SOYBEAN POPULATION MANAGEMENT SEEKING GREATER GRAIN PRODUCTIVITY

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ABSTRACT

Objective: The objective of this research was to evaluate plant growth, soybean grain yield and production cost depending on the use of different populations.

Theoretical reference: Among management practices, plant population is an extremely important stage for the establishment of soybean crops. In many cases, just changing the plant population is enough to result in high gains in crop grain productivity.

Methodology: A randomized block design was used, with four treatments and four replications. The treatments consisted of densities of 200, 250, 300 and 350 thousand seeds ha\(^{-1}\). Plant height, insertion height of the first pod, number of pods per plant, number of grains per pod, mass of one thousand grains and grain productivity were evaluated.

Results and conclusion: Populations influenced grain productivity, with the highest productivity being achieved in the population of 250 thousand, 5905 kg ha\(^{-1}\). It was concluded that sowing density affects the number of pods per plant and soybean grain productivity. The density of 250 thousand seeds ha\(^{-1}\) was the one that provided the highest productivity of soybeans and the lowest sowing cost.

Research implications: Determining the best population of soybean plants in different locations is essential to reduce producer costs.

Originality/value: Most research works focus on the use of inputs, disregarding that the plant population can affect crop performance and production costs.

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MANEJO DE POPULAÇÃO DE SOJA BUSCANDO MAIOR PRODUTIVIDADE DE GRÃOS

RESUMO

Objetivo: O objetivo dessa pesquisa foi avaliar o crescimento da planta, a produtividade de grãos de soja e o custo de produção em função do uso de diferentes populações.

Referencial teórico: Dentre as práticas de manejo, a população de plantas é uma etapa extremamente importante para o estabelecimento da cultura de soja. Em muitos casos, apenas a alteração de população de plantas é o suficiente para resultar em altos ganhos de produtividade de grãos da cultura.

Metodologia: Foi utilizado o delineamento em blocos ao acaso, com quatro tratamentos e quatro repetições. Os tratamentos foram constituídos pelas densidades de 200, 250, 300 e 350 mil sementes ha¹. Avaliou-se a altura de plantas, altura da inserção da primeira vagem, número de vagens por planta, número de grão por vagem, massa de mil grãos e produtividade de grãos.

Resultados e conclusão: As populações influenciaram na produtividade de grãos, sendo que, na população de 250 mil foi atingida a maior produtividade, 5905 kg ha¹. Concluiu-se que a densidade de semeadura interfere no número de vagens por planta e na produtividade de grãos de soja. A densidade de 250 mil sementes ha¹ foi a que proporcionou maior produtividade de grãos de soja e menor custo na semeadura.

Implicações da pesquisa: Determinar a melhor população de plantas de soja em diferentes localidades é fundamental para reduzir custos do produtor.

Originalidade/valor: A maioria dos trabalhos de pesquisa focam no uso de insumos, desconsiderando que a população de plantas pode afetar o desempenho da cultura e o custo de produção.

Palavras-chave: Glycine max, Arranjo de Plantas, Densidade de Semeadura.

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1 INTRODUCTION

Brazil is the world's largest producer of soybeans, reaching 154.6 million tons in the 2022/23 crop, with an average productivity of 3,508 kg ha¹, registering historical records in planting area, productivity and production (CONAB, 2023). Farmers and companies invest heavily in this crop (BRAZIL et al., 2018), resulting in several research projects with the potential to improve their grain productivity. Among the studies, one can highlight the positioning of cultivars in relation to the plant population, as well as their spacing, handling and fertilizing. The interaction between the intrinsic genetic factors of the cultivars and the production environment is essential for achieving gains (BALBINOT JUNIOR et al., 2015).

Among the management practices, the establishment of plant density is an extremely important stage for the formation of crops with high productive potential. Only the change in the plant population in many cases is sufficient to result in grain productivity gains from the crop (MORO et al., 2021). According to Roese et al., (2012), the plant arrangement is directly linked to competition, between lines and within lines, which may reflect on the development of soybeans and the control of weeds and diseases.

