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Sesame seed Production in Function of Populational Density

Produção de Sementes de Gergelim em Função da Densidade Populacional

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Abstract
This study aimed to evaluate the effect of plant population density on the agronomic characteristics and seed quality of sesame. Sesame seeds of the BRS-Seda cultivar were sown in a randomized block design with four plant population densities and a row spacing of 0.80 m, divided into four replications. The agronomic characteristics evaluated were plant height, height of first capsule insertion, number of branches, number of capsules per plant, lodging index, yield, and initial and final plant stand.For seed quality, a completely randomized design with four replications was used. The evaluated seed quality parameters included moisture content, purity analysis, thousand-seed weight, germination, field emergence, accelerated aging, and electrical conductivity. Means were compared using the Scott-Knott test at a 5% probability level, with statistical analysis performed using the Sisvar software.Sesame cultivation presents variability in the number of capsules per plant, without a defined standard. When correlating yield and final stand, it was observed that in the denser planting treatment, the number of plants per linear meter was four times higher than in the least dense treatment, although the number of fruits per plant was greater in the latter. Thus, when cultivated at a density of 50 plants per meter, sesame showed higher yield compared to the other planting densities. It was evident that increased plant density influences seed quality, and that lower planting density promotes a greater number of branches and fruits. Yield increases with higher sowing density.

Keywords: *Sesamum indicum L.* Plant Arrangement. Productivity. Physiological Quality.

Resumo
O presente trabalho teve como objetivo avaliar o efeito da densidade populacional de plantas sobre as características agronômicas e qualidade de sementes de gergelim. As sementes de gergelim da cultivar BRS-Seda, foram semeadas em blocos casualizados com 4 densidades populacionais e espaçamento de 0,80 m entre linhas, divididos em 4 repetições. As características agronômicas avaliadas foram altura das plantas, altura da inserção da 1ª cápsula, número de ramificações, número

de cápsulas por planta, índice de acamamento, produtividade e o estande inicial e final. Para a qualidade de sementes, o delineamento utilizado foi inteiramente casualizado com 4 repetições e as qualidades avaliadas foram umidade, análise de pureza, peso de 1000 sementes, germinação, emergência em campo, envelhecimento acelerado e condutividade elétrica. As médias foram comparadas pelo teste de Scott-Knott a 5% de probabilidade pelo programa computacional Sisvar. A cultura do gergelim é variável quanto ao número de cápsula por planta, não mantendo um padrão definido. Quando se relaciona a produtividade e o estande final da cultura, observou-se que no tratamento adensado o número de plantas por metro linear foi quatro vezes maior do que o menos adensado, embora o número de frutos por planta seja superior. Desta forma, quando cultivado sobre densidade de 50 plantas m^{-1} o gergelim apresentou maior produtividade quando comparado com as demais densidades de plantio. Pode-se evidenciar que o adensamento influencia a qualidade das sementes e que o plantio menos adensado proporciona maior número de ramificações e de frutos. A produtividade é superior com o aumento da densidade de semeadura.

Palavras-chave: *Sesamum indicum* L. Arranjo de Plantas. Produtividade. Qualidade Fisiológica.

1 Introduction

Sesame grain production in Brazil, the Central-West and South-Central regions stand out as the largest producers. In the state of Mato Grosso alone, 246.1 thousand tons were harvested in the 2023/2024 season (CONAB, 2024). Sesame is gaining increasing market space due to the nutritional characteristics of its oil, especially the presence of linoleic acid, oleic acid, lignans, tocopherols, phytosterols, phenolic acids, and minerals (Wacal *et al*., 2024).

Sesame cultivation is a viable alternative for the second crop cycle in Mato Grosso due to its broad adaptability to edaphoclimatic conditions, its growth cycle duration of approximately 100 days, and the phenological characteristics of the plant itself. Although Brazil has all the conditions that favor sesame development, the total cultivated area remains small.

