environmental responsibility and commitment to excellence, thus bringing benefits to companies and consumers, conferring a reputation for quality, credibility, competitive differential, conquest of new markets and consumer loyalty for companies, while for consumers, it represents the guarantee of safe, authentic, and quality products, promoting the protection of health and satisfaction (ABICAB, 2022).

GENERAL OBJECTIVE

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- To investigate the occurrence of toxigenic fungi in peanut kernels that have undergone the process of drying, roasting, peeling and packed in plastic bags, in commercial establishments in the city of Inhumas.

SPECIFIC OBJECTIVES

- Inoculate peanut seeds of five different brands, marketed raw, with skin, without the pod, with a red film;
- Isolate fungal strains from 200 peanut kernels;
- Purify isolated fungal strains using specific culture media;

Identify the isolated fungi through microculture technique, using morphological, macroscopic and microscopic descriptors.

METHODOLOGY

The experiments were carried out in an aseptic environment, in the laminar flow chamber, of the microbiology laboratory of the Inhumas Campus, of the Federal Institute of Education, Science and Technology of Goiás (Figure 1). 200 grains of processed peanuts, raw, peeled, with only the outer skin, of five different brands, selected according to popularity, sold in plastic packaging, at room temperature and purchased in the city of Inhumas, were used.

Figure 1 – Aseptic laminar flow chamber, where the inoculation of the sampled peanut grains in culture medium was performed.

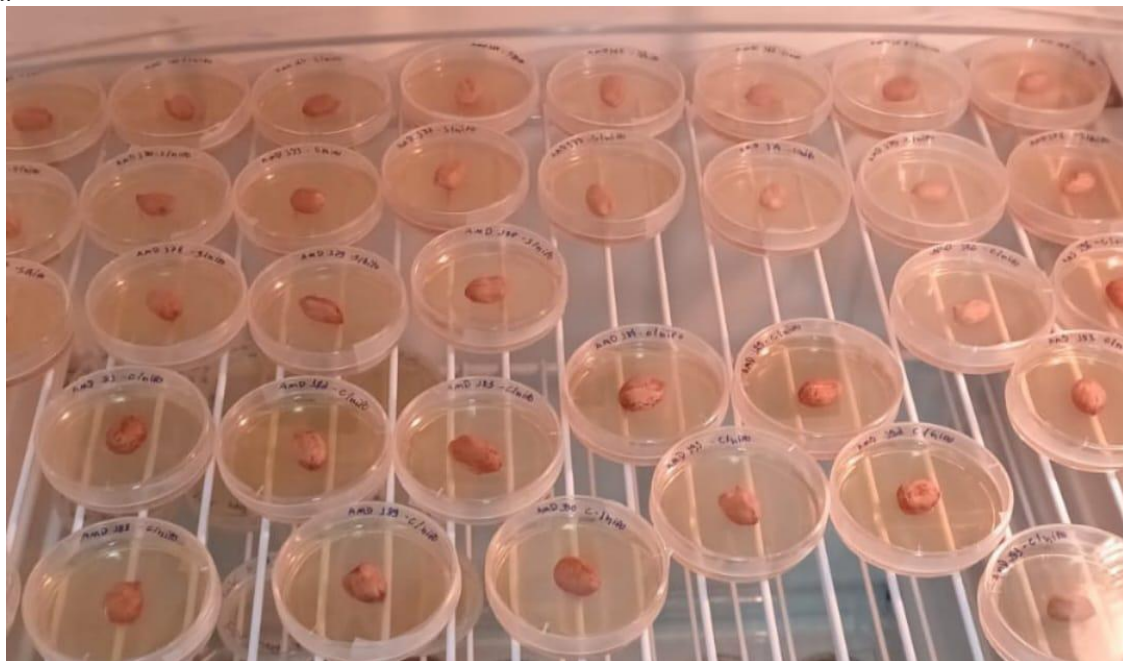


Source: The authors (2023)

From each of the selected brands, 40 grains were randomly sampled, which were separated into two lots: in one of the lots (50% of the grains) a superficial disinfection with 1% sodium hypochlorite was carried out for two minutes. The other batch of grains did not undergo superficial disinfection with hypochlorite. The differential treatment given to the grains aimed to evaluate the levels of contamination to which the grains were subjected when they went through the processing and storage stages.

The grains treated with sodium hypochlorite were subsequently immersed in 70% ethyl alcohol (1 minute) to remove residual hypochlorite and then immersed in sterile distilled water (1 minute) to remove the residual alcohol. After the disinfection procedure, all grains were inoculated in polystyrene Petri dishes, containing BDA culture medium. In each plate, only one grain was inoculated. After inoculation, the plates were incubated in a BOD incubator for seven days at a temperature of 28°C (Figure 2).

Figure 2 - Petri dishes containing BDA medium, inoculated with peanut kernels with and without disinfestation randomly sampled.



Source: The authors

In some plates, the growth of more than one type of fungus was observed (Figure 3), and it was necessary to perform re-pricking for the purification of the isolates. Peaking was performed with the aid of sterilized tips in an autoclave, transferring them to new Petri dishes containing BDA and incubating again for seven days at 28°C temperature. The procedure adopted for the isolation of fungi in the present study is described in Rezende *et al.*, (2013), and some adaptations were used.

After isolation and obtaining pure cultures, the isolates were identified using the microculture technique (RIDDELL, 1950). The identification of each isolate was carried out through the observation of morphological patterns traditionally used, as described by DE HOOG *et al.*, (2000), KERN and BLEWINS (1999) and by PITT and HOCKING (2009).

All objects and utensils used during the experiments were sterilized in an autoclave before being taken to the laminar flow hood. Contamination control to avoid false-positive results was performed using Petri dishes containing BDA. For this, a plate containing the medium was left uncovered in a corner of the laminar flow hood during the inoculums, and was later capped and incubated with the others. This procedure demonstrated that the environment where the experiments were being carried out did not cause external contamination, since all the control plates evaluated did not show fungal growth.

Figure 3 - Plate containing BDA and peanut grain contaminated by two types of fungi



Source: The authors

RESULTS AND DISCUSSION

The samples analyzed in the present study showed high levels of contamination, with the presence of at least one contaminating microorganism in 98% of the grains evaluated. In some plaques, the growth of more than one type of microorganism was observed (Figure 4). The 200 grains evaluated resulted in the obtaining of 102 fungal isolates, of which approximately 23.5% belong to the genus *Fusarium*, 16.5% to the genus *Rhizopus*, 11% to *Aspergillus niger*, the only microorganism identified at the species level, in addition to other findings of unidentified fungi and microorganisms that together add up to 47% (Table 1).

Figure 4 – Petri dishes with different types of contamination.



Source: The authors (2023)

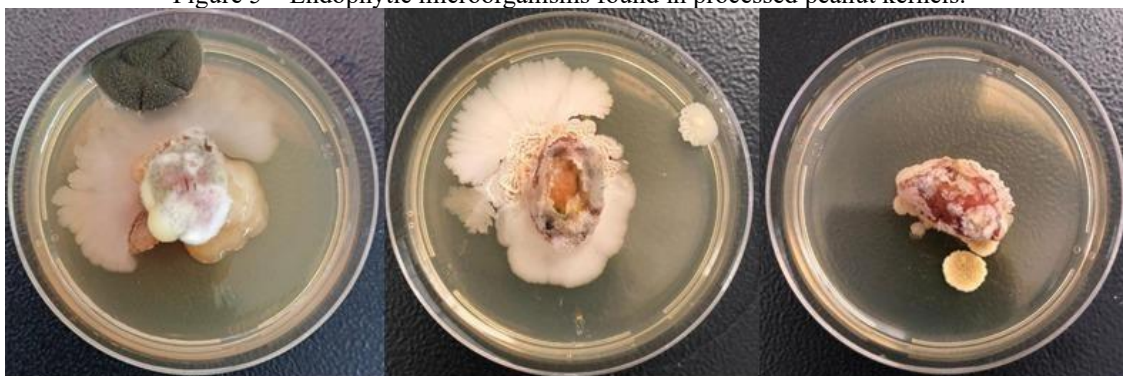
Table 1 – Numbers in % of fungi isolated from the sampled peanut kernels.

Samples	<i>Aspergillus Niger</i>		<i>Rhizopus sp.</i>		<i>Fusarium sp.</i>		Other			
	In the Isolated Sector	%	In the Isolated Sector	%	In the Isolated Sector	%	No. of unidentified fungi	%	No. of Other Microorganisms	%
A1	5	2,5	2	1	5	2,5	3	1,5	25	12,5
A2	10	5	13	6,5	7	3,5	4	2	6	3
A3	3	1,5	10	5	5	2,5	8	4	12	6
A4	3	1,5	7	3,5	15	7,5	3	1,5	12	6
A5	1	0,5	1	0,5	15	7,5	13	6,5	8	4
TOTAL	22	11	33	16,5	47	23,5	31	15,5	63	31,5

Source: The authors (2023).

The treatment adopted for grain disinfestation (described in the methodology) did not result in a difference in contamination levels. However, it was observed that almost all the samples that underwent disinfestation did not show fungal growth, but rather other endophytic microorganisms (Figure 5). These results suggest that most of the fungi identified in the samples were on the surface of the grains and probably infected them during some post-harvest stage.

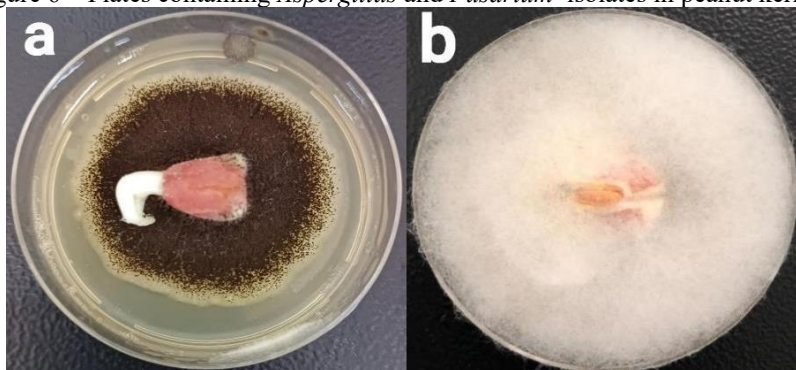
Figure 5 – Endophytic microorganisms found in processed peanut kernels.



Source: The authors (2023)

The analysis of the results also allowed us to observe that, in general, the peanut brands analyzed have a low level of hygienic-sanitary quality, thus being unsuitable for human or animal consumption, since *Aspergillus* and *Fusarium* are toxigenic fungi, producers of mycotoxins and were identified in all the brands analyzed. (Table 1, Figure 6).

Figure 6 – Plates containing *Aspergillus* and *Fusarium* isolates in peanut kernels.



Source: The authors (2023)

In general, fungi of the genus *Aspergillus* are a recurring concern for the food industry, given that their species have the ability to produce a series of mycotoxins, which can cause serious health problems in humans and animals (COSTA, 2014). *Aspergillus niger*, for example, identified in all peanut brands analyzed in the present work, is a species known to be toxigenic, producing ochratoxins (MIRABILE *et al.*, 2021), whose effects on humans and animals include immunosuppression, carcinogenesis, teratogenesis, among others (MAZIEIRO; BERSOT, 2010; HOELTZ *et al.*, 2012). Within the group of ochratoxins, ochratoxin A is one of the most studied, given its potential for diffusion and toxicological importance (MIRABILE *et al.*, 2021). Ochratoxin A has carcinogenic action and nephrotoxic effects that lead to nephropathy, a condition that affects the functioning of the kidneys (PERAICA; DOMIJAN; SARIĆ, 2008; MANNAA; KIM, 2017).

Other species of the genus *Aspergillus* also produce important mycotoxins, with rich description in the scientific literature. Aflatoxins, produced by *Aspergillus parasiticus* and *Aspergillus flavus* and usually found in stored foods such as the peanut kernels analyzed in this study, can cause liver cancer, chromosomal aberrations, among other serious problems (SMITH *et al.*, 2015; AWUCHI *et al.*, 2020; DIOGO *et al.*, 2020). Sterigmatocystin, produced by *Aspergillus versicolor*, *Aspergillus nidulans* and *Aspergillus rugulosus* also causes liver cancer, in addition to being able to chemically transform into eight different compounds capable of inhibiting DNA synthesis (ARRUDA; BERETTA, 2019).

The results obtained in the analyses with peanuts sampled in this work corroborate a series of studies previously carried out in Brazil and described below.

Nóbrega and Suassuna in (2004), carried out a sanitary analysis on 300 peanut grains, from five different cities, in the state of Paraíba. The study revealed the presence of *Aspergillus flavus*, *Aspergillus niger* and *Fusarium sp.*, among others, and pointed to contamination in 71.66% of the samples analyzed. The authors emphasized that humidity and temperature control help prevent peanut kernel infection by fungi, both for *fresh* and industrialized products.

Nakai *et al.*, (2008), monitored the peanut microflora for 12 months in the region of Tupã, São Paulo. In this work, the authors used both the peanut shell and the peanut kernels as substrate for isolating the fungi. The results of this study demonstrated the prevalence of *Fusarium* sp. in the husk and *Aspergillus* and *Penicillium* in the grains. According to the authors, the results can be explained by the fact that *Fusarium* sp., considered as a field fungus, is directly in contact with the peanut shell in the soil, while *Aspergillus* and *Penicillium*, considered storage fungi, are well adapted to the environmental conditions to which they are subjected during this stage of the production chain. The work of Atayde *et al.*, (2012), also pointed out the presence of fungi of the genus *Aspergillus*, *Fusarium*, *Rhizopus* sp, in addition to *Penicillium*, during the analyses on fungal diversity and the presence of Aflatoxins in different peanut species, from different regions of the state of São Paulo.

Bonifácio *et al.*, in (2015), evaluated peanuts sold in bulk in the city of Ji-Paraná, Rondônia. The results revealed high rates of fungal contamination also found in the processed peanut samples analyzed in the present work, such as *Aspergillus* sp. and *Rhizopus* sp. Such levels of contamination, according to the authors, can probably be explained by the adoption of inappropriate practices initiated in the field and also during the post-harvest stages.

In Ijuí, RS, Krahn *et al.*, (2020) evaluated different peanut samples, including shelled grains, bulk marketed grains, and shelled industrialized grains, confirming the presence of *A. niger*, *A. flavus*, *A. nidulans*. The authors stated that these fungi can be commonly found in almost all stages of the production chain, and pointed out that the presence of these organisms in the product is a consequence of failures in the operational stages of sanitization, facilitating their propagation, which can compromise the health of the consumer through toxic substances, such as Aflatoxins and Ochratoxins.

Like *Aspergillus niger*, isolates of the genus *Fusarium* identified in the present study represent an important finding from the hygienic-sanitary point of view, with regard to the brands of processed peanuts analyzed. Although these organisms are commonly found in peanut samples (GONÇALEZ *et al.*, 2008; DE OLIVEIRA; CASTILHO, 2011; SANTOS, 2013), species of *Fusarium* sp. are producers of dangerous mycotoxins and their presence in grains may be due to several factors, such as temperature, humidity, residues of other contaminated plants, as well as inadequate practices along the production chain.

One of the mycotoxins produced by *Fusarium* species is Fumonisin, a secondary metabolite produced by these fungi and associated with health disorders in humans and animals with hepatotoxic, carcinogenic, teratogenic and cytotoxic effects, which can cause leukoencephalomalacia in horses, pulmonary edema in pigs, as well as cancer in humans, the main one being esophageal cancer (ARRUDA; BERETTA, 2019; PRADO, 2017).

Fusarium sp. can also produce other important mycotoxins, listed in the literature, such as Zearalenone, synthesized mainly by *Fusarium moniliforme*, *Fusarium oxysporum*, *Fusarium graminearum* and *Fusarium roseum* (SMITH and HENDERSON, 1991). Zearalenone is associated with problems such as muscle atrophy, reduced testosterone levels, and infertility (RICHARD, 2007).

The work by Amancio *et al.*, (2023), on the growth of mycotoxin-producing fungi in raw peanut kernels in natura, without the pod and roasted peanuts without the pod, carried out in Juiz de Fora, MG, results are similar to those obtained in the present study. *Fusarium* was the most incident group (23.3%), followed by *Aspergillus* (20%), *Penicillium* (13.3%), *Alternaria* (13.1%) and *Rhizopus* (10%).

The occurrence of mycotoxin-producing spoilage fungi in other agricultural products is relatively common. Sabbadini *et al.*, (2009) studied the occurrence of toxigenic fungi in corn and bean grains, commercialized in the municipality of Campo Mourão, finding high rates of infection by storage fungi such as *Aspergillus* and *Rhizopus*. In coffee, sold in Inhumas, GO and its surroundings, LIMA (2022), observed the presence of fungi of the genus *Aspergillus*, *Fusarium* and *Rhizopus*, in raw, dried, shelled beans ready for roasting and consumption.

As widely discussed previously, two of the three genera of fungi identified in the present work, *Aspergillus* and *Fusarium* are known producers of mycotoxins whose harmful effects on humans and animals are widely described in scientific records, in the specialized literature on the subject. *Rhizopus* sp., also identified in the peanut kernels analyzed, produce mycotoxins that have been less studied, without much description in the literature about their effects in humans. These fungi are potential spoilages, which with their saprophytic activity, alter the sensory characteristics of the grains, causing significant economic losses (PINTO, 2000).

CONCLUSION

The five brands of processed peanuts, analyzed in this study, are in hygienic-sanitary conditions that are inadequate for human consumption or even for animal feed composition, since in all of them toxigenic organisms were identified, potentially producing mycotoxins, whose effects on animals and humans can cause serious health problems.

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Productive performance of cowpea lines and cultivars cultivated in the second harvest period in Fernandópolis – SP

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ABSTRACT

The correct choice of strains for a given environment and production system is decisive for obtaining high yields. It is important to carry out regional studies, aiming to select superior lines, both for cultivation and for use in genetic improvement programs. The objective of this study was to evaluate the productive performance and morphological characteristics of fifteen lines and five cowpea cultivars of erect and semi-erect size, identifying the most productive cultivars/lines well adapted to the region of Fernandópolis-SP. The work was conducted at the Teaching and Research Farm of the Universidade Brasil, Fernandópolis Campus/SP. The experiment consisted of 20 treatments, 15 lines and 5 upright and semi-erect cowpea cultivars from the Embrapa Mid-North Breeding Program. The experimental design was in randomized blocks with 20 treatments and four replications. The experimental unit consisted of 4 lines with 5 meters in length each with a spacing of 0.50m between rows, and the two central lines were considered as useful area. The following evaluations were carried out during crop development: flowering, average pod length, pod weight, grain weight, number of grains per pod, grain index and grain yield. The data were submitted to analysis of variance using the SISVAR statistical program and the means were compared by the Scott-Knott test at 5% probability. The lines and cultivars showed high precocity in the study region, which is one of the main characteristics needed for cultivation in the second harvest period. Among the genotypes evaluated, MNC04-792F-146, MNC04-795F-153, MNC04-782F-104, MNC04-769F-48, MNC04-769F-62, MNC04-795F-159, MNC04-762F-9 and MNC04-795F-168 stood out, and the cultivars BRS GUARIBA and BRS CAUAMÉ with the highest values for grain yield. The results obtained suggest that it is possible to select productive lines and cultivars for cultivation in the second harvest period in Fernandópolis – SP.

Keywords: *Vigna unguiculata*, Productivity, Genotype x environment interaction, Plant science.

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INTRODUCTION

Brazilian agriculture has been undergoing major technological changes in recent decades, most of which is due to the globalization of agribusiness, which has caused reflections on the production chain of several crops, especially those that depend on the use of large volumes of pesticides and agricultural fertilizers. Thus, these crops have been presenting a higher production cost every year, and as a result, producers have sought new options for their production arrangements (Freire Filho *et al.*, 2011).

The cowpea crop was long seen as a subsistence crop, in which small farmers and, in a minority of medium-sized farmers, cultivated it in unsuitable environments and, in addition, with restricted use of technological inputs. However, as Damasceno-Silva (2008) describes, the Embrapa Mid-North Cowpea Improvement Program, in recent years, has incessantly sought to reach beyond the small farmer the corporate producer and the results have been favorable.

Research has contributed to improving the productivity and profitability of the crop, which has aroused the interest of medium and large producers (Bezerra *et al.*, 2008; Freire Filho *et al.*, 2005;), mainly in the Midwest and Southeast regions, for cultivation in the second harvest period. The market has also been expanding beyond the borders of the North and Northeast regions, including being traded on commodity exchanges in the Southeast region (Freire Filho *et al.*, 2001).

In 2019, the world production of cowpea was 8.9 million tons (FAO, 2020). Brazil exported 46,353 tons of cowpea in 2022, with the United States, Afghanistan, Pakistan, Canada, and China being the main buyers.

In the 2023/24 harvest, 1.3 million hectares of cowpea were cultivated, despite the increase in recent harvests both in cultivated area and productivity, the production values are considered low, not exceeding 600 kg ^{ha}⁻¹ the national average productivity of cowpea (Conab, 2024). The absence of separation in the statistics of cowpea and common bean production is still an obstacle to Brazilian cowpea exports, as the world is unaware that Brazil produces this crop, since official agencies do not expose the data. However, with the efforts of producers and some companies, cowpea produced in Brazil has been exported in recent years, opening up another marketing alternative for rural producers (Damasceno-Silva, 2009).

The average productivity of cowpea in Brazil, between the years 2005 and 2009, was 369 kg ^{ha}⁻¹ (Freire Filho *et al.*, 2011), and in 2011, it was 525 kg ^{ha}⁻¹ (CONAC, 2012). It is worth mentioning that states such as Goiás, Mato Grosso do Sul and Mato Grosso have yields greater than 1,000 kg ^{ha}⁻¹.

Despite the expansion of cowpea when compared to other crops, it is observed that its genetic potential has been very little explored, however, it has already been obtained, under experimental conditions, yields of dry grains above 3,000 kg ^{ha}⁻¹, and the expectation is that its genetic potential will exceed 6,000 kg ^{ha}⁻¹ (Bezerra, 1997). However, in order to reach this level of productivity, it is

necessary to invest more in research with the crop, in studies related to physiology and ecophysiology, in order to verify the response of this crop to environmental factors in different regions of the country, since most of this information is obtained through work carried out in other countries such as Nigeria and the United States (EMBRAPA mid-north, 2003).

Improved cultivars and elite lines of cowpea have shown yields higher than 2,600 kg ha⁻¹ (Bezerra, 1997), demonstrating that the productivity of this crop can be increased through the use of improved cultivars, contributing to reduce production costs and improve product supply (Sponholz *et al.*, 2006). The launch of the first semi-erect cultivar in Brazil, in 2004, BRS Guariba, was the trigger for this change and, a typical northeastern product, produced mainly by the North and Northeast regions, is also being cultivated in extensive areas of the Midwest region (Damasceno-Silva, 2008).

The characteristics that form the plant architecture in cowpea, such as growth habit; length of the hypocotyl, internodes, main and secondary branches; and size of the peduncle can influence for a higher or lower lodging of the plants, as well as allow mechanical harvesting or facilitate manual harvesting. According to Freire Filho *et al.* (1991), the genetic improvement of cowpea has several objectives: to develop resistance to viruses and insects; to develop cultivars with modern architecture, that is, with a more compact, upright size and with a low lodging index; and to develop cultivars for the production of green beans with characteristics for the industrial process.

Cowpea, in relation to other crops, is little improved, however, it has a wide genetic variability for practically all traits of agronomic interest (EMBRAPA, 1990; Freire Filho *et al.*, 1988).

The first studies aimed at improving cowpea began in the Northeast in the sixties and had as their basic objective the increase of productivity (Krutman *et al.*, 1968; Paiva *et al.*, 1970). Local cultivars were collected and characterized, which then went through a process of elimination of atypical plants and were tested in competition trials. Subsequently, introductions were started and rehearsals began to contain materials from different origins.

The correct choice of genotype for a given environment and production system is of great importance to obtain good productivity. However, this alone is not enough for the success of the exploration. It is also necessary that the cultivar has characteristics of grains and pods, which meet the requirements of merchants and consumers (Freire Filho *et al.*, 2000).

The second crop, also called "off-season", is characterized by sowing between the months of January, February, March and later in irrigated systems, with predominance in the Midwest region and in the states of Paraná and São Paulo (Esteves *et al.*, 1994). The cultivation of corn in the period of the second harvest has gained great importance, as a result of the few viable economic alternatives for the autumn/winter harvest (Shioga *et al.*, 2004). However, this type of cultivation has presented a risk of loss of productivity. The main risk factor for loss for off-season corn is prolonged dry spells,

which can occur throughout the crop cycle, and can cause losses that can reach 80% to 100% in some years (Clemente Filho; Leão, 2008). In the search for a crop that is more resistant to weather and with greater precocity, cowpea has become in recent years a new crop option, in the second harvest, since it is relatively more tolerant to drought, mainly due to the faster cycle.

Research with cowpea in the southeast region is scarce and the available cultivars are being used without considering their possible differences in behavior and adaptation in the various cultivation regions. It is important that regional studies be carried out in order to select superior genotypes both for cultivation and for use in breeding programs.

The objective of this study was to evaluate the behavior of fifteen lines and five cowpea cultivars of erect and semi-erect size, cultivated in the second agricultural season ("off-season") in Fernandópolis-SP, identifying the most productive and well-adapted cultivars and lines for the region.

MATERIAL AND METHODS

The experiment was conducted at the Teaching and Research Farm of the Universidade Brasil, Fernandópolis/SP Campus, located between the coordinates 20°16'50" south latitude and 50°17'43" west longitude and at an altitude of 520 m.

The climate of the region, according to the Koppen classification, is humid tropical, Aw, with a dry and mild winter and a hot and rainy summer (Rolim *et al.*, 2007). The region is characterized by a period of 6 months of the year with water deficit and an average temperature of 23.5°C.

According to Oliveira *et al.* (1999) the soil of the experimental area is of the PVA1 group, that is, Ultisols Yellow Red Yellow Ultisols eutrophic abruptic A moderate sandy/medium relief smooth and undulating

Before the installation of the experiment, soil samples from the experimental area of the 0-10 and 10-20 cm layer were collected and analyzed for chemical characteristics. The experiment was carried out in a minimum cultivation area previously occupied with corn, in which desiccation was carried out 15 days before the implementation of the experiment with the use of the herbicide glyphosate (1,560 g of the active ingredient (a.i.) ha^{-1}).

A total of 16 lines were evaluated (MNC04-762F-3, MNC04-762F-9, MNC04-769F-30, MNC04-769F-48, MNC04-792F-146, MNC04-769F-62, MNC04-782F-104, MNC04-792F-143, MNC04-792F-144, MNC04-792F-144, MNC04-792F-144 48, MNC04-795F-153, MNC04-795F-154, MNC04-795F-155, MNC04-795F-159 and MNC04-795F-168) and 4 cowpea cultivars (BRS GUARIBA, BRS TUMUCUMAQUE, BRS NOVAERA, BRS ITAIM, BRS CAUAMÉ) from the Embrapa Mid-North Improvement Program, located in Teresina, PI. The lines were selected in the Preliminary Yield Assay – EPR.

The experimental design was randomized blocks with four replications. The experimental plots consisted of 4 rows with 5 meters in length using a spacing of 0.50m between rows with the two central rows as useful area.

Sowing was carried out on March 12, 2015, a three-row no-tillage seeder was used, where it opened the sowing furrows and deposition of fertilizer, the sowing and covering of seeds was carried out manually, thirteen seeds were sown per meter of row. At 15 days after sowing (DAS), manual thinning was performed, leaving eight plants per meter of row, totaling a population of 160 thousand plants per ha^{-1} .

By means of soil chemical analysis (Table 1), implantation fertilization was performed manually in the planting furrow, the equivalent of 290 kg ha^{-1} of fertilizer formulated 08-28-16 (N, P_2O_5 and K_2O) was applied, and top dressing was carried out at 15 days after plant emergence (DAE), applying the equivalent of 60 kg ha^{-1} of nitrogen, using urea as a source, even in the case of a legume, it was necessary to top dress, because the inoculation of the bean seeds was not performed.

Table 1. Chemical characteristics of the soil, in the 0-10 and 10-20 cm layer, before the installation of the experiments.

Layer	pH(CaCl ₂)	M.O (g dm^{-3})	Presina (mg dm^{-3})	H+Al (mmolc dm^{-3})	K (mmolc dm^{-3})	Ca (mmolc dm^{-3})	Mg (mmolc dm^{-3})	CTC (mmolc dm^{-3})	V (%)
0-10	5,3	18	13	21	1,2	17	6	45,2	53,54
10-20	5,1	15	11	26	1,0	13	5	45,0	42,22

Source: From the authors, 2015.

During the development of the plants, two manual weeds were carried out, with the objective of eliminating invasive plants, for ant control baits were distributed in the experiment area, for pest control was carried out the application with insecticides (S-methylcarbamate oxime), 160 g of the active ingredient (a.i.) ha^{-1} at 30 DAE and (N-nitroimidazolidim-2-ilidineamino), 105 g of the active ingredient (a.i.) ha^{-1} at 50 DAE, in the same period for disease control, the fungicide (N-methoxy) was applied, 75 g of the active ingredient (a.i.) ha^{-1} at 51 DAE.

In the physiological maturation of each genotype, phylotechnical evaluations were carried out on the two central lines, with 0.5m from each end of the lines being disregarded. The following evaluations were carried out:

- Cycle:** Number of days elapsed from emergence to physiological maturity of the plants in each plot.
- Flowering:** The number of days for flowering was evaluated considering the number of days elapsed from plant emergence to full flowering of the treatments.
- Average pod length (CPMV):** Determined in centimeters, by averaging five pods per plot taken at random. In the case of curved pods, the longest straight line from the base of

the pod to its end was measured. The pods were evaluated at the Seed Laboratory of the University of Brazil.

- d) Pod weight (PVG):** Evaluated by weighing 5 pods, these pods being the same as those referred to in item c.
- e) Grain weight (PGR):** Evaluated by weighing the total number of grains of 5 pods, these pods being the same as those referred to in item c.
- f) Number of grains per pod (NGV):** Determined by the ratio between the total number of grains in 5 pods, these pods being the same as those referred to in item c.
- g) Grain index (GI):** It was obtained by the ratio between grain weight/pod weight, harvested at the maturity stage of the pods, taking five pods per plot at random and calculating the index according to the expression: $GI (\%) = (PG5V/P5V).100$ where, $PG5V$ = grain weight of 5 pods and $P5V$ = weight of 5 pods.
- h) Grain yield:** All pods contained in the two central rows of each plot were harvested manually, disregarding 0.5 meters from the end of each row. After harvest, the grains were manually threshed and weighed, transforming the grain mass to $kg^{ha^{-1}}$, corrected to 13% moisture (wet basis).

The data were submitted to analysis of variance using the SISVAR statistical program (Ferreira, 2000) and the means were compared by the Scott-Knott test at 5% probability.

RESULTS AND DISCUSSION

The average plant population of the experiment was 73,850 plants ha^{-1} . Among the genotypes studied, the cultivars BRS Cauamé, BRS GUARIBA and BRS TUMUCUMAQUE presented the lowest final plant establishment, while the highest populations were observed in the cultivars BRS NOVAERA and BRS ITAIM. Among the strains, the smallest populations were: MNC04-762F-9, MNC04-792F-146, MNC04-782F-104, MNC04-792F-144, MNC04-795F-159 and MNC04-795F-168 (Table 02).

Table 2. Final plant population (plants ha^{-1}), flowering (DAE) and cycle (DAE) of cowpea lines and cultivars, in Fernandópolis -SP, 2015.⁽¹⁾

Genotypes	Plant Population	Flowering
MNC04-762F-3	79.242a	40,0c
MNC04-762F-9	66.333b	39,0b
MNC04-769F-30	78.750a	42,5d
MNC04-769F-48	78.750a	42,0d
MNC04-792F-146	64.167b	40,5c
MNC04-769F-62	78.833a	41,5d
MNC04-782F-104	67.083b	40,8c
MNC04-792F-143	75.833a	37,5a
MNC04-792F-144	66.667b	41,0c
MNC04-792F-148	80.833a	42,3D
MNC04-795F-153	83.750a	42,0d
MNC04-795F-154	85.500a	39,0b
MNC04-795F-155	76.583a	38,5b
MNC04-795F-159	69.417b	38,5b
MNC04-795F-168	66.250b	36,5a
BRS GUARIBA	61.833b	38,5b
BRS TUMUCUMAQUE	65.834b	38,0b
BRS NOVAERA	90.833a	37,3a
BRS ITAIM	75.417a	37,5a
BRS CAUAMÉ	65.083b	38,8b
Average	73.850	39,6
C.V. (%)	13,1	2,4

⁽¹⁾ Means followed by distinct, lowercase letters in the column, differ statistically by the Scott-Knott test at 5% probability. Source: From the authors, 2015.

The low final plant population was due to failures in seed germination. The low germination was possibly caused by the low vigor of the seeds that presented weevil attack. In the initial phase of plant germination, some plots suffered attacks by birds, which fed on the apical buds of the seedlings, leading to their death.

In the edaphoclimatic conditions of Fernandópolis, SP, the cultivars showed different behavior regarding flowering and maturation. For all the lines evaluated, the plants emerged between 7 and 9 days after sowing, flowering occurred at 37 to 43 DAE (days after emergence) (Table 2).

The average flowering of the evaluated lines was 39.6 DAE, and the earliest flowering lines were: MNC04-795F-168, BRS NOVAERA, BRS ITAIM, MNC04-792F-143. According to Matoso (2014), the shorter cycle of the crop sown in the off-season is economically interesting for the rural producer, because after the cowpea harvest it is possible to sow another crop, in the winter period, such as wheat or triticale in irrigated conditions for the study region. In addition, cowpea cultivars that reach maturity within 90 days after sowing are less subject to water deficits, common to the second harvest, because the greatest water requirement of the crop is until flowering.

The earliest genotypes represent a rich source of genes for the development of early and medium-early cultivars. Precocity is an important characteristic, as it represents the possibility of carrying out up to three crops per year, including rainfed and irrigated crops; favoring the increase

and/or stabilization of production and in regions with long periods of drought (Cisse *et al.*, 1995; Machado *et al.*, 2008).

The genotypes evaluated differed from each other for CMV (average pod length), and the highest values for this trait were observed in the lines MNC04-762F-3, MNC04-762F-9, MNC04-792F-146, MNC04-782F-104, MNC04-792F-143, MNC04-792F-148, MNC04-795F-153, MNC04-795F-154, MNC04-795F-155, MNC04-795F-159 and in the cultivar BRS TUMUCUMAQUE (Table 3).

Table 3. (CMV) Average pod length (cm) and (NGV) number of grains per pods of cowpea lines and cultivars, in Fernandópolis -SP, 2015.⁽¹⁾

Genotypes	Average Pod Length	Mass pod	Number of grains per pod
MNC04-762F-3	20,1a	2,62a	12,2a
MNC04-762F-9	20,4a	2,72a	12,1a
MNC04-769F-30	18,3b	2,44a	13,0a
MNC04-769F-48	18,7b	2,10a	11,0a
MNC04-792F-146	19,3a	2,62a	12,0a
MNC04-769F-62	18,6b	2,69a	13,5a
MNC04-782F-104	19,5a	2,40a	12,2a
MNC04-792F-143	19,6a	2,55a	11,4a
MNC04-792F-144	18,7b	2,00a	9,9b
MNC04-792F-148	19,1a	2,40a	11,6a
MNC04-795F-153	19,2a	2,80a	13,5a
MNC04-795F-154	21,2a	2,33a	12,6a
MNC04-795F-155	20,2a	2,64a	12,1a
MNC04-795F-159	19,1a	2,54a	11,7a
MNC04-795F-168	17,9b	2,26a	9,9b
BRS GUARIBA	16,8b	1,83a	9,0b
BRS TUMUCUMAQUE	21,2a	2,54a	11,6a
BRS NOVAERA	16,6b	2,39a	8,9b
BRS ITAIM	16,8b	1,89a	8,7b
BRS CAUAMÉ	18,1b	2,28a	11,5a
Average	19,0	2,4	11,4
C.V. (%)	8,5	17,3	13,6

⁽¹⁾ Means followed by distinct, lowercase letters in the column, differ statistically by the Scott-Knott test at 5% probability. Source: From the authors, 2015.