The correct distribution of plants in low populations means that soybean plants can emit more branches, increasing the number of pods per plant, and compensating for a possible lower
number of individuals per area, as it results in higher production per plant, not altering crop productivity (LI et al. 2021). The lower plant density can also increase the efficiency of spraying plant protection products (CARMÔ et al. 2019).

Thus, the productive potential of soybean plants is related to some morphophysiological characteristics, such as the length and number of branches per plant, which represent greater photosynthesizing surface, number of pods and number of fertile knots (MAUAD et al., 2010). Therefore, soybeans are highly responsive to the spatial arrangement of plants, due to their high plasticity, adjusting according to environmental and management conditions (SILVA et al., 2010). The high phenotypic plasticity of soybeans may constitute a strategy for the reduction of crop population, lowering seed costs and providing higher profit to the producer (MORÔ et al., 2021).

Cost management is extremely important for agribusiness, as it manages to control unnecessary spending. Due to the high costs of seeds, the tendency is to decrease the plant population, using less seeds. In this way, researchers and farmers are increasingly looking for knowledge about the density of sowing for each cultivar, in order to obtain a greater margin of profit in marketing. It is worth remembering that several abiotic factors differentiate one producing microregion from another, which can result in morphological changes and consequently change the recommendations of plant density (FERREIRA et al., 2018).

The region of Chapadão do Sul, has very favorable soil and climatic characteristics for the adoption of a population management of reduced plants, with well distributed rains, temperature conducive to the development of the crop, incidence of adequate solar radiation, and some regions with plenty of fertile soil, besides the high investment of the producers in technologies in the composition of the crops. Accordingly, it is possible to establish the hypothesis that the reduction in the plant population does not jeopardize the productivity of soya beans, favoring an increase in the producer's profit margin.

Accordingly, the objective of this research was to evaluate the plant's growth, the productivity of soybean grains and the cost of production, as a function of the use of different populations.

2 THEORETICAL FRAME

2.1 Soybean cultivation

Brazil is the world's largest producer of soybeans (Glycine max (L) Merrill) (CONAB, 2023), and the major production of this oilseed is due to high consumption worldwide, as it is a constituent in the production of animal feed, food products for human consumption and in the chemical industry, with oil percentages of approximately 20% and protein of 40% (SILVA et al. 2018, CALÇADO et al., 2019; MUNIZ et al. 2022).

Since the arrival of soybeans in the Brazilian territory, it has gone through various studies that have made great advances in the practices of handling and genetics. These improvements resulted in higher yields for the crop, mainly by the development of more erect cultivars, presenting greater efficiency in the use of photosynthetically active light, converting it into energy. This all results in higher number of pods per plant, higher grain weight and higher yield (UMBURANAS et al., 2022). With this, Brazil has managed to reach average productivity of 3508 kg ha⁻¹ (CONAB 2023), although many producers reach up to 6000 kg ha⁻¹. Although genetic characteristics and environmental conditions are determinant for the productivity of the crop grains, management can also contribute markedly to the productivity of the crop (KUMAGAI, 2020).

It is also important to highlight that soybeans have a broad socio-economic participation, influencing a large number of agents and organizations from various sectors such as resales of
2.2 Plant Population in Soybeans

The plant population is an important factor that affects grain productivity and depends on several other factors for a suitable recommendation, such as the cultivar used, soil management, sowing period within the indicated season, sower precision, seed quality, water distribution in the region, plant health care applied to seeds, among others (GUIMARÃES et al., 2008).

Over time, the standard population used in soybean cultivation has been reduced from 400,000 plants per hectare to around 300,000 plants per hectare, using densities of around 10 to 15 m\(^{-1}\) plants and increased yields and reduced seed costs have been observed (TOURINO et al., 2002).