In the pursuit of higher productivity in the field, combined with seed quality, plant population density becomes a key agronomic factor in crop establishment. Proper management of this variable is essential, as it directly influences plant architecture, growth, and development, in addition to affecting the production and partitioning of photoassimilates, which ultimately impacts final grain and seed yield (Carvalho *et al*., 2014).

High population densities can provide good interception of photosynthetically active radiation, though with poor distribution quality throughout the canopy. On the other hand, low population densities compromise the interception capacity of photosynthetically active radiation, thus reducing its efficient use. They also tend to increase the incidence of weeds and lead to uneven maturation, negatively affecting seed quality and the crop's yield potential (Jańczak-Pieniążek *et al*., 2021; Rigon *et al*., 2020).

The arrangement of plants along the sowing row is a crucial agronomic factor, as it directly affects the vegetative and reproductive phases of crops (Degenhardt; Kondra, 1981), mainly due to increased intraspecific competition. This spatial arrangement can reduce the number and weight of fruits per plant (Postma *et al*., 2021), affect the rate of row closure, biomass production, disease incidence, lodging, and, consequently, harvest yield (Lollato *et al*., 2024). Moreover, plant genotype also influences the ideal sowing density, considering that, with advances in biotechnology, improved cultivars show better productive performance at higher population densities. In this regard, the combination of spatial arrangements and ideal plant populations has emerged as a potential tool to increase yield per area (Oliveira; Knies; Wolffenbüttel, 2022). The ideal plant density depends on the production environment, and growth parameters, production, and yield components are significantly affected by row spacing and their interaction (Ali *et al*., 2020).

This study aimed to evaluate the effect of plant population density on the agronomic characteristics and seed quality of the sesame cultivar BRS-Seda.

2 Material and Methods

The experiment was conducted at the experimental station of the Mato-Grossense Company for Research, Technical Assistance, and Rural Extension (EMPAER), in the municipality of Cáceres, from May to October 2018. The region's coordinates are 16º 43' 42"S latitude, 57º 40' 51"W longitude, and an average altitude of 118 m. The soil, classified as Eutrophic Red-Yellow Argisol with Chernozemic characteristics, was mechanically prepared through harrowing and subsequent leveling. Soil samples were collected from the 0–20 cm layer for chemical analysis, and fertilization at planting followed technical recommendations: 50 kg ha^{-1} of N, 14 kg ha^{-1} of P_2O_5, and 60 kg ha^{-1} of K_2O. Topdressing fertilization was carried out using urea as a nitrogen source at 30 days, and potassium chloride at 35 days.

The sesame cultivar used for sowing was BRS-Seda, an early-cycle cultivar (90–110 days), with branching and white seeds, produced during the 2017 season in the same area. The experimental design was a randomized complete block with four replications, using a row spacing of 0.80 m and four plant population densities: 83,000 plants ha^{-1}, 125,000 plants ha^{-1}, 250,000 plants ha^{-1}, and 625,000 plants ha^{-1} (corresponding to 7, 10, 20, and 50 plants m^{-1}). Each experimental plot consisted of four rows, each 4 meters long, with 1-meter spacing between blocks.

Sowing was done manually in furrows, and irrigation was maintained using the sprinkler method three times a week. At the end of the crop cycle, irrigation was suspended to allow the plants to reach maturity. Manual weeding and pest and disease control were carried out as needed.

Fifteen days after sowing, thinning was performed, leaving only the number of plants per meter corresponding to each treatment. At 30 days, the initial plant stand was evaluated, and at 60 days after anthesis (DAA), the final stand was determined by counting the number of plants in the two central rows of each plot. Harvesting was performed on these two central rows, excluding 0.5 meters from the ends as borders.

Lodging was rated using a scale from 1 (all plants erect) to 9 (all plants lodged), as proposed by Antunes and Silveira (1993). Ten randomly selected plants per plot were measured for height and the position of the first fruit. The number of branches and fruits on these same plants was also counted. The useful plot was harvested manually 60 days after anthesis, starting when 70% of the flowers were open. The plants were placed in raffia sacks, dried in the shade, processed, and the seed moisture content was determined using the oven method at 105 °C for 24 hours, according to Brazil (2009). Yield was determined by weighing the seeds harvested from the useful area, adjusted to 6.7% moisture, and converted to kg m^{-2}.