The cultivar BRS TUMUCUMAQUE and the lines MNC04-795F-154, MNC04-762F-9, MNC04-795F-155 and MNC04-762F-3, presented CMV equal to or greater than 20 cm, a value considered within commercial standards, for the commercialization of green pods (Silva; Oliveira, 1993), (Table 3). According to Freire Filho (2011), the green bean market requires large and attractive pods. It is worth mentioning that large pods are one of the desirable characteristics for manual harvesting, as it facilitates manual plucking.

Currently, for mechanized harvesting, smaller pods with fewer grains and, consequently, lighter, are preferred, as they allow better support, reducing the possibility of bending and breaking the stalk. Because they are lighter, the pods are less likely to touch the ground, which reduces the possibility of losses due to rot (Silva; Neves, 2011).

The pod mass did not present significant difference between the genotypes evaluated, the average obtained by the genotypes for this trait was 2.4 grams (Table 3).

For the number of grains per pods, the average was 11.4 grains, where the lines BRS ITAIM, BRS NOVAERA, BRS GUARIBA, MNC04-795F-168, MNC04-792F-144 presented the lowest values for NGV, being a consequence of a lower CMV.

NGV has high genetic heritability, being little influenced by the environment, in addition, this trait generally does not correlate with productivity (Andrade *et al.*, 1998), in this experiment this was observed in the MNC04-769F-30 lineage, which presented one of the highest values for NGV, but was one of the least productive (Table 3 and 4). Sampaio *et al.* (2006) observed that the semi-erect and erect lines presented an average of 15 to 11 grains per pod, values similar to those found in this study. Teixeira, *et al.* (2007); Bevilaqua, *et al.* (2007) evaluating 22 genotypes, observed that the lines that stood out in number of grains per pod were TVX5059-09C-02 and IT82G-9, both with values of 11.

There was no significant difference for the genotypes evaluated for grain mass by MGW pods, the lowest MGW value was obtained in the line MNC04-792F-144 and the highest by the line MNC04-795F-153 (Table 4).

The grain index, determined by the grain weight/pod weight ratio, is a very important trait in cultivars intended for the production of green and/or dry grains, since it measures the efficiency of the cultivar in the allocation of photoassimilates to the grains (Freire Filho *et al.*, 2005). Silva and Oliveira (1993) obtained values ranging from 42.8 to 71.7% for this character. In the present study, the values found ranged from 62.6% for the MNC04-792F-144 lineage to 76.6% for the MNC04-795F-154 lineage (Table 4).

Table 4. (MGV) Grain mass per pod (grams), grain index (%) and grain yield (kg ha⁻¹) in Fernandópolis -SP, 2015.⁽¹⁾

Genotypes	Grain Mass Per Pod	Grain index	Grain productivity
MNC04-762F-3	1,86a	70,2b	815,1b
MNC04-762F-9	1,88a	68,9b	1024,4a
MNC04-769F-30	1,65a	67,1b	754,7b
MNC04-769F-48	1,41a	66,3b	1065,5a
MNC04-792F-146	1,85a	70,4b	1165,4a
MNC04-769F-62	1,92a	71,1a	1059,0a
MNC04-782F-104	1,60a	66,1b	1080,9a
MNC04-792F-143	1,80a	69,9b	930,3b
MNC04-792F-144	1,27a	62,6b	863,0b
MNC04-792F-148	1,72a	71,1a	931,9b
MNC04-795F-153	2,14a	76,4a	1124,8a
MNC04-795F-154	1,79a	76,6a	935,3b
MNC04-795F-155	1,84a	69,4b	910,8b
MNC04-795F-159	1,85a	72,9a	1047,5a
MNC04-795F-168	1,66a	73,3a	990,2a
BRS GUARIBA	1,33a	72,3a	989,2a
BRS TUMUCUMAQUE	1,77a	69,3b	912,5b
BRS NOVAERA	1,73a	72,2a	952,9b
BRS ITAIM	1,41a	74,1a	754,5b
BRS CAUAMÉ	1,66a	72,4a	975,8a
Average	1,7	70,6	964,2
C.V. (%)	20,5	6,2	13,5

⁽¹⁾ Means followed by distinct, lowercase letters in the column, differ statistically by the Scott-Knott test at 5% probability. Source: From the authors, 2015.

Grain yield ranged from 755 to 1165 kg ha⁻¹, forming two groups, one with grain yield above 1000 kg ha⁻¹ and the other below, and it was also possible to verify that of the twenty genotypes evaluated, ten presented productivity above 1000 kg ha⁻¹.

The genotypes with the best yield performance were: MNC04-792F-146, MNC04-795F-153, MNC04-782F-104, MNC04-769F-48, MNC04-769F-62, MNC04-795F-159, MNC04-762F-9, MNC04-795F-168, BRS GUARIBA and BRS CAUAMÉ.

All the genotypes studied showed satisfactory development and productivity in the study region, since the productivity obtained is higher than the national average production.

Productivity is an important criterion when choosing a cultivar, but it is not the only one, at the time of its choice, the cost/benefit ratio must also be considered, based on the price of seeds, productivity, the efficiency of technology in pest control, tolerance to diseases of regional occurrence and, of course, the technological level that the producer uses in the crop.

CONCLUSIONS

The lines and cultivars showed high precocity in the study region, which is one of the main characteristics needed for cultivation in the second harvest period. Among the genotypes evaluated, the lines MNC04-792F-146, MNC04-795F-153, MNC04-782F-104, MNC04-769F-48, MNC04-769F-62, MNC04-795F-159, MNC04-762F-9 and MNC04-795F-168, and the cultivars BRS



GUARIBA and BRS CAUAMÉ, obtained the highest values for the production components. The results obtained suggest that it is possible to select productive lines and cultivars for cultivation in the second harvest period in Fernandópolis – SP

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Interactions between forest species as indicative of management and economic possibilities in the Amazon

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ABSTRACT

The floodplains of the Amazon estuary are environments recognized for their soils with a high level of water saturation, for the dominance of few tree species and the presence of a high number of palm trees that are important in the maintenance of riverside communities. The objective of this study was to highlight floristic composition and phytosociology as silvicultural tools for sustainable management in floodplain forest. For this, the study was carried out in a floodplain forest located on Conceição Island, Santa Bárbara do Pará, Pará State. Two hectares were randomly selected, divided into two plots of one hectare each, 100 x 100 m, where to facilitate the floristic survey, each hectare was subdivided into strips of 20 x 100 m. In each plot, individuals were sampled at 1.30 m from the ground with a CAP $\geq$ 30 cm, estimating the commercial height of the timber species; botanical identification was made in the herbarium João Murça Pires - MPEG for some species. The analysis was carried out through the horizontal structure of the forest with the parameters density, frequency, dominance and importance value index, all relative, as well as the number of individuals and basal area. It was found that the species with the highest phytosociological importance value index were *Euterpe oleracea*, *Pterocarpus officinalis*, *Symphonia globulifera*, *Hevea brasiliensis*, *Virola surinamensis* and *Carapa guianensis*, of which *E. oleracea* stands out as the species of greatest socioeconomic importance followed by *Carapa guianensis*. The values found regarding the number of individuals, relative density and importance value index, denote that the species, especially those of economic importance, are viable for management to increase production, requiring special management techniques in order to increase their volumes.

Keywords: Silviculture, Amazon forest, Floodplain economy, Forest management.

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INTRODUCTION

Part of the economy of countries, especially those in "development", is concentrated on the basis of natural resources, whether in the primary, secondary and even tertiary sectors. This has generated strong clashes and the strengthening of discussions around issues related to sustainable development, especially when it comes to equating problems between environmental sustainability and economic and social development. On the issue, Ehlers (1999) stressed that sustainable development must reconcile economic growth and the conservation of natural resources for long periods.

It cannot be denied that in the search to achieve excellence among the means of production in line with environmental conservation, efforts have been intensifying towards maximizing production with the minimization or mitigation of environmental damage. In this context, extractive communities in the Amazon, here in this study those that occupy the floodplain areas, are inserted in the process of using natural resources for profit or just family maintenance. Lima and Tourinho (1996) reported that the Amazon floodplains have been exploited since pre-Columbian times due to the economies of times such as rubber, cocoa and jute, today with multiple products, the authors emphasized that the search for açaí (*Euterpe oleracea* Mart.) has been since the beginning in the economic process. Ribeiro et al. (2004) highlighted that the Amazon floodplains have been exploited since the sixteenth century by Europeans and continue to the present day. According to Santos (2004), the availability of natural resources, such as various species of wood and especially the fruit and heart of palm of the açaí palm tree, have served to sustain varzeira and surrounding families.

The knowledge about shrub-tree potential in floodplain areas is given by the floristic survey, because it allows at first glance to have a view of the initial conservation status of the vegetation, from there, other analyses can be developed, such as the use of phytosociology that allows an understanding of the structural behavior that forest species establish among themselves as a function of biotic and abiotic variables and, especially, as a result of human action. For Santos (2012), the floristic survey and the study of the phytosociological behavior of species are of fundamental importance, as they allow us to understand the action or pressure of man on the main species and, from the point of view of science and traditional knowledge, to infer changes or adaptations in the best use of the species.

According to Leitão Filho (1987), the Amazonian vegetation is floristically quite distinct, representing an immense task its floristic study, even today, due to several factors such as territorial extension, floristic diversity itself, access to sampling areas, difficulty in collection, scarcity of taxonomists, among others. For Jardim et al. (2008), even today the floristic composition is little known due to some peculiarities such as species distribution, demography, preferential habitats and the dynamics itself, being important aspects to be considered in management and development,

therefore, in order to contribute to the adoption of the best management, the authors reinforced that the use of phytosociology provides the first information about the dynamics of the stand, leading silvicultural decisions to have greater chances of success. Higuchi et al. (2012) reinforced by saying that when one wants to design conservation and restoration strategies, it is necessary to know the floristic and structural patterns of the forests, as well as the knowledge about the environmental variables that act on these patterns. For Pedreira and Sousa (2011), when it comes to flooded areas, studies in the interior of the country are still scarce, even for mistaken reasons of considering them as economically unattractive areas. Seeing the floodplains as economically unattractive is refuted by Lima and Tourinho (1996) because they have several economic species, be it wood, fruits, seeds, oils, latex, etc.

In order to strengthen knowledge about plant diversity and its dynamics in floodplain forests, especially in the Amazon estuary, it is possible to cite several studies such as (ANDERSON et al., 1985; CONCEIÇÃO, 1990; ANDERSON et al., 1995; JARDIM and VIEIRA, 2001; RABELO et al., 2002; JARDIM et al., 2004; SANTOS et al., 2004; SANTOS et al. 2014; FERREIRA et al., 2005; SANTOS and JARDIM, 2006; CARIM et al., 2008; BATISTA et al., 2011; SANTOS, 2012) in which they highlighted the floodplains as an ecosystem of low tree diversity, usually of high floristic similarity and with the presence of timber and non-timber species with high market potential, such as: *Euterpe oleracea*, (açaí); *Carapa guianensis* (andiroba); *Virola surinamensis* (virola); *Symphonia globulifera* (ananin); *Mauritia flexuosa* (buriti); *Hevea brasiliensis* (syringe) etc.

These species, due to their high occurrence in floodplain areas and commercial prominence, suggest that management should be carried out in order to ensure their sustainability. The definition of forest management according to the Brazilian Forest Code is "management of natural vegetation to obtain economic, social and environmental benefits, respecting the mechanisms of sustainability of the ecosystem, object of management, considering cumulative or alternative, the use of multiple timber species or not, multiple products and by-products of flora, as well as the use of goods and services. In this way, it is perceived in all the possibilities of use of the floodplain forest its previous knowledge and this permeates the floristic survey and phytosociological study as fundamental contributions to the adoption of management.

METHOD

PLACE OF STUDY

The study was conducted on Conceição Island, in the Furo das Marinhas community, in the municipality of Santa Bárbara do Pará, in the State of Pará (Figure 1). The municipality belongs to the metropolitan region of Belém (capital) only 40 km away by the PA 391 highway, better known as Belém-Mosqueiro. According to SUDAM (1993) it has an annual rainfall intensity with peaks in the

months of January, February, March and April, with an average annual temperature of 26 ° C with warmer months in September and October, the soil is of the Gley Low Humic Hydromorphic type, most of which is characterized as low-lying lowland soils where, it suffers floods daily according to the flooding of the tide. 2.500 mm

Conceição Island is cut by the hydrological flow of streams and the Furo das Marinhas River, its relief is predominantly lowland and its arboreal vegetation is composed of understory and canopy species, palm trees and vines. According to local residents there is the presence of animals such as: armadillo, paca, agouti, tapir, monkey etc. All this information from the biophysical environment is important because they act together in the establishment of forest species.

FIGURE 1: Location of Conceição Island in Santa Bárbara do Pará, in the State of Pará.



Source: Santos *et al.* (2014).

DATA ANALYSIS

2 ha of forests were delimited distributed in two plots of size 100 x 100 m () with a distance of approximately 200 m from each other. Each plot was subdivided into five 20 x strips only to facilitate the floristic survey, i.e., they did not have the function of sample subplots. In each plot, individuals with CAP (circumference at breast height) ≥ 30 cm to 1.30 m from the ground were sampled, estimating their heights from a 12 m graduated pole. In the case of the açai palm (1 ha100 m *Euterpe oleracea*) as this occurs in clumps, each stem was considered as an individual, as each stem produces fruit bunches and seeds. The botanical identification carried out in the Herbarium of the Emílio Goeldi Museum of Pará. The floristic analysis was carried out by the horizontal structure

as proposed by Cottam and Curtis (1956), using the Mata Nativa 2 software, (CIENTEC, 2006). The parameters of the phytosociological horizontal structure served as indicators for possible practices that help in the development of the species.

RESULTS AND DISCUSSION

The two areas analyzed presented similar physiognomic characteristics such as the presence of lianas that dominate a certain area, preventing the development of other species, especially those in the understory, leaving herbaceous and arboreal canopy species. However, there are peculiarities, in area 1 there is evidence of traditional logging causing canopy opening; Area 2 is close to the creek, where the tide invades the soil twice a day, determining part of the gene flow and dynamics in the ecosystem.

The floristics found in the two sampled areas are composed of 31 species distributed among timber and multiple-use (wood, fruits, seeds and hearts of palm). By highlight of economic importance, the main exclusively timber companies are: *Virola surinamenis*, (ferrule); *Symphonia globulifera*, (Ananin); *Vatairea guianensis*, (Faveira); The multiple-use ones are: *Euterpe oleracea*, (açai); *Carapa guianensis*, (andiroba); *Hevea brasiliensis*, (syringe); *American Genipa*, (genipap) and *I think it's a really good time to have a good time*. (Buriti).

In the first hectare (Table 1), 22 species were found, and are presented according to the highlight of the phytosociological importance value index (IVI) below:

TABLE 1: Species and phytosociology in 1 ha of floodplain, area 1 on Conceição Island, Santa Bárbara do Pará, Pará State, Brazil.

Scientific Name	N	G m ²	DR	FR	DoR	IVI %
<i>Euterpe oleracea</i>	1758	9,56	87,33	4,55	31,89	41,26
<i>Pterocarpus officinalis</i>	60	10,77	2,98	4,55	35,93	14,48
<i>Symphonia globulifera</i>	24	2,45	1,19	4,55	8,17	4,64
<i>Hevea brasiliensis</i>	28	1,11	1,39	4,55	3,72	3,22
<i>Virola surinamensis</i>	11	1,24	0,55	4,55	4,14	3,08
<i>Carapa guianensis</i>	25	0,73	1,24	4,55	2,45	2,75
<i>Pachira aquatica</i>	12	0,60	0,6	4,55	2,01	2,38
<i>Licania blackii</i>	13	0,55	0,65	4,55	1,83	2,34
<i>Pentaclethra macroloba</i>	14	0,50	0,7	4,55	1,68	2,31
<i>American Genipa</i>	4	0,60	0,2	4,55	2,00	2,25
<i>Macrolobium angustifolium</i>	13	0,33	0,65	4,55	1,11	2,10
<i>Licania longistyla</i>	10	0,23	0,50	4,55	0,79	1,95
<i>Licania heteromorpha</i>	9	0,16	0,45	4,55	0,53	1,84
<i>Swartzia racemosa</i>	5	0,19	0,25	4,55	0,66	1,82
<i>Vatairea guianensis</i>	5	0,19	0,25	4,55	0,64	1,81
<i>Chamaecrista adiantifoli</i>	6	0,17	0,30	4,55	0,58	1,81
<i>Xylopia nitida</i>	6	0,11	0,30	4,55	0,37	1,74
<i>I think it's a really good time to have a good time.</i>	1	0,15	0,05	4,55	0,52	1,71
<i>Mora paraensis</i>	2	0,14	0,10	4,55	0,50	1,71
<i>Platymiscium trinitatis</i>	4	0,04	0,20	4,55	0,14	1,63
<i>Licania macrophylla</i>	2	0,07	0,10	4,55	0,24	1,63
<i>Sterculia speciosa</i>	1	0,02	0,05	4,55	0,10	1,56

Where: N = number of individuals; G = basal area; DR = relative density; FR = relative frequency; DoR = relative dominance; IVI = importance value index. Source: The authors.

Regarding the number of individuals, there is a wide dominance of *Euterpe oleracea* in relation to the other individuals of the other species, because this species occurs in clumps (several stems with a high concentration of shoots) and for production purposes, each stem is the source of several fruit clusters, from this perspective that each stem was considered as an individual. For the other species, *Pterocarpus officinalis* stands out in second position with 60 individuals, followed by *Hevea brasiliensis* with 28 individuals. Species of notorious appreciation in the timber market, such as *Carapa guianensis*, *Symphonia globulifera* and *Virola surinamensis*, occupied the fourth, fifth and ninth positions, respectively, in relation to the number of individuals.

Regarding the basal area, a parameter related especially to timber species, *Pterocarpus officinalis* was the most prominent, followed by *Euterpe oleracea*. In relation to the first species, this is not a kind of market, but at the local level for medicinal purposes; in relation to the second species, the basal area is influenced by the high number of stems that can be used in local rustic constructions such as bridges and animal shelters. Regarding the other phytosociological parameters, these species also dominated in positioning, a fact linked exclusively to the high number of individuals.

The importance value index (IVI) for the species *Symphonia globulifera*, *Hevea brasiliensis*, *Virola surinamensis* and *Carapa guianensis* deserve to be highlighted, which shows a good parameter to be considered for the timber management of these species, especially due to the good values presented in relative dominance. Santos and Pimentel (2023), analyzing the volumetric coverage of *Virola surinamensis* from its density in 6 floodplain areas, mention that the species in one of the areas showed good levels of recomposition in abundance and that this may be linked to a moderate exploitation of the species.

The species *Vatairea guianensis* and *Mora paraensis*, appreciable in the timber market, occupied the 15th and 16th positions in phytosociological importance and with only 5 and 2 individuals respectively, becoming information to be considered by silvicultural practices in order to increase their abundance and volumetric potential.

In the second area, the relationship of species and their phytosociological parameters are presented in table 2 below:

TABLE 2: Species and phytosociology in 1 ha of floodplain, area 2 on Conceição Island, Santa Bárbara do Pará, Pará State, Brazil.

Scientific Name	N	G m ²	DR	FR	DoR	IVI %
<i>Euterpe oleracea</i> .	741	3,45	66,64	3,57	10,85	27,02
<i>Pterocarpus officinalis</i>	86	11,49	7,73	3,57	36,08	15,8
<i>Symphonia globulifera</i>	37	2,55	3,33	3,57	8,04	4,98
<i>Avicennia germinans</i>	5	3,43	0,45	3,57	10,77	4,93
<i>Hevea brasiliensis</i>	32	1,85	2,88	3,57	5,82	4,09
<i>Carapa guianensis</i>	39	1,56	3,51	3,57	4,9	3,99
<i>Virola surinamensis</i>	19	1,68	1,71	3,57	5,3	3,53
<i>Licania blackii</i>	18	0,72	1,62	3,57	2,28	2,49
<i>Pentaclethra macroloba</i>	21	0,61	1,89	3,57	1,95	2,47
<i>Swartzia racemosa</i>	14	0,81	1,26	3,57	2,56	2,46
<i>Macrolobium angustifolium</i>	16	0,50	1,44	3,57	1,58	2,20
<i>Licania heteromorph</i>	17	0,29	1,53	3,57	0,93	2,01
<i>Aquatic pachira</i>	10	0,48	0,90	3,57	1,52	2,00
<i>Chamaecrista adiantifoli</i>	7	0,39	0,63	3,57	1,25	1,82
<i>Licania macrophylla</i>	9	0,32	0,81	3,57	1,03	1,80
<i>Coccoloba latifolia</i>	9	0,23	0,81	3,57	0,73	1,70
<i>Gustavia Augusta</i> .	10	0,18	0,90	3,57	0,58	1,68
<i>Vatairea guianensis</i>	4	0,31	0,36	3,57	1,00	1,64
<i>Ficus maxima</i>	2	0,31	0,18	3,57	1,00	1,58
<i>Xylopia nitida</i>	5	0,15	0,45	3,57	0,48	1,50
<i>Ocotea dissimilis</i>	1	0,15	0,09	3,57	0,50	1,39
<i>American Genipa</i>	1	0,07	0,09	3,57	0,24	1,30
<i>Pthecelobium inaequale</i>	2	0,04	0,18	3,57	0,15	1,30
<i>Inga alba</i>	2	0,03	0,18	3,57	0,11	1,29
<i>The Manilkara Siqueli</i>	2	0,03	0,18	3,57	0,11	1,29
<i>Mora exelsa</i>	1	0,04	0,09	3,57	0,13	1,26
<i>Micropholis guianensis</i>	1	0,02	0,09	3,57	0,09	1,25
<i>Platymiscium trinitatis</i>	1	0,01	0,09	3,57	0,03	1,23

Where: N = number of individuals; G = basal area; DR = relative density; FR = relative frequency; DoR = relative dominance; IVI = importance value index. Source: The authors.

In this area, most of the species found in area 1 were found, with the exception of *Sterculia speciosa*, *Mauritia flexuosa* and *Mora paraensis*. In area 2, ten species were found that did not occur in area 1, namely: *Avicennia germinans*, *Coccoloba latifolia*, *Gustavia augusta*, *Ficus maxima*, *Ocotea dissimilis*, *Pthecelobium inaequale*, *Inga alba*, *Manilkara siqueirali*, *Mora exelsa*, *Micropholis guianensis*. With the exception of *Avicennia germinans*, the others did not present high values of phytosociological importance, with the best placed being *Coccoloba latifolia* followed by *Gustavia augusta* with 1.70 and 1.68 % respectively.

It is noteworthy as an interesting fact the lower concentration of *Euterpe oleracea* (the açai) with only 741 individuals in relation to the first area, a fact that may be conditioned by the presence of the species *Avicennia germinans* because its root system dominates a wide area making it difficult

for other species to germinate and also by the tidal water that invades the soil carrying part of the seeds of the (açai). *Avicennia germinans*, popularly known as ciriúba, despite the low number of individuals, had a high basal area, relative dominance and the fourth best index of importance value, facts linked to its good diametric development. This is information that constitutes good data for the economic management of the species.

The timber species *Symphonia globulifera*, *Hevea brasiliensis*, *Carapa guianensis* and *Virola surinamensis* had an increase in the number of individuals and consequently higher values for phytosociological parameters, keeping them in the first positions. Santos *et al.* (2014) cite in their study these same species as well represented numerically and with possibilities of economic use.

It is notorious in both areas that species of market timber potential such as *Vatairea guianensis*, *Ocotea dissimilis*, *Manilkara siqueirali* and *Mora exelsa* occurred in low densities, basal area and phytosociological representation, this denotes the need to adopt silvicultural practices in order to favor their development, especially with regard to the number of individuals and commercial volume.

Comparing the species found to those of other studies, Arina *et al.* (1998) mentioned that the possession of the resource is a conflicting factor because there is little incentive in programs for the management of wood and açai trees in the floodplains and the lack of guarantees that the products will not be extracted by other people. The authors add that normally the "possession" of the land is based only on many years of occupation and when the areas are in the interior of the state, the lack of documentation is accentuated, due to the lower value of the land. Considering this reality, a good part of the floodplain areas functions only as a generator of resources, yielding to overexploitation mainly of wood and the heart of palm of açai, causing the fragmentation of vegetation, reduction of species that generate food and income.

The fragmentation of the floodplain vegetation as a result of the non-use of sustainable practices for the extraction of resources, leads to the fragility of the environment and the multiplication of poverty in the riverside environment. Jardim *et al.* (2004) stated that in the Amazon estuary the process of forest fragmentation affects plant populations, causing a decrease in population density, especially of timber and/or extractive species, this is a considerable change in the local floristic composition. The authors pointed out that proximity to the consumer center may or may not be a factor that contributes to fragmentation, depending on the resource demanded. Santos and Jardim (2006), based on information from local residents, cited that due to the advent of the exploitation of the heart of palm in the floodplains of Santa Bárbara do Pará, there were changes in the physiognomy of the forest. According to Scipioni *et al.* (2012), the variation in forest diversity and structure is dynamic and constant, sometimes slow and natural, but also harsh when there is human intervention without adequate management, and can assume different proportions.

According to Anderson and Jardim (1989), when there are some management practices such as planting fruit trees, girdling undesirable species, favoring others of an economic nature and thinning, this leads to satisfactory and sustainable economic returns. In the case of the floodplain on the island of Conceição there are several species that, if well managed and marketed at a fair price, can promote the income of local residents, they are: *Euterpe oleracea* (açai), *Symphonia globulifera* (ananin), *Hevea brasiliensis* (rubber tree), *Carapa guianensis* (andiroba), *Virola surinamensis* (virola/ucuuba), *Genipa americana* (genipap), *Mora paraensis* (pracuuba), *Vatairea guianensis* (faveira) among other species.

For the adoption of proper management, it is necessary before any decision making, the knowledge of what is intended to be managed and to outline the objectives well. For the timber and non-timber resources of the floodplain, the primary tool is the floristic survey. Thus, the floristics found in this study, in general 32 species, are in line with several studies carried out in the Amazon estuary, such as Santos and Jardim (2006), which found 31 species in one of the inventoried hectares; Ferreira et al. (2005), studying 1 hectare in flooded areas (igapó and floodplain), found 30 species in the igapó and 19 in the floodplain, considering half a hectare (0.5 ha) in each type of environment, about the greater richness in the igapó forest, the authors stated that it was conditioned to the geological origin of the two types of forests; Almeida et al. (2004), analyzing areas of different floodplains, both of 1 ha, found a variation between 36 and 78 species and pointed out that this variation in the number of species may be conditioned by flood height, soil erosion and salinity content; Queiroz et al. (2005), studying 1 ha of high floodplain with an inclusion level of 5 cm DBH or more, found 69 species and reported that the patterns of floodplain use influence the floristic composition.

According to Venzke et al. (2012), the low richness in flooded areas is conditioned by the ability of species to germinate and develop in high water saturation soils, being one of the main factors that act in natural selection regarding the occurrence and colonization of species in these environments. Santos and Jardim (2004), reported to species richness a variant dependent on environmental variation, such as soils with a high level of saturation, where only adapted species can survive and dominate the landscape, however, they emphasized that there are several adaptive mechanisms. Ferreira et al. (2005) commented that in flooded areas the maintenance of biodiversity is conditioned by physical and biological factors, especially hydrological cycles and sedimentation. Ferreira (2000) stated that the richness of tree species in the flooded areas of the Amazon is influenced by soil types, duration of the flood period, flood tolerance, erosion and sedimentation. Carim et al. (2008) mentioned that in the floodplains the soil fertility imposes intrinsic restrictions at the biotic and abiotic levels for their occupation.

Here in this study, the environmental factors that are possibly acting in the maintenance of floristic diversity are topographically low areas, flood height, flood time, efficient adaptation mechanisms, highly adapted reproduction mechanisms for some species and even anthropic factors such as tree cutting. Regarding the highly adapted adaptation and reproduction mechanisms, Santos and Jardim (2004) mentioned that the Leguminous and Arecaceae families harbor several species with this profile.

The environmental characteristics and others resulting from human action, such as fruit collection, logging and empirical management attempts, have contributed to the forest dynamics as well as to the possibilities of management in the floodplain areas of the Amazon, especially in relation to those species of economic value. In this study, the species of economic potential with the highest phytosociological importance value (IVI) indexes, between the two areas, were: *Euterpe oleracea*, *Symphonia globulifera*, *Hevea brasiliensis*, *Carapa guianensis* and *Virola surinamensis*, the result of the combination of density, frequency and dominance, where especially dominance suffers direct effects from the number of individuals and the basal area, which makes these species strong income potentials whether timber or non-timber. Other studies in the Amazon have confirmed the same species among those with greater phytosociological expressiveness (JARDIM and VIEIRA, 2001; SANTOS et al., 2004; QUEIROZ et al., 2005; QUEIROZ and MACHADO, 2008; ALMEIDA and JARDIM, 2011; BATISTA et al., 2011).

For these species, the concentration of individuals, the basal area and the other phytosociological parameters indicate good possibilities for the adoption of sustainable management, requiring the application of silvicultural treatments in relation to timber species in order to increase their basal areas and consequently the volumetric potential. Queiroz and Machado (2008) found in areas of low and high floodplain, good phytosociological indices for the species *Euterpe oleracea*, *Carapa guianensis* and *Virola surinamensis*, emphasizing that these have a good capacity to adapt to the environment, influencing their densities. Gama et al. (2005) found that these same species and also *Hevea brasiliensis*, *Symphonia globulifera*, *Licania heteromorpha* and *Vatairea guianensis* were reported at high densities and frequencies, calling attention to the existence of adaptability mechanisms. Maués (2006), studying the reproduction strategy of some species in the Amazon, mentioned that *Symphonia globulifera* has a reproduction mechanism and adaptability favored by the dispersion of its fruits, either by birds still in the tree canopy or by mammalian animals. This justifies the good values of the number of individuals, relative density and value of phytosociological importance found in this work, which would facilitate its management for conservation or economic production purposes.

Jardim and Vieira (2001) cited *Euterpe oleracea* as dominant in the floodplain environment, with emphasis on its relative density, which is more than 50 % of the individuals when compared to

individuals of other species, and this advantage is a function of environmental and structural factors such as luminosity, soil nutrients and tillering capacity. This information was proven here in this study, which makes this species a high potential for sustainable management, new business and income generation. Almeida et al. (2004) cited *Euterpe oleracea*, *Hevea brasiliensis* and *Virola surinamensis* as the ones that contributed the most to 51.94% of the individuals inventoried.

Santos et al. (2004) highlighted *Euterpe oleracea*, *Virola surinamensis*, *Hevea brasiliensis* and *Carapa guianensis* as outstanding species in density, frequency, dominance and importance value, however, they stressed that the simple availability of the natural resource, in itself, is not attractive, it is necessary to use technologies for market purposes. In the case of the floodplains analyzed here in this work, it is understood as technologies for species of phytosociological prominence, management technologies, especially those of community forest management, as these can offer a product in better quantity, quality and competitiveness in the market, without depleting resource stocks.

Mota et al. (2001) cited *Virola surinamensis* as having high concentrations in floodplains and igapó in the Amazon and of recognized economic value through the oil of the seeds and wood, the authors emphasized that the pressure on this species has led to investment in research, especially on conservation and management. One of these pieces of information is the use of phytosociology that informs patterns of structural behavior as seen here in this research, which showed for this species a good development, easy adaptability to the environment and that, if added to other studies such as market research, can strengthen conservation practices and economic management.

Pinã-Rodrigues (2000), analyzing the exploratory process of *Virola surinamensis* populations, showed that the unmanaged activity affected the productive system of the riverside dwellers and showed that the stocks vary according to the practices to which they are submitted. The author mentioned that in the low floodplain high densities of ferrule were found, but with a small commercial volume, she also stressed that it is necessary to define control, protection and technical parameters in the evaluation of impacts. The density found in this research is in agreement with what was reported by the author and the basal area also suggests the concentration of individuals with low volumetry, requiring attention from silvicultural interventions. Santos and Pimentel (2023) reported that extractive logging of ferrule wood without management results in a decrease in the volumetric stock.

Gama et al. (2002), when analyzing structural and floristic patterns in a floodplain environment, cited among other species, *Euterpe oleracea*, *Symphonia globulifera*, *Gustavia augusta* and *Virola surinamensis* among those of greatest importance in biocenosis, they also mentioned *Hevea brasiliensis*, *Licania macrophylla* and *Inga alba* As potential species for the non-timber market, all these species were found here in the current study. Other species of recognized value in

the market can stand out in quantities and importance, thus, Queiroz et al. (2005) cited *Mora paraenses* in high concentrations and high basal area, calling attention to the ways of using the estuarine environment that interfere in the floristic structure, as well as the attempts at empirical management.

For Queiroz and Machado (2008), empirical management attempts cause a reduction in the number of individuals and changes in the floristic structure, as well as phytosociological. This fact is evidenced by Queiroz et al. (2007) who detected significant reductions in the populations of *Euterpe oleracea* and *Carapa guianensis* because they are the target of local practices aimed at greater quantities for the market. In the present work, such practices were also observed and with the same purpose, especially in relation to species of economic value such as *Euterpe oleracea*, *Symphonia globulifera*, *Carapa guianensis*, *Virola surinamensis*, *Ficus maxima*, *Mora exelsa* among others. It is important to observe the floristic and phytosociological aspects as guidelines for practices related to management, especially for production and marketing purposes.

In this sense, Pereira and Tonini (2012) reported that no action of exploitation of natural resources can be sustainable over time if there is no scientific research on the ecology of species with economic potential and that the sustainability of forest management aiming at the multiple use of tropical forests must have criteria and indicators that guarantee the genetic variability of the species and the processes involved.

Several studies on the ecology of tree species in floodplain environments have been observed, one of them is on *Carapa guianensis*, a species found in high abundance and with good phytosociological importance in this work. Regarding this abundance and floristic importance, Pereira and Tonini (2012) showed that it is related to fruit dispersal (fruit drop) and seed dispersal in the rainy season, with germination and seedling establishment benefiting from soil water and organic matter. Another important observation in the abundance of this species is, according to Maués (2006), the dispersion carried out by tidal water, especially in low areas where the water reaches the base of the producing plant. This is an event that occurs daily in the place studied and that possibly has fundamental importance in the establishment and adaptation of this species.

In these terms, the floristic survey and the phytosociological analysis of the tree component linked to the knowledge of the autoecology of the species, serve as good indicators for the adoption of good management practices in floodplain environments, whether for the purposes of species conservation, income generation and also, especially for the sustenance of riverside populations. It is important to emphasize that when the economic maintenance of lowland families is desired, it is also important to consider the hidden, parallel or underground economy and, on this subject, Postea and Achim (2023) postulate some methods for evaluating the participation of this economy in a more systemic context.

CONCLUSIONS

The floodplain studied has an abundance of several species of local, regional, national and international economic prominence and that exert phytosociological relevance, indicating aptitudes for timber and non-timber management, requiring the effective participation of the local government as a facilitator of the production process.

The basal area values of timber species indicate that the adoption of management, if there is an interest in boosting commercialization by extractivists, should include silvicultural treatments in order to increase both the quantitative and qualitative volumetric potential of these species.

Among the fruit-producing species, the açai *Euterpe oleracea stands out* as highly promising for management, justified by the high occurrence of palm trees, in order to increase the production and quality of the fruits. Following the same reasoning, the management of the andiroba *Carapa guianensis* is recommended, as the oil of its fruits is medicinal and of high marked value.

Floristics and phytosociology are suitable as preliminary tools for the analysis of forest populations, providing current information on the dynamic state and serving to assist in the definition of management practices aimed at the conservation and use of species.

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CEAGESP in the far west of the state of São Paulo as an integral agent of the horticultural productive spatial circuit

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ABSTRACT

The Companhia de Entrepasto e Armazéns Gerais de São Paulo (CEAGESP) was created in 1969, currently has the largest public network of warehouses in the State of São Paulo and a complex of 13 wholesale units, being a mixed economy company linked to the Ministry of Agriculture, Livestock and Supply (MAPA). The objective of this work is to analyze the three units of the Companhia de Entrepasto e Armazéns Gerais de São Paulo (CEAGESP), namely: Araçatuba, Presidente Prudente and São José do Rio Preto and their spatial circuit of fruit and vegetable production. The analyses were undertaken based on the notion of spatial circuits of production, developed by Milton Santos in 1986. To achieve the objectives of the investigation, documentary and bibliographic research was carried out on technical objects, supply centers and horticultural productive spatial circuits and data collection in publications of the National Supply Company (CONAB), in addition to CEAGESP itself.