A completely randomized design with four treatments (7, 10, 20, and 50 plants m^{-1}) and four replications was used for seed quality evaluations. The following tests were conducted: purity analysis (Brazil, 2009), thousand seed weight (Brazil, 2009), germination test (Brazil, 2009) at 25 °C and a 12-hour photoperiod, electrical conductivity (Vieira; Krzyzanowski, 1999) using 50 seeds in 75 mL of distilled water kept in a BOD-type chamber at 25 °C for 4 hours, seedling emergence in a seedbed (Vieira; Krzyzanowski, 1999) with assessments on the 5th day (initial stand) and 10th day (emergence), and accelerated aging (Marcos Filho, 1999).

The results were subjected to analysis of variance, and the means were compared using the Scott-Knott test (1974) at a 5% probability level. Plant population density was analyzed through regression analysis using the statistical software Sisvar version 5.6 (Ferreira, 2011).

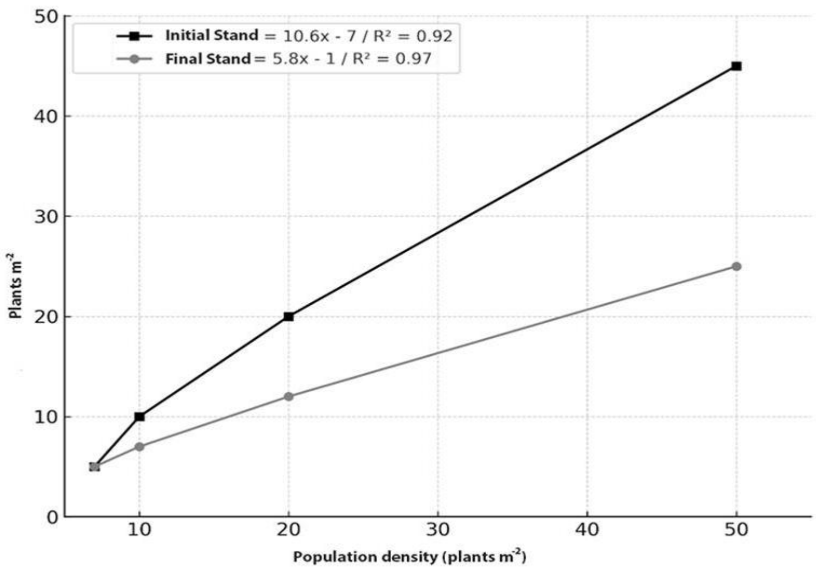
3 Results and Discussion

During the period from May to October 2018, the minimum regional temperature was 22 °C and the maximum was 28 °C, with relative humidity ranging from 56.2% to 75.6% (INMET, 2018). The temperature data recorded during sesame seed production coincided with the recommended range for the crop, which is between 24 °C and 27 °C (Gebregergis; Baraki, Fiseseha, 2024). For sesame, temperatures below 20 °C cause delays in germination and plant development, and at 10 °C, all metabolic activity ceases, leading to plant death (Baath *et al.*, 2022; Beltrão *et al.*, 2013). Temperatures above 40 °C alter floral development and can cause flower abortion, compromising seed yield. An average temperature of 27 °C promotes vegetative growth and fruit maturation; however, temperature drops during the maturation period affect seed and oil quality, negatively impacting the levels of sesamin and sesamolin (Baath *et al.*, 2022; Dahiru; Tanko, 2018).

When evaluating the initial and final plant stands (Figure 1), the increase in the number of plants per linear meter corresponded to higher initial and final stand densities due to the arrangement in the sowing row. However, this number of plants was not maintained until the end of the crop cycle. At planting densities of 20 and 50 plants m⁻¹, there was a reduction of 23% and 38%, respectively, in the number of plants, compared to reductions of 17% and 22% at densities of 7 and 10 plants m⁻¹. These results are consistent with Santos *et al*. (2018), who found that densities of 8 plants m⁻¹ in soybean resulted in a smaller reduction in field plant numbers. The decrease in plant density per meter reduced competition for light, thus ensuring that photosynthesis was not affected and allowing plants to develop satisfactorily (Jańczak-Pieniążek *et al.*, 2021).

The reduction in plant stand due to increased planting density is associated with competition among plants for water, nutrients, and light (Bagateli *et al.*, 2020; Ferronato *et al*., 2022; Gurmu, 2023). More vigorous plants develop faster and consequently reduce the quality of light available to less vigorous plants, causing morphological changes and favoring plant lodging (Postma *et al*., 2021).

Figure 1 - Initial and final stand of sesame plants per linear meter according to population density



Source: research data.

In this context, the plant lodging index in the field (Table 1) serves as a relevant agronomic indicator. The results showed that the population density of 50 plants per linear meter presented the highest lodging index, which can be attributed to the intensification of intraspecific competition (Carvalho *et al*., 2014). This competition induces changes in plant architecture, making them more susceptible to lodging, which compromises the efficiency of mechanical harvesting, reduces yield, and may negatively impact seed quality (Isaac *et al*., 2020). Conversely, at lower densities, this effect is not observed, allowing for greater efficiency in solar radiation interception and promoting a higher allocation of resources to grain production rather than excessive vegetative growth.

Table 1 - Lodging index scores for sesame plants as a function of population densities

Blocks	Population density (plants m^{-1})			
	7	10	20	50
	------------------------ Lodging Index*-------------------------			
I	2	3	2	2
II	8	8	2	4
III	2	3	5	8
IV	2	2	7	7
Mean	3.5	4	4	5.25

*Lodging index scale:1 – all plants upright; 2 – few plants fallen or slightly leaning; 3 – 25% of plants fallen or all leaning around 25 degrees; 5 – 50% of plants fallen or all leaning at 45 degrees; 7 – 75% of plants fallen or all leaning around 65 degrees; 8 – most plants fallen or almost touching the ground; 9 – all plants fallen.
Source: research data.

In addition to lodging, plant density, plant height, and the height of insertion of the first capsule (Table 2) are also characteristics that directly affect crop performance in the field, due to increased competition among individuals (Bagateli *et al.*, 2020; Oloniruha; Ogundare; Olajide, 2021). However, for these characteristics, no significant differences were observed as a result of increasing plant density per linear meter.

Table 2 - Plant height (PH, m), first capsule insertion height (FCI, m), number of branches (NB), number of capsules per plant (NCP), and sesame yield (YIELD, $Kg.m^{-2}$) as a function of plant population density (plants m^{-1})

Population Density	PH	FCI	NB	NCP	YIELD
7	1,44A	0,76A	8A	128A	101.28B
10	1,33A	0,79A	6A	74B	99.91B
20	1,28A	0,80A	5B	42B	132.33B
50	1,33A	0,83A	4B	45B	202.92A
CV %	13.37	13.84	26.63	34.58	26.33

*Means followed by the same uppercase letter in the column do not differ statistically according to the Scott-Knott test at 5% probability.
Source: research data.

The number of branches was influenced by plant density, with higher densities (20 and 50 plants per meter) resulting in a lower number of branches. In contrast, the densities of 7 and 10 plants per meter resulted in a higher number of branches per plant. When plants are in competitive conditions, there is a lower availability of photosynthates for vegetative growth, which consequently affects the reduction in branching (Isaac *et al.*, 2020; Wang *et al.*, 2023).

The densities that resulted in a higher number of branches also increased the number of fruits per plant, which occurred at the lowest planting density (7 plants per meter). For the other densities, no differences were observed regarding the number of fruits per plant (Table 2).