Keywords: CEAGESP, Supply, Fruit and Vegetables, Space circuits.

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INTRODUCTION

This work was prepared for the discipline: Socio-spatial formation, productive circuit and hybrid regulation of the territory, of the Graduate Program in Human Geography, Faculty of Philosophy, Letters and Human Sciences of the University of São Paulo, which we attended as a special student.

The work was configured in a text about the horticultural productive spatial circuits, which permeate the Companhia de Entrepósito e Armazéns Gerais de São Paulo (CEAGESP), that is, the supply centers of the west of São Paulo as a technical object and their respective productive spatial circuits, the objective of the work goes through three units of CEAGESP in the interior, namely: Araçatuba, Presidente Prudente and São José do Rio Preto and their spatial circuit of fruit and vegetable production, which was the object of research of the master's degree and gave rise to a dissertation and is currently part of the object of research for the subsequent elaboration of a doctoral thesis.

It was after the Second World War that the advent of the technical-scientific-informational environment took place, which established the computerization of the territory, the connection between agricultural activities and scientific knowledge in Brazil, giving rise to the new locations of industries, agro-industrial expansion, globalized scientific agriculture and modernization of transport, although the technical-scientific-informational environment was only instituted in 1970. The emergence of supply centers also occurred in the 1970s in Brazil, through an initiative of the federal government, their function was to facilitate the connection between primary producer and final consumer and regulate the prices of fruit and vegetable products.

The work was configured in a text containing introduction, methodology, theoretical framework, results and discussion and final considerations. In the theoretical framework, the concept of space used in the text is addressed, as well as the elements that constitute it, such as fixed and flows, the notion of technical object, the advent of the technical-scientific-informational environment and the innovations derived from it; In the Results and Discussion section, the emergence of supply centers and their relationship with globalized scientific agriculture, derived from the technical-scientific-informational environment, were analyzed; in addition to the concept of cooperation circle and the spatial circuits of production linking both to the supply centers.

METHODOLOGY

The work was configured in a text about the spatial productive circuits, constituting as a technical object the supply centers of the far west of São Paulo and their respective spatial productive circuits, the objective of the work lies in the units of the Companhia de Entrepósito e Armazéns Gerais de São Paulo (CEAGESP) in the interior and its spatial circuit of horticultural production.

For the development of the work, the theories of Milton Santos were used, that is, the concept of technical-scientific-informational means developed in the works of 1986; 1996 and 2006; the theory of spatial circuits of production in the works of the same author in 1986, as well as in the works of Milton Santos and Maria Laura Silveira, 2001; the authors were also used for the discussion of productive spatial circuits and circles of cooperation: Raimundo Edson Pinto Botelho and his 2010 dissertation and Ricardo Abid Castillo and Samuel Frederico, with the 2010 work.

For the discussion of technical objects, as well as their definition, the works of Milton Santos, entitled "The Nature of Space", from 2006 and Gilbert Simondon with his work "El modo de existência de los objetos técnicos", from 2007, were used.

For analysis, contextualization and discussion about the supply, the 1979 work of Maria Yedda Leite Linhares and Francisco Carlos Teixeira da Silva, the 2014 thesis of Danton Leonel de Camargo Bini and the 2012 article by Viviane Vedana were used.

For the discussion about supply centers, as well as their definition and historical contextualization, the dissertations of Thiago Augusto Nogueira Queiroz and Larissa Oliveira Dionisio, respectively 2014 and 2021, were used.

A survey of documentary data was also carried out in publications of the National Supply Company (CONAB), in addition to the Company of Warehouses and General Warehouses of São Paulo (CEAGESP).

THEORETICAL FRAMEWORK

Space is made up of distinct flows, of varying levels, which can be slow or agile, with greater or lesser efficiency, according to Santos (1994), global space is made up of flows and objects, which its scale, both material and immaterial, is greater, thus establishing evidence of a higher innovation. It will be from the technique that the relationship between man and the environment will take place, the techniques constitute social resources that will allow both to realize life and to create space.

Material and immaterial flows have gained more importance since the First Industrial Revolution, between the eighteenth and nineteenth centuries, integrating fundamental elements of the production process, an example is the exchanges and exchanges that occurred between places, as well as the development of technical objects.

The technical object is part of a whole, dealing with a continuity in time and space, aggregating its historicity and transformations throughout its historical context, that is, "the technical object is that which is not prior to its becoming, but is present in each stage of this becoming; the technical object is a unit of becoming" (Simondon, 2007, p. 42). The author also mentions the industrial objects that hold the power to shape a civilization, in contrast to abstract technical objects

that promote the possibility for the emergence of other objects, not being fundamentally essential, being in a system of requirements.

Therefore, technical objects can be divided, as well as converge in their definition, and can vary between abstract technical objects at their beginning, transforming themselves into industrial technical objects, as Simondon (2007) points out, constituting a unified and coherent system. It is necessary to highlight that there was and is inequality in the dissemination of techniques, "in the same piece of territory, differently dated technical subsystems coexist, that is, technical elements from different times." (Santos, 2006, p. 25). The author also delimits that the arrangements of technical systems need to be adequate to their various parts that constitute it, otherwise there would be no effectiveness in the system.

In the case of Brazil, it is from the 1960s onwards that the regions begin to demonstrate significant differences, in which the Southeast becomes more modernized, with a more salient urbanization process; in the 1980s, the Southeast region became preeminent compared to the others, Santo (2005) points out that the distinction between urbanization rates is proportional to the division of labor that occurred in the regions, that is, the difference lies in the way they were affected by the inter-regional division of labor. Therefore, material and social innovations correspond to the expansion of the development process.

With regard to the social division of labor, according to Arroyo (2012), São Paulo was of fundamental importance, because it promoted the expansion of economic activities, as well as concentrating public and private investments, while such economic activities accelerated the construction of engineering systems, which served as a material base. The new relations between city and countryside influenced the development of the metropolis, according to Santos (2008), through the combination of the agglomeration added to the city-field and interurban relations inherited by São Paulo, there was the development of this into a metropolis of metropolises.

The dynamics between the South and Southeast regions were different from the other regions, because their urban networks were more advanced, demonstrating a process of acceleration of the territorial division of labor through the interaction between the cities, there was a broad incentive to reach another level of the international division of labor, incorporating the area designated by Santos (2005) as a concentrated region.

With the accelerated propagation of information, promoted by the technical-scientific-informational environment, there was an increase in local productivity, it is from the functional specialization of the subspaces that there was a tendency to create a more homologous creation of everyday life, Santos (2006) points out that this occurred through the interdependencies that are constituted horizontally, in the case of cities, this specialization is visible in the industrial production

or services, In the countryside, some areas turned to the production of one or more agricultural products.

There are areas where the production of a certain product is more profitable, which gave rise to the need for greater exchange, according to Santos (2006), this expanded the circulation of goods and people between different states and regions, since productive specialization allowed the regions not to need to produce everything for their subsistence, that is

Before this possibility, most regions produced almost everything they needed for their reproduction; almost everything was produced everywhere; people lived practically in autarchies. Today, we are witnessing the functional specialization of areas and places, which leads to the intensification of the movement and the growing possibility of exchanges. That is why not only large cities, but also medium-sized cities are growing. The greater the insertion of science and technology, the more a place specializes, the more the number, intensity and quality of the flows that arrive and leave an area increases (Santos, 1988, p. 57).

From the modernization of transport, there was a greater connection between the command centers, allowing some stages of agricultural production to be spatially dispersed, as Silva (2013) points out, the modernization of transport was relevant because it provided the spatial ramification of fruit and vegetable production, since it would be deciphered from the perspective of the territorial division of labor, even if it added stages to which production passes until it reaches the thin consumer, resulting in an increase in the value of the product.

RESULTS AND DISCUSSION

FOOD CRISES AND THE CREATION OF SUPPLY CENTERS

According to Santos (2006), a technical object can be one or more artificial elements, as well as one or more natural elements, if the use intended for these elements is considered, Simondon (2007) points out that it is difficult to define the genesis of all technical objects, since their individuality changes in the course of their trajectory, distinguishing only in abstract and concrete technical objects, Although for the author concrete objects, because they are further away from nature, are more perfect, since they allow a more efficient human dominion over them, constituting themselves more perfect than nature itself, however "each time the object is inserted in a set of objects and its operation is included in a set of operations - all of this forming a system - the hypertelia of the concrete technical object becomes conditioned" (Santos, 2006, p 23), in the same way, technical objects must be studied together with their surroundings, since space is formed by objects, however, it is space that determines and organizes objects, that is,

It is the space that redefines technical objects, despite their original vocations, by including them in a coherent set where contiguity obliges them to act together and in solidarity. This discussion must be approximated to Simondon's idea of *naturalization of the concrete object*, that is, its complete imimisation in the environment that welcomed it, which he calls the

process of adaptation-concretion. It is in this way that what he will call a technogeographic environment is created. This technogeographical environment is only possible, in his view, by virtue of man's intelligence and always suggests the presence of an inventive function of anticipation. This anticipation is not found, he says, in nature, nor in the technical objects already constituted (1958, 1989, p. 56).

In reality, according to Simondon, it would not be a simple addition of the technical environment to the natural environment, but the production of something else, in such a way that the technical object appears as a condition for the existence of a mixed environment, which is technical and geographical at the same time, (p. 55). This is what Simondon will call *the associated medium*. Simondon's proposal should help us to construct an adequate notion of geographical environment, previously as a technical environment and now as a technical-scientific-informational means. (Santos, 2006, p 24).

The technical-scientific-informational environment was responsible for the computerization of the territory, through investments in infrastructure, Santos (2005) points out that it is in this period that information expands and becomes instantaneous, objects are endowed with informational content and space gains fluidity due to the integration of the territory, which culminates in production gaining mobility. It is from the technical-scientific-informational environment that the circles of cooperation will have a broader action, according to Santos and Silveira (2006), the circles of cooperation are incorporated on broader geographical scales, with a wider degree of complexity, resulting in more selective and intense flows, but it is the circulation that regulates production.

However, until the 1960s, food crises were frequent, even though there had been a process of industrialization and urbanization accentuated in the 1950s, this only culminated in the worsening of these crises. In Brazil, there were three major crises that resulted in the adoption of measures by the State, aimed at restructuring, they were: the crises of 1910, 1937 and 1962.

The first crisis in 1910 was the result of obstacles in the circulation of food transport to large urban centers, Queiroz (2014) points out that as a measure adopted to overcome this crisis, there was the emergence of the Public Food Commissariat in 1918, which became the Superintendence of Supply, in addition to the practice of minimum price policies.

There was a reduction in time and costs provided by the modernization of the transport of goods and people, also resulting in production, since an area would no longer need to produce everything for its maintenance and subsistence, as mentioned above, Harvey (2004) points out that this would provide adjustments in both production and consumption, although, as Santos (1988) points out, the reduction in transport time and costs did not cause an increase in quality, nor diversity and quantity.

The second crisis, which occurred in 1937, was due to the economic crisis of 1929 that affected several global sectors, according to Linhares and Silva (1979), the measure adopted by the federal government was the advent of the Regulatory Commission for Tariffs, whose function was to analyze the food markets, as well as their prices, inspecting the quality and quantity of production.

The third crisis of the food system occurred in 1962, also a result of circulation, differing from the first no longer by the problem of transportation, but by the obstacle of products reaching

consumers. It should be emphasized that from the 1970s onwards, there was a significant advance in science and technique, as evidenced by Santos (2005), this advance took place in the process of integration of the territory, marking the establishment of the technical-scientific-informational period in the remodeling of the territory, since the territory would be used to facilitate circulation, as well as information would be a driving agent of the social process.

Therefore, with the food crises, the federal government intended to institute a new organization to facilitate the commercialization of fruit and vegetable products, at the end of the 1960s, through the implementation of logistical marketing platforms, the State Supply Center Sociedade Anônima (CEASA) was established, but it was only in the 1970s that the model began to be implemented on a large scale. The advent of the technical-scientific-informational environment and the faster dissemination of information allowed an increase in local productivity, also resulting in the specialization of areas, so the regions would no longer need to produce everything for their own subsistence.

Linhares and Silva (1979) point to the emergence of the Brazilian Food Company (COBAL), the Brazilian Storage Company (CIBRAZEM) and the National Supply Superintendence (SUNAB) in the 1960s and 1970s. According to Hespanhol (2010), State intervention was essential for underdeveloped countries after 1945, with the end of World War II, however the objective was not to offer basic public services to the population, but to favor the process of economic expansion, which ended in the early 1970s, with the emergence of the oil crisis. Queiroz (2014) points out that the food crisis was intensified by the oil crisis that had a global impact in 1973.

According to Linhares and Silva (1979), the third supply crisis resulted in the creation of supply centers during the 1970s. Silveira (2010) points out that the informational technique promoted the constitution of a technical system with a tendency to uniqueness, in addition to providing the circulation of information inherent to the way of working, enabling the movement of speculative money in large quantities.

As mentioned above, at the end of the 1960s, the federal government, aiming to regulate and organize the commercialization of fruit and vegetable products, through logistical marketing platforms, created the State Supply Center Anonymous Company (CEASA), however its large-scale implementation only took place in the 1970s. The Company of Warehouses and General Warehouses of São Paulo (CEAGESP) emerged from the merger between the State Supply Center (CEASA) and the Company of General Warehouses of the State of São Paulo (CAGESP) in 1969, the two companies were state-owned and São Paulo, the objective of both was to store grains and sell fruit and vegetable products.

In the 1990s, there were privatizations and the reduction of the presence of the federal government, the CEASAs became the responsibility of the states and municipalities, remaining so to

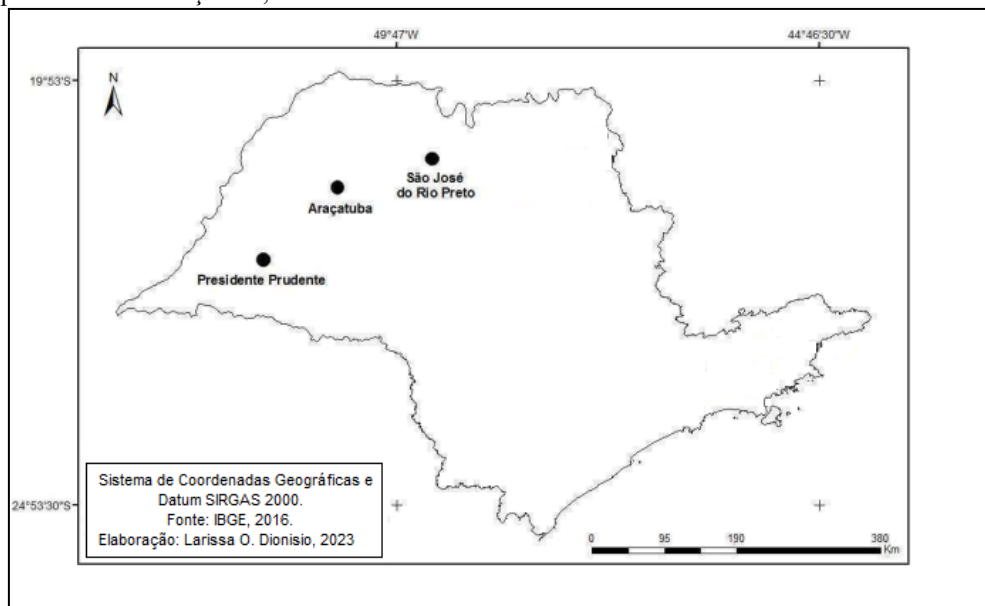
the present day. The exceptions were CEAGESP, in the state of São Paulo and CeasaMinas, in the state of Minas Gerais, which remain federalized.

The supply centers aimed to promote direct commercialization between primary producers and final consumers, however, according to Vedana (2012), both in São Paulo and Rio de Janeiro, a significant part of the commercialization is done by middlemen, Santos (2008) points out that the intermediaries, truck owners or wholesalers, make the connection between demand and supply, which did not occur at the same time as the quantity, nor quality, let alone over time, this placed them in a privileged and strategic position, resulting in speculation, since they were the only ones to have bank credit.

Currently, the main function of supply centers, according to CEAGESP (2022), is to provide an infrastructure so that agribusinesses, wholesalers, cooperatives, exporters, importers, rural producers, and retailers can develop their activities with qualified services, efficiency, and safety. It is also important to highlight that CEAGESP has the largest public network of warehouses and silos, used for the deposit and conservation of agricultural products, in addition to bulk carriers, which are places for the storage of bulk goods.

The CEASAs are important for regulating supply, as they are responsible for the commercialization of a large part of the vegetables, according to Dionisio (2021), in cities in the far west of the state of São Paulo, such as São José do Rio Preto, Presidente Prudente and Araçatuba, according to Map 1, the supply centers supply the fairs significantly, as well as some neighborhood markets and supermarkets, it is also the support of some hypermarkets when there is a lack of vegetables in stock, as is the case of Presidente Prudente, Firetti *et al.* (2011) points out that the supply centers are responsible for supplying industrial kitchens, supermarkets, hotels, penitentiaries, etc.; Bengozi (2007) states that the supply centers also maintain the stability of the quantities sold, constituting an important regulator.

Map 1 – Units of Araçatuba, Presidente Prudente and São José do Rio Preto in the state of São Paulo.



Source: IBGE (2016).

In the Brazilian case, the State was of fundamental importance in the process of economic development, according to Lima and Simões (2010), the activities developed between 1950 and 1980 had very strong State intervention,

The equipping of ports, the construction of railroads and the new forms of the country's participation in the industrial phase of the capitalist mode of production allowed the beneficiary cities to increase their command over the regional space, while navigation, much more important for the outside, only gave rise to a minimum of contacts between the various regional capitals, as well as between ports of importance. In this way, the regency of "natural" time was broken to give way to a new mosaic: a slow time inside the territory that was associated with a fast time outside. This was embodied in ports, railways, telegraphs and mechanized production (Santos; Silveira, 2006, p. 37).

The supply centers also allow greater fluidity in the distribution and circulation of goods, promoting the integration of the territory, making the territory gain a new perspective starting from fluidity, according to Santos and Silveira (2006), due to the possibility of broader production and the circulation of inputs, the territory imposes new behaviors, as well as receives new contents, As information and finance become essential in the space of a country, it becomes a support in all segments of the territory, becoming equal to the market.

PRODUCTIVE SPATIAL CIRCUITS AND CIRCLES OF COOPERATION

With the development, mainly and fundamentally, of transport and communications, material and informational flows were expanded, according to Castillo and Frederico (2010), it was from this increase in flows that the distance between the places of production and consumption gradually occurred, leading different stages of production to different places.

Through the exchange of these flows of objects, the formation of productive circuits took place, which were previously constituted as regional, with the expansion of the demand for these flows, the regional circuits, limited spatially, did not institute a care support between the circles of cooperation and the circuits of production, consequently, resulting in isolation, thus succeeding in the replacement by spatial circuits. According to Joly (2007), the added value occurred through circulation, ensuring spatial selectivity, which, in turn, resulted in the increasing decrease in the importance of regional circuits, culminating in the emergence and expansion of spatial circuits.

One of the factors that made it possible to replace regional circuits with spatial circuits was the limitation of the former with regard to scientific content in its production process, Botelho (2010) points out that both the fluidity of the flow and the command and information were unsatisfactory, which ended up restricting production to a local scale and horizontally, turning only to commerce.

Another essential fact was globalization, since it influenced and expanded the productive spatial circuits, as well as the circles of cooperation, according to Elias and Pequeno (2007), the city-country relations became more complex proportionally to globalization, that is, the more globalized, the more heterogeneous the relations, so a new arrangement of the urban system occurred, resulting in a new articulation of the territory. With the increase in the number of medium and small cities, fundamental places for the proliferation of globalized agribusiness, there was an expansion of the so-called "agribusiness city" that resulted in social exclusion and socio-spatial inequality.

Through the replacement of regional circuits by spatial circuits, there was a greater intertwining between different regions, Santos and Silveira (2006) point out that this intertwining resulted in the articulation of production processes. Although it also fostered a more divergent territorial division of labor, which was fundamental for the emergence of new forms of cooperation and control over the scales.

It is from the existence of cooperation circles that productive specialization originated, according to Antas Jr. (2014), industrial firms were able to overcome dependence on local and regional demands, that is, productive specialization depends on the so-called cooperation circles, since their formation

[...] It belongs to the logic of capitalist production itself, and they are often identified with public (state or autarchy) and private institutions in the creation of spatial contexts that stimulate cooperation between different productive agents. Here we argue that, in addition to these two legal figures, the organizations of certain social groups also end up stimulating production, by claiming certain rights. Although it is secondary in their struggles, this effect on the expansion of cooperation cannot be ignored, given the strategic importance it assumes in the current period, especially due to the volume of production it engenders (Antas Jr., 2014, p. 39).

It is a fact that circulation is fundamental in the production process, so that, according to Catillo and Frederico (2010), the indispensable element to analyze the flows of the productive

circuits is logistics, because it assimilates the different stages of the production process, covering scales from the local to the global, while each place contains different stages of the spatial circuits of production, which provides the identification of the hierarchy between places, as well as their temporality. The spatial circuits of production still have an influence on the reduction of time, although, as Joly (2007) points out, different ways of traveling distance are not proportional to the necessary reduction of time, however access to the ways of traveling distance is restricted, demonstrating a type of hierarchy organized through the uses of these systems.

Productive specialization has provided different spatial circuits with divergent degrees of production. Bini (2014) points out that the products organized from the most modern space circuits are mostly directed to the international market or to more elite markets in metropolitan regions, as products whose space circuits are not so modern can be captured by other markets before being sold in the producing region, which raises the price and makes it difficult for the lower-income population to access the products.

The technical-scientific-informational environment promoted the incorporation of cooperation circles on a larger geographical scale, Santos and Silveira (2006) point out that the technical-scientific-informational environment increased the complexity of the cooperation circles, which began to command production, making the flows more selective and with greater intensity. The productive spatial circuits, as well as the circles of cooperation, have facilitated the analysis of the hierarchy of places at different scales, from regional to global.

According to Catillo and Frederico (2010), both the circle of cooperation and the spatial productive circuits allow the understanding of the interdependence of the productive spaces, as well as the understanding of the circularity and uniqueness of the movement, distinguishing the phases of production, thus promoting their understanding, while the spatial circuits of production are based on the concept of centrality of circulation and the spatial relationship of the different stages of production. The circles of cooperation are based on the relationship between agents and places through information flows, constituting fundamental elements in the connection of the different stages of the productive process that are separated and distributed spatially, organizing various agents and places that integrate the spatial productive circuits.

The two authors also scrutinize the two concepts, differentiating them as: the circles of cooperation are based on communication, that is, demonstrated by immaterial flows, which provides the organization of both places and agents distributed geographically; Spatial circuits of production, on the other hand, have the particularity of the flows of materials disseminated in instances with continuous movements, that is, production, distribution, exchange and consumption, and with geographical differentiation.

Catillo and Frederico (2010) also mention that it is through cooperation circles that there is the overcoming of the territory, made up of financial agents and international companies, and effective logistics is essential, given the expansion of spatial production circuits, while there is a vast grouping of regions and agents integrated in spatial circuits, and it is crucial to establish norms that facilitate and systematize the circulation of goods, Bini (2014) points out that this vastness can bring disadvantages, so that the wider circuits have steps, often unnecessary, which will result in greater expenditure of time and space, causing an increase in the final price of a product.

The above premise can be analyzed in the case of São Paulo, since many vegetables pass through the CEAGESP unit in São Paulo before being relocated to the warehouses in the interior, even if their origin is the municipalities in the interior themselves, demonstrating an illogical double circulation, in the same way that, according to Castillo and Frederico (2010), There is a hierarchy in the spatial productive circuits in which those who command circulation and create a movement of production are the true holders of power.

CEAGESP organizes and participates in the spatial circuits of production, as its function is to facilitate access to horticultural products, consequently establishing a connection between consumers and producers, according to Santos and Silveira (2006), CEAGESP regulates the circulation of goods through the issuance of *warrants*³ and storage time, which directly interferes in the spatial circuits of production and in the cooperation circles.

The integration of a market in a territory is essential, according to Santos and Silveira (2006), this would guarantee the frequency of both industrial and agricultural production, so it is through a territory that the distribution and consumption circuits are carried out, as an example, the two authors use the case of the supply centers, CEASA, which were spread over twenty states of the Federation, in the 1970s, according to data from CONAB (2017), supply centers are now distributed in twenty-seven states of the Federation.

In addition to constituting an agent of the spatial circuit of fruit and vegetable production, the supply centers are also responsible for intermediating the relationship with the two circuits of the urban economy. According to Dionisio (2021), supply centers are part of the circulation process, resulting in the integration between the two circuits of the urban economy. Sposito (1999) defines that the upper circuit includes activities that benefit from more advanced technologies and more abundant capital, such as the storage of products and the workforce; according to Santos (2008), the lower circuit, on the other hand, has simpler activities, such as traditional manufacturing, provision of services, handicrafts and traditional transportation.

CEAGESP in both Araçatuba, Presidente Prudente and São José do Rio Preto are essential for supplying the lower circuit of the urban economy, according to Dionisio (2021), the lower circuit

³ "Special Credit Securities that enable the financing of inventories of stored products" (CEAGESP, 2021).

comprises fairs and small markets as integral agents of this circuit, the study demonstrated absolute dependence on CEAGESP units in the interior for activities that are part of the lower circuit, in the three municipalities studied. The upper circuit, on the other hand, would comprise supermarkets and hypermarkets, which do not have so much dependence on these warehouses, occasionally using them when something is missing from stock.

Distribution has a relevant participation when analyzing the production process, Marx (2008) emphasizes that distribution is integrated between product and producer due to social laws, not being an inert process, while through circulation and distribution the emergence of circuits occurs, even if production reproduces consumption, being part of the production process. Therefore, supply centers are part of the spatial circuits of fruit and vegetable production, since they are used for the distribution of fruit and vegetable products from different regions, as well as establishing the relationship between final consumers and primary food producers, as well as their respective distributors. By understanding the integration between the productive spatial circuits and the theory of the two circuits, it is possible to scrutinize the social implications generated in the circulation, distribution and trade that a given product obtains, while this results in a differentiated structuring of space.

FINAL CONSIDERATIONS

The supply centers were created in the 1960s and 1970s, in response to the food crises that occurred in the twentieth century, their purpose was to solve distribution problems and facilitate access to fruit and vegetables, as well as facilitate circulation. Over time, these centers were restructured, becoming important for the supply of Brazilian capital.

Its function is currently to accelerate or reduce the distribution flows of fruit and vegetable products, which pass through agents that are part of the spatial circuit of production, such as the primary producer, the middleman or intermediary, the supply center itself, markets, supermarkets, fairs and other establishments to the final consumer. This reduces possible food supply crises and circulation problems, even if they promote a higher price of fruit and vegetable production, where the added value does not remain with the producer and the high price is disadvantageous to final consumers.

CEAGESP integrates different agents and varied spatial circuits of production at different scales, circulating between local, regional and even national; The local scales are more expressive in the units in the interior, since the flow in the regions themselves is greater than in others. In addition, the supply centers have a wide influence on the definition of prices, launching the CEAGESP Price Index on a monthly basis, which is nothing more than a record of the variation in the values practiced

in the sector of fruits, vegetables, fish, fish and various (such as garlic, potatoes, eggs, among others) in the wholesale sector.

In the warehouses in the interior, the supply centers maintain a hierarchical relationship with the lower circuit, such as fairs and neighborhood markets, simpler activities that are absolutely dependent on the warehouses, allowing merchants easier access to fruit and vegetables, essential to replenish stocks, in addition to defining the prices that will be practiced in these circuits, It also has a geographical distribution that promotes logistics and expands the access of the final consumer, although it also strengthens the presence of the middleman, by determining minimum quantities to be sold in the warehouse, adding another step in the productive spatial circuit, influencing a higher price to production.

Therefore, the supply centers are part of the cooperation circle and are agents of the horticultural productive spatial circuit, because they facilitate access to fruit and vegetable products, as well as regulate the price of these products and systematize circulation, in addition to integrating the two circuits of the urban economy.

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Perception and risk tolerance of family farming managers

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ABSTRACT

Objective: to analyze the relationships between the constructs of perception and tolerance, perceived by rural property managers.

Theoretical framework: it is based on the literature through family farming and risk tolerance and uncertainties in agriculture.

Method: A survey was carried out with 137 farmers. This is a quantitative study of a described nature. The data were collected through a questionnaire and reveal that the behavior of the interviewees is restricted to actions that do not put them in situations of financial risk.

Results and conclusion: In the analysis of the means of the risk behavior factor, the results revealed that risk perception precedes risk tolerance, and the relationship between the constructs is of an inverse order, in which managers perceive more risk in a situation in which they have the least tendency to incur risks. In this context, the greater the perceived risk, the less chances the manager will have of carrying out the deal. The findings allowed us to broaden the understanding of the relationships between risk constructs within the decision-making process. In general, family farming managers show signs of the need to manage finances more efficiently and in most cases seek to improve these practices.

Implications of the research: the implications of this study for the management of family farming show that managers perceive risk situations, and are unwilling to take this risk (risk tolerance).

Originality/value: broadens the understanding of the tolerance to risk linked to the financial of families that live from family farming.

Keywords: Risk Perception, Risk Tolerance, Decision-Making Processes, Family Farming, Financial Risks.

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INTRODUCTION

The decision-making process is a preference of managers, as well as their responsibility, that is, such preference will provide subsidies for the formation of the vision and choices of managers in the decision-making process, thus the choice of an efficient information system is determined by the vision that managers have in positioning the company in the market and in front of the competitor (Nutt, 1986).

In this context, decisions always involve some type of risk and are made considering the characteristics and attitudes adopted by decision makers, and the process demands calibrating rationality or intuition, as it is influenced by the beliefs and values of managers (Lobão, 2012; Tversky & Kahneman, 1974; Vergara, 1991). The decision-making process occurs in all types of organizations regardless of the field of activity or size, however, they are influenced by personal values (Maccrimmon & Wehrung, 1990) and are subject to failures (Shore, 2008), as competitiveness seeks quick and satisfactory decisions for the organization (Hough & White, 2003).

In the context of decision-making in the agricultural environment, decisions are also at risk and are often not controllable, such as climatic factors, price variations caused by the market, risks related to workers' health, etc. (Sepulcri, 2006). Agriculture has very specific characteristics when compared to other sectors of the productive economy, one of which stands out the most is the magnitude and nature of the risks to which it is subjected, risks that are not often seen in sectors of industrial production (Embrapa, 2020).

According to Djanibekon *et al.* (2018), agricultural risks are sometimes related to variants, such as low production levels, and may arise not only due to poor management practices, but also due to production risks, for example, due to climate variability or limited access to some inputs, such as irrigation water. Komareki *et al.* (2020), also states that without a knowledge base to design possible risk management strategies and policies on a multiplicity of variables, farmers become vulnerable. For Salvodi and Cunha (2010), they state that all these risk possibilities impact the financial performance of organizations, therefore, understanding the behavior of family farmers in relation to risk can contribute to better management in relation to the finances and economic sustainability of their property.

For Morgan *et al.* (2015), also point out that such contributions lead the manager to better risk management and may result in a reduction in revenue variability over time, which will increase the long-term viability of the business, thus avoiding getting involved in risk factors through poorly made decisions. Thus, the present work focused on the influence of the behavioral factors of financial risk on the perceived risk and risk tolerance of managers in family farming in RN. Most of the farmers' decisions are linked to the management of their property, with two simultaneous perspectives, one linked to family sustenance and the other related to the commercialization of

surplus production, establishing parameters of action linked to the cultural and symbolic dimension (Baiardi & Alenar, 2014).

However, there is evidence that rural managers would be associated with a more conservative profile, as evidenced by Flores (2012), when they found that they faced financial risks, presenting a low level of indebtedness and conservative behavior. For the purposes of this study, risk was related to the organization's opportunities and uncertainties, demonstrating its own characteristics and thus requiring specific management or analysis (Hopkin, 2010). In this context, the question that guides this research is: ***What is the relationship between risk perception and risk tolerance in family farming in RN?*** This research aims to analyze the relationships between the constructs of risk perception and risk tolerance, perceived by the managers of rural properties of family farming in the city of Mossoró/RN. For a more specific analysis, the aspects of financial risk were listed, divided into two factors: risk perception and tolerance. Risk perception is related to the expectation of negative consequences, while risk behavior is associated, there are investments or actions with a probability of adverse implications, being influenced by individual perception in a given context in which the behavior occurs (Blais & Weber, 2006).

The study showed that the risk perception of that group of small farmers influences their work practices and the way they respond to the risk represented by decision-making, and should therefore be the object of analysis in decision-making actions related to the farmer and in the scope of risk management initiatives. From a financial planning perspective, risk tolerance plays an important role in guiding individuals to make psychologically satisfying and comfortable investments (Sivasankaran & Selvakrishnan (2023); Chandu, Reddy, Srilakshmi & Shifaly, 2022).

You (2008) considers that risk tolerance represents an individual's intention to behave. Thus, the need for educational actions aimed at passing on information and clarification to farmers regarding the risks inherent to agricultural activity and the dangers arising from the decision-making process becomes evident (Assunção, Pedrotti, Santos & Brandão, 2019).

THEORETICAL FRAMEWORK

FAMILY FARMING

According to Savoldi and Cunha (2010), family farming has an influential conduct of the family in the structure of organization of social reproduction, through the elaboration of family and individual strategies that influence the transfer of material and cultural heritage. For the Ministry of Agriculture, Livestock and Supply (2019), family farming is agricultural and livestock production carried out by small producers, generally employing labor related to the family nucleus, who have blood or marriage ties. Law 11.326, of July 24, 2006, defines that, in order to be considered family farming, it must meet the following criteria: those who practice activities in rural areas have an area

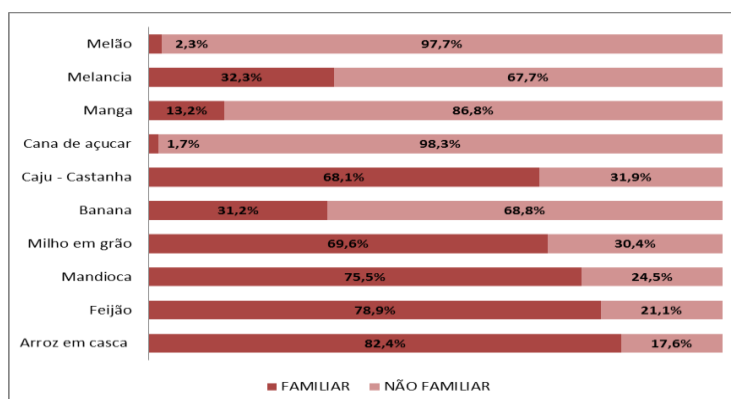
of up to four fiscal modules, labor from the family itself, family income linked to the establishment itself and management of the establishment or enterprise by the family itself.

It is worth noting that in Brazil the National Program for the Strengthening of Family Agriculture – PRONAF is one of the main sources of funding for this type of activity, thus, the importance of family farming in the organization and structuring of the agrarian space in Brazil is perceived, even if it, admittedly, does not have an appreciation with regard to public policies and the performance of the National State.

The IBGE reveals that in the twenty-first century family farming still occupies a relevant place in national agriculture since it represents 4.3 million establishments, occupies 74% of the workforce and is responsible for an important portion of food production. However, among the northeastern states, Rio Grande do Norte has the lowest number of family farmers. Even with low quantitative representativeness, in regional terms, family farming is an important sector in its agrarian structure (De Aquino, Freire & De Carvalho, 2017).

In Graph 1 regarding production in family farming, we can see that the data reveal that Brazil nuts are the only product with higher added value in which family farming has a significant participation, and even that the production of this segment is significant in the production of basic foods (De Aquino *et al.*, 2020).