The sesame crop is variable in terms of the number of capsules per plant, without a defined pattern. When relating productivity to the final stand of the crop, it was observed that in the higher-density treatment, the number of plants per meter was four times higher than in the lower-density treatment, although the number of fruits per plant was greater. Thus, when grown at a density of 50 plants per meter, sesame exhibited higher productivity compared to the other planting densities.

Ali *et al*. (2020) observed that population densities influenced sesame crop productivity. Jańczak-Pieniążek *et al*. (2021) concluded that lower densities make better use of photosynthesis, and the reduction in productivity can be influenced by other variables. Cruz *et al*. (2016) found that higher production is related to increased population density.

Thus, the seeding density can influence the productive and qualitative performance of sesame, as the number of plants in an area determines the balance of yield components and, consequently, seed productivity and quality. The densification of the crop influenced the plant architecture, which can affect its efficiency in absorbing solar radiation (Ren *et al*., 2021; Silva *et al*., 2021).

For seed quality evaluation (Table 3), it was observed that the physical purity of the seeds varied across densities, with values ranging from 97.8% to 98.9%, all within the standards for sesame seed production and commercialization, and 6.89% to 7.19% for moisture content.

Table 3 - Germination (G, %), Emergence (E, %), Electrical conductivity (EC, $\mu S.cm^{-1}.g^{-1}$), Accelerated aging (AA, %), and 1000-seed weight (TSW, g), Seed moisture (SM, %), and Physical purity of sesame seeds (PS, %) under different population densities (plants m^{-1})

Population Density	**G**	**E**	**CE**	**AA**	**TSW**	**SM**	**PS**
7	94A	78A	43.57A	94A	3.45B	7.17	98.25
10	84B	58B	52.62B	88B	3.29C	6.95	98.30
20	82B	69B	46.35A	87B	3.37B	7.19	97.78
50	90A	72A	40.22A	95A	3.68A	6.89	98.89
CV (%)	5.39	12.40	8.21	4.15	2.10		

*Means followed by the same uppercase letter in the column do not differ statistically according to the Scott-Knott test at 5% probability.
Source: research data.

The highest averages for germination, emergence, and accelerated aging were observed at densities of 7 and 50 plants per meter, however, the result for 1000-seed weight did not follow the same trend, maintaining the highest value in seeds produced under the highest density (Table 3).

Population density interfered differently with the seed quality of the crops, as the number of plants in an area can affect seed vigor (Cardoso *et al*., 2021; Garcia *et al*., 2022). Furthermore, in soybeans, the increased population density positively affected productivity and seed size, with larger seeds showing better physiological quality performance (Bianchi *et al*., 2022).

Differences in the quality results may be related to planting time, seed moisture content correction, and row spacing. It is worth noting that in this study, the highest value was observed in seeds harvested from the plot with the highest plant population (50 plants per meter).

Golla (2020) also observed that in sesame cultivation, densities had a significant effect on 1000-seed weight. In soybean cultivation, Cruz *et al*. (2016), and in bean cultivation, Sadiq *et al.* (2023) observed increases in 1000-seed weight with increased planting density. Worku *et al*. (2020), in maize cultivation, observed that the increase in plant population density significantly affected 1000-seed weight due to resource competition. It is possible to verify that these variables were influenced by plant population, and for each crop, the weight responses varied between species.

The electrical conductivity test has proven to be proportional to the decrease in seed germination and emergence, as it is possible to measure the release of solutes from seeds with compromised membrane systems (Vieira; Krzyzanowski, 1999). On the other hand, very vigorous seeds make it more difficult to determine this difference. However, it was possible to observe that treatments with population densities of 7, 20, and 50 plants per meter provided seeds of higher quality compared to the density of 10 plants per meter (Table 3).

According to Araújo *et al.* (2022), the lower the electrical conductivity result, the better the seed quality, as it confirms membrane integrity through the test. On the other hand, the higher this value, the poorer the physiological quality of the seeds, which are characterized as low vigor.

4 Conclusion

Sowing density influences the seed quality of sesame.

The number of branches and capsules per plant is higher at a planting density of 7 plants per meter.

A population density of 50 plants per meter provides higher productivity.

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