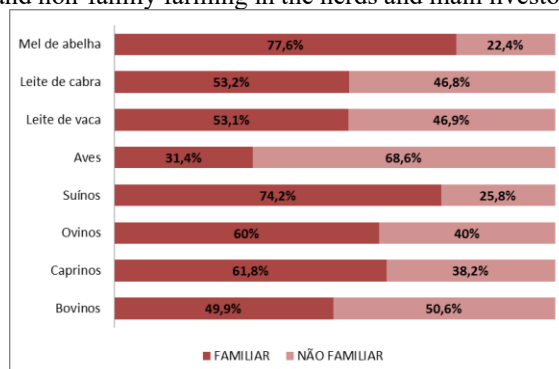
Graph 1 - Participation of family and non-family farming in the number of tons (in %) produced by the main crops in Rio Grande do Norte



Fonte: adapted from De Aquino *et al.*, (2020, p. 122).

In relation to livestock production, family farming in RN stands out in some aspects, as shown in Graph 2.

Graph 2 - Participation of family and non-family farming in the herds and main livestock products of Rio Grande do Norte



Fonte: adapted from De Aquino *et al* (2020, p. 123).

The data show a good participation of family farming in the segment of goats, sheep, pigs, cow's and goat's milk. The most relevant performance is with bee honey. De Aquino *et al.* (2020) draws attention to the numbers related to the total value of production and observes that, although the participation of family farming was significant, it generated only 29.7% of the wealth produced by agriculture in RN, and only 12 thousand employer farmers were responsible for 70.3%. These data reveal that there is an inequality in the capacity to generate wealth that somehow reveals the fragility of family farming, which faces limitations related to the scarcity of land, water, technologies, technical assistance, credit, among other assets.

Such a scenario demonstrates that family farming in RN has an important economic, environmental (due to agro-ecology) and social role, however it is necessary to create public policies that minimize its weaknesses and strengthen this segment.

PERCEPTION OF RISK

At the end of the 90s, Michell (1999) stated that the concept of risk reached maturity and established a tradition of investigation in research on aspects of consumption. For Bauer (1960), the theory of perceived risk was initially defined under two dimensions: uncertainty and the meaning of the consequences (or importance). Serving as essential input for the development of a person's risk profile, however, these terms are not interchangeable (Grable, 2017). For Bauer (1960), consumers are faced with a dilemma when trying to make a certain purchase and hesitate when they realize the risk involved in the transaction, which can cause future losses. In the findings of Johnson, Sivadas and Garbarino (2008), the individual's commitment to a particular product or brand has an inverse relationship with the perception of risk.

Seeking to develop decision strategies and means of reducing risk, which allow for relative confidence and tranquility on occasions when their information is inadequate and the consequences of their actions are in some sense significantly incalculable (Bauer, 1960). Cox and Rich (1964) clarify that, as the consumer does not feel safe in the purchase, he will seek to minimize uncertainties

as a strategy to reduce risk, preventing possible unfavorable consequences. Perceived risk has been understood as a multidimensional phenomenon and, for this reason, it is subdivided into several categories of risks or losses (Stone & Gronhaug, 1993), a phenomenon that we highlight in the sequence of this text.

RISK TOLERANCE

Attitude toward risk used to be analyzed as the exclusive domain of human rationality, i.e., the issue of attitude toward risk was seen as a primarily cognitive construct. In the financial domain, investors would be driven by cognitive risk assessments, considering the *trade-off* between market risk and reward, before they make their financial decisions.

Therefore, risk tolerance tends to favor the individual's tendency to accept negative changes that are prone to adverse outcomes, i.e., differ from expectations in terms of (Grable & Lytton 1998; Kannadhasan, 2015). Based on the definition of financial risk tolerance, it can be compared as a psychological component of decision-making under financial uncertainty. In this case, individuals would assess the appropriateness of possible outcomes and the likelihood of their occurrence. (Kahneman & Tversky, 1979).

From a financial planning perspective, risk tolerance plays an important role in guiding individuals to make psychologically satisfying and comfortable investments You (2008), considers that risk tolerance represents an individual's behavioral intent.

The authors Grable and Lytton (2001) consider that risk tolerance represents an individual's intention to behave. The first way is to view risk tolerance as a single input into a manager's overall risk profile. The lack of a standard model causes financial professionals to develop and use "self-made" methods usually limited to simple conversations about the level of good in different scenarios.

For Carr (2014), for example, it showed that a client's perception of risk and need for risk, in addition to risk tolerance, were the most important characteristics that shape an individual's profile. Nobre and Grable (2015), for example, observed that an individual's willingness to take financial risks is influenced by their risk perception, risk need, and risk profile which they defined as being composed of risk capacity, risk preference, and risk composure. When viewed in this way, a manager may be willing to take risks when presented with a financial decision, but not be willing to take risks in another situation (Grable, 2017).

RISKS AND UNCERTAINTIES IN AGRICULTURE

Risks and uncertainties are the basis of any decision-making structure in agriculture. When knowledge is imperfect, you can define risks and know the probabilities of possible outcomes, and when those probabilities are unknown, there is uncertainty Frey *et al.* (2017). It is difficult to imagine

an environment in which risks and uncertainties are more important than the agricultural sector (Aimin, 2010). In turn, the decision-making process is characterized by its complexity, which eventually inserts uncertainties and risk factors, even if it is complex in nature (Nelson, 1997).

The authors Ondersteijn, Giesen and Huirne (2003) state that farmers who practice strategic management in their businesses are more successful than those who do not, even though the farmer is the manager and at the same time belongs to the workforce. The authors also state that farmers analyze the strengths and weaknesses of their businesses, that is, they assess the risks related to the activity they propose.

Still from this perspective, Nelson (1997) pointed out that uncertainty refers to a situation in which the consequences include many possible outcomes, regardless of convenience. Corroborating the premises presented by Nelson (1997), Aimin (2010) and Rosa *et al.* (2018) highlight, in Chart 1, the types of risks linked to agriculture.

Table 1 – terms and definitions of the types of risks in agriculture

Terms	Definitions
Uncontrollable elements	Climate, insect pests, and diseases that play a key role in agricultural production.
Uncertainties and Market Risks	Decisions about what and how much to produce have to be made well in advance, since the market price for production is usually not known at the time these decisions occur. Market uncertainty is more relevant because of the inherent volatility of agricultural markets.
Family risk	It corresponds to the loss of work of family members because of illness or accident.
Political uncertainties and risks	Economic policies have an impact on all sectors through their effects on things, such as taxes, interest rates, exchange rates, regulation, provision of public goods.

Source: adapted from Aimin (2010) and Rosa *et al.* (2018).

Thus, understanding the origin and specificity of certain types of risks leads to the development of a strategy for their management, in the case of agricultural production, the objective of risk management should be to improve or maintain the yield of agricultural production and its financial and organizational stability within the framework of the traditionally distinct stages of identification, risk assessment and response.

METHODOLOGICAL PROCEDURES

CHARACTERIZATION OF THE RESEARCH

This research is characterized as a descriptive and explanatory study, since it seeks to understand the behavior and several factors and elements that influence a given phenomenon. According to Oliveira (2002), research of this nature seeks to cover the correlation between the variables, giving rise to the explanation of the cause-and-effect relationship of the phenomena.

A field study was carried out, based on a *survey*, from the questionnaires applied to family farming managers. 137 family farmers from the State of Rio Grande do Norte, with more than 2 years of activity in the field, participated in the research.

The concept used to characterize farmers was the one proposed by FAO/INCRA (1994, p. 04) as described below:

- The management of the production unit and the investments made in it are made by individuals who maintain blood or marriage ties among themselves;
- Most of the work is also provided by family members;
- The ownership of the means of production (although not always of the land) belongs to the family and it is within it that it is transmitted in the event of the death or retirement of those responsible for the productive unit.

The distribution of the sample collected is restricted to family farming managers in the state of Rio Grande do Norte, as shown in Chart 2:

Chart 2 – locations and numbers of interviewees

LOCATIONS AND NUMBERS OF RESPONDENTS			
Municipalities belonging to the Apodi region	31	Municipalities belonging to the Mossoró region	22
Apodi	25	FOR Paulo Freire Mossoró	2
Sítio Carpina/Apodi	2	Favela Settlement	4
Closed Downtown II	1	Jurema Settlement	1
Closed Downtown I	3	Casqueira I	3
Municipalities belonging to the Serra do Mel region	57	Serra Mossoró	4
Vila Ceará	15	Oziel/Maísa Farm	1
Vila Minas Gerais	1	Mulugunzim	4
Vila Goiás	15	Maísa	1
Vila Alagoas	21	Bom Jesus	1
Vila Sergipe/Serra do Mel	5	Alagoinha Recanto da Esperança	2
Municipality of Natal	1	Municipality of Açu	2
Municipalities belonging to the region of Baraúna	2	Municipality of Upanema - 4S São Manoel II	20
Riacho Grande	1	Municipality of Pedro Avelino	1
Saint Anthony	1	Municipality of Jandaíra	1
TOTAL			137

Source: Management and Culture Questionnaire (2019)

DATA COLLECTION AND DATA ANALYSIS INSTRUMENT

The research instrument used to analyze the two dimensions of risk was the scale created by Weber, Blais and Betz (2002), adapted and validated in Brazil by Paulino (2009). The original scale, consisting of 40 items, covers five dimensions: financial decisions, health/safety, legal/ethical, social, and recreational. However, in this study, the authors used the items referring to financial risk, composed of five questions, used for the dimensions of risk perception and behavior.

The risk perception scale is structured on a 5-point *Likert* scale (1 - No risk and 10 - Extreme Risk), and the Risk Behavior scale also used a 5-point *Likert-type* scale (1 - Very Unlikely and 10 - Very Likely). The scale of risk and intention of risk behavior was organized as follows, as shown in Table 1:

Table 1 – risk scale and intention of risk behavior

BEHAVIORAL VARIABLES		
Spending large amount of money on lotteries	How much risk do you perceive?	How Likely Are You to Accomplish?
Being someone's guarantor		
Spending Money Impulsively, Without Thinking About the Consequences		
Investing in a business that has a high possibility of not working out		
Lending to a friend/family member most of your salary or monthly income		

Source: Management and Culture Questionnaire (2019)

In the column – How much perceived risk? - Indicate how much risk you perceive in the situations mentioned, being 1 for no perceived risk and 10 for perceived extreme risk. In the column – How likely are you to perform? - Indicate the probability that you will perform the activity or behavior, with 1 for no perceived probable risk and 10 for perceived probable extreme risk.

The data were statistically analyzed using the *IBM SPSS Estatistics 24.0* © software, where initially for the treatment and organization of the data, a tabulation was elaborated in electronic spreadsheets. Second, descriptive statistical analyses of risk perception and tolerance factors were performed in order to identify the means and deviations from standards, respectively. Third, the reliability test, Cronbach's alpha, was used to identify the reliability of the risk perception and risk tolerance scale. This test refers to the internal consistency and reliability of the scale data, in which the result can be greater than 0.90, which indicates that the data are free of bias. For Hair (2019), this bias occurs when the process of missing data causes certain data to be missing from the tabulation, leading to incorrect results. According to Hair *et al.* (2019), in exploratory studies, values above 0.60 and up to 0.70 are acceptable.

Fourthly and finally, Pearson's correlation analysis was performed in order to evidence the existence of correlations and associations (Figueiredo Filho & Silva Júnior; 2009) between the dimensions of risk perception and tolerance, in view of the financial risk behaviors perceived by the property managers.

ANALYSIS AND DISCUSSION OF THE RESULTS

RESPONDENT PROFILE

Most of the respondents are male, have been on the property for more than ten years, access to land was through agrarian reform, most of the properties have more than 12 hectares. They produce fruits, vegetables, vegetables and animal husbandry. They participate in the association (62%), but a portion of the respondents do not participate (38%). Decisions about what to produce, what to buy, are made by the owner, even if the position of the rest of the family is different, the owner's premise is the one that prevails.

The gains from production are enough to support the family for 53% of the interviewees. They do not assume themselves as entrepreneurs and consider that the property is an inheritance for their children. Where daughters are interested in working on the property (62%), and the study of the sons divides this position, because for 53% the training will allow them to continue in rural activities, and for 47% of the interviewees, it should be a possibility for them to leave the rural area. However, for 64%, formal education will not help in improving rural property.

Most of the farmers interviewed do not identify with working in the field, but they justify that even so, this is their only alternative for survival, and that they do not aspire to any other profession than that of rural worker. Regarding agribusiness, 59% of the farmers interviewed do not consider themselves part of it. Even so, 56% of respondents understand that prices are defined by the market, and therefore do not follow production costs. The definition of what to produce divides the position of the interviewees on this aspect, where 53% disagree that the consumer is the one who defines what to produce.

Regarding production, 65% of rural producers clarify to their consumers about the benefits of family farming, where most of them (63%) prefer to sell to the final consumer. There is no dependence on the government or on a cooperative/association for the commercialization of products.

Still on production, 54% is primarily destined for family consumption. However, for 71% of the respondents, the priority of the destination of production is commercialization, establishing an inconsistency in the statements. On the other hand, when they affirm that the main objective of production is profit, we understand that the commercialization trend prevails, although the theme of environmental preservation prevails as a productive practice.

RISK PERCEPTION AND TOLERANCE

Five items related to the questionnaire designed to assess the level of perception and risk tolerance of family farming managers in Rio Grande do Norte were analyzed. The table below presents the general values related to the descriptive analysis of the variables regarding the perception of the interviewees.

Table 2 - descriptive analysis of the variables regarding risk perception and tolerance

VARIABLES BEHAVIORAL	RISK PERCEPTION		TO RISK	
	AVERAGE	STANDARD DEVIATION	AVERAGE	STANDARD DEVIATION
Spending large amount of money on lotteries	8,25	2,86	1,81	2,03
Being someone's guarantor	8,85	2,49	2,9	2,69
Spending Money Impulsively, Without Thinking About the Consequences	8,89	2,48	1,63	1,66
Investing in a business that has big ones that don't work out	8,39	2,63	2,23	2,36
Lending to a friend/family member most of your salary or monthly income	7,85	2,82	4,8	3,15
Perception Factor	8,44		2,67	

Source: Management and Culture Questionnaire (2019)

Taking into account that the risk perception scale varies between 1 and 10 points, on an ascending scale, in which 1 represents no perceived risk and 10 represents extreme perceived risk, it is verified in general terms that family farming managers living in the interior of Rio Grande do Norte, perceive a high risk in the discriminated actions. In this sense, the risk perception factor with a value of (8.44) presents evidence that family farming managers developed a slightly higher risk perception in relation to the financial risk behavior variables. The results found confirm that there are significant differences where the (sig. 0.000), between the managers' answers and in all the variables investigated, as well as in the risk perception factor point to this interpretation.

However, for some variables, the mean values are close enough that their location on the *Likert scale* does not indicate large differences in perception among the participants. For example, the variable "Being someone's guarantor" with an average of 8.85, despite the statistical significance indicating that, on average, managers consider this perception to be very risky. On the other hand, the variable that presented the lowest average was "Lending to a friend/family member most of their salary or monthly income" (with an average of 7.85), which reveals that the interviewees understand that lending money to a friend/family member is an action with the lowest risk among the others that were questioned. Thus, according to Halfeld, Alfeld & Torres, (2001), in behavioral finance, man is not totally rational, he is a normal being who often acts irrationally, because he is influenced by emotions and errors that lead him to interpret a certain situation differently, according to the context and the way it is analyzed.

Regarding Risk Tolerance, it is perceived that managers will hardly develop any of the behaviors, as the variable "Lending to a friend/family member most of your salary or monthly

income" is highlighted by managers (average 4.80), as the alternative with the highest probability of being performed. While the variable "Spending money impulsively, without thinking about the consequences" with (average 1.63), is revealed by managers with the least tendency to be developed.

A result similar to that of this study is evidenced by Grable and Lytton (1998), who also identified the largest share of answers based on the same alternatives, showing that the interviewees are averse to high risks. Ozaki (2007) states that in any sector of economic activity there are risks that vary to a lesser or greater degree. Therefore, in the agricultural sector, in addition to market risk, there are other factors that make the activity risky, one of the main factors is that agricultural activity is completely dependent on weather conditions, and that the farmer has no control over this factor. Such uncertainties can justify the conservative behavior of the farmer in relation to finances, since the difficulties related to the agrarian environment do not offer him security for expenses in uncertain situations and have government support to deal with such unforeseen events.

In risky situations, risk is (only one) significant aspect of the available options. In addition, risk represents an interaction between the alternative and the decision-maker at risk, that is, it is a subjective construct, since loss has different meanings for different people, as well as the perception of its probability of occurrence (Yates & Stone, 1992). In order to develop the strategic objectives and suggest measures to guide family farmers in their learning and organizational growth, it was sought to evaluate through a questionnaire, seeking through indicators to measure the perception of financial risks and how tolerable they are in the face of the dimensions explained, and this is the proposal of using *Cronbach's* alpha coefficient, express, by means of a factor, the degree of reliability of the answers resulting from a questionnaire.

According to Hair Jr. *et al.* (2019), for a factor to present satisfactory internal consistency, it must have *Cronbach's alpha* greater than 0.60, below this value the internal consistency of the scale used is considered low. On the other hand, the maximum expected value is 0.90; above this value, it can be considered that there is redundancy or duplication, that is, several items are measuring exactly the same element of a construct; therefore, redundant items should be eliminated. The estimate of the internal reliability of the construct and its descriptive statistics are shown in Table 3.

Table 3 – construct reliability, risk perception and tolerance

Reability Statistics		
	Risk Perception	Risk Tolerance
Cronbach's Alpha	0,875	0.560
Cronbach's Alpha bases on Standadized Items	0, 880	0,585
N. of Items	5	5

Source: Management and Culture Questionnaire (2019)

It can be observed, in Table 3, that the reliability of the risk perception scale obtained *Cronbach's* alpha of 0.8, thus achieving adequate internal consistency, the same did not occur in risk

tolerance where it obtained 0.5 reliability in relation to the scale. Table 4 shows the behavioral variables and their respective Cronbach's alphas. Thus, it was noticed that the item "Lending to a friend/family member part of your salary or monthly income" had a high degree of variability in relation to the other data. So, it was decided to eliminate him.

Table 4 – Construct reliability for item variance

BEHAVIORAL VARIABLES	RISK PERCEPTION	RISK TOLERANCE
	Cronbach's Alpha IF item Deleted	Cronbach's Alpha IF item Deleted
Spending large amount of money on lotteries	0,845	0,554
Being someone's guarantor	0,826	0,431
Spending Money Impulsively, Without Thinking About the Consequences	0,824	0,556
Investing in a business that has great Possibilities of not working out	0,842	0,550
Lending to a friend/family member most of your salary or monthly income	0,898	

Source: Management and Culture Questionnaire (2019)

Table 5 shows a comparison involving all items and then the removal of the item "Lending to a friend/family member most of your salary or monthly income", evidencing the impact on Cronbach's alpha. The removal of this item shows an improvement in Cronbach's alpha in the remaining items, i.e., the consistency and reliability of the construct improves.

Table 5 - degree of reliability increased after removal of the tolerance item

TENS	Item Total	Alpha if you exclude	Item Total	Alpha it.excluído
Spending large amount of money on Lotteries	0,314	0,511	0,348	0,554
Being someone's guarantor	0,429	0,433	0,494	0,431
Spending money impulsively, without thinking about the consequences	0,328	0,513	0,359	0,556
Investing in a business that has a high chance of not working out	0,403	0,457	0,358	0,55
Lending to a friend/family member most of your salary or monthly income	0,208	0,601	*	*

Source: Management and Culture Questionnaire (2019)

In this work, we also sought to analyze the association between the factors of Perception and Risk Tolerance. Thus, in order to identify the strength and direction of the association between the

factors that impact risk perception and tolerance, the correlation test was calculated using *Pearson's correlation coefficient* (Hair Jr. *et. al.*, 2019). Table 6 presents the correlation coefficients for each factor of Perception and Risk Tolerance.

Table 06 - Pearson's correlation of risk perception and risk tolerance

CORRELATIONS					
BEHAVIORAL VARIABLES	Mr.	N	Risk Perception	Risk Tolerance	Results
Spending large amount of money on lotteries	0,024	137	- 0,19*	- 0,19*	Weak Negative Correlation
Being someone's guarantor	0,006	137	- 0,23**	- 0,23**	Weak Negative Correlation
Spending money impulsively, without thinking about the consequences	0,002	137	- 0,26**	- 0,26**	Weak Negative Correlation
Investing in a business that has a high chance of not working out	0	137	- 0,52**	- 0,52**	Moderate Negative Correlation
Lending to a friend/family member most of your salary or monthly income	0	137	- 0,52**	- 0,35**	Weak Negative Correlation

*significant correlation at 0.05

**Significant correlation at 0.01

Source: Management and Culture Questionnaire (2019)

Based on the value of *Pearson's* linear correlation found between the constructs of risk perception and tolerance, in the face of financial risk behaviors. It can be concluded that all variables presented statistically significant coefficients, with a weak negative correlation, presented by the modeling of structural equations. With the exception of the item "Investing in a business that has a high chance of not working", which obtained a moderate negative correlation, in which the level of significance is less than 0.05, with a correlation of -0.522. According to Sahm (2012) and Grable, Joo and Park (2009), these data indicate the degree to which people feel comfortable in relation to risk/return. They also understand risk tolerance as "the level of volatility that people can tolerate," or even the willingness to take risks (Grable, 2017). The influence of these elements on the decision-making process depends on the way managers interpret the environment, that is, the influence of the external environment depends on the way information is collected and processed.

Simon, Houghton and Aquino (2000) found an inverse and significant relationship between risk perception and willingness to invest. As verified through correlation, and presented in Table 06. It is clear that the factors of perception and risk tolerance are inversely proportional when correlated with each other, that is, they are negative associations at the level of perception, which confirms a tendency of managers to be averse to risk when the possibilities present terms of potential losses.

Table 7: Person correlation coefficient

		Risk Perception	Risk Tolerance
Risk Perception	Pearson Correlation	1	-, 368**
	Sig. (2-tailed)	, 000	
Risk Tolerance	N	137	137
	Pearson Correlation	-, 368**	1
	Sig. (2-tailed)	, 000	
	N	137	137

**Significant correlation at 0.01 level (2-caldas)

Source: Management and Culture Questionnaire (2019)

In Table 7, Pearson's correlation coefficient between Risk Tolerance and Risk Perception is equal to -0.368, and is weak and negative, where it is presented as an indirect but significant effect (Sig. 0.000).

Grable and Rabbani (2014) point out that, although risk tolerance does not change much in different fields, it is natural that, at some point in life, people behave differently from their standards and act contrary to risk acceptance. Since this association is inversely proportional (interpreted by the negative sign of the coefficients), managers perceive a lower risk tolerance when they identify risks in their decisions, and is therefore effective in the indirect selection of risk tolerance, which is with greater perception. The recognition of risk, as it is an individual activity, is influenced by the characteristics of the decision-maker (Sjoberg, 2000; Rooij *et.al*, 2011).

The results obtained in this research corroborate the propositions of Nobre and Grable (2015), where these authors observed that an individual's willingness to take financial risks is influenced by their risk perception, risk need, and risk profile — which they defined as being composed of risk capacity, risk preference, and risk composure. When viewed this way, a manager may be willing to take risks when presented with a financial decision, but is not willing to take risks in another situation.

FINAL CONSIDERATIONS

Risk behavior is of paramount importance for the economic development of a country, on the other hand, risk perception retracts attitudes that may be highly observable, and that protect individuals from compromising their financial health. In view of this, the study sought to analyze the relationships between the constructs of risk perception and risk tolerance, perceived by managers of rural properties in family farming. For this, it was based on an investigation with 137 rural producers in the municipality of the city of Mossoró/RN.

Regarding financial risk behavior, "Spending money impulsively, without thinking about the consequences", with an average of 8.89, was observed by managers as the riskiest variable. While "Lending to a friend/family member most of the income from your salary or monthly income", with an average of 4.80, was considered the behavior most likely to be performed by rural managers. The

results achieved pointed to a high reliability coefficient, which indicates that the research instrument is considered reliable, because the internal consistency, obtained through *Cronbach's* alpha, presented a degree of 0.8 with 5 variables for risk perception.

In the results of the associations between the factors, it was possible to conclude that, in view of the *Pearson* correlations analyzed, the financial behavior of the variable "Investing in a business that has a high probability of not working", obtained a correlation with statistical significance of moderate negative magnitude, when the level of significance is less than 0.05, to a correlation of -0.522, indicating that rural managers consider it as an act that must be well thought out and calculated, to prevent this risk from becoming a failure.

Finally, in the correlation analyses between risk perception and risk tolerance, they presented weak and negative correlation coefficients, but significant (-0.368), which affirm the predicted relationship between the constructs. Therefore, when the manager realizes that a decision is riskier, he is less likely to take that risk, that is, his tolerance decreases. Shefrin (2002) argues that the perception of agents is highly influenced by the way problems are presented and structured. Corroborating the data, Grable, Joo and Park (2009) state that when one item is evaluated as satisfactory, the other tends to be unsatisfactory.

The implications of this study for the management of family farming show that managers perceive risk situations, and have a low willingness to take this risk (risk tolerance). This factor may be indicative that managers are risk-averse in investing their resources in the family business, because as their resources are limited, they try to invest in what they perceive to be as safe as possible and with that, intuitively, they reduce the risk of loss.

The study shows evidence that the managers' relationships with their families/friends, and the variable referring to lending money, showed a high risk perception, but lower than the other items analyzed, and also, a low degree of risk tolerance, but higher than the other items. This may indicate that managers observe in family relationships and with friends a channel of mutual financial help, considering that community life is above competitive business relationships.

The interpretation of rural managers in the face of risk situations indicates that other factors, in addition to those mentioned in the survey, can change the decision to apply scarce resources in their business. This is linked to the subjectivity of the judgment of the choice process in risk situations, directly influencing their perception and respectively how much they tolerate this behavior (Slovic, 1991).

This research was successful in achieving its proposed objectives. For a better understanding of the decision-making process in risk situations, it is suggested for future research to include a qualitative stage, in order to evaluate the criteria that the respondents indicate through decision-making, or even decision contexts related to investments in real assets. It is also necessary to carry

out more in-depth studies between the perception and behavior of risk related to debt levels in decision-making.

It is also suggested that future research be deepened in the existing context of the great path of behavioral finance, especially in its sets of theorists, where these are not compatible and do not have sufficient significance to replace the current model of finance applied to forms of production and popular organization, where these demand new models of analysis.

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Crop-livestock integration in Brazilian lands

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ABSTRACT

Integrated agricultural production systems (SIPA's) consist of growing grain-producing crops with forage crops in the same area, in rotation, succession or intercropping. These systems, in addition to diversifying agricultural production, promote efficiency and sustainability in rural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at soil conservation. As, among the objectives of integrated systems, when well managed, they are capable of promoting improvements in soil quality, nutrient cycling, environmental adequacy and economic viability of the activities involved. As a result, the Integrated Crop-Livestock (ICL) system becomes a very important method, because it seeks to renew soil conditions, in order to make the most of natural processes, avoiding using external inputs. The ICL system is a viable alternative in edaphoclimatic conditions, there are many potentialities of the systems, enabling an increase in productivity and reduction of expenses for irrigation, fertilizers, soil conditioners and other agricultural inputs, integrating production, environmental conservation and socioeconomic benefits.

Keywords: Agriculture, Production, Integrated systems, Sustainability.

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INTRODUCTION

Integrated agricultural production systems (SIPA's) consist of growing grain-producing crops with forage crops in the same area, in rotation, succession, or intercropping (Barbosa *et al.*, 2022). These systems, in addition to diversifying agricultural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at soil conservation (Coser *et al.*, 2018).

Due to their ability to provide economic and environmental benefits (Barbosa *et al.*, 2022) LPIS have received special attention from researchers and have been adopted by farmers in Brazil (Bonetti *et al.*, 2015). Thus, Brazil leads the research in LPIS in relation to the rest of the countries in the world, according to Moraes *et al.* (2017), with approximately 11.5 million hectares are occupied by different arrangements of LPIS's. Of these, the subtropical region accounts for 44% of this area (Skorupa; Manzatto, 2019). However, its adoption in crops intended for the cultivation of irrigated rice is still incipient, especially with regard to the availability of data to support management recommendations. In these areas, called lowlands, the cultivation of irrigated rice in spring/summer and ryegrass in autumn and winter is predominant. In Rio Grande do Sul, about 1.1 million hectares are cultivated with flood-irrigated rice (CONAB, 2019) due to the characteristics of the soil in these regions. These have a low rate of water infiltration, low macroporosity and high compaction close to the surface, which makes it difficult for other crops to be inserted, according to Denardin *et al.* (2019) to achieve positive results in LPIS.

Therefore, it becomes a challenge to deploy and conduct systems in LPIS and lowlands. Countering this challenge, as rice cultivation is costly and expensive in terms of labor, water, energy, and as these resources are becoming increasingly scarce, this activity is becoming less profitable (Kumar; Ladha, 2011). Therefore, the implementation of LPIS in current agricultural production models can help generate income in the off-season of summer crops, and/or increase productivity in rice crops.

This increase would be possible because the SIPA's advocate the adoption of no-tillage as a cropping system, thus, the absence or minimal disturbance of the soil minimizes its degradation (Coser *et al.*, 2018). In the same way, the constant maintenance of living or dead cover in the soil contributes to the increase in the production of dry matter per unit area, according to Mazzuchelli *et al.* (2020) that can be used as a ground cover (Skorupa; Manzatto, 2019). This also contributes to the increase of soil carbon (C) stocks, according to Guesmi *et al.* (2019) that act as a subsidy for the supply of nutrients, according to Soares *et al.* (2019), with a consequent increase in crop productivity (Sousa *et al.*, 2020). How can the SIPA's have their time-culture-space arrangements adjusted according to the needs of each reality, according to Barbosa *et al.* (2022), research contemplating lowland environments can be conducted under the principles of SIPA's. Furthermore, although the

benefits of adopting LPIS are known, in lowlands they are still incipient, and require further studies to generate more consistent technical recommendations (Carmona *et al.*, 2018).

It is also worth noting that the conventional agricultural system model is in evidence, because over the years the loss of forage diversity and environmental pollution by excess nutrients and pesticide residues, according to Anghinoni *et al.* (2013) has made society currently demand that specialized production models commit to producing food in the most connected way possible with nature (Carmona *et al.*, 2018)element.

LITERATURE REVIEW

BRIEF HISTORY OF CROP-LIVESTOCK INTEGRATION

Culturally, Crop-Livestock integration systems are considered as innovative systems of agricultural exploitation. However, they were already developed in Europe since the Middle Ages. At the time, various forms of plantations were used associated with annual or perennial crops, or between fruit crops and timber trees (Lourençano; Cavichioli, 2019). Also, in the sixteenth century there was integration of fruit trees with the livestock production of cattle or sheep, however, due to the mechanization and intensification of agricultural systems, such integration almost disappeared (EMBRAPA, 2019).

In the mid-to-late 1970s, especially in the southern region of Brazil, there were efforts to reverse soil degradation, with integrated terracing systems in watersheds, and the development of technologies for the no-tillage system (Lourençano; Cavichioli, 2019). This scenario encouraged research into sustainable production systems, which harmonized the increase in animal and plant productivity, and preserved natural resources, according to EMBRAPA (2019), thus resulting in the beginning of scientific research on Crop-Livestock Integration (Lourençano; Cavichioli, 2019).

FOOD DEMAND AND THE BRAZILIAN AGRICULTURAL AREA

The increase in the world population, according to Sene; Bacha (2024), which has been accelerated in recent years, according to Cabral Neto *et al.* (2024), will lead to growth in food demand in the medium and long term (Sene; Bacha, 2024). This increase will be intensified by the increase in purchasing power resulting from the development of industries (Cabral Neto *et al.*, 2024). Among the countries that will meet this demand, Brazil is a country that will certainly provide an increase in food supply through agricultural and livestock expansion (Cabral Neto *et al.*, 2024). This expansion can occur in two ways, either by expanding the cultivated area and/or by increasing its agricultural productivity (Oliveira *et al.*, 2013).

In Brazil, according to data from the 2017 Agricultural Census (IBGE, 2019) there are 5,073,324 agricultural establishments. These properties occupy a total area of 351.289 million of the

851 million hectares (ha), that is, 41% of the total area of the country is allocated to agricultural establishments (Sene; Bacha, 2024). Of these areas, 18.1% of the Brazilian agricultural area in 2017 (IBGE, 2019) was occupied by crops (temporary and permanent), 45.4% by pastures (natural and planted), 32.8% by forests (natural and planted) (Sene; Bacha, 2024). When considering the total areas of pastures in comparison to the total area of our territory, we have 160 million hectares of pasture, according to Cabral Neto *et al.* (2024), which correspond to 18.94% of its entire Brazilian territorial extension, evidencing its broad agricultural potential (Sene; Bacha, 2024).

However, about 52% of these pasture areas are at some level, degraded (Cabral Neto *et al.*, 2024). This factor means that when compared to the world scenario, Brazil has one of the lowest cattle stocking rates (Lapig, 2022). This aspect causes several consequences, which directly interfere with production performance, increased costs and decreased revenue on properties (Leão *et al.*, 2021). In view of this scenario, integrated crop-livestock systems can be a good option for agricultural expansion, according to Cabral Neto *et al.* (2024), inhibiting or eliminating the need for deforestation to advance the agricultural frontier, in addition to generating less environmental impact (Carlos *et al.*, 2022).

DEGRADATION OF SOILS AND PASTURES AND BIOMES

Soil degradation induced by traditional agricultural or livestock production systems has been studied by Cabral Neto *et al.* (2024), as it is an important factor in compromising the sustainability of agricultural production (Macedo; Araújo, 2019). In agriculture, traditional agricultural production systems, which are those of annual crops, with continuous crops, without crop rotation, in which there is excessive soil preparation, as is the case with the conventional cultivation of irrigated rice (Cabral Neto *et al.*, 2024).

Traditional soil preparation, combined with inadequate practices and monoculture, has caused low productivity, degradation of soil and natural resources (Lourençano; Cavichioli, 2019). These effects are the result of the damage caused to the physical and chemical quality of the soil (Cabral Neto *et al.*, 2024). Also, with the growing increase in demand for food, there was an intensification of agricultural activity, according to Lourençano; Cavichioli (2019), with aggravation of the aforementioned losses and problems with invasive pests and diseases (Cabral Neto *et al.*, 2024). And with constant technological evolution, modern agricultural activity has been standardized into simplified monoculture systems, in addition to the use of machinery, agrochemicals, and irrigation (Lourençano; Cavichioli, 2019).

In pasture degradation, there is a decrease in the supply of forage for animal feed, since there is a loss of the ability to sustain plant production due to soil depletion and overgrazing (Sene; Bacha, 2024). This generates a vicious cycle, intensifying environmental and economic problems on

properties (Cabral Neto *et al.*, 2024). It is estimated that in Brazil, in 2020, there were 40.16 million ha of pastures with severe degradation (Senne; Bacha, 2024).

Soil degradation in agricultural and/or pastoral environments, in addition to harming the conservation of ecosystems, also leads to the degradation of Brazilian biomes (Cabral Neto *et al.*, 2024). For this reason, they have been questioned and require intervention for their mitigation. The recovery of these areas, with the objective of maintaining soil quality and promoting higher biomass yield, consequently, leads to an increase in productivity rates and allows competitiveness in the economic sector (Souza *et al.*, 2021). Part of these degraded areas, once recovered, represents a good opportunity for the country to expand its plant and animal production and meet the expansion of world food demand, without having to deforest new areas (Sene; Bacha, 2024).

The degradation process needs to be controlled in the early stages, as the impacts are more drastic over time (Cabral Neto *et al.*, 2024). There are several ways of intervening in pastures, such as recovery, in which the same cultivar is maintained and the productive potential of forage is restored; renewal, which is the introduction of a new species replacing the one that is degraded; and finally, the reform, which is characterized by corrections or repairs after the establishment of a pasture (Rocha; Viana-Filho, 2021). The recovery of degraded areas takes place from the integration of techniques involving air, soil, water, fauna and flora, in order to obtain ecological balance with a view to achieving sustainability and being productive in the long term (Cabral Neto *et al.*, 2024). In general terms, it means using all the strategies necessary for the quality of the soil to reach standards similar to, or even higher than, its original condition.

Some integrated systems have been widely used, such as the no-tillage system (NTS), integrated crop-livestock system (ICL) and integrated crop-livestock-forest system (ICLF), which have numerous benefits aimed at improving the physical quality of the soil, favoring carbon accumulation and greater water availability (Silva *et al.*, 2021). Aiming to associate production and environmental conservation, and with a view to recovering areas that are already in a state of degradation, integration systems emerge as options for the adoption of more sustainable food production practices (Sene; Bacha, 2024). From this perspective, the interaction between crops and livestock is a good strategy to achieve these goals, since it is directly linked to sustainability (Junior *et al.*, 2020).

CONCEPTUALIZATIONS AND BENEFITS OF ILP

Integrated systems are strategies for sustainable production, where agricultural, livestock and/or forestry activities are integrated, carried out in the same cultivation area (Lourençano; Cavichioli, 2019). The interaction between crops enables rotation in the use of agricultural production systems, and aims to raise the quality of the final product, allowing natural conservation,

especially in degraded areas (Silva *et al.*, 2022). When the forestry component is contemplated, the use of these systems enables the production of grains, meat and wood, with sustainability and conservation of natural resources, according to Magalhães (2019) by allowing the combination of two or more agricultural activities in the same productive area, that is, bringing together agriculture, livestock and/or forestry on the same farm (Sene; Bacha, 2024).

Integration systems have numerous advantages, especially in relation to the traditional cultivation system, according to Lourençano; Cavichioli (2019), because in integrated systems, crops can be intercropped, in succession or in rotation (Cordeiro *et al.*, 2015). With this, there is an improvement in productivity, use of residual fertilization from the crop and supply of nutrients and organic matter to the soil, according to Lourençano; Cavichioli (2019) as the main results of the synergistic effects between its components (Cordeiro *et al.*, 2015).

As among the objectives of integrated systems we have the intensification of land use, environmental adequacy and economic viability of the activities involved, according to Cordeiro *et al.* (2015), in addition to the benefits mentioned above, there is also a reduction in the emission of greenhouse gases (GHG) per unit of food produced (Reis *et al.*, 2020). An improvement in soil quality is also obtained, according to Reis *et al.* (2020) by the formation of straw, which will be used for the no-tillage system, and diversifies the cultivation of forages, according to Alvarenga *et al.* (2010) allowing the recovery of degraded pastures, water conservation and increased animal performance (Reis *et al.*, 2020). There are many benefits obtained from the implementation of the system, which provide diversification of production, as well as increased production efficiency and reduction of environmental damage (Cabral Neto *et al.*, 2024).

There is also a significant reduction in the application of inputs, since it breaks the cycle of pests and reduces invasive plants, in addition to reducing the cost of production or pasture reform (Lourençano; Cavichioli, 2019). Also, aiming at the effective use of available resources, the possibility of implementing diversified production systems, leading to the rationalization of the use of inputs, in addition to improving soil and water quality, resulting in greater profitability per area (Cabral Neto *et al.*, 2024). Thus, in summary, production in an integration system brings several benefits, not only for the producer, with the reduction of production costs over time; reduction of idleness in the use of agricultural areas; diversification in production and income stability, but also in the environment, where there is improvement in the physical, chemical and biological conditions of the soil; there is an increase in cycling and efficiency in the use of nutrients; enables the recovery of areas with degraded pastures; there is an increase in animal welfare and productivity (Cordeiro *et al.*, 2015).

DIFFICULTIES IN IMPLEMENTATION AND CONDUCTION

Integrated systems provide several benefits, however, as they are more complex production systems, it may be necessary to consider some difficulties present in this system, such as soil compaction by animal trampling (Lourençano; Cavichioli, 2019). However, these negative impacts are limited to the surface layers, in addition to being temporary and reversible, for the most part (Vilela *et al.*, 2011). Compaction combined with the removal of vegetation, also caused by trampling, can lead to a series of soil problems, as well as a decrease in water infiltration, increasing surface soil erosion, consequently reducing plant growth (Lourençano; Cavichioli, 2019).

For this reason, it is necessary to properly manage pastures, avoiding overgrazing/overgrazing and ensuring the maintenance of remaining residual dry matter. Also, even if the presence of the animal causes trampling and compaction, grazing stimulates the root growth of forage plants, that is, the harm can be compensated by the benefits. Thus, both obviously depend on a series of factors to be considered in an integrated system, including: soil type, moisture content, animal stocking rate, forage mass, species and vigor of the forage used (Lourençano; Cavichioli, 2019). There is also a need for financial investment for the implementation and maintenance of the system, so small farmers find it difficult in this regard (Balbino *et al.*, 2012a). For the reasons described, even with several benefits, there is still resistance to the adoption of new technologies by producers, in short, due to the requirement of their qualification, in addition to the need for technicians and specialized labor (Lourençano; Cavichioli, 2019).

INTEGRATED SYSTEMS MODALITIES

Integration consists of the implementation of different production systems of grains, fibers, meat, milk and agroenergy in the same area, in intercropping, which can be sequential or rotational (Vilela *et al.*, 2011). Integrated systems have been disseminated throughout the country, in different combinations of their components, namely: crop-livestock integration (ICL), crop-livestock-forest integration (ICLF), livestock-forest integration (IPF) and crop-forest integration (ILF) (Vilela *et al.*, 2015; EMBRAPA, 2019). In crop-livestock integration (ICL) or agropastoral, there is integration of the components: agricultural, with annual or perennial production (grains, pastures), and livestock (EMBRAPA, 2019). In this system, the combination of two components is adopted: agricultural (crop), with annual or perennial production (grains, pastures), and livestock (beef cattle, milk), which can be in rotation, intercropping or succession, but in the same area and in the same agricultural year, or for multiple years (Lourençano; Cavichioli, 2019). This system seeks the diversity of forage crops, the reduction of the application of inputs on the property (Lourençano; Cavichioli, 2019). The most used species are intercropped into winter species (white oats, black oats, ryegrass), and summer species (sorghum, millet, soybean, beans) (Assis *et al.*, 2019).

The integrated crop-livestock-forest (ICLF) system, or agrosilvopastoral, is the combination of three components: agricultural (crop), forestry (tree and/or fruit species) and livestock (beef cattle, dairy), aims at the efficiency of the biological cycles of plants, animals and their residues, where it minimizes and improves the use of inputs, in addition to reducing impacts on the environment (Assis *et al.*, 2019). When the forestry component is integrated, the benefits observed are: the afforestation of pastures, allowing the grass to remain green in the drought, in addition to the thermal comfort provided to the animals (Lourençano; Cavichioli, 2019). It also enables the recovery of degraded areas, as it optimizes the use of the soil through the production of grains and wood in pasture areas (Lourençano; Cavichioli, 2019). Thus, it can be varied among its components, arriving at an integration that best suits its area, soil and climate (Cordeiro *et al.*, 2015). This integration system is part of agroforestry systems, being subdivided with another nomenclature, namely: agropastoral; agroforestry; silvopastoral and silvoagricultural (Lourençano; Cavichioli, 2019).

Livestock-forest integration (IPF) or silvopastoral, integrates the livestock component (pasture and animal) and the forestry component in the form of consortium (Lourençano; Cavichioli, 2019). The most suitable trees for planting are those that best respond to expectations of economic return and have a lower risk of loss due to damage caused by cattle, so producers usually opt for: eucalyptus, Australian cedar, teak, pink cedar, guanandi and African mahogany (Vilela *et al.*, 2015; EMBRAPA, 2019). And finally, the crop-forest integration (ILF) or silviagricultural, integrates the forestry and agricultural component (crop), through the intercropping of tree species with agricultural, annual or perennial crops (Lourençano; Cavichioli, 2019). Trees are planted between the rows of crops so that there is the production of leaf biomass and an increase in the content of organic matter in the soil (Assis *et al.*, 2019; EMBRAPA, 2019).

Crop-forest integration (ILF) integrates the forestry and agricultural component (cropping) by the intercropping of tree species with agricultural crops, annual or perennial. And in turn, the integrated crop-livestock-forest (ICLF) is the integration of the three components: agricultural (crop), forestry (tree and/or fruit species) and livestock (beef cattle, dairy), in rotation, intercropping or succession, in the same area. This system aims at the efficiency of the biological cycles of plants, animals and their residues, minimizing the use of inputs and reducing impacts on the environment (EMBRAPA, 2019).

VARIATIONS OF INTEGRATED SYSTEMS IN BRAZIL

In any region where the implementation of an integrated production system begins, good planning is required. This should include a detailed project of all stages of the process, considering the different aspects, including: edaphoclimatic conditions, existence of infrastructure for the supply

of inputs, storage and flow of production (Lourençano; Cavichioli, 2019). Thus, it can be applied to any rural producer, regardless of the size of their property (Kichel *et al.*, 2014).

In Brazil, due to the edaphoclimatic diversity of our territory, we have great variability of integrated systems implemented (Lourençano; Cavichioli, 2019). In the Amazon region, the crop-forest and livestock-forest systems are widespread, where forest species such as paricá, eucalyptus, teak and African mahogany are used (Balbino *et al.*, 2011). In these systems, the most common forage species are: brachiaria, kikuyu, gingergrass, Jaraguá, Pueraria, and composing the livestock, there are cattle, buffaloes and woolly sheep. The ICF system is usually used in degraded areas, with grain planting between two and three harvests, with a predominance of rice, corn, soybeans and cowpea in rainfed crops, thus disseminated in regions suitable for these crops (Lourençano; Cavichioli, 2019).

In the caatinga, in turn, the system with the greatest applicability is ICLFS, due to the response to the pressures for food production. They are part of the exploitation of perennial woody species, associated with crops and pastures (Balbino *et al.*, 2011). In the Cerrado, ICLFS are used with the agricultural species of cotton, soybeans, corn, sorghum, beans, rice and sunflower. In the Atlantic Forest of the southern region, systems based on the succession of crops in the summer are predominant (Lourençano; Cavichioli, 2019). In the Southeast, there is a predominance of forage rotations with annual crops of soybean, corn and cotton for straw production. In the Northeast, the predominant systems are livestock-forest (EMBRAPA, 2019). In practically half of Rio Grande do Sul, the most common system is the crop-livestock system. Finally, in the Pantanal, the most used system is the extensive livestock-forest system, adapted to the characteristics of the place (Balbino *et al.*, 2011).

INTEGRATED SYSTEMS AND METHANE EMISSION MITIGATION

Results and benefits from the adoption of the Integrated Crop-Livestock (ICL) system There are many benefits obtained from the implementation of the ICL system, among them the improvement of the animal diet, which culminates in a reduction in slaughter time, thus generating lower rates of methane gas emission (CH_4) per animal production (Cabral Neto *et al.*, 2024). These aspects provide better economic direction, in addition to preventing new areas of native vegetation from being converted into pastures (Carlos *et al.*, 2022). The technology used for pasture recovery has the ability to remove carbon from the atmosphere, in order to fix it in the soil (Cabral Neto *et al.*, 2024).

Some evidence points out that it is possible to neutralize emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector, since, by recovering 27.5 million hectares (Mha) by the year 2030, about 6.028 million tons (Mt) of carbon dioxide equivalent (CO_2eq) are accumulated in

the soil, which is equivalent to 463.7 Mt CO₂eq per year (Cabral Neto *et al.*, 2024). These data contribute to a positive mitigation balance for the country (Assad *et al.*, 2021). When properly managed, pastures accumulate carbon at significant levels, being similar to, or even higher than native vegetation, according to Cordeiro *et al.* (2024), in addition to promoting higher nutritional quality for the herd (Cabral Neto *et al.*, 2024). Degraded pastures, on the other hand, in addition to interfering with animal performance, provide the loss of accumulated carbon (Cabral Neto *et al.*, 2024).

Thus, it can be considered that the ICL system is a powerful alternative to the difficulties encountered in the production chain, since it reduces the commitment to the environment and maximizes the production and revenues of the property (Assis *et al.*, 2019). In general terms, the purpose of the ICL system is to promote interactions between soil, plant, animal, and atmosphere, which culminate in a reduction in risks and costs, as well as in the increase of production efficiency, mitigation of Greenhouse Gas (GHG) emissions, and reduction of pests (Cabral Neto *et al.*, 2024). In view of broader aspects, the system allows for diversified food production, in addition to mitigating possible risks related to food insecurity in underdeveloped countries (Capitani; Farina, 2022). Aiming at the effective use of available resources, there is the possibility of implementing diversified production systems, leading to the rationalization of the use of inputs, in addition to improving soil and water quality (Cabral Neto *et al.*, 2024). These benefits can be obtained in properties of all sizes and even in properties that require the exploration of permanent preservation areas (Martins; Rezende, 2020).

TYPES OF CROP-LIVESTOCK INTEGRATION

The Integrated Crop-Livestock System or Agropastoral System, aims to increase productivity and achieve favorable environmental levels from the rotation and diversification in pasture and crop production in NTS, using the same surface at different times. There are several methodologies to be adopted within the ILP System, which can and should be adapted according to the needs of each region, namely: Barreirão, Santa Brígida, Santa Fé, São Mateus and Gravataí (Camporezi, 2022).

The Barreirão System is a type of technology that provides the establishment of pasture followed by the harvest of grains, that is, it takes place from the total preparation of the area, with correction and fertilization before the insertion of grain crops, in which, at the same time, forage and perennial grasses, especially brachiaria grasses, are inserted (Bungestab *et al.*, 2018). The Santa Brígida System aims to promote the increase of nitrogen input to the soil from the biological fixation of atmospheric nitrogen, this practice is consolidated with the insertion of green manures in the corn production system. In this organization, there can be processing for subsequent cultivation, since the

supply of nitrogen from legumes provides a decrease in the supply of mineral nitrogen (Queirós *et al.*, 2020).

The Santa Fé System promotes the insertion of forage species of the genus *Urochloa* and *Megathyrsus*, mainly by intercropping, in a grain production system. It aims to produce forage in the off-season, in addition to producing straw for the NT of the next crop (Ponciano *et al.*, 2021). The São Mateus System aims to promote NTS to introduce, along with pasture, crops in rotation. It is directed to regions that have sandy soils, poor in nutrients and with impaired water retention capacity, and those where rainfall distribution is irregular during the year, causing water restriction (Fontaneli; Fontaneli,; Panisson, 2022). The Gravataí System is based on the intercropping of cowpea (*Vigna unguiculata*) and grasses of the genus *Brachiaria*, such as *B. ruziziensis* and *B. brizantha* cvs. BRS Paiaguás and BRS Piatã, in order to obtain greater accumulation of forage with high nutritional value, as well as high crude protein (CP) content and digestibility (Camporezi, 2022).

In general terms, the Barreirão System promotes increased profitability with the diversification of the activity, in addition to expanding animal support capacity, as well as resistance during the dry season and suppression of termites and invasive plants (Cabral Neto *et al.*, 2024). The Santa Fé and Santa Brígida System, on the other hand, from forage straw, provides an improvement in the physical, chemical and biological conditions of the soil, benefiting the development of a next cultivar in that location under NT, in addition to offering the possibility of increasing the supply of forage to meet the needs of cattle during the dry season. there is also, in these systems, the feasibility of using the area for agriculture in the summer and livestock during the winter (Leão *et al.*, 2021).

FORAGE COMPONENTS IN SIPA'S

As in the rest of Brazil, in the southern region the activity is based on the use of pastures as the main food resource. Also, as the well-defined cold season, characterized by the reduction of the photoperiod, low temperatures and the occurrence of frost, limits the production and quality of tropical forages, according to Peretti *et al.* (2017), forage strategies should be adopted to fill this food gap. LPIS in Brazil comprise a great diversity of forage species due to the diversity of our edaphoclimatic conditions. However, of the pastures cultivated in winter, the most used species is ryegrass (*Lolium multiflorum* Lam.) according to Bohn *et al.* (2020), due to its productive potential and good adaptation to the environmental conditions of the region (Dotto; Robaina; Scotti, 2022). In addition to being a good alternative to compose subtropical systems of crop-livestock integration, according to Moraes *et al.* (2014), as it has a high potential for dry matter production, according to Peterson *et al.* (2019) can be used for both grazing and ground cover (Bohn *et al.* 2020).

As the SIPA's aim at social, environmental and economic sustainability, among the challenges, the adoption of pasture management strategies that aim to maximize plant and animal production are extremely important (Dotto; Robaina; Scotti, 2022). Thus, in addition to the choice of forage species, the grazing method and the fertilization strategy must be defined in order to meet the principles mentioned. In continuous stocking, the animals have unlimited and uninterrupted access to the entire area to be grazed during the entire grazing period, and in rotational stocking, there is an alternation between defoliation and rest (Dotto; Robaina; Scotti, 2022). Due to the interspersed rest and grazing periods, in the rotating stocking, the regrowth process occurs in isolation from the grazing process (Ongaratto; Romanzini, 2021). On the other hand, continuous stocking is characterized by milder changes in pasture condition over the period (Dotto; Robaina; Scotti, 2022). This is the most suitable option for adoption in SIPA systems, as the constant soil cover maintained by the higher residual grazing height provides the sponge effect, minimizing soil compaction (Coser *et al.*, 2018).

In ryegrass, when used for grazing, in its management it is recommended the entry of animals into the area when the ryegrass is approximately 30 cm high, for a better use of the pasture (Flores *et al.*, 2008). However, grazing management should prioritize a pasture height always higher than 10-15 cm to stimulate regrowth (Peretti *et al.*, 2017). The period of use of ryegrass pastures can last up to 80 days, subject to the climate, soil fertilization and especially area management (Pelegri *et al.*, 2010). Although it is a forage species extensively studied in the southern region of Brazil, its dynamics in LPIS in lowlands is not yet fully elucidated. Thus, studies contemplating the performance of ryegrass inserted in alternative LPIS systems in lowlands will support technical recommendations for the management of this pasture.

ANIMAL COMPONENT IN SIPA'S

The livestock phase of LPIS in the sub-tropical regions of Brazil is commonly adopted in the winter period and the main plant species used are winter forage grasses (Bertol *et al.*, 2022). Of these, ryegrass is the predominant one in lowlands, with dry matter productions that can reach 10 tons/ha and total digestible nutrient concentrations that can reach more than 80%, providing excellent animal performance (Fontaneli *et al.*, 2016). However, this is dependent on the management of grazing intensity in the livestock phase, which determines the amount of forage available to the animal: higher grazing intensities will provide lower forage availability and vice versa (Bertol *et al.*, 2022). This is directly linked to the animal load used, which is one of the main challenges for increasing the area of LPIS in Southern Brazil. There are paradigms linked to the consumption of forage material that would cover the soil and the potential compaction of the soil by animal

trampling, according to De Faccio Carvalho *et al.* (2021), that is, both are linked to the grazing intensity of the livestock phase (Bertol *et al.*, 2022).

Although grazing should be moderate to minimize soil compaction and maximize forage production, it should be present, as it is responsible for plant root growth. In other words, the animal component is fundamental for the sustainability of the system, because in addition to promoting defoliation with root growth of forage plants, it also provides the cycling of nutrients through feces and urine. Integrated crop-livestock systems are based on the premise that livestock activity can contribute to organic residues, improvement of soil physical and chemical characteristics, crop rotation, interruption of the cycle of plant diseases and reduction of losses resulting from climate variability. Additionally, these systems can provide fresh and highly nutritious forages for livestock, including in winter, while in other systems forage can be scarce (Vinholis *et al.*, 2021). For this reason, the adoption of animals with genetic potential can enhance the SIPA's, providing greater animal gain and greater efficiency in the use of the forages offered.

AGRICULTURAL COMPONENT IN SIPA'S

In the subtropical regions of Brazil, the agricultural cultivation phase of SIPA's is commonly adopted in the summer period, and includes irrigated rice (*Oryza sativa*), soybean (*Glycine max*) and/or corn (*Zea mays*) crops. In lowlands, corn is rarely cultivated, except when used to produce silage for animal feed. Rice cultivated in the irrigated form is the predominant crop in lowlands in the agricultural phase. However, the sustainability of its cultivation has been declining season after season, with increased production costs and reduced water availability.

Soybeans are the most important economic commodity in Brazil and widely used around the world. In recent years, new areas have been used for soybean production, mainly in the lowlands of agricultural fields in southern Brazil historically managed by cattle ranching (Theisen; Scivittaro, 2023). However, most areas presented limiting factors for production, such as low soil fertility and reduced water retention, reducing the potential for grain yield. However, the gains related to soybean cultivation would not be directly economic.

As it is a leguminous crop, it has the ability to fix nitrogen biologically. Also, its pivoting root system could contribute to the decompaction of the superficial layers of the soil, contributing in the long term to the improvement of its structure. Combined, these characteristics could contribute to a more favorable soil condition for ryegrass, providing higher DM productivity and higher animal load (Silva *et al.*, 2020).

ECONOMIC COMPONENT IN SIPA'S

The adoption of technologies enables productivity gains and/or lower production costs through the use of new inputs and new combinations of resources (Vinholis *et al.*, 2022). These gains have been observed in Brazilian agriculture. In recent decades, the generation and adaptation of agricultural technologies to tropical conditions has enabled the country to sustain a consistent increase in food production. In 2020, agribusiness GDP reached 26.6% of share in the national GDP (Center for Advanced Studies in Applied Economics, 2020). Monoculture crop production and conventional livestock farming not integrated with crops were designed for a rapid increase in productivity and food supply (Vinholis *et al.*, 2021). Thus, monoculture is the predominant plant and animal production system in Brazil, based on the intense use of natural resources, chemical formulas, and non-renewable energy (Mendonça *et al.*, 2020).

However, some of these production systems have shown signs of saturation and negative environmental impacts (Vinholis *et al.*, 2021). However, in the face of an imminent scarcity of natural resources, production systems need to be rethought (Mendonça *et al.*, 2020). Crop-livestock integration systems have been developed as an alternative that offers increased productivity and greater environmental sustainability (Vinholis *et al.*, 2021). These systems enable the economic exploitation of production areas throughout the year, allowing greater production of grains, milk and meat, at lower costs due to the interaction between crops and pasture. In economic theory, any economic gains obtained from the diversification of production systems are justified by the so-called "scope economy", which occurs when the cost of producing two items in a given production system is lower than when the same items are produced separately (Mendonça *et al.*, 2020).

However, measuring and demonstrating the economy of scope in production systems is not so simple, according to Gameiro *et al.* (2016), probably due to the difficulty in calculating the cost of production of an integrated system, especially for farmers (Araújo; Mendonça, 2020). This can be explained because there is no "standard protocol" for estimating the cost of an integrated system, which means that there are several ways to conceptualize costs in nature-related production systems. The different possibilities of CLI system configurations in relation to the crops implanted and the management carried out are challenged to demonstrate the economic advantages of this system (Araújo; Mendonça, 2020).

INTEGRATED SYSTEMS IN SOUTHERN BRAZIL

LPIS are production models planned in space and time, in the same area or in different areas, jointly or sequentially, with the purpose of associating agricultural production with beef or dairy cattle, benefiting from the synergism between activities to increase productivity levels and promote greater income diversification. in a sustainable way (Sandini *et al.*, 2011; Anghinoni *et al.*, 2013).

Currently, research institutes promote the diversification of crops integrated with livestock production in soil conservation management, in areas historically intended for rice cultivation, from the introduction of soybeans, corn, Sudan grass and winter forages. What has been studied are irrigated rice production systems that vary the diversity of agricultural crops and the temporal intensity of the pasture phase and the cultivation of irrigated rice (Moraes *et al.*, 2017).

Although areas intended for integrated production systems of agricultural production have the potential to mitigate environmental problems, meet consumption demand and economic development, the sector lacks studies for the application of sustainable tools and strategies (Carmona *et al.*, 2018). It is also worth noting that the conventional agricultural system model is in evidence, because over the years the loss of forage diversity and environmental pollution by excess nutrients and pesticide residues, according to Anghinoni *et al.* (2013) has made society currently demand that specialized production models commit to producing food in the most connected way possible with nature (Carmona *et al.*, 2018)element.

In lowlands, irrigated rice is predominant in spring/summer and ryegrass in autumn and winter. This practice occurs in approximately 1.1 million hectares in Rio Grande do Sul (CONAB, 2019) due to the characteristics of the soil in these regions. However, it is known that rice cultivation is costly and expensive in terms of labor, water, energy, and as these resources are becoming increasingly scarce, this activity is becoming less profitable (Kumar; Ladha, 2011). Therefore, the implementation of LPIS in current agricultural production models can help generate income in the off-season of summer crops.

The soil of areas cultivated with rice tends to have a low rate of water infiltration, low macroporosity and high compaction close to the surface, which makes it difficult to insert other crops, according to Denardin *et al.* (2019) to achieve positive results in LPIS. One of the most recent concepts studied in LPIS is system fertilization, which refers to the biological cycling of nutrients between the phases of a rotation system, that is, it is believed that in a system that includes agriculture and livestock, there can be a use of the nutrients deposited in the soil for successive crops (Assmann *et al.*, 2017). In the highlands this concept is already applied and studied by Souza (2008), but in the lowlands there is much to be explored. According to Carvalho (2018), the insertion of animals in LPIS areas modifies some properties of the system, such as nutrient recycling and soil aggregation, promoting the improvement of its quality. Knowing that the recycling of nutrients to the soil through cattle in the pasture is possible, there are still studies that prove the benefits of introducing forage and animal components to these systems.

ANNUAL RYEGRASS (*Lolium multiflorum*) IN LOWLANDS

Native pastures are the main source of food for cattle in the Pampa of Rio Grande do Sul, but they have better nutritional value in the warmer seasons of the year (Flores *et al.*, 2008). Not only in the Pampas region, but throughout southern Brazil, the well-defined cold season, characterized by the reduction of the photoperiod, low temperatures and the occurrence of frost, limits the production and quality of tropical forages (Peretti *et al.*, 2017). The cold season is the most restricted in forage production, characterized by the scarcity and loss of quality of feed fed to the animals (Pavinato *et al.*, 2014). This seasonality in forage production has been one of the main factors responsible for the low production rates in Brazilian livestock, where climatic factors such as precipitation and temperature are the most important (Gerdes *et al.*, 2005). However, the same climatic conditions that limit the production of tropical forages favor the strategic use of annual forage species, adapted to these conditions (Peretti *et al.*, 2017).

Annual ryegrass is one of the most cultivated winter species in Rio Grande do Sul, according to Bohn *et al.* (2020), in addition to being a good alternative to compose subtropical systems of crop-livestock integration (Moraes *et al.*, 2014). According to Gerdes *et al.* (2005), ryegrass is characterized by high productivity and excellent nutritional value. This crop is resistant to cold, has a high capacity for natural reseeding, is resistant to crop diseases and for the animal, acceptance is great when grown in intercropping with other grasses and legumes (Cassol *et al.*, 2011). Because it has a high potential for dry matter production, according to Peterson *et al.* (2019) can be used for both grazing and ground cover, according to Bohn *et al.* (2020) and can also be used in the form of silage and hay (Pedroso *et al.*, 2004).

To further improve its productive potential, research aimed at the genetic improvement of ryegrass has aimed to select cultivars that are even more productive, earlier and better adapted to different edaphoclimatic conditions. When used for grazing, in its management it is recommended the entry of animals into the area when the ryegrass is approximately 30 cm high, for a better use of the pasture (Flores *et al.*, 2008). Animals should be removed from the area when the plants reach a residual height of 10-15 cm to stimulate regrowth (Peretti *et al.*, 2017). The period of use can last up to 80 days and depends on climate, soil fertilization and especially area management (Pelegrini *et al.*, 2010). There are several studies elucidating the productive potential of ryegrass in various regions of southern Brazil (Lang *et al.*, 2004; Lopes *et al.*, 2009; Battiston *et al.*, 2020, Bohn *et al.*, 2020), but as the rice-ryegrass-soybean rotation in the Lowlands is recent, studies that measure ryegrass production in this LPIS model are scarce in the scientific literature.

NUTRITIONAL VALUE OF FORAGE PLANTS

The nutritional value of a forage is defined by its chemical composition and the potential for use by animals to generate energy and convert it into production. Thus, the result of a chemical analysis becomes an important tool for the correct balance of the animals' diet, with greater responses in milk and meat production (Serafim *et al.*, 2017). In the analytical quantification of the nutritive value of foods, several parameters are used, such as dry matter (DM), mineral matter (MM), crude protein (CP) or total nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, digestibility, among others (De Macêdo Carvalho *et al.*, 2021). However, the estimates of nitrogen and crude protein content, and the fibrous fractions are the most relevant. These are determined by analyzing neutral detergent fiber, acid detergent fiber that can be fractionated to lignin, cellulose and hemicellulose.

In order to determine the nutritional value of a forage species, it is necessary to carry out studies that allow the joint evaluation of the chemical composition (MS, OM, PB, EE, NDF, FDA and lignin), digestibility and secondary constituents that can interfere in the intake and use of the forage consumed by ruminants (De Macêdo Carvalho *et al.*, 2021). Thus, based on the chemical composition, estimates can be made to contribute to the nutritional assessment, such as those that allow us to know the levels of total carbohydrates (CHOT), non-fibrous carbohydrates (NFC) and structural carbohydrates (EC) (Sniffen *et al.*, 1992). Still other parameters can be estimated from the chemical composition, such as dry matter intake expressed as a percentage of live weight (DMSPV) obtained from NDF (Mertens *et al.*, 1997). The dry matter digestibility (DIGMS) and total digestible nutrients (TDN) that can be estimated from the ADF, according to Bolsen, (1996), and the relative forage value (VRF) estimated from the DGMS and the CMSPV (Bolsen, 1996).

In addition to the parameters described, others can be estimated to determine the nutritional value of a forage in its natural or preserved form, for use in ruminants. However, when considering the protein fraction and the fibrous constituents, we can quickly estimate the nutritional value of a forage. The protein content in forage is also a determinant in nutritional value because it has a positive correlation with dry matter intake, according to Oliveira *et al.*, (2017), and this effect is partially due to the increase in degradable protein in the rumen and improved feed digestibility (Cardoso *et al.*, 2014).

Likewise, the levels of fibrous constituents directly interfere with consumption capacity and digestibility. NDF is a determinant of CMSPV because the higher the NDF content of a forage, the slower its digestion will be, and therefore, the longer it will be retained in the rumen environment, causing the filling effect (Mertens *et al.*, 1996). In the filling effect, the animal is satiated by the physical effect provided by the fiber of the digesting forage, thus limiting the consumption of a larger volume of DM (Oliveira *et al.*, 2017). For this reason, the higher the NDF content of a forage, the

lower its consumption capacity, and the lower the WASPS (Detmann; Gionbelli; Huhtanen, 2014). As described by Mertens (1992) proposed a maximum intake value of 1.2% of live weight in NDF, however, as the CMSPV is influenced by the physiological state of the animals, when in production as dairy cows they will have a higher demand for CMSPV than beef cattle in maintenance, for example (Cardoso *et al.*, 2014). Thus, it is important to know the CMSPV of each forage to balance its inclusion in the diets so that there is no limitation of consumption by filling effect, thus avoiding the limitation of animal performance.

In its composition, NDF has lignin, cellulose and hemicellulose. While the last two are potentially digestible, according to Silva; Queiroz (2009) lignin is indigestible and because it is made up of phenolic compounds, it is toxic to rumen microorganisms. Thus, in addition to repelling the approach of microorganisms to the particles, it inhibits the digestion of fibrous carbohydrates by imposing a physical barrier to the microorganisms, preventing the attack on the cell wall of the ingested forage. These cell wall constituents have their content increased with plant maturation, reducing the nutritive value of the forage. This process occurs through the directing of photosynthetic carbon to the plant structure (Battiston *et al.*, 2020). This accumulation of structural cell wall dilutes the proportion represented by cell content with an increase in the fibrous portion and simultaneous reduction of soluble carbohydrates from cell content, through growth stimulation and the use of reserves (Battiston *et al.*, 2020).

DIGMS is a measure of the proportion of food consumed that is digested and metabolized by the animal (De Macêdo Carvalho *et al.*, 2021). It is an important parameter for evaluating the nutritional value of forages because in addition to the potential for nutrient supply, they also act in the CMSPV. Both DIGMS and NDF digestibility interfere with DMSPV, according to Cardoso *et al.* (2014), as they influence the rate of fiber degradation in the rumen environment, reducing the feeling of satiety and stimulating consumption in animals (Oliveira *et al.*, 2017). It is estimated that the maximum DM intake occurs in forages with digestibility values in the diets 66 and 68%, according to Cardoso *et al.* (2014), however, it is difficult for a tropical forage to have digestibility higher than 60%, noting that consumption under these conditions is always limited by filling (Nascimento *et al.*, 2009). In this way, the use of winter forage grasses enhances not only the LPIS and the use of fallow areas in the winter period, but also the performance of the animals due to the higher nutritional value of the forage.

The relative forage value (VRF) is a widely accepted forage quality index in the U.S. hay market, and has been used to characterize pastures. VRF is calculated by combining estimates of digestibility and forage intake that are obtained from NDF and ADF values. The VRF combines the estimates of digestibility and intake of forages into a single number calculated from the ADF and NDF levels (Ward; Ondarza, 2008). The parameter of 100% would be equivalent to alfalfa hay, so

when estimating the VRF of different forages, these are indirectly compared to alfalfa. However, its use in forages under grazing should be used with discretion, because as it is dependent on parameters that change with plant growth, it is subject to the same dynamism.

ANIMAL COMPONENT AND ANIMAL WELFARE IN ICL

It is characterized by the harmony between the animal and the environment, considering the physical and physiological conditions and high quality of life of the animal. It also refers to the animal's ability to adapt to the woolly environment (Lourençano; Cavichioli, 2019). Physiological stress is one of the main indicators used in the assessment, because as it increases, well-being decreases. Currently, to establish the degree of animal welfare in a production system, the concept of the "five freedoms" is used, where they define conditions for this.

Physiological freedom is characterized by the supply of water and food in quantity and quality appropriate to the conditions of the animals; environmental freedom, characterized by a correctly planned environment, which has physical and thermal comfort; sanitary freedom, characterized by the absence of pain, injuries and diseases, met by the correct sanitary management of animals; behavioral freedom, characterized by the possibility of expressing behaviors characteristic of the species; and psychological freedom, which is characterized by the absence of fear and stress, where the conditions of the environment are facilitated, avoiding animal suffering (Alves; Nicodemus; Silva, 2015; Alves; Porfírio Da Silva; Karvatte Junior, 2019). Integration systems, when well planned, meet all these precepts and, when compared to traditional pasture production systems, generate better animal welfare.

This is because the trees present in the pasture, as a forest component of the integration system, promote considerable changes in the local microclimate, such as wind speed, temperature, vapor saturation pressure, air humidity and incident solar radiation, according to Lourençano; Cavichioli (2019), the latter being reduced by up to 30%, depending on the forest species, and also protecting them from excessive cold (Alves; Nicodemus; Silva, 2015; Alves; Porfírio Da Silva; Karvatte Junior, 2019). On the other hand, it is important to pay attention to the amount of shade offered, as it is essential that there are uncovered areas (simple rows), so that the density of the shadows does not harm the development of forage, thus compromising animal nutrition and crops, in addition to interfering with air movement, compromising the efficiency of temperature regulation of the animals (Alves; Nicodemus; Silva, 2015; Alves; Porfírio Da Silva; Karvatte Junior, 2019).

CONCLUSION

Integrated agricultural production systems (SIPA's) present an alternative potential to increase productivity and minimize the effects of environmental impact, from the rotation and diversification



in the production of grain crops with forage crops in the same area. Due to the great diversity of ICL systems, they can be applied in all regions of Brazil, and in all sizes of properties and bring benefits to producers, consumers, and especially to the environment and production systems.

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Competitiveness of Brazilian fruit exports to the European market

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ABSTRACT

This study aims to evaluate the competitiveness of Brazilian fruit exports to the European market, through the *Constant Market Share* model and the Revealed Comparative Advantage, in the period from 1990 to 2009 and from 2000 to 2009, for the two models, respectively, using the following crops: mango, grape, papaya and melon. The result obtained through the applied model showed that in the first and second periods Brazil was competitive in the exports of grapes, melons and mangoes to the European market and that this competitiveness is due to quality; As for papaya, it was found that, to the detriment of the destination market, it was exported in the first and second periods without distinction. The country has a Comparative Advantage in all the fruits that make up the analyzed basket, however, even with this advantage in the production and generation of surplus, there are other determining factors in Brazilian fruit exports. Although national companies in this sector have shown a good performance, Brazilian exports are affected by systemic competitiveness that adds the costs of energy, internal transport, exchange rate and precarious infrastructures, which includes roads, ports and airports.

Keywords: Competitiveness, Comparative Advantage, Exports, Fruits.

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INTRODUCTION

The international fruit market points to figures above US\$ 29 billion/year and the growth is 5% per year. To a large extent, this market is made up of temperate climate fruits, typical of production and consumption in the Northern Hemisphere – although the market potential for tropical fruits is high –, and when the values of processed fruits are added, the figures exceed US\$ 100 billion dollars (ANDRIGUETO; NASSER; TEIXEIRA, 2008).

Over the last few years, the international fruit market has been growing at significant rates and this growth has been accompanied by a significant increase in production. Some countries with vast territories such as China, India and Brazil had a strong productive participation. In the Brazilian case, the Northeast region stood out, having excellent performance in the production and export of fruits. Despite this, the Food and Agriculture Organization of the United Nations (FAO, 2010) found that in 2008 the sum of the production of mangoes, melons, grapes and papayas was 125,753 (one hundred and twenty-five million, nine hundred and fifty thousand) tons, thus showing a slight decrease of 0.35% in relation to the previous year.

The world's top three fruit producing countries, China, India and Brazil, hold more than 40% of all world production (FAO, 2010). These three countries are privileged by vast territories and each one has a large domestic market, however, this does not justify the weak participation of these nations in the international market, since fruit exports are conditioned by several factors. For example, according to Galvão (2010), with regard to the world's main fruit producing countries, Ecuador occupied the seventeenth position in 2008. However, in 2007, this country was the world's first exporter of fruit among the main exporting countries.

Among the fruits that make up the analysis basket studied here, grapes, in relation to the others, are the most produced, followed by mangoes, melons and papayas, as illustrated in Table 1, below:

Table 1: World production of grapes, mangoes, melons and papayas in the period 2004-2008 (Ton.)

Types of fruits	2004	2005	2006	2007	2008
Grape	59.556.350	59.387.981	59.293.871	57.101.503	59.013.092
Manga	26.900.991	28.932.198	30.636.179	31.459.632	31.934.668
Melon	23.043.606	24.386.028	25.333.705	25.664.112	25.746.395
Papaya	8.260.919	7.724.553	8.566.564	8.846.516	8.723.050

Source: Prepared by the author based on FAO data (2010).

Ecuador's participation is due to the presence of five multinational companies³ that operate in this South American country and in others throughout Latin America, including in the Brazilian Northeast, as well as in several nations on the African continent. These five companies alone together

³ As empresas são: Dole Food Company, Chiquitita Brands International, Del Monte Fresh Produce ou Fresh Del Monte Produce and Fyffes and Noboa.

dominate more than 70% of world exports, establishing themselves based on locational advantages and in areas where labor is quite cheap (ALBANO, 2009).

Table 2: Main world fruit exporting countries (in volume and %) - 2007

Country	Quantity (Ton.)	% Total
Ecuador	5.330.868,00	9,24
Spain	4.851.648,00	8,41
Chile	4.069.311,00	7,05
Costa Rica	3.889.293	6,74
United States	2.902.312,00	5,03
Belgium	2.333.996,00	4,04
Italy	2.279.046,00	3,95
Mexico	2.137.313,00	3,70
South Africa	2.111.166,00	3,66
China	2.103.559,00	3,65
Philippines	2.101.040,00	3,64
Holland	2.045.952,00	3,55
Guatemala	1.894.217,00	3,28
Colombia	1.652.356,00	2,86
Argentina	1.473.277,00	2,55
France	1.177.084,00	2,04
Turkey	962.376,00	1,67
Brazil	918.307,00	1,59
Honduras	845.754,00	1,47
Panama	840.946,00	1,46
Other 153 Countries	11.784.105,00	20,42
Total	57.703.926,00	100,00

Source: Prepared by Galvão (2010), based on FAO data (2009).

The Brazilian agricultural sector has contributed positively to the growth of production and exports in the national economy as a whole and has contributed with a significant portion in the performance of the Brazilian trade balance, especially in the generation of employment in the countryside, especially in the irrigated fruit growing segment (GALVÃO, 2010).

Data from FAO (2010) and COMTRADE (2011) show a growth in the international fresh fruit market, thus giving possibilities of inclusion in this context to countries with extensive territories, and Brazil is inserted in this reality with the possibility of increasing its participation and productivity. The Northeast region of the country has a fundamental role, and over the last few years, it has been seeking to articulate regional public policies in order to develop productive and commercial efforts, with the aim of expanding its insertion in the international fruit market (MARTINELLI; CAMARGO, 2002).

However, entering the highly demanding and highly competitive European market, which imports fruit from all continents, is not a simple, banal task. It is an international fruit market that is far from being easy to master, due to phytosanitary barriers, trade preferences and significant changes related to production, marketing, legislation and logistics.

This paper analyzes the competitiveness of Brazilian fruit exports, seeking to answer the following question: as a result of the dynamism of the international fruit market, how do Brazilian fruit producing and exporting companies position themselves to compete in the international market? In addition, as a specific objective of the study, it seeks to evaluate the competitiveness of Brazilian fruit exports based on the *Constant Market Share indicators*.

METHODOLOGY

MODELO CONSTANT MARKET SHARE

To achieve one of the objectives of the present work, the *Constant Market Share (CMS)* method was used, which enables the understanding of the determining factors that influence the performance of exports of a given product, from the destination market and in relation to total world imports.

According to Leamer and Stern (1970), (1) exports can be concentrated in *commodities* whose demand is growing relatively slowly; (2) exports may be going primarily to relatively stagnant regions or (3) of the country in question, which may have been unable or able to compete effectively with other sources of supply.

Once again, it is worth noting that the CMS model analyzes the growth of the share of exports in the following indicators: growth of international trade, composition of the export basket, destination of exports and competitiveness determined by the residue of other exports.

According to Sereia, Nogueira and Câmara (2002), the CMS model has as its main advantage the possibility of analysis by component and by the behavior of the product in the destination market, thus indicating the markets where the country is more competitive. Leamer and Stern (1970) developed the CMS model as follows:

V_i = total value of exports of product i of country A, period I;

r_i = increase in world exports of product i from period I to period II. V_{ij} = total value of exports of product i from country A to country B in period I;

V^*_{ij} = total value of exports of product i from country A to country B in period II; r_{ij} = increase in world exports of product i to country B from period I to period II.

This time, the resulting equation can be gathered into:

$$V^* - V \equiv \sum \sum r_{ij} V_{ij} + \sum \sum (V^*_{ij} - V_{ij} - r_{ij} V_{ij})$$

$$V^* - V \equiv rV + \sum (r_{ij} - r_i) V_{ij} + \sum (V^*_{ij} - V_{ij} - r_{ij} V_{ij}) \quad (1)$$

(a)
(b)
(c)

According to Leamer and Stern (1970), considering the equations above, we have effects (a) and (b), associated with external factors, and effects (c) in which:

- (a) = represents the effect of the growth of world trade – whether the increase or decrease in the exports of country A had the same rate of growth or decrease in relation to world trade;
 - (b) = destination effect of exports – changes as a function of the exports of products to the market with more or less effective growth;
 - (c) = residual effect, representing competitiveness – implies the difference between the current increase and the growth that would have occurred in the exports of country A if the export share of each good to the country had been maintained.
- $r_i V_i$ = growth of the i-market;
 - $\sum (r_{ij} - r_i) V_{ij}$ = destination of exports of i;
 - $\sum (V_{ij}^* - V_{ij} - r_{ij} V_{ij}) = \text{Competitividade}^4$

COMPARATIVE ADVANTAGE REVEALED

Another element to measure competitiveness that several authors have already used is the Revealed Comparative Advantage indicator. This indicator measures the share of a certain product in the total exports of a given sector of a country in relation to the share of the same product in the total world exports of the same sector (TURINA; BURNQUIST, 2005).

According to Holanda (2002), a country benefits from comparative advantage when its insertion in international trade is efficient in terms of allocation of its factors of production, that is, conceptually, the country presents Comparative Advantage when it effectively dedicates itself to sectors/products that are only more efficient in comparative terms and this efficiency makes it more advantageous in international trade.

According to Vitti (2009), in the real world the distribution of factors happens differently and for this reason the opportunity costs are different. Countries should focus on the production of products in which comparative advantages are presented, and this is the case of Brazil, which, roughly speaking, exposes it in the production of fruits in relation to the countries of the European Union (EU) bloc.

Thus, the Revealed Comparative Advantage indicator is defined by:

$$VCR_K = (X_{\text{país}} / X_{\text{país}}) / (Y_{\text{mundo}} / Y_{\text{mundo}}) \quad (2)$$

⁴ Detailed demonstrations of the model can be found in Leamer and Stern (1970) and Rodrigues (2012).

Where:

VCR_{kj} = Revealed comparative advantage of product k of country j ;

$x_{kj}^{country}$ = exports of good k from country or region j ;

$X_{zj}^{country}$ = total exports of the country or region j ;

Y_k^{world} = exports of the good k in the world;

Y_z^{world} = total world exports.

Therefore, when $VCR_{kj} > 1$, it is concluded that product k presents the Revealed Comparative Advantage; if $VCR_{kj} < 1$, then product k has a Comparative Disadvantage Revealed. If $VCR_{kj} = 1$, the country or region j will have no advantage or disadvantage in the production of the product, in this case, local production meets the needs of domestic consumption, and it is stated that there is no surplus to be exported, as characterized by Silva (2006).

FACTORS OF COMPETITIVENESS IN THE FRUIT EXPORT SECTOR

Competitiveness stood out between the mid-1980s and 1990s through debates on industrial policy. According to Farina (1999, p. 149), "competitiveness does not have a precise definition, on the contrary, it comprises so many facets of the same problem that it is difficult to establish a definition that is both comprehensive and useful". The author went even further to define competitiveness as the ability of the company to remain in the market and, preferably, to grow in competing markets or in new markets.

The term *competitiveness* is applied to both nations and companies. According to Di Serio and Vasconcellos (2009), one of the most accurate definitions of competitiveness is the share of the world market that a country has for its products, which makes it become a game in which the gains of each country occur as a function of other countries. For Porter (2004), the success or failure of any company depends on its competitive advantage, and competitive strategy is the search for a privileged strategic position in a company, the important arena where competition occurs.

Benites and Valério (2004) clarify that the company is competitive when it is efficient in the performance of its activities and the final value created can be measured by the willingness of consumers to pay for the products it offers.

In the view of Santos (2006), competitiveness relates the company and its market. Conceptually, competitiveness is a positive result of this direct relationship, that is, the ability of the company to create and efficiently conduct relationships that generate favorable results for it, which means that an organization is only competitive if it has the ability to produce products and services of superior quality and at lower costs than its competitors.

THE DETERMINANT FACTORS OF COMPETITIVENESS IN THE BRAZILIAN FRUIT EXPORT SECTOR

In the last decade (2001-2010), the Brazilian fruit growing sector has improved a lot with the participation of different actors, especially the Ministry of Agriculture, Supply and Livestock, as well as other state agencies, since being competitive in the foreign market requires joint effort and competence. However, despite the efforts made, the country has bottlenecks that hinder competitiveness and affect the sector, such as the high cost of freight, problems in ports and the devaluation of the dollar.

The quality of Brazilian fruits as a determining factor for competitiveness in the international market. The global concern with the type of food to be consumed makes quality an important factor for the competitiveness of fruit producers/exporters on all continents.

According to Souza and Amato Neto (2006), the expansion of *fast food* chains, which sell foods rich in fats and carbohydrates and low in fruits, has generated serious health problems in most developed countries. In the specific case of England, studies have proven that poor diet is related to heart disease, and it is estimated that the British government spends around US\$ 7 billion to treat them.

As a result of these facts, the concern about consuming healthy foods arose. In developed countries, experts have been recommending the intake of at least five servings of fruits and other vegetables a day for a balanced diet. The concern, however, does not only concern consumption, but also the quality of these foods.

The importing market evaluates the quality of fruits from two perspectives; one is extrinsic quality, in which the attributes of the product can be visualized through prices, appearance, shape, color and size, while intrinsic quality is related to damage to the environment in its production process, absence of additives and preservatives, absence of chemical residues, adequate nutritional values and consumer confidence in products or companies (SOUZA; AMATO NETO, 2006, p.404).

The certification seal enters precisely into the intrinsic quality, which is the one that cannot be seen by consumers. Through certification, however, it is possible to make certain attributes of the product known, thus ensuring its quality. For Souza and Amato Neto (2006), the main certification standards required by the fresh fruit importing market are global and private.

According to FAO (2010, p. 22) "nowadays consumers are increasingly concerned with consuming healthy food and respecting the environment and the well-being of workers". Due to this concern, Good Agricultural Practices (GAP) and Hazard Analysis and Critical Control Points (HACCP) were created, the latter being a system recommended by international organizations, such as the World Trade Organization (WTO), World Health Organization (WHO) and MERCOSUR, in addition to the European Community and the United States. Maia (2011, p. 13) states that, "in the

case of Brazil, the Ministry of Health and the Ministry of Agriculture, Supply and Livestock already have actions aimed at adopting the HACCP System".

The nominal exchange rate as a determining factor for competitiveness in Brazilian fruit exports

The nominal exchange rate is one of the variables that determine the volume of a country's exports. In Brazil, the contracts between the national fruit exporting companies and the European import market are signed in foreign currencies (euro and US dollar) and the expenses in the fruit production chain are made in reais (national currency), which, obviously, demonstrates how much exports depend on the exchange rate.

The disadvantage comes primarily from the low production costs of competing countries. For example, the labor of a worker on a mango farm is US\$ 100.00 in Peru and Ecuador, while in Brazil the salary of a person with the same function is US\$ 500.00; another advantage is organic production in those countries, as Brazil still produces with the help of chemical fertilizers and pesticides. In short, the high cost of Brazilian production ends up making the country less competitive compared to its competitors in the international market.

Brazilian infrastructure as a determining factor in the competitiveness of fruit exports

According to studies by the Institute of Applied Economic Research (IPEA, 2010), the road sector is of great importance for cargo transportation in Brazil and, throughout the 1990s and 2000s, the road modal corresponded to more than 60% of the total cargo transported in the country. This means that, with the inclusion of iron ore, which is transported by railroads, highways have a share equivalent to 70% of general cargo.

The problems of the Brazilian road modal are reflections of a long process that has been consolidated for several decades, although there has been a rapid expansion of the road segment in relation to the set with the other modalities. The strong dependence of Brazilian cargo transport on highways is more evident when compared to other countries of continental dimension: in the United States, the share of highways in cargo transport is 26%; in Australia, it is 24%; in China, this dependence is only 8% (BARTHOLOMEU, 2006, *apud* IPEA, 2010).

IPEA (2010) also states that the dependence on Brazilian highways is greater in the agricultural sector, either for the receipt of inputs or for the flow of production. For this reason, the inefficiency of road transport has a direct impact on the income of agricultural producers, who, consequently, suffer a strong negative influence on the profitability of their exports, since the prices of exported products, especially fruits, are determined by the importing market, regardless of the costs generated in production and transportation.

ANALYSIS AND DISCUSSION OF THE RESULTS

Through the results obtained through the *Constant Market Share* model, it is possible to analyze the three indicators, which are: market growth, destination of exports and the residual effect, that is, competitiveness, and how each of these indicators contributed to the growth of Brazilian fruit exports.

RESULTS OF THE APPLICATION OF THE *CONSTANT MARKET SHARE MODEL*

Table 3 shows that, in the first period, the decomposition of the sources of growth shows that the main culprit was the competitiveness effect, which boosted Brazilian exports, and to a lesser extent is due to the growth effect of the world market.

Table 3: Results of the *Constant Market Share*, using data on the quantity exported from Melon, for the following effects: market growth, destination of exports and competitiveness.

Melon		1990/91/92	1999/00/01	2007/08/09
Effect		Effective growth	Effective growth	Effective growth
Variation	Of	62%	59,62%	-7,52%
Exports				
Growth	of	0,92%	1,56%	-2,88%
the				
market				
Destination of exports		-87,62%	-3,45%	-0,87%
Competitiveness effect		149,53%	61,50%	-3,77%

Source: Survey results, 2012.

In this regard, it should be noted that, according to FAO (2010), almost 100% of Brazilian melon exports are directed to Europe, therefore, in this period, the European market has regressed and the world market has grown at a slight rate. Therefore, the drop of -87.62% is explained by the lack of access of Brazilian producers and exporters to other markets, remembering that the US has the world's largest melon market, so the country has no participation in this area. Although in the first and second sub-periods Brazil was very competitive in the European market, it is believed that if Brazilian exporters had access to other markets, national exports of melon could grow by about 149.53%. It is worth noting that the destination effect of exports will only be positive if the country has concentrated its exports in markets that experienced greater dynamism in the period analyzed, and negative if concentrated in more stagnant regions.

In the second period, Brazilian melon exports grew 59.62%, and the determining factor of growth was the competitiveness effect, with 61.50%, followed by the growth of the world market, with a modest rate of 1.56%. Once again, the destination effect of exports did not contribute to Brazilian melon exports due to the lack of access of Brazilian producers and exporters to markets with a high growth rate such as the USA, Canada and Japan. It is important to note that in this period

the European market imported below the world import, that is, the European market imported below the main melon-importing countries that are outside the European continent.

Also as shown in Table 3, in the last period, especially in 2009, Brazilian exports fell by - 7.52%, and the determining factor of this decrease was the competitiveness effect, followed by the decrease in the growth effect of the world market and also, finally, the destination market effect, which showed a retraction. According to the Brazilian producers and exporters interviewed, in this period the nominal exchange rate or fall in the dollar was a factor that made competitiveness unfeasible. FAO data (2010) show that, in this same period, and due to the crisis in Europe, the European market decreased the import of melon significantly and other potential importers, such as the USA and Canada, increased their imports in the same year of 2009, remembering that Brazilian exporters of melon practically do not participate in the North American market.

In the case of grapes, for the first subperiod analyzed (Table 4), Brazilian exports grew by 190%, and this growth was driven by the competitiveness effect, which developed by 166.83%, followed by the growth of the world market and the destination of exports. It is important to remember that in this period, despite the high growth rate of Brazilian grape exports, Brazil had not entered the list of the top twenty grape exporters according to FAO statistics, which only happened from 2001 onwards.

Table 4: Results of the *Constant Market Share*, using data on the quantity exported of grapes, for the following purposes: market growth, export destination and competitiveness

Grapes	1990/91/92	1999/00/01	2007/08/09
Effect	Effective growth	Effective growth	Effective growth
Variation that Exports	190%	346%	-36%
Growth of the market	12,41%	26,50%	7,55%
Destination of exports	11,57%	-1,38%	-4,40%
Competitiveness effect	166,83%	321%	-39,84%

Source: Survey results, 2012.

In the second period, Brazilian exports grew 346%, and the competitiveness effect was the determining factor of growth, with 321%; Another factor that contributed positively was the growth of the world market (26.50%) and the destination of exports did not contribute to the exports of Brazilian grapes in this period.

In the last period analyzed, Brazilian grape exports fell by -36%, remembering that, among all the crops that make up the analysis basket studied here, grape production is the most expensive and, therefore, in case of crisis, the drop can be abrupt. The competitiveness effect was the main responsible for the decline in Brazilian grape exports, and it is important to remember that, since 2008, the competitiveness of Brazilian fruit exports has been affected by the nominal exchange rate,

that is, the devaluation of the "US dollar", since the sector's expenses are made in national currency. The growth of the world market was the only effect that contributed positively, but even so, it could not compensate for the losses in exports in this period. With regard to the growth of the world market, according to FAO data (2010), despite the significant drop in the volume of grape imports by European countries, some others – such as Canada; China, Hong Kong; China; Bangladesh; Thailand; Pakistan, etc. – increased their exports in the period from 2008 to 2009, and Brazil does not export to these countries or has an insignificant share in some, as is the case with the USA.

As seen in Table 5, the world mango market in the first sub-period (1990/1991/1992) grew 48.63%, and during this time Brazil exported a large volume of the fruit due to the growth effect of the world market, which developed 37.73%, followed by the competitiveness effect, 10.89%, and the destination effect of exports, which contributed negatively. Traditionally, Brazil is a country known as one of the main producers and exporters of mangoes to the international market, therefore, over the past few years, the country has been configured in FAO statistics as one of the top five exporting countries.

Table 5: Results of the *Constant Market Share*, using data on the quantity exported from Mango, for the following effects: market growth, destination of exports and competitiveness.

Manga	1990/91/92	1999/00/01	2007/08/09
Effect	Effective growth	Effective growth	Effective growth
Variation that Exports	48,63%	76%	-0,76%
Growth of the market	37,73%	25%	12%
Destination of exports	-2,56%	-14,86%	-18%
Competitiveness effect	10,89%	65,49%	5,25%

Source: Survey Results

Brazilian exports increased by 76%, and the decisive factor for this growth was the competitiveness effect, with 65.49%, followed by the increase in the market by 25%; The destination of the product did not participate in the exports of Brazilian mangoes, and, compared to others, the European market remained stagnant in this period, which implies that, although Brazil is competitive in this context, Brazilian exporters could earn more if they had the opportunity to trade in other markets.

In the last sub-period analyzed, Brazilian exports registered a slight drop of -0.75%, driven by the destination of exports. It is important to note that in 2009 European countries reduced imports drastically, and this reduction is due to the crisis that occurred on that continent. The growth effect of the world market increased by 12%, while the competitiveness effect increased by 5.25%. According to producers and exporters, the drop in Brazilian mango exports in 2009 is due to the devaluation of the nominal exchange rate, which made the competitiveness of the sector unfeasible.

Regarding papaya (Table 6), in the first subperiod analyzed (1990/91/92), the factor that most contributed to the increase in Brazilian exports was the destination effect of exports with 51.67%, in relation to the competitiveness effect, the country showed unfavorable in this aspect with a significant drop of -35% and also the world market effect registered a retraction of -11.25%.

Table 6: Results of the *Constant Market Share*, using data on the quantity exported from Papaya, for the following effects: market growth, destination of exports and competitiveness.

Papaya		1990/91/92	1999/00/01	2007/08/09
Effect		Effective growth	Effective growth	Effective growth
Variation	Of	5,42%	58,80%	-0,76%
Exports				
Growth	of	-11,25%	38,36%	12%
the				
market				
Destination of exports		51,67%	32%	-18%
Competitiveness effect		-35%	-11,56%	5,25%

Source: Survey results, 2012.

In the second sub-period analyzed, the important factor that contributed to Brazilian papaya exports was the growth effect of the world market, with 38.36%, followed by the destination of exports, which also showed an increase of 32%, so the competitiveness effect ceased to contribute - 11.56%, it is important to note that in this sub-period Brazilian papaya exports grew to the world market at 58%.

In the last sub-period, the country recorded a slight drop of 0.76% in papaya exports, this drop was not worse only due to the world market that boosted Brazilian exports to 12%, followed by the competitiveness effect of 5.25%, the destination of exports retracted as a result of the crisis in the Eurozone.

According to FAO (2010), Spain is the largest exporter of melon in the world, and the Brazilian melon harvests coincide with the off-season of Spanish production, which greatly facilitates exports from Brazil to the old continent.

In 2010, the European Union (EU) was the largest importer of Brazilian melon: the countries of this economic bloc influenced more than 98% of the total volume exported from Brazil. Among the EU countries, the Netherlands alone imported 59.68% of all Brazilian melon exports, taking into account that most Brazilian fruits enter Europe through the port of Rotterdam, which is one of the largest and most important ports on the European continent. NAFTA emerges with the effective participation of the United States and Canada in the import of this fruit, and Mexico has its own production capacity; among the South American countries, Argentina, Uruguay and Paraguay stand out, which, together, imported only 0.12% of the volumes of Brazilian melon exports.

RESULTS OF THE APPLICATION OF THE REVEALED COMPARATIVE ADVANTAGE MODEL

The results of the application of the Revealed Comparative Advantages (VCR) of melon, grape, mango and papaya fruits are presented in Table 7. The data for the calculation of the RCVs were collected through FAO and the United Nations Statistics Division (COMTRADE). Initially, the intention was to make an analysis of this model for a longer period equal to that used in the application of the *Constant Market Share* model, but due to the unavailability of data, the analysis was restricted to a period of 10 years, which ranged from 2000 to 2009.

Of the four crops analyzed, papaya has the greatest advantage, despite the fluctuations over the years analyzed. In fact, all products presented indexes above the unit, demonstrating that they have comparative advantages in relation to their international competitors. Within the period analyzed, papaya presented an average of 4.74% of the Revealed Comparative Advantage, followed by melon with 3.87%, mango with 3.47% and grapes with 2.15%. Brazil stands out in the production and export of all these crops, thus occupying the prominent places in the world ranking of exporters based on the official statistics of FAO and COMTRADE.

Table 7: Revealed Comparative Advantages (VCR) in % for each product (2000-2009).

Period	Melon	Grape	Manga	Papaya
2000	1,17	1,72	2,83	4,61
2001	1,49	2,53	3,68	4,26
2002	1,36	3,40	3,69	4,36
2003	1,19	3,68	2,63	3,40
2004	7,86	1,93	1,37	1,55
2005	7,23	2,36	1,01	3,28
2006	5,04	1,96	7,49	1,03
2007	4,62	1,74	4,90	8,64
2008	3,60	1,07	4,12	6,85
2009	5,17	1,11	5,67	9,54

Source: Survey results, 2012.

The competitiveness in the export sector of Brazilian fruits is due to several factors, among which we can highlight the nominal exchange rate that in recent years has been hindering Brazilian exports, remembering that contracts, whether formal or informal, are signed in dollars or euros, and the cost of production of national companies is made in local currency; Therefore, any appreciation of these foreign currencies raises the costs of companies in the country.

The quality of fruits is one of the determining factors of competitiveness, remembering that in this sector quality is seen from two perspectives: both in the internal attributes of fruits (fundamentally related to damage to the environment in their production process, absence of additives and preservatives, absence of chemical residues, nutritional value and consumer confidence

in products or companies) and external attributes, referring to the color, appearance, shape of the products, etc. (SOUZA; AMATO NETO, 2006).

CONCLUSION

The work developed here proposed to evaluate the competitiveness of Brazilian fruit exports to the European market, based on the *Constant Market Share model*, emphasizing that this model shows whether the country in question is exporting as a function of the growth of the world market, export destination or competitiveness.

In terms of production, Brazil occupies the third position, behind only China and India; with regard to exports, the country still leaves something to be desired, since the commercialization of fruits to the international market does not reach 10% of its total production, therefore, the low volume of Brazilian fruit exports is explained not only by its large and potential domestic market, but by the lack of access to the international market of national producers and exporters (FAO, 2010).

Access to the international fruit market is costly due to several factors, such as the value of quality certification (seal) of fruits and the precariousness of the Brazilian modal infrastructure (highways, railways, ports and airports), which compromises the flow of agricultural production, that is, in the transport of fruit from the farms to the points of shipment, Often the cost of this displacement exceeds the expense of exporting by ship or plane.

Despite these obstacles, the country has the capacity to substantially increase its participation in international markets, through a compilation of specific investments from the public and private sectors.

The country has a Comparative Advantage in all the fruits that make up the analyzed basket. However, even with this advantage in production and generation of surplus for export, there are other determining factors in Brazilian fruit exports. Based on the results obtained with the application of the CMS model, Brazil is competitive in the European melon market, and it was observed that the growth of this market in the analyzed period exceeded that of the world market and influenced the commercialization of Brazilian melon in this context.

Exports of Brazilian grapes have grown at significant rates, and the country is competitive in the European market due to the quality of the production of this fruit. In fact, the Brazilian grape is widely accepted in the European market, especially in the United Kingdom.

Over the last few years, Brazil has been meeting the demand of the importing market in relation to the new production practice aimed at reducing the level of pesticides and preserving the environment. This means that the country currently produces quality fruits, remembering that Brazil is the only country in the world that produces mangoes all year round, and these two factors are responsible for the competitiveness of Brazilian mangoes in the European market.

Although Brazil is the second largest exporter of papaya (FAO, 2010), the country is not competitive in exports of this product, doing so only due to the destination market (European market) that grows at significant rates. In the last period analyzed, Brazil became competitive, despite having been a time of crisis that affected the import market.

In 2009, world exports increased while Brazil followed the opposite path due to the exchange rate. This made some producing and exporting companies give up supplying their fruits to the international market and decide to remain only delivering to the domestic market. In the same period, while producers and exporters of Brazilian fruits were facing exchange rate difficulties, the European market also decreased the demand for imports of Brazilian fruits, due to the crisis in Europe, especially in the so-called Eurozone.

Even so, the results point to ample possibilities for growth in the export of the fruits analyzed, provided that there are infrastructure improvements, sufficient policies to promote production and support for producers by the entities responsible for regulating the sector.

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Analysis of lactose content and fat content in "zero lactose" and "light" dairy products

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ABSTRACT

Milk and its derivatives are considered complete foods and the greatest source of calcium that can be absorbed by man. However, a large percentage of people cannot consume this food due to lactose intolerance. Because of this factor, they tend to opt for products labeled "zero lactose", however, some products do not follow the determination of the legislation for lactose content, compromising the health of consumers who trust these brands. The same practice is carried out in products labeled "light", where the consumer chooses the product in the hope that there will be a reduced fat content compared to its original version and finds products totally outside the parameters determined in Brazilian legislation and once again putting the consumer's health at risk. In this work, the lactose content in milks labeled "zero lactose" was analyzed, in addition to the fat content in cream cheese labeled "light" and/or "reduced in total fats" produced by three brands and marketed in the region of Alegre-ES and which were in disagreement with the parameters established by the legislation.

Keywords: Milk, Lactase, Intolerance, Obesity, Cottage Cheese, Legislation.

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INTRODUCTION

The milk and dairy products production chain in Brazil is a sector of great economic and social importance. It is the third largest milk producer in the world, with more than 34 billion liters per year, with production in 98% of Brazilian municipalities, with a predominance of small and medium-sized properties, employing close to 4 million people. The country has more than 1 million milk-producing properties and the projections are that, by 2030, the most efficient producers will remain, who adapt to the new reality of technology adoption, improvements in management and greater technical and economic efficiency.

Milk is a stable, complex emulsion rich in nutrients such as fat, protein, lactose, vitamins, minerals and other ingredients suspended in water (MILK; SIQUEIRA; CARVALHO, 2009).

Lactose is the main carbohydrate in milk, and this and its whey are actually the only sources and is made up of two monosaccharides, glucose and galactose, characterizing a disaccharide. About 40 to 50% of milk is made up of lactose, while whey is made up of 75%. However, the use of lactose in dairy products is limited due to its low sweetening capacity, low solubility and individual food intolerance to this sugar (PESSELA *et al.*, 2003).

Lactose intolerance occurs due to a lack of the enzyme β -galactosidase or lactase in the small intestine with the ability to hydrolyze lactose into glucose and galactose and it is estimated that approximately 65% of the population has a reduced ability to digest lactose after childhood, and symptoms and signs persist throughout life (HEYMAN, 2006; PEREIRA *et al.*, 2012).

As a result, lactose is not absorbed in the small intestine and when it reaches the colon, fermentation occurs with the production of short-chain fatty acids and the formation of gases such as carbon dioxide, hydrogen and methane through the action of microorganisms in the colonic region and can cause abdominal pain in addition to discomfort such as nausea, colic, flatulence, diarrhea, bloating (MATTAR and MAZO, 2010; FRYE, 2002).

Lactose hydrolysis can lead to the development of new products for consumers intolerant to this carbohydrate, in addition to providing technical advantages such as the reduction of lactose crystals in dairy products and increased sweetness power, demonstrating that lactose hydrolysis is a promising industrial process and can occur by acid or enzymatic route, the enzymatic pathway being the most favorable, as it occurs under mild pH and temperature conditions (30 °C to 40 °C), unlike acid hydrolysis with strong acids.

β -galactosidase in free or immobilized form is a commercially important enzyme in this process (OBÓN *et al.*, 2000). Currently, there are several products on the market with reduced lactose content, classified by ANVISA (National Health Surveillance Agency) according to lactose concentration. To obtain these products, different processes are used that use enzymatic hydrolysis, separation processes or a combination of these methods. These methods hold promise for the food

industry due to the low availability of lactose and the increase in lactose intolerance in the world's population.

In view of the above, the objective of this study was to evaluate the content of these constituents in dairy products called "light" and "zero lactose" sold in supermarkets in the city of Alegre-ES, in order to verify if these products follow the values described on their packaging and if the results obtained are consistent with the Brazilian legislation in force.

LITERATURE REVIEW

MILK

Milk is considered one of the most complete foods because it is rich in proteins, carbohydrates and mineral salts, as well as one of the sources of absorbable calcium for the human species, in addition to containing conjugated linoleic acid, β -carotene, butyric acid, in addition to vitamins A and D.

The relationship between its different components is very stable and can be used to indicate if there has been any tampering with its components. Under normal conditions it contains approximately 87.5% water, 3.8% fat, 4.6% lactose, 3.1% protein and 0.8% minerals/vitamins. The main physicochemical parameters that determine milk quality are: pH (20 °C) from 6.5 to 6.7; titratable acidity from 15 °D to 18 °D; density from 1.028 g/mL to 1.034 g/mL; fat 3 g/100 g and freezing temperature between -0.510 °C and -0.550 °C (BRASIL, 2008).

Despite high rates, government economic plans and deregulation of the economy, milk production in the last 50 years has had an exponential and significant growth (VILELA *et al.*, 2017). The largest milk-producing region in Brazil is the southeast region, which produced about 9,995.024 thousand liters in 2020, contributing with 39.2% of the national production. The southern region occupies the second position, with its share of around 37.9% of cow's milk production in Brazil (CONAB, 2021). Brazil is the world's third largest producer of cow's milk, and its share in world dairy production is only 4.4%, behind countries such as the European Union, which has a share of around 29.3%, the United States with 19%, India with 17.8%, among others (CONAB, 2021).

LEGISLATION

Normative Instruction No. 76, of November 26, 2018 of the Ministry of Agriculture, Livestock and Supply - MAPA (BRASIL, 2018) is the one in force in the country. It contains some technical parameters that must be followed in order to improve the quality of the milk, such as conservation, sensory, physicochemical and microbiological parameters.

According to the current legislation, Normative Instruction 76 (BRASIL, 2018), pasteurized milk defined as type A can be classified in terms of fat content as whole, semi-skimmed and skimmed, and must be automatically packaged in a closed circuit.

In this same NI, there are several physicochemical parameters to be followed for pasteurized whole milk, such as the minimum required fat content of 3.0 g/100 g, and the anhydrous lactose content must be 4.3 g/100 g of milk sample. In pasteurized skimmed milk, it is determined that the fat of the same has a maximum of 0.5 g/100 g. These parameters determined by the Ministry of Agriculture, Livestock and Supply aim to maintain a standard of quality of dairy products.

The Technical Regulation on Identity and Quality of Milk UAT (BRASIL, 1997a) points out other parameters to be followed to ensure the quality of milk, its titratable acidity must be between 0.14 and 0.18, minimum protein content of 2.8 g/100 g and must be refrigerated up to a maximum of 4 °C after pasteurization, in addition, for UAT milk there is only the microbiological parameter of mesophilic aerobes.

CREAM CHEESE

Milk and its derivatives are a group of foods that have proteins of high biological value and essential nutrients such as calcium, phosphorus, vitamins A, D, B2, biotin and other components (PHILIPPI, 2014). There are numerous dairy derivatives and among them is cream cheese, which is a type of processed cheese, widely consumed in our country, being manufactured throughout the national territory, but with variations in technology and characteristics (SILVA *et al.*, 2012).

According to Ordinance No. 359, of September 4, 1997 of MAPA (BRASIL, 1997b, p.1), "Cream cheese is that obtained by melting a drained and washed curd mass, obtained by acid and/or enzymatic coagulation of milk, with the addition of cream and/or butter and/or anhydrous milk fat or butteroil".

Studies report that cottage cheese appeared at a time when the most valued milk derivative was butter. At that time, cottage cheese was manufactured from skim milk and through the use of milk that coagulated due to the action of the milk's natural lactic microbiota (MUNCK; CAMPOS, 1984).

At that time, artisanal factories had creamers that separated the cream, and the resulting skimmed milk was allowed to coagulate naturally to obtain the dough that would later be transformed into cottage cheese (MUNCK; CAMPOS, 1984). Today, the food industry obtains cottage cheese through acid and/or enzymatic coagulation of milk (BRASIL, 1997b).

The Technical Regulation for fixing the identity and quality of cottage cheese (Ordinance No. 359, of 09/04/1997, p. 24), calls cottage cheese the product in which the dairy base does not contain fat and/or protein of non-dairy origin.

Currently, there are products available in the retail market analogous to traditional cream cheese, called "cream cheese with starch" and "cream cheese with starch and vegetable fat". However, the analogues found on the market have a wide variety of composition and functional properties, and the sensory quality characteristics are very different from the original product, which has caused dissatisfaction among consumers (CUNHA; DAYS; VIOTTO, 2010).

One of the food substances used in the manufacture of analogous cheeses is starch. Starch is a reserve polysaccharide found in most vegetables. It has great application in the food industry, mainly as a thickener and stabilizer (DEMIATE; KONKEL; PEDROSO, 2001).

Until 2005, products added with vegetable fat were called dairy specialties, foods or products based on cottage cheese. After studies, the DILEI/DIPOA (Department of Inspection of Milk and Dairy Products/Department of Inspection of Products of Animal Origin) suspended the approval of dairy specialties and determined that these products should be called "cottage cheese with...", and the name should be complete and highlighted (VAN DENDER, 2006).

Another substance often added in the manufacture of cream cheese is vegetable fat, used to replace milk fat. In a study carried out with different concentrations of vegetable fat, it was observed that the replacement of part of the cream (25% and 50%) by hydrogenated vegetable fat promoted significant changes in texture, sensory properties, color and, mainly, in the microstructure of the processed cheese (CUNHA *et al.*, 2010).

Although vegetable fat has certain operational advantages compared to dairy fat, its greatest disadvantage is the loss of sensory attributes (flavor and aroma) in the final product, requiring the complement with flavored bases or condiments flavored cheese, cream and cottage cheese (RODRIGUES, 2006).

FAT PRESENT IN DAIRY PRODUCTS AND PUBLIC HEALTH

With an exponential growth curve, obesity is a public health issue today. Certain surveys indicate that about 50% of the Brazilian population is overweight, and the cause of this increase is multifactorial, and may be linked to genetic and emotional issues, among others (SILVA; ANDRADE; PUCCI, 2022). The weight factor affects other comorbidities such as insulin resistance, arterial hypertension, hyperglycemia and metabolic syndrome (DA COSTA; DE SOUZA; SANCHES, 2020).

The excess fat present in an unbalanced diet can lead an individual to obesity, a disease that is characterized by the accumulation of adipose tissue in the human being that ends up exposing him to serious pathologies leading to the risk of life in addition to the emotional factors already proven such as depression, suffering and social distancing behaviors (ADES; KERBAUY, 2002)

In 17 years, the obese population in Brazil has had an extremely significant increase, from 12.2% in 2002 to 26.8% in 2019 (AGÊNCIA IBGE NOTÍCIAS, 2020), data that end up worrying doctors and nutritionists in the country due to the high danger of this disease that is linked to major chronic non-communicable diseases such as diabetes, cancer and cardiovascular diseases, these diseases have been gaining strength year after year, causing irreversible lesions in the life of the obese (DUNCAN *et al.*, 1993).

The World Health Organization (WHO, 2000) states that there is an "epidemic of obesity on a global scale". In the United States, about 25% of children are overweight or obese, a worrying situation for the future considering that an overweight of 5% already exposes a human being to risks.

Milk and dairy products have saturated fatty acids that help raise cholesterol levels in the blood plasma (SCHERR; RIBEIRO, 2011), in addition to having a high caloric load in their composition that, associated with an unbalanced diet, can lead to chronic non-communicable diseases such as those mentioned above.

Currently, dairy products such as cream cheese have about 6.5 g of total fats in their nutritional table, which represents, according to the label, 11% of the daily consumption value in a tablespoon, a value to be rethought since the human being has an average of five to six meals a day, There are high chances that the daily fat values for a normal human being will be exceeded.

LACTOSE INTOLERANCE

Faedo et al. (2013) describe that lactose is used by mammals, being converted into glucose and galactose soon after hydrolysis by the enzyme lactase in the small intestine, enabling intestinal absorption. People with lactase deficiency do not have this ability, and when they consume milk, lactose is not hydrolyzed, leading to increased intestinal osmotic pressure and, consequently, water retention. In these cases, lactose enters the large intestine, where it is fermented by the gas- and water-producing microflora, or hydrolyzed by bacteria into short-chain organic acids. Unabsorbed gas can cause bloating, and the acid produced can irritate the intestinal wall and increase peristalsis, which, combined with water from the intestines, can cause diarrhea.

Woltmann, Simon, and Silveira (2013) emphasize that in most people, lactase levels drop significantly after weaning, meaning that some individuals with very low lactase activity experience undesirable digestive symptoms after milk intake. Unlike other disacrases such as sucrase and maltase, lactase is not an adaptive enzyme, that is, its level does not change based on the amount of carbohydrates ingested. The term hypolactosia refers to decreased lactase activity, which can be a primary or secondary condition. Primary can be of two types, HPTA (primary adult-onset hypolactasia) and congenital hypolactatemia (a rare congenital lactase deficiency). Secondary is due to the involvement of the mucosa of the small intestine in conditions such as acute gastroenteritis,

giardiasis, celiac disease, inflammatory bowel diseases, among others (WOLTMANN, 2013). In Figure 01 below we have two examples: in scheme A the flow of lactose with normal enzyme activity in the small intestine, where the carbohydrate is hydrolyzed into its respective corresponding monosaccharides and absorbed. In regimen B, lactose, which is not hydrolyzed by the enzyme, remains in the intestine. Fermentation occurs generating short-chain fatty acids, carbon dioxide and hydrogen gas, which results in abdominal bloating, flatulence, cramps and diarrhea (WOLTMANN, 2013).

HYDROLYSE THAT LACTOSE

Lactose hydrolysis is a promising process for the food industry, as it makes it possible to develop new products for intolerant consumers, reducing crystallization of this carbohydrate in dairy products and increasing its sweetening power (FISHER, 2010). There are two methods of hydrolysis of lactose: the acid method and the enzymatic method.

Acid method

It reacts very quickly, but involves dilute strong acid solutions, such as sulfuric and hydrochloric acid, pH (1.0 - 2.0) and high temperatures (100 °C to 150 °C); Therefore, it is a restriction on the food industry, as it causes changes in the flavor and color of food, in addition to causing denaturation of milk proteins.

Enzymatic method

It can be applied to milk or whey without the need for further processing. Hydrolysis is catalyzed by β -galactosidase and proceeds under mild pH and temperature (30 °C to 40 °C). This not only reduces changes in heat-sensitive compounds, but also requires lower energy consumption, decreases environmental corrosive effects, and the formation of unwanted by-products. The products obtained through this process maintain their properties, increasing the relative sweetness capacity. Hydrolysis of lactose catalyzed by β -galactosidase primarily produces an equimolecular mixture of glucose and galactose, however, galactose can polymerize or bind lactose to form oligosaccharides (HYDE; HUSSAIN, 2009; MAHONEY, 1998)

Enzymatic hydrolysis maintains the desired nutritional and quality properties of the products, as well as adding sweetness to them. Therefore, it can be seen that enzymatic hydrolysis of lactose is more convenient for the food industry (GROSOVÁ; ROSENBERG; REBROTH, 2008). As a result, a great deal of effort has been devoted to the research and development of viable biotechnological processes to obtain low-lactose dairy products.

ENZIMA β -GALACTOSIDASE

Segundo Mahoney (2003) a enzima β -galactosidase (β -D-galactosideo-galactohidrolase, E.C.3.2.1.23):

it is usually called lactase since it catalyzes the hydrolysis of lactose into its constituent sugars (PARK; OH, 2010). All enzymes generically referred to as lactases are β -galactosidases, but the reverse is not true. Certain β -galactosidases, including some plant cells and mammalian organs, other than those in the gut, have low or no lactose hydrolysis activity since their catalytic function is the breakdown of other galactosyl groups, such as glycolipids, glycoproteins and mucopolysaccharides.

According to Neri *et al.*, (2009), this enzyme is also responsible for the synthesis of GOS, when there is a high concentration of lactose in the system, through a galactosylation reaction not conducive to hydrolysis. When the concentration of this disaccharide is low, hydrolysis occurs, producing glucose and galactose. β -galactosidase is one of the most studied and reported enzymes in the literature. It is found in almonds, apricots, peaches, pears and other plants, in the intestines of mammals, or is produced by a variety of microorganisms (DWEVEDI; KAYASTHA, 2009; MAHONEY, 2003).

METHODOLOGY

SAMPLE COLLECTION

The samples were purchased in local stores in the city of Alegre-ES, available in supermarkets. Three samples of different brands named A, B and C of UHT Semi-skimmed Milk "Lactose-Free" and three samples of different brands of Light Cream Cheese were acquired that were named E, F and G. The samples were taken to the Food Technology Laboratory (LTA) of the Federal University of Espírito Santo, UFES-Alegre, ES where the analyses were performed.

FAT ANALYSIS

Fat determination was performed by the Gerber method, using 3 g of the samples. Each sample was weighed in the butyrometer cup and completed with 5 mL of distilled water, 10 mL of sulfuric acid (H₂SO₄; density 1.825) and 1 mL of isoamyl alcohol. Subsequently, the butyrometer was placed in a water bath at 65 °C for 3 min. until the sample is dissolved and centrifuged at 1200 rpm for 10 min. Then, it was completed with distilled water up to a value of approximately 30% in the meter of the butynometer itself to take the reading (BRASIL, 2006).

LACTOSE ANALYSIS

The determination of lactose in the milk sample was made by the determination of reducing sugars expressed in lactose, by oximetry. 10 mL of the homogenized and fluid sample were pipetted

in a 250 mL volumetric flask. Then, 5 mL of potassium ferrocyanide solution (15%) and 5 mL of zinc acetate solution (30%) were added to this sample, shaking and completing the volume of the flask with distilled water. The sample was sedimented for 15 minutes and then taken for filtration in a paper filter. The filtered sample was transferred to a burette. In a 250 mL erlenmeyer solution, 5 mL of Fehling A, 5 mL of Fehling B, 40 mL of water and a small amount of glass pearls were added, and heated until boiling. Then, the sample solution placed in the burette was dripped without agitation until the supernatant fluid was slightly bluish. Subsequently, if the boiling was maintained, 1 drop of methylene blue (1%) was added, continuing titration until the discoloration of the indicator and the appearance of a brick-red color (SILVA *et al.*, 2014).

RESULTS AND DISCUSSION

The lactose analysis, as described in the methodology, was performed through oximetry, thus, in the titration of the Fehling solution, 9.6 mL of the standard glucose solution (0.5 g) was spent, which resulted in the Fehling solution titer equal to 0.048.

The milk samples analyzed were named A, B, C and D, and sample D was whole milk, therefore containing lactose, used as a control. All samples were acquired in the local market of the city of Alegre-ES, and were stored at around 2° to 3° degrees Celsius.

The lactose content of each milk sample analyzed can be seen in Table 1, in which it can be observed that the results obtained were above 2% lactose for brands B and C and 4.17% for brand A, all of which were called "Lactose-Free" on their respective labels. Brand D, which had the denomination of "Whole Milk" on its packaging, had an average value of 5.30% lactose.

Table 1 - Lactose content (%) of the four brands of milk analyzed in this study (mean value $\pm$ standard deviation).

Milk brands	Teor de Lactose (%)
The	4.17 $\pm$ 0.25
B	2.43 $\pm$ 0.16
C	2.58 $\pm$ 0.08
D (Control)	5.30 $\pm$ 0.24

Source: The author (2022).

The brands A, B and C analyzed are in disagreement with what is determined by the legislation that provides for "zero lactose" products that the content of the same is a maximum of 0.1% (BRASIL, 2017).

In a study carried out by Piccolo *et al.* (2019), it was also possible to observe that the milks analyzed presented parameters above those established by the current legislation mentioned above.

Milks labeled "lactose-free" had between 4% and 5% lactose in their composition, since whole milk usually has around 4.7% lactose, a fact of concern in relation to consumer health, making it necessary, therefore, to take legal action against the companies that manufacture these products.

Vasconcelos *et al.* (2020) obtained a positive result for lactose in products labeled "zero lactose", in samples purchased in the city of Belo Horizonte-MG, presenting more than 300% above the provisions of the legislation. Alves and Pedroni (2021) demonstrate that the practice of omitting information to the consumer is not limited to UAT milk but also to powdered milk, where in 3 samples of powdered milk and 2 of dairy compound labeled "zero lactose" lactose content was found above the allowed, being in disagreement with RDC No. 135, of 2017 (BRASIL, 2017).

The lactose intolerant population can suffer serious nutritional deficiencies with the removal of milk and dairy products from their diet, foods that are essential for their perfect physiological functioning but which can be a problem with such high levels of lactose in products labeled "zero lactose".

In addition to hypolactasia, already mentioned previously in this study, Oliva and Palma (2001) state that the ingestion of lactose by intolerant individuals can cause aggression to the mucosa of the small intestine and can lead to severe diarrhea, which can lead to protein-calorie malnutrition or even death. Moreira, Padovani and Maffei (1996) refer to diarrhea as responsible for high mortality rates in children under 5 years of age in developing countries.

Fat analyses were performed on three brands of cream cheese called E, F and G in the "Wholemeal" and "Reduced in Total Fat and Calories" versions. The conclusion of the experiment leads us to the same type of practice as in the previous analysis, consumer negligence. In Table 2 we can see that the results obtained in this work are contrary to the provisions of the current legislation that determines that this product must have a minimum 25% reduction of its traditional version (IN nº 75 - BRASIL, 2020). It is important to note that the differences presented in the analyses were small and may mean a danger to the population, especially for individuals with certain pathologies who need to reduce fats in their diet.

Table 2 - Fat content (%) of the three brands of cream cheese, in the Integral and Light versions, analyzed in this study (mean value $\pm$ standard deviation).

Brands of Cream Cheese	Mean fat value (%)
E (Full)	33.0 $\pm$ 0.76
E (Light)	25.7 $\pm$ 1.27
F (Integral)	32.0 $\pm$ 1.85
F (Light)	24.8 $\pm$ 1.12
G (Integral)	34.0 $\pm$ 0.53
G (Light)	28.7 $\pm$ 0.69

Source: The author (2022).

According to Drake and Swanson (1995), cheeses with low fat concentration tend to have a lower yield when compared to whole cheeses, this is because normally the lipid constitutes about 50% of the total dry extract of these dairy products, which in the point of view of the industry can be an economic loss compared to the amount produced of the same product in the whole version.

Another factor that must be considered is the sensory acceptance of this product because the fat gives texture, flavor and a good presentation in food in general, therefore, increasing the lipid content in the mixture so that this type of cottage cheese resembles its original version is the key to sales success and failure in terms of honesty with the consumer.

Gomes and Penna (2010) observed that it is possible to use new techniques to obtain products with reduced fat content, close in sensory terms to products in the whole version. In the aforementioned study, it was possible to make cream cheese a functional product with the use of inulin and soy protein in the dough and, despite some physicochemical and sensory divergences such as moisture, viscosity and brightness, this type of alternative is indeed viable for sale, benefiting the consumer and the trade with new alternatives to conventional products.

CONCLUSION

Samples of milk labeled "zero lactose" and cream cheese labeled "light" and/or "reduced in total fats and calories" were found sold in supermarkets in the city of Alegre-ES and, probably, are also sold in neighboring municipalities, which are in disagreement with the current legislation, leading the consumer to purchase a dairy product that is inappropriate to what is recommended on the label and to its purpose of consumption.

There has been an increase in consumer demand in recent years for fermented dairy products or products with claims of functionality on their labels, and it is essential that the industries and all

those involved in the production processes are committed in order to ensure the supply of products suitable for consumption, ensuring the sustainability of the sector and the health of the consumer.

And from the point of view of consumer safety and of corresponding to what the legislation determines, it is recommended for further studies to use other more effective analytical techniques for the determination of lactose, specifically for hydrolyzed milks, such as enzymatic methods, near-infrared (NIR) spectroscopy and/or chromatography.

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Knowledge of the importance of breast milk and its donation in milk banks

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ABSTRACT

The objective of this study was to collect information through a questionnaire with pregnant women about the level of knowledge and intention to donate surplus breast milk to the Human Milk Bank (HMB) or to a nearby Collection Point. The sample consisted of 60 pregnant women, with an average age of 25 to 30 years, and most of them had elementary and secondary education, were brown and primiparous. About 95% of these pregnant women intended to breastfeed their offspring, often being "when to cry" and, in their majority (80%), choosing not to give any complement to breastfeeding. When asked about information about the HMB, 51 pregnant women were already aware of the presence of the institution, most of whom had a level of knowledge considered average. The main source of information spread about HMB was the Family Health Unit/Hospital itself, and this information was classified as "very important" by the majority of participants (43%). About 73% of the pregnant women wanted to donate breast milk, 85% would use HMB milk and 83% thought the HMB's work was reliable. Of the total number of pregnant women, only 2 (3%) reported that they had already donated breast milk, and their experiences were classified as "very good" or "good", but only 50% of them would donate again. It is imminent that these results will be analyzed by health managers so that they can develop strategies to increase both information and the intention to donate surplus breast milk among pregnant and future breastfeeding women.

Keywords: Human Milk Donation, Nursing Mother, Collection Stations.

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INTRODUCTION

Nutrition in the first six months is crucial, with human milk offering a range of benefits for child development, including protein, sugars, and lipids that promote healthy growth and strengthen the immune system (CARR et al, 2021; PARKER et al, 2021)element. Studies show that children fed exclusively with breast milk show adequate growth and reduce the risk of malnutrition (GEORGE et al, 2021). Breastfeeding also brings advantages to mothers, such as emotional bonding, faster postpartum recovery, and financial savings (VENANCIO, 2015; ROLLINS, 2016). However, preterm newborns require additional care due to their specific nutritional needs (SBP, 2022).

The donation of human milk (HL) in Brazil is an extremely important social issue, due to the numerous benefits that are transmitted to children who receive it, especially premature newborns, low weight newborns or hospitalized in Neonatal Intensive Care Units (ICU). However, in addition to the difficulties and factors that limit the process of collecting and donating LH, it is known that the practice is still little publicized and known among women.

Human Milk Banks (HMB) play a crucial role in promoting and supporting breastfeeding by providing donated milk to babies in various situations. However, the lack of information and incentive undermines the effectiveness of this practice, resulting in the purchase of milk formulas and inadequate nutrition in some communities (BRASIL, 2022). The situation in Colatina, Espírito Santo, despite the presence of a Human Milk Bank in the region, there are no high numbers of breast milk donation. This contributes to the prevalence of nutritional deficiencies and poor health in infants, highlighting the need for more education and support to promote breastfeeding.

In this chapter, information about the knowledge about milk donation among pregnant women who attended the Women's House in the city of Colatina, Espírito Santo, will be addressed, in addition to their intention to donate or not the surplus human milk, as well as their obstacles to not doing so. In addition, the objective was to share the information collected with the population about the social, nutritional and affective importance of the act of donating and receiving breast milk in order to contribute to the health of newborns unable to receive it.

THEORETICAL FRAMEWORK

According to studies, in relation to the protein composition of human milk (formed mainly of lactoferrin, lactalbumin and beta-lactoglobulin), composition of sugars (such as lactose, glucose and galactose) and, finally, its lipid composition (formed by triglycerides and cholesterol) act beneficially in the formation and evolution of the infant in several aspects. In addition, human milk has 45 different types of bioactive factors, such as platelet-activating factor acetylhydrolase (PAF-AH), antioxidants, interleukins 1, 6, 8, and 10, and B cells, which contribute to antimicrobial factors, anti-inflammatory agents, digestive enzymes, various hormones, and neonate growth factors (CALIL,

2003; YI, 2021; NUZZI et al., 2021; DINLEYICI, 2023). With this, obesity, childhood diabetes and allergies are prevented, as well as helping in the development of the immune and motor system and contributing to healthy growth (VENANCIO, 2015; ROLLINS et al., 2016; WHO, 2017). In addition, human milk is a synbiotic, a natural source of lactobacilli and bifidobacteria, which are probiotics, and a natural source of oligosaccharides, which are prebiotics, which, by themselves and independently of all the other substances of which it is composed, constitute protection against infectious and non-infectious diseases at all stages of life, particularly in adulthood (BORBA et al., 2018), (EDWARDS; PARRET, 2002; OKBURAN, 2023)

Regarding the essential maternal advantages, we can mention the increase in the bond with intimate contact between the dyad, the faster decrease in weight gained during pregnancy and the risk of breast and ovarian cancer, in addition to diabetes and heart attack and, finally, an increase in endorphins, the hormone of happiness, and an increase in the woman's self-esteem. essential elements for a smooth postpartum (SBP, 2022). It is also important to highlight the financial savings of this act, since it is free and its production is natural, with no need for supplementation with formulas or other milks. There are cases that need care, such as preterm newborns, since they lack a higher content of macro and micronutrients that are indispensable for their growth. (MEYERS et al., 2006). In view of these advantages, the Human Milk Bank was created in partnership between the Ministry of Health and the Figueira Fernandes Institute (FIOCRUZ), with the main functions of being a specialized center and mandatorily linked to a maternal and/or infant hospital, promoting breastfeeding, being able to perform the collection activity, selection, classification, clinical control, processing and quality control of expressed human milk, being responsible for the operation of the establishment and, in addition, seeking certification of the quality of products and processes. It is the largest and most complex network of milk banks on the planet, and is exported even to other Latin American countries. Per year, donated LH is offered to about 160 thousand newborn children with its 222 banks and 217 collection points (BRASIL, 2022). Even though it is very important, there are several obstacles to the spread of donation and even the implementation of Collection Stations and, finally, of a Human Milk Bank, in addition to scarce information in the pre and postpartum, about its use or even guidance for donations of surplus milk (NEVES et al., 2011). According to the study carried out at the Leonor Mendes de Barros Maternity Hospital (HMLMB), located in São Paulo, where 70% of the Human Milk Banks are concentrated, the lack of information for both nursing and hospitalized women, who really needed the help of the HMB to breastfeed their infants, was negligible and did not have the desired effect, which harmed both the functioning of the bank and the women and newborns who are cared for by them. In Colatina, a city located in the northwest region of the state of Espírito Santo, there is a lack of information and incentive strategies for donating and receiving human milk, even with the presence of a HMB. Families living in these

regions are led to buy milk formulas, when they have the financial conditions accessible to this solution, or even resort to the use of whole cow's milk (MILAN, 2020). As a result of the lack of information and campaigns, the prevalence of nutritional deficiencies, overweight and obesity in infants is facilitated, due to the insufficient or absent use of breast milk, also reflecting on the child's guardians, both psychologically and financially (ARAÚJO et al., 2004).

METHODOLOGY

TYPE OF RESEARCH AND DATA COLLECTION

The present study was cross-sectional, exploratory, where there is a greater purpose of familiarity with the problem, with a view to making it more explicit and provoking solutions (GIL, 2019). The approach of the work was quantitative, that is, an approach based on quantification with data collection and explaining the phenomena that occur in its results (KIRSCHBAUM, 2013). The questionnaire for evaluation had, as standardization, 29 questions, 5 open and 24 closed. As a classification, they were divided into 9 questions about the sociodemographic condition and feeding of the newborn and 20 questions encompassing human milk donation and Human Milk Bank. The approaches were in consonance, awareness and consent of the person responsible for the Women's House with a predetermined time, so as not to interrupt or generate friction in the service related to women. It was an individualized, respectful treatment, with the use of a specific room and comfortable accommodations.

PLACE OF STUDY AND TARGET AUDIENCE

Colatina is a municipality in the state of Espírito Santo, located in the southeast of the country. It is one of the main cities in the interior of Espírito Santo, influencing municipalities in the east of Minas Gerais. Its estimated population in 2022 was 119,992 inhabitants, most of whom were female, reaching 57,497 inhabitants. The Women's House is a humanized care center that facilitates access to services to ensure conditions to confront violence, female empowerment and women's autonomy.

The Women's House serves, in total, per year, about 786 pregnant women who need specialized prenatal care. The sample size was determined by convenience.

INCLUSION AND EXCLUSION CRITERIA

Pregnant women who were aged between 18 and 40 years, who had their prenatal care, on the specific date of collection, at the Women's House. Women who used medications that are incompatible with breastfeeding, used illicit drugs or alcohol, smoked more than ten cigarettes a day,

had an STI during pregnancy, and women who did not sign and did not declare support for the informed consent were excluded.

ETHICAL ASPECTS

According to the criteria of Resolution No. 196/96 of the National Health Council (CNS), the study was approved by the Human Research Ethics Committee of the Federal University of Espírito Santo, UFES campus Alegre – ES according to opinion number 6.251.253. To adhere to the research, it was necessary for the pregnant women to sign the Informed Consent Form (ICF).

DATA ANALYSIS

Data analysis was performed using Microsoft Excel 2016, which were tabulated and presented in the form of tables, for better visualization.

RESULTS AND DISCUSSION

60 pregnant women were interviewed, who agreed to the project's Free and Informed Consent Form, as well as the application of the questionnaire.

Table 1 – Sociodemographic characteristics of the participating pregnant women.

Categories	n	%
Maternal age		
18 – 19 years old	1	2
20 – 24 years old	12	20
25 – 30 years old	19	32
31 – 35 years old	16	27
36 – 40 years old	12	20
Maternal schooling		
Incomplete Elementary School	5	8
Complete Elementary School	13	22
Incomplete High School	13	22
Complete High School	13	22
Incomplete Higher Education	9	15
Complete Higher Education	7	12
Skin color/race		
White	18	30
Yellow	3	5
Black	16	27

Brown	23	38
He can't tell	0	0
Number of children		
1	27	45
2	14	23
More than 2	19	32

There is a prevalence of women with an average education of complete elementary school and incomplete higher education, both of which are completed by more than 40% of the interviewees. It is noticeable that, for the most part, the level of education greatly influences the understanding of the capture of the message about the practice of breastfeeding, making them breastfeed for longer. In these cases, it is preferable for mothers to have a higher level of education (ESCOBAR et al., 2002). It is stated that the average age among nursing mothers is 24.8 years, ranging from 20 to 30 years. Finally, understanding and analyzing the number of children is essential. Of the mothers surveyed, half were considered primiparous, which indicates that the first practice of motherhood and breastfeeding, and consequently, insecurity and inexperience become present, causing a search for information and instructions by health professionals from the HMB. For this reason, the chance of the pregnant woman practicing the act of LH donation is greater, decreasing with the increase in the number of children (WESCHENFELDER et al., 2012).

Table 2 – Possible methods of feeding the newborns of the pregnant women interviewed.

Variables	n	%
Baby feeding		
You want to give it to your baby		
Breast milk	57	95
Fórmula láctea	5	8
Whole cow's milk	1	2
And how often do you intend to give?		
When to cry	23	38
3/3 hours	22	37
Pediatrician's recommendation	20	33
Are you going to give other types of liquids?		
Yes, water	8	13
Yes, tea	3	5
No, only breast milk	48	80
No, only milk formula	1	2
No, only whole cow's milk	0	0

According to Table 2, it is noticeable how much breast milk is still valued by society, being the "gold standard" diet in 95% of the pregnant women analyzed. The evidence regarding breastfeeding is totally satisfactory, since the practice of breastfeeding is recommended until the age of two, with the main advantages of digestive, immunological and neurological evolution for the

newborn and, for the mother, protection against breast cancer, natural contraceptive, among others (SANTANA et al., 2013). In addition, the stimulation of milk for longer periods of time during breastfeeding causes the ideal surplus for donation to HMB, making other children enjoy the expressed and capable human milk for their nutrition. Regarding the frequency of breastfeeding, mothers were divided, however, the World Health Organization (WHO) recommends that breastfeeding be done on demand, that is, when the baby wants, and not to control a schedule every 3 hours (WHO, 2009).

Regarding the complementation of breastfeeding, most mothers were in line with the WHO recommendation that breastfeeding should be exclusive in the first six months, with the offer of only breast milk, without the presence of other liquids for cases of "hunger" or "thirst". This attitude is appropriate, since the composition of breast milk is adequate enough to meet all the needs of the infant. When complementary feeding is chosen before the appropriate stipulated age (6 months), there is a high risk of chronic diseases such as diabetes, obesity and high cholesterol, which impair the patient's life in the future (CAETANO et al., 2010).

Table 3 - Research on knowledge about HMB.

Variables	n	%
Research on the HMB		
Have you ever heard of the Human Milk Bank?	51	85
How much have you heard about the Human Milk Bank?		
Little	5	8
More or less	40	67
Very much	6	10
And where did you hear about the Human Milk Bank?		
By family members	3	5
For friends	8	13
Na USF/Hospital	25	42
On television	7	12
On the internet	8	13
On the radio	0	0
On posters or flyers	1	2
This information that you have received, you classify as...		
Very important	26	43
Important	18	30
Unimportant	2	3
He can't tell	0	0

Of the pregnant women interviewed, 84% of them knew about the Human Milk Bank located at the São José Hospital and Maternity, which served all of them regardless of the neighborhood in which they lived. However, most classified the information about the place as "Average", that is, it was not satisfactory information. In Galvão et al. (2009) it is emphasized that the information was only disseminated when the participants were about to give birth, that is, they were not instructed

about the HMB and its benefits in the prenatal period, which is considered worrying, since they could have been welcomed, informed and clarified, in order to ensure positive experiences of dissemination, helps in decision-making and reorientation in the practices exercised by health professionals (DIAS et al., 2006). When asked about the main vehicle for disseminating information about the HMB that they had contact with, the main and most important was obtained through the USF/Hospital, which could be during prenatal care for primiparous women and at the time of delivery for multiparous women. This result reinforces how important it is to know about breastfeeding from conception to delivery, so that women do not feel insecure and insufficient in this period of life. Therefore, it is necessary to carry out campaigns to reach all audiences and specialized training for health professionals, so that they feel able to manage and guide pregnant women (WESCHENFELDER et al., 2012).

Table 4 - Investigation about knowledge of the process of collection and donation of human milk and intention to donate and use of milk from the HMB.

Variables	Yes		No	
	n	%	n	%
Information about the HMB				
Do you know the process of collecting and donating human milk?	27	45	26	43
If you haven't donated, do you feel like donating?	44	73	9	15
If your baby needed it, would you use human milk from Human Milk Banks?	51	85	2	3
Do you find the work of Human Milk Banks reliable?	50	83	3	5

It was observed that about 45% of the interviewees were unaware of the process of collecting and donating human milk, which encompasses the physical, chemical, and microbiological processes until the offer of milk to the newborn in need, which was reflected in the study by Ellsworth et al. (2021), which illustrated that 49% of pregnant women interviewed had minimal knowledge and had restrictions when asking about the same problem. Regarding the intention to donate milk, 85% of the interviewees agree to donate LM to HMBs. Some reported that they would do this thinking, mostly, *of the mother of the child in need*, since they would not want to go through the same situation and not have the support they need. Those who opposed it cited factors such as *fear of not having milk, insufficient milk, and weak milk*. These answers, however, reflect the lack of information they have about breastfeeding and insecurity, which is a determining factor for them to find it necessary, in the future, to use inadequate complementary foods (MARQUES et al., 2011).

Table 5 - Investigation about the process of collection and donation of human milk and intention to donate breast milk again to HMB.

Variables	n	%
Research on the HMB		
Have you ever donated human milk to Collection Stations and/or Human Milk Banks?	2	3
And did you find it easy to donate?	1	2
Would you donate breast milk again to the Collection Stations and/or Human Milk Banks?	1	2
And how was your experience?		
Very good	1	2
Good	1	2
Median	0	0
Regular	0	0
Bad	0	0
How much did you donate?		
Very much	1	2
More or less	0	0
Little	1	2

The table expresses the tiny number of women who have had previous pregnancies, and who had experience in donating breast milk, with only two out of 33 pregnant women. Only one of them found it easy to donate the milk to the HMB, contradicting the study by Seidl (2009) who, according to the donors' reports, said that the action was quick and worry-free.

Regarding the intention to donate again, only 1 of the pregnant women who had already donated said they would do it again. Although the experience was considered good or very good by the donors, with all of them rating their experiences positively, other factors may be discouraging repeat donation. In addition, the amount of milk donated was also minimal, with 1 pregnant woman reporting having donated "a lot" and the other "a little". The variability in the amount donated may be related to individual factors, such as milk production or the availability of time and resources to donate continuously. According to Rodrigues et al. (2017), adequate support during the lactation period, such as guidance and follow-up, can positively influence both the amount and frequency of donations. These results indicate that, despite some positive experiences, there are significant barriers that limit the donation of human milk among pregnant women. Factors such as the perception of difficulty in the donation process, the lack of continuous support and the lack of adequate incentive are aspects that need to be addressed by public policies and incentive campaigns. In addition, it is essential that Human Milk Banks offer additional support to make donation a more common and accessible practice among pregnant women.

CONCLUSION

It was found in this study that there are still many obstacles, such as fears, fears and lack of information that directly affect the number of human milk donors, consequently failing to help



newborns and mothers who need this milk for survival. It is necessary to use other means of communication, such as social media and television, to reach more women who intend to donate and, thus, further foster this desire, in order to maintain adequate milk stocks in HMBs.

It is imminent that these results will be passed on to the Health Departments, so that pregnant women and others involved expand their knowledge and information about breast milk donation. The adoption and implementation of these measures will contribute to the health of newborns and improve the quality of life of the population. In addition, it is essential that there is an improvement in the distribution of information so that it reaches pregnant women properly.

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Polyploidy: Perspectives and practical applications for genetic improvement

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ABSTRACT

This work explores polyploidy and its significant implications for plant genetic improvement. Polyploidy, which is characterized by the presence of multiple sets of chromosomes, is an essential evolutionary force that impacts the evolution of plant species. This phenomenon is associated with several advantages, such as greater genetic diversity, vigor and resistance to abiotic and biotic stresses, making it crucial for the development of more productive cultivars adapted to adverse conditions. The study reviews methods of polyploidy induction, including physical, chemical, and biotechnological techniques, and discusses their practical applications, such as in the production of seedless fruits and in increasing biomass. In addition, it addresses the challenges and future prospects, highlighting the need for more research to fully understand its genomic and phenotypic consequences. It is concluded that the exploitation of polyploidy is vital to meet the growing demand for food and face climate change, providing new opportunities in the improvement of several species, including ornamental and medicinal, expanding their economic and ecological potential.

Keywords: Polyploids, Antimitotics, Autopolyploids, Allopolyploid, Genetic variation.

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INTRODUCTION

Polyploidy, characterized by the presence of multiple sets of chromosomes in a cell, is a significant evolutionary force that has played a crucial role in the evolution of plants (Mezzasalma *et al.*, 2023; Van de Peer *et al.*, 2020). This phenomenon, common in many plant species, has profound implications for genetic improvement, as it is associated with several structural, physiological and biochemical changes that can directly influence the agronomic characteristics of plants (Van de Peer; Mizrachi; Marchal, 2017; Madani *et al.*, 2021).

The study of polyploidy has become increasingly relevant, especially in the context of plant breeding. Polyploid plants generally have greater genetic diversity, vigor and resistance to abiotic and biotic stresses, characteristics that are of great interest for the development of new cultivars that are more productive and adapted to adverse conditions (Sattler; Oak; Clarindo, 2016; Zhang *et al.*, 2018). In addition, polyploidy has been explored as a tool for seedless fruit production, biomass increase, and improvement of plant nutritional quality (Zhang *et al.*, 2018). These advantages allow polyploid plants to play a crucial role in food security, as they make it possible to create more resilient and efficient cultivars, especially in the face of climate change and increased demand for food (Van de Peer *et al.*, 2020). The exploitation of polyploidy also opens up new opportunities in programs for the improvement of ornamental and medicinal species, expanding the economic and ecological potential of vegetable crops (Madani *et al.*, 2021).

Therefore, this work aims to investigate the role of polyploidy in plant species, focusing on its implications for genetic improvement. The main methods of polyploidy induction, their practical applications in the development of new cultivars, as well as the challenges and future perspectives in this field of study were explored. The research seeks to answer the following question: what are the effects of polyploidy on the agronomic characteristics of plant species and how can this phenomenon be used for genetic improvement?

METHODOLOGY

For the conception of this study, a narrative literature review was carried out, literature reviews play a crucial role in the foundation of any type of research and are essential for the advancement of knowledge. When done properly, they can also generate new ideas and direct the development of a specific field. For Greenhalgh, Thorne and Malterud (2018) a narrative review is an academic summary associated with interpretation and criticism. Sukhera (2022) points out that properly performed narrative reviews provide a readable, thoughtful, and practical synthesis on a subject, allowing authors to address other ideas while describing and interpreting what is known in the literature on the topic of interest of the research. They make it possible to conduct a subjective and critical examination while providing *insights* into the advancement of the field of study, new

theories, or current evidence seen from different or unusual perspectives to build a scientific knowledge base.

RESEARCH PROCEDURES

The bibliographic research was conducted using scientific articles and relevant documents found in databases such as Google Scholar, Scielo, Science Direct, ResearchGate, Lilacs, PubMed, Thesis Bank and Capes Journals, and with textbooks. The keywords used for the search included the terms "polyploidy", "plant species", "genetic improvement", "genetic variability" and "agronomic traits", in Portuguese, and "polyploidy", "plant species", "genetic improvement", "genetic variability" and "agronomic characteristics", in English, in different combinations. The time window used to guide and restrict this search was the last 10 years, so relevant articles from the period 2014 to 2024 were filtered.

STAGES OF THE REVIEW

The literature review was carried out in three main stages:

- Initial search: the first stage consisted of bibliographic research in the aforementioned databases and textbooks, using the defined keywords;
- Selection of texts: in the second stage, the selected texts were screened, based on the reading of the abstracts and the relevance of the studies to the central theme of the work, meeting the proposed objective;
- Detailed analysis: in the third stage, complete and analytical readings of the selected texts were carried out, extracting relevant data that allowed the analysis and elaboration of the present work.

LITERATURE REVIEW

POLIPLOIDIA

Polyplody is a powerful evolutionary force that played a key role in the early genomic evolution of plants (Mezzasalma *et al.*, 2023)element. It is a common phenomenon among plant species, in which there is an increase in the number of chromosomes, generating organisms or cells with more than two complete sets of chromosomes. It is associated with a wide variety of changes, including structural, physiological, biochemical, and plant development, which offers new opportunities for breeders in the selection of plants with the ideal characteristics for various purposes, such as medicinal, ornamental functions, and increased resistance (Madani *et al.*, 2021; Ghasemi *et al.*, 2021; Passos *et al.*, 2023; Salma; Kundu; Mandal, 2017).

Polyploidization is the name for the process of formation of polyploid organisms, and is widespread and particularly common in angiosperms. The resulting genetic redundancy has a very important impact on species formation and diversity, phenotypic variation, environmental tolerance, and interactions between species (Van de Peer; Mizrachi; Marchal, 2017).

Polyploids are not restricted only to crops of agronomic interest such as wheat, corn, potatoes, and brassicas, but also occur frequently in wild species and in natural habitats (Guerra, 2020; Heslop-Harrison; Schwarzacher; Liu, 2023).

Polyploidy in plants can arise naturally or be induced under laboratory conditions by physical, chemical, or biotechnological methods (Islam *et al.*, 2022), and has been used as a tool in plant genetic improvement for several decades.

As for origin, how the size of the genome is increased, polyploids are classified as autopolyploids, resulting from the duplication of only one genome, and allopolyploids, which are the combination of two or more different genomes, resulting from the crossing of different species (Griffiths *et al.*, 2022; Ramalho *et al.*, 2022). Polyploid organisms also arise spontaneously by the fusion of unreduced gametes, and can give rise to bilateral polyploids (by the union of two unreduced gametes) or unilateral polyploids (formed from the fusion of a reduced gamete with another unreduced gamete) (Sattler; Oak; Clarindo, 2016). Darmasaputra, Rijnberk, and Galli (2024) cite that polyploid cells can form as a result of failures in the cell division process, DNA damage, or tissue injury.

According to Ravandi, Rezanejad and Dehghan (2014), polyploidy can cause alterations in gene regulation and biosynthesis of plant growth regulators, enabling significant changes in the way genes are expressed and in the way plants produce chemicals essential for their growth and development.

Regarding the purpose of somatic polyploidy, what seems to be the most accepted in the scientific community is that it would be a strategy for the production of larger cells, since fewer cells of larger sizes would have functional advantages over a similar total mass of a larger number of smaller cells, implying an increase in gene expression and metabolism (Frawley; Orr-Weaver, 2015).

Polyploid plants have greater genomic and genetic diversity compared to other plants. Early ripening varieties, seedless fruits, sterile lines, highly productive crops, resistance to adversity, and plants with therapeutic properties are obtained through the use of polyploidy (Guerra, 2020; Yali, 2022).

Soltis *et al.* (2016) gathered data, in tables, on the most studied polyploid systems regarding genome size, structural and/or karyotypic evolution, gene expression, tissue-specific gene expression, methylation patterns, transposable elements, alternative splicing, ecogeography, population genetics, reproductive ecology and physiology, reporting that the genomic/genetic

systems *Gossypium*, *Brassica*, *Nicotiana*, *Glycine*, *Arabidopsis*, *Senecio*, *Spartina*, *Aegilops-Triticum* and *Tragopogon* are the ones with multiple temporal polyploidy samplings.

Fox *et al.* (2020) point out that polyploidy is a resource to be better explored in many fields. These authors propose a broad interdisciplinary challenge, 'polyploidy 2030', a collective study involving researchers from across the whole tree of life and in diverse fields, including evolutionary biology, ecology, agriculture, and medicine, working in an integrated manner to provide a meaningful synthesis of the role of polyploidy in biological systems and subsystems.

IMPORTANCE OF POLYPLOIDY FOR PLANT BREEDING

Polyploidy has been used for the development of new cultivars, including large crops such as wheat, cotton, potatoes and sugarcane, for example. Its genetic implications can lead to significant increases in yield, disease resistance, and grain quality, making it an area of great interest for researchers and plant breeders. Understanding and manipulating polyploidy can therefore contribute significantly to meeting the growing demand for sustainable food and agricultural resources (Zhang *et al.*, 2018).

It can have several important genetic implications, such as increasing genetic variability, which can be beneficial for plant adaptation and evolution. Polyploidy has been shown to be a crucial mechanism for adaptation and speciation in plants, with great relevance to agriculture, as many important agricultural species are polyploid. Its consequences on natural populations aroused the interest of breeders for its application in crop breeding, and the "giga" effect, which increases the size of commercial organs, is especially valued. In addition, genome "buffering", heterozygosity, and heterosis (hybrid vigor) are phenomena that can confer greater vigor to polyploids compared to their diploid relatives, making them a focus in breeding programs (Guerra, 2020; Renny-Byfield; Wendel, 2014; Sattler; Oak; Clarindo, 2016).

Regarding the effects on phenotype, Madani *et al.* (2021) highlight that the change in chromosome groups and the number of genes in a cell trigger consequences that can be desirable or undesirable, and that polyploidy occurs in more than 80% of plant species, accounting for 2-4% of speciation in flowering plants.

Another factor that makes polyploidy an object of study of great interest for plant breeding is the growing accumulation of evidence that biotic interactions, such as those with pathogens or mutualists, affect polyploids differently compared to non-polyploids, and depending on the context, this difference can be exploited to develop resistance mechanisms in agricultural crops, for example (Van de Peer *et al.*, 2020).

Due to its impacts on plant growth and development, chromosomal duplication has been applied in plant breeding to increase the levels of specific compounds and enhance morphological characteristics (Madani *et al.*, 2021).

With *Stevia rebaudiana* plants, Zhang *et al.* (2018) observed significantly improved morphological and physiological characteristics of tetraploid plants compared to diploid plants. They found a notable increase in the density of glandular trichomes, which was approximately two to four times higher, potentiating the secretion of steviol glycosides. In addition, this study also showed that the chlorophyll content in tetraploid plants was significantly high, indicating a superior photosynthetic capacity. The plants also showed vigorous growth, with larger and thicker leaves, more robust stems and shorter internodes, resulting in a higher biomass in the aerial part. In terms of glycoside production, the levels of stevioside and rebaudioside A in tetraploid plants were, respectively, 2.5 and 1.5 times higher than in diploid plants. With these results, the authors highlighted that polyploidy induction can be an effective strategy to improve the production and quality of desirable compounds in *Stevia rebaudiana*.

A study by Ravandi, Rezanejad and Dehghan (2014) points to a disadvantage of polyploidy in relation to diploidy. In an experiment with plants in vitro, the authors concluded that polyploidy exerted a significant impact on the regeneration capacity, specifically in the plant species *Cichorium intybus* L. One of the main observations was the loss of organogenic potential in calluses of tetraploid origin, which demonstrated a lower regeneration capacity compared to calluses of diploid origin. This suggests that polyploidy may be associated with a decrease in the ability of plants to regenerate in controlled environments.

Another aspect to be highlighted is that polyploidy expands the potential base of variability, increasing the number of genes that can be mutated. It contributes to increasing genetic diversity in the plant kingdom, allowing deleterious recessive mutations to be masked by its dominant alleles in the polyploid condition (Yali, 2022).

In addition to improving yield by the "giga" effect of autopolyploidy, polyploids are essential for gene transfer between species where direct breeding is unfeasible and for restoring the fertility of sterile hybrids, caused by meiotic errors. Thus, the application of polyploidy has been crucial in the development of more productive, adapted cultivars that add economic value (Sattler; Oak; Clarindo, 2016).

It is important to note that a polyploid organism, after being originated, goes through several critical stages during growth until it generates a plant that is capable of maintaining itself for several generations. One of the difficulties to overcome is to perform regular meiotic division, to make a balanced distribution of homologous chromosomes in anaphase I to produce viable gametic cells,

thus avoiding the formation of cells with an unbalanced number of chromosomes, and/or to resort to asexual reproduction (Guerra, 2020).

In the context of abiotic and biotic stress management, the identification of the implied mechanisms represents the most significant line of research in polyploidy. Genetic improvement based on polyploidy combines the advantages of heterosis and apomixis, and may be a promising option for crop improvement in the future (Islam *et al.*, 2022)element.

Within the forestry sector, polyploidy has been an alternative biotechnological strategy with great potential for the generation of more robust plants within breeding programs. Silva (2016), considering the absence of natural eucalyptus polyploids, developed protocols for the induction of in vitro polyploidization in *Eucalyptus grandis* seedlings, aiming to obtain tetraploid plants. The methodology established in the research presented promising results to be used in the acquisition of synthetic polyploids on a large scale in experimental fields and in breeding programs of this species.

Still on eucalyptus, Muniz *et al.* (2023) compared tetraploid with diploid materials, in relation to the quality of wood for the production of pulp and paper, this work was carried out through the analysis of physical and anatomical properties of wood. The results of the study indicated that the diploid clone had an average basic density of 552 kg/m³, 7% higher than the average of tetraploid clones, which ranged between 502 and 524 kg/m³. Regarding the lignin content between the clones, there were no significant differences. However, in relation to fibers, tetraploid clones had fibers with length and width about 16% and 20% larger than diploids. The fiber quality indices were similar between the polyploids and the control clone. The tetraploid clones stood out in volume after five years of cultivation. These results support the premise of the benefits of polyploidy in plant breeding, suggesting that polyploidy is a promising strategy for the genetic improvement of eucalyptus, with benefits for pulp and paper production.

METHODS OF POLYPLOIDY INDUCTION

Artificial polyploidy induction is a technique that can be used to support plant breeding and aims to double the number of chromosomes to generate plants with greater genetic variability. This leads to a broader recombination of enhanced traits (Barichello *et al.*, 2019). This is done through the use of antimitotic agents that bind to the tubulin protein, blocking the formation of microtubules and inhibiting the formation of the achromatic spindle. During the cell division process, chromatids are unable to separate and migrate to the cell poles, preventing the formation of a new membrane around the duplicated DNA (Souza *et al.*, 2019).

Polyploidy induction can be performed by more than one method, using chemical, physical and biological agents, and by several antimitotic substances, with colchicine, oryzalin, 8-

hydroxyquinoline and trifluralin being the most used. However, the polyploidization process does not depend only on the method or inducing agent used, but also on other variables (Madani *et al.*, 2021).

Several protocols have been developed to induce polyploidy in a wide variety of cultivated species. Since the discovery of colchicine, *in vitro* polyploidization with this antimitotic agent has become one of the main techniques to induce artificial polyploidy. Although only a few induced autopolyploids have achieved commercial relevance, polyploidy has become a highly valuable tool in breeding programs (Sattler; Oak; Clarindo, 2016; Souza *et al.*, 2019).

Colchicine works by stopping the formation of the mitotic spindle during cell division, which prevents the separation of duplicated chromosomes and results in cells with twice the number of chromosomes. This method is widely used due to its effectiveness, although it requires specific care regarding dosage and exposure time to avoid toxic effects and irreversible damage to plants. In a study carried out by Abou and El-Shereif (2014), with citrus seeds, it was found that the survival of these structures decreased with the increase in colchicine concentration and exposure time. The control, without colchicine, had the highest survival (92.3%), while treatment with 0.2% colchicine for 48 hours resulted in the lowest percentage (37%). This shows that higher concentrations and times increase toxicity, negatively affecting seed survival.

Melloni *et al.* (2015) mentioned that treatments with the herbicides trifluraline, oryzalin and 8-hydroxyquinoline had increased use due to their low toxicity content and for having a greater affinity with the β -tubulin protein, even at low concentrations.

In the research by Bonn, Karsburg and Gallo (2016), trifluralin was used as an antimitotic aiming at the induction and identification of polyploidy in jatoba root meristematic cells through morphological and cytological characteristics. The preliminary results indicated that the concentration of 3 μ M of trifluralin for 96 hours at 4°C was effective in inducing polyploidy, causing the duplication of the genome of *Hymenaea courbaril* L. var. *stilbocarpacom* ($2n = 4x = 48$) and the increase in the mean size of the stomata (0.215 mm), statistically higher than the other three treatments.

When studying ploidy stability in cassava (*Manihot esculenta* Crantz) plants treated with oryzalin, Souza *et al.* (2019) carried out experiments that identified tetraploid samples with no significant difference in the level of chromosomal duplication between 0.5 cm and 1 cm explants. After six cycles of subcultures, it was found that 92% of the individuals maintained the stability of the ploidy level, with peak values ranging from 2.98 to 3.28, while only 8% presented mild chromosomal variation, with peaks between 2.90 and 2.93. These results analyzed by flow cytometry indicate that the technique of polyploidy induction with oryzalin was effective in the generation of cassava tetraploid plants, and that most of these plants maintained chromosomal stability after

multiple subcultures, with the exception of some individuals that required new subcultures to confirm the chromosomal content.

On the other hand, Carvalho *et al.* (2016) after conducting the research with the same species and also aiming to develop a methodology for in vitro induction of polyploidy with oryzain and colchicine, concluded that the concentrations of oryzain (3 and 15 μM) and the time of exposure affected the development of cassava plants, producing only a few tetraploid individuals, while the concentrations of colchicine (1.25 to 6.25 mM) caused phytotoxic effect and, death of the explants.

Chromosomal duplication can also occur naturally, but it is a much slower process compared to artificially induced techniques (Souza *et al.*, 2019).

IMPACT OF POLYPLOIDY ON PLANT SPECIES CHARACTERISTICS AND PRACTICAL APPLICATIONS

Polyploidy, by introducing multiple sets of chromosomes into the cells of a plant, can have profound and varied effects on its agronomic and physiological characteristics. Studies have shown that polyploidy exerts significant effects on several aspects of plants, such as genome structure, gene expression, metabolism, among others, which ends up promoting changes in the phenotype. These changes can occur soon after polyploidization and be retained or lost later. Therefore, plant breeders should be aware of and be aware of the stability of these modifications when analyzing their experiments (Yu *et al.*, 2021).

Polyploid plants generally demonstrate greater hardiness and vigor, with a significant increase in tissues compared to the same diploid genotype, resulting in thicker and larger leaves, stems, and roots (Souza *et al.*, 2019).

Another impact of polyploidy on plant species is on the production of secondary metabolites, which are compounds that are not essential for growth, but that have important functions, such as defense against pests, for example. Polyploidy can modify its production since it alters the enzymatic activity of plants, impacting biosynthetic pathways and, consequently, the production patterns of secondary metabolites (Madani *et al.*, 2021).

Polyploidy can have a profound impact on the agronomic and physiological characteristics of plants, often resulting in reduced fertility due to meiotic irregularities. This condition is associated with the production of seedless fruits (Sattler; Oak; Clarindo, 2016), being advantageous to add value to the final product.

Heslop-Harrison; Schwarzacher and Liu (2023) highlight it as an important driver of evolution. Thus, the influence of polyploidy on the evolution of the genome and chromosomes has been the subject of numerous investigations. This genetic mechanism, which can trigger a series of phenotypic changes, offers numerous opportunities for practical applications in breeding (Segraves;

Anneberg, 2016). These applications can be targeted at developing varieties with desirable traits, including increased yields, improved disease resistance, and increased tolerance to environmental stresses. For example, polyploid cassava plants resulting from induction by oryzalin exhibited significant morphological changes, including larger leaf blade, larger diameter stems, and greater robustness compared to diploid genotypes (Souza *et al.*, 2019).

Vilcherrez-Atoche, Iiyama and Cardoso (2022) highlight that orchids represent the largest flower market in the world and that for this reason the objectives of breeding programs are aimed at obtaining flowers with greater size, durability, intense colors and resistance to pathogens, being the genera *Cymbidium*, *Dendrobium* and *Phalaenopsis* those with the largest number of studies and published reports on obtaining polyploid plants.

To verify whether polyploidy plays a significant role in expanding the environmental tolerance of species with polyploid cytotypes, Silveira (2014) analyzed the chromosome numbers of 14 *Eugenia* L. species (26 populations) with conventional cytogenetic techniques. His initial hypothesis was confirmed after submitting the results to statistical tests. The polyploid and diploid populations showed different spatial distribution patterns and environmental conditions. The polyploid individuals were collected in places where the environmental conditions were considered more adverse. These findings reinforce the importance of polyploidy in the diversity and survival of plant species in different environmental conditions.

However, while polyploid lineages have a greater capacity to face challenging environments, they are often equally or even more susceptible to extinction than their diploid predecessors. It is necessary to consider that polyploidization comes with several costs to new polyploid individuals, such as genomic instability, mitotic and meiotic abnormalities, reduced fitness, and exclusion of minority cytotype. Duplication of the entire genome can have important effects not only on genetics, but also on the ecology and life history of populations. Therefore, in order to understand the behavior of polyploids and the consequences of polyploidization on the adaptive potential of populations, different areas of research need to be linked, as many aspects remain understudied (Clo, 2022).

CHALLENGES AND FUTURE PERSPECTIVES OF POLYPLOIDY.

In recent decades, significant progress has been made in the study of polyploidy, with the discovery of several mechanisms related to its causes and consequences. However, many questions remain unanswered, highlighting the need for more research to clarify the effects of autopolyploidy and allopolyploidy on plant genomes. An in-depth understanding of the connection between genomic changes and the expression of new phenotypes after polyploidy holds promise for crop breeding, allowing breeders to manipulate polyploid genomes with greater precision and achieve better results (Sattler; Oak; Clarindo, 2016).

Despite the advantages, the possible negative effects of generating new polyploid organisms should be considered, regardless of the specific purposes. This is because, although polyploidy is a powerful tool, its use must be carefully planned to avoid unintended consequences (Madani *et al.*, 2021).

The genomic complexity of polyploidy is one of the main obstacles, due to the multiple sets of chromosomes, so understanding their genetic interactions requires advanced genomics and bioinformatics approaches. Interpreting phenotypes associated with polyploidy is challenging, which means that a deeper understanding has great potential for crop breeding, by enabling a more precise association between genotype and phenotype, and by filling gaps in the genetic transmission of desirable agronomic traits between cultivated species and their wild relatives (Bharadwaj, 2015).

In addition, understanding how polyploidy affects gene regulation and gene expression is not yet fully understood. To begin to try to solve this question, modern integrative approaches, which combine molecular, cytogenetic, and bioinformatics techniques, can provide clarification on the still poorly understood genetic and developmental mechanisms related to the formation, reproduction, and sex determination of neopolyploids (Mezzasalma *et al.*, 2023).

Polyploidy can be a valuable source of genetic variability for plant breeding and functional studies are essential to understand the molecular mechanisms underlying polyploidy, including the identification of key genes and affected metabolic pathways. Although it is now widely recognized that polyploid cells tend to be larger and produce nutrients or signaling molecules to the surrounding environment, there is a lack of experimental studies examining how polyploidization specifically affects cell growth rates, mRNA transcription, protein synthesis, and nutrient secretion (Darmasaputra; Rijnberk; Galli, 2024).

Interdisciplinary collaboration between molecular biology, genetics, and agronomy is crucial to address the challenges of polyploidy in a comprehensive way, given that despite the advances achieved, a complete understanding of the polyploidization process is still not possessed (Islam *et al.*, 2022).

All in all, while research on plant polyploidy faces significant challenges, it offers exciting opportunities to improve crop yields and sustainability.

FINAL CONSIDERATIONS

Polyploidy is a biological phenomenon of great relevance for the evolution and genetic improvement of plants. By introducing multiple sets of chromosomes into plant cells, this process offers a range of advantages that include increased genetic variability, contributing significantly to the adaptation of species to adverse environmental conditions and to obtaining more productive and resistant cultivars.

The study of polyploidy, both natural and induced, has shown profound impacts on the agronomic characteristics of plants, such as hybrid vigor, seedless fruit production, increased biomass and greater resistance to biotic and abiotic stresses. These changes are extremely important for the development of new cultivars, especially in a global agricultural scenario that requires sustainable and efficient food production.

However, the complexity involved in the manipulation of polyploids, especially with regard to genomic stability and fertility, still poses a challenge for plant breeders. The need for additional research to better understand the genetic and physiological mechanisms underlying polyploidization is evident. Integrative approaches that combine genetics, biotechnology, and bioinformatics are essential to overcome these obstacles and optimize the use of polyploidy in crop breeding.

It is concluded that polyploidy is a promising and strategic tool for plant genetic improvement, with the potential to boost agricultural innovation and ensure the production of more robust, resilient and productive cultivars. However, it is necessary to continue advancing in technical and scientific knowledge to fully explore the possibilities offered by this phenomenon, seeking solutions to the challenges that still exist.

This review process allowed for a critical and reflective approach, providing an understanding of the role of polyploidy in plant species and some of its implications for genetic improvement.

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Integrated agricultural production systems in lowlands

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ABSTRACT

Integrated agricultural production systems (SIPA's) are systems where crop crops are carried out in an integrated manner, with grain and forage cultivation in the same area, in rotation, succession or intercropping, in addition to the presence of grazing animals. These systems, in addition to diversifying agricultural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at preserving soils. Integrated crop-livestock systems are based on the idea that livestock activity can contribute to the generation of organic waste, improvement of the physical and chemical characteristics of the soil, crop alternation, interruption of the cycle of plant diseases and reduction of losses caused by climate variability. In addition, although the benefits of the adoption of LPIS in lowlands are known, they are still incipient and need more research to produce more consistent technical recommendations.

Keywords: Rice, Ryegrass, Production, Integrated Systems, Sustainability.

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INTRODUCTION

In the Western Border of Rio Grande do Sul, the main activities developed are extensive cattle ranching and the cultivation of irrigated rice. However, for both activities, profit margins have become smaller, challenging producers to adopt more sustainable production strategies (Carmona *et al.*, 2018).

In addition, the activities have isolated challenges such as the scarcity of forage for cattle in the winter period, and soil degradation due to turnover, irrigation and intense use of inputs in rice farming. As integrated systems allow the association between agricultural and livestock activities with benefits to both, they would be an alternative to mitigate the proposed challenges (Carvalho *et al.*, 2018). As it is a summer crop, rice is grown only in spring/summer, opening a gap for winter forage cultivation. These, especially ryegrass, could supply the forage shortage that occurs in this period and also provide quality food for beef cattle herds (Mantai *et al.*, 2015).

The cultivation of pastures and the introduction of cattle in agricultural areas under integrated systems and with adequate management provides benefits to soil structure and summer crops. Forage grasses have a root system that contributes to the improvement of soil structure. The presence of animals, on the other hand, accentuates the production of forage roots through defoliation, while promoting nutrient cycling through feces and urine (Reis; Silva, 2011). The benefits mentioned above have been measured and are consolidated for integration systems implemented in tropical and subtropical areas in Brazil. However, for lowlands, information is still scarce, lacking other indicators to support technical recommendations (Bohn *et al.*, 2020).

Also, although the environmental and social gains have already been measured in research with integrated systems, economic evaluations are still incipient or incomplete. However, they are as relevant as the others to validate the proposed systems and subsidize their dissemination on properties (Mantai *et al.*, 2015). Thus, the objective of this review was to list the main issues related to the implementation and conduction of PIS systems in lowlands.

LITERATURE REVIEW

INTEGRATED AGRICULTURAL PRODUCTION SYSTEMS

Integrated agricultural production systems (SIPA's) consist of growing grain-producing crops with forage crops in the same area, in rotation, succession, or intercropping (Barbosa *et al.*, 2022a). These systems, in addition to diversifying agricultural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at soil conservation (Coser *et al.*, 2018).

Due to its ability to provide economic and environmental benefits, according to Barbosa *et al.* (2022b) LPIS has received special attention from researchers and has been adopted by farmers in

Brazil (Bonetti *et al.*, 2015). Thus, Brazil leads the research in LPIS in relation to the rest of the countries in the world, according to Moraes *et al.* (2017), with approximately 11.5 million hectares are occupied by different arrangements of LPIS's. Of these, the subtropical region accounts for 44% of this area (Skorupa; Manzatto, 2019). However, its adoption in crops intended for the cultivation of irrigated rice is still incipient, especially with regard to the availability of data to support management recommendations. In these areas, called lowlands, the cultivation of irrigated rice in spring/summer and ryegrass in autumn and winter is predominant. In Rio Grande do Sul, about 1.1 million hectares are cultivated with flood-irrigated rice, according to (CONAB, 2019) due to the characteristics of the soil in these regions. These have a low water infiltration rate, low macro porosity and high compaction close to the surface, which makes it difficult for other crops to be inserted, according to Denardin *et al.* (2019) to achieve positive results in LPIS.

Therefore, it becomes a challenge to deploy and conduct systems in LPIS and lowlands. Countering this challenge, as rice cultivation is costly and expensive in terms of labor, water, energy, and as these resources are becoming increasingly scarce, this activity is becoming less profitable (Kumar; Ladha, 2011). Therefore, the implementation of LPIS in current agricultural production models can help generate income in the off-season of summer crops, and/or increase productivity in rice crops.

This increase would be possible because the SIPA's advocate the adoption of no-tillage as a cropping system, thus, the absence or minimal disturbance of the soil minimizes its degradation (Coser *et al.*, 2018). In the same way, the constant maintenance of living or dead cover in the soil contributes to the increase in the production of dry matter per unit area, according to Mazzuchelli *et al.* (2020) that can be used as a ground cover (Skorupa; Manzatto, 2019). This also contributes to the increase of soil carbon (C) stocks, according to Guesmi *et al.* (2019) that act as a subsidy for the supply of nutrients, according to Soares *et al.* (2019) with a consequent increase in crop productivity (Sousa *et al.*, 2020).

How can LPIS be to have their time-culture-space arrangements adjusted according to the needs of each reality, according to Barbosa *et al.* (2022a), research contemplating lowland environments can be conducted under the principles of SIPA's. Furthermore, although the benefits of adopting LPIS are known, in lowlands they are still incipient, and require further studies to generate more consistent technical recommendations (Carmona *et al.*, 2018).

It is also worth noting that the conventional agricultural system model is in evidence, because over the years the loss of forage diversity and environmental pollution by excess nutrients and pesticide residues, according to Anghinoni *et al.* (2013), has made society currently demand that specialized production models commit to producing food in the most connected way possible with nature (Carmona *et al.*, 2018)element.

FORAGE COMPONENTS IN SIPA's

As in the rest of Brazil, in the southern region the activity is based on the use of pastures as the main food resource. Also, as the well-defined cold season, characterized by the reduction of the photoperiod, low temperatures and the occurrence of frost, limits the production and quality of tropical forages, according to Peretti *et al.* (2017), forage strategies should be adopted to fill this food gap.

LPIS in Brazil comprise a great diversity of forage species due to the diversity of our edaphoclimatic conditions. However, of the pastures cultivated in winter, the most used species is ryegrass (*Lolium multiflorum* Lam.), according to Bohn *et al.* (2020) due to its productive potential and good adaptation to the environmental conditions of the region (Dotto *et al.*, 2022). In addition to being a good alternative to compose subtropical systems of crop-livestock integration, according to Moraes *et al.* (2014), because it has a high potential for dry matter production, according to Peterson *et al.* (2019), can be used for both grazing and ground cover (Bohn *et al.*, 2020). As SIPA's aim at social, environmental, and economic sustainability, among the challenges, the adoption of pasture management strategies that aim to maximize plant and animal production are extremely important (Dotto *et al.*, 2022). Thus, in addition to the choice of forage species, the grazing method and the fertilization strategy must be defined in order to meet the principles mentioned.

In continuous stocking, the animals have unlimited and uninterrupted access to the entire area to be grazed throughout the grazing period and in rotational stocking there is alternation between defoliation and rest (Dotto *et al.*, 2022). Due to the interspersed rest and grazing periods, in the rotating stocking, the regrowth process occurs in isolation from the grazing process (Ongaratto *et al.*, 2020). On the other hand, continuous stocking is characterized by milder changes in pasture condition over the period (Dotto *et al.*, 2022). This is the most suitable option for adoption in SIPA systems, as the constant soil cover maintained by the higher residual grazing height provides the sponge effect, minimizing soil compaction (Coser *et al.*, 2018).

In ryegrass, when used for grazing, in its management it is recommended the entry of animals into the area when the ryegrass is approximately 30 cm tall, for a better use of the pasture (Flores *et al.*, 2008). However, grazing management should prioritize a pasture height always higher than 10-15 cm to stimulate regrowth (Peretti *et al.*, 2017). The period of use of ryegrass pastures can last up to 80 days, subject to the climate, soil fertilization and especially area management (Pelegrini *et al.*, 2010). Although it is a forage species extensively studied in the southern region of Brazil, its dynamics in LPIS in lowlands is not yet fully elucidated. Thus, studies contemplating the performance of ryegrass inserted in alternative LPIS systems in lowlands will support technical recommendations for the management of this pasture.

ANIMAL COMPONENT IN SIPA's

The livestock phase of LPIS in the subtropical regions of Brazil is commonly adopted in the winter period and the main plant species used are winter forage grasses (Bertol *et al.*, 2022). Of these, ryegrass is the predominant one in lowlands, with dry matter productions that can reach 10 tons/ha and total digestible nutrient concentrations that can reach more than 80%, providing excellent animal performance (Fontaneli *et al.*, 2016).

However, this is dependent on the management of grazing intensity in the livestock phase, which determines the amount of forage available to the animal: higher grazing intensities will provide lower forage availability and vice versa (Bertol *et al.*, 2022). This is directly linked to the animal load used, which is one of the main challenges for increasing the area of LPIS in Southern Brazil. There are paradigms linked to the consumption of forage material that would cover the soil and the potential compaction of the soil by animal trampling, according to Carvalho *et al.* (2021), that is, both are linked to the grazing intensity of the livestock phase (Bertol *et al.*, 2022).

Although grazing should be moderate to minimize soil compaction and maximize forage production, it should be present, as it is responsible for plant root growth. In other words, the animal component is fundamental for the sustainability of the system, because in addition to promoting defoliation with root growth of forage plants, it also provides the cycling of nutrients through feces and urine. Integrated crop-livestock systems are based on the premise that livestock activity can contribute to the generation of organic waste, improvement of the physical and chemical characteristics of the soil, crop rotation, interruption of the cycle of plant diseases and reduction of losses resulting from climate variability. Additionally, these systems can provide fresh and highly nutritious forages for livestock, including in winter, while in other systems forage can be scarce (Vinholis *et al.*, 2021). For this reason, the adoption of animals with genetic potential can enhance the SIPA's, providing greater animal gain and greater efficiency in the use of the forages offered.

AGRICULTURAL COMPONENT IN SIPA's

In the subtropical regions of Brazil, the agricultural cultivation phase of SIPA's is commonly adopted in the summer period, and includes irrigated rice (*Oryza sativa*), soybean (*Glycine max*) and/or corn (*Zea mays*) crops. In lowlands, corn is rarely cultivated, except when used to produce silage for animal feed. Rice cultivated in the irrigated form is the predominant crop in lowlands in the agricultural phase. However, the sustainability of its cultivation has been declining season after season, with increased production costs and reduced water availability.

Soybeans are the most important economic commodity in Brazil and widely used around the world. In recent years, new areas have been used for soybean production, mainly in the lowlands of agricultural fields in southern Brazil historically managed by cattle ranching (Maranhão *et al.*, 2019).

However, most areas presented limiting factors for production, such as low soil fertility and reduced water retention, reducing the potential for grain yield.

However, the gains related to soybean cultivation would not be directly economic. As it is a leguminous crop, it has the capacity for biological nitrogen fixation. Also, its pivoting root system could contribute to the decompaction of the superficial layers of the soil, contributing in the long term to the improvement of its structure. Combined, these characteristics could contribute to a more favorable soil condition for ryegrass, providing higher DM productivity and higher animal load (Silva *et al.*, 2019).

ECONOMIC COMPONENT IN SIPA's

The adoption of technologies enables productivity gains and/or lower production costs through the use of new inputs and new combinations of resources (Vinholis; Souza Filho; Carrer, 2023). These gains have been observed in Brazilian agriculture. In recent decades, the generation and adaptation of agricultural technologies to tropical conditions has enabled the country to sustain a consistent increase in food production. In 2020, agribusiness GDP reached 26.6% of share in the national GDP (Center for Advanced Studies in Applied Economics, 2020).

Monoculture crop production and conventional livestock farming not integrated with crops were designed for a rapid increase in productivity and food supply (Vinholis *et al.*, 2021). Thus, monoculture is the predominant plant and animal production system in Brazil, based on the intense use of natural resources, chemical formulas, and non-renewable energy (Mendonça *et al.*, 2020).

However, some of these production systems have shown signs of saturation and negative environmental impacts (Vinholis *et al.*, 2021). However, in the face of an imminent scarcity of natural resources, production systems need to be rethought (Mendonça *et al.*, 2020). Crop-livestock integration systems have been developed as an alternative that offers increased productivity and greater environmental sustainability (Vinholis *et al.*, 2021). These systems enable the economic exploitation of production areas throughout the year, allowing greater production of grains, milk and meat, at lower costs due to the interaction between crops and pasture.

In economic theory, any economic gains obtained from the diversification of production systems are justified by the so-called "scope economy", which occurs when the cost of producing two items in a given production system is lower than when the same items are produced separately (Mendonça *et al.*, 2020).

However, measuring and demonstrating the economy of scope in production systems is not so simple, according to Gameiro *et al.* (2016), probably due to the difficulty in calculating the cost of production of an integrated system, especially for farmers (Mendonça *et al.*, 2020). This can be explained because there is no "protocol" for estimating the cost of an integrated system, which means

that there are multiple ways to conceptualize costs in nature-related production systems. The different possibilities of CLI system configurations in relation to the crops implanted and the management carried out are challenged to demonstrate the economic advantages of this system (Mendonça *et al.*, 2020).

CONCLUSION

Integrated agricultural production systems (SIPA's) provide an alternative to increase productivity and reduce the effects of environmental impact, standing out for being a sustainable and competitive technology to boost the agricultural sector. However, information on lowlands is still scarce, and other indicators are lacking to support more consistent technical recommendations.

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