In order to obtain the maximum gain in the distribution of the plants in the area, it is necessary to refine the local information, which is only possible by way of scientific research. However, a lot of attention has been paid to the work with inputs and little research has been carried out in order to possible alterations in the components of production, productivity and growth of soybeans as a function of sowing densities. Thus, producers use the population information passed by seed companies, without considering the intrinsic local information (BALBINOT JUNIOR et al., 2015; FERREIRA et al., 2018).

As soybeans have good phenotypic plasticity (LI et al., 2021), the crop can adjust to small reductions in plant density and thus compensate for productivity, without significant changes (FERREIRA et al., 2018). With this, it is possible to take advantage of the plant's own potential, improving the capture of photosynthetically active light, as well as improving the control of pests, diseases and weeds (MAUAD et al, 2010; SILVA et al., 2010; CARMO et al., 2019; MORO et al., 2021), with the potential to reduce costs both in seed spending and in more efficient phytosanitary management (SILVA & DOBASHI, 2021).

In several studies, it was found that the plant population had no effect on morphological characteristics, growth and grain productivity. However, plant populations compared to the reference population need to be well studied because genotype characteristics and environmental conditions can affect the results (MAUAD et al., 2010; LUDWIG et al., 2011). Typically, population variations between 200,000 and 500,000 plants per hectare do not affect grain yield, depending on several factors.

3 METHODOLOGY

3.1 Characteristics of the Experiment Site

The experiment was carried out on a rural property located close to the municipality of Chapadão do Sul-MS, with latitude 18°71'1938" South, longitude 52°42'39" South, latitude 52°47'06" West and altitude of 835 meters. The climate is classified as humid tropical, the temperature varies between 13 to 28°C, the average precipitation is 1893 mm, with concentration of rainfall in the summer and drought in the winter. The experimental area soil was classified as Dystrophic Red Latosol (SANTOS et al., 2018).

The average data on rainfall during the conduct of the experiment are shown in Figure 1.
The experiment was conducted from October 3, 2022 to March 6, 2023, and prior to the installation of the experiment, soil sampling was performed at the 0-0.20 m layer. The soil analysis showed the following pH values (CaCl$_2$) = 5.0; P (Honey), K, Cu, Mn, Zn = 15,42; 0,26; 1,06; 19,10; 5,40 mg dm$^{-3}$, respectively; Ca, Mg, H+Al and CTC = 3,73; 1,31; 4,93; 10,23 cmolc dm; V% 51,83 and MO = 36,42 g dm The soil texture was considered clay, with the value for soil texture of 486.64 g dm$^{3}$ of clay.

3.2 Experimental Design, Treatments and Plots

The experimental design used was in random blocks, with 4 treatments and 4 repetitions, totaling 16 plots. The treatments were formed by the populations of 200, 250, 300 and 350,000 plants per hectare. The experimental plots were made up of five lines of four meters in length each, spaced 0,45 m apart. the useful area of the plot was considered to be the three central lines. The cultivar used was 98R30 CE, long cycle (maturation group 8.3), with undetermined growth, high productive potential, and the Conkesta E3 technology.

3.3 Experimental Driving

Soybean sowing was carried out mechanically together with fertilization with MAP (7-40-00) in a dose of 250 kg + 200 kg KCL ha$^{-1}$. The herbicide glyphosate was used to control weeds in the dosage of 2 L ha$^{-1}$, at 20 DAP (days after planting). For control of fungi and diseases, such as: mildew; cercospora foliar crestamento; Asian rust; white mold; target spot, applications of fungicides were carried out, with the active ingredients of the products that were: Bixafem; Prothioconazole; trifloxystrobin; Mancozeb and Chlorotalonil; and for control of pests, such as caterpillars and bedbugs, active ingredients were used: Benzolate; Chlanrantraniliprole; Tiametoxan, Lambda-Cyathrin; Acetamiprid and Bifliprole entrine.
3.4 Characteristics Assessed

The harvest was carried out on 6 March 2023, and one day before the harvest, five plants were collected per plot to determine the total plant height (ALT), the time of the insertion of the first pod (ALTV), the number of pods per plant (NPV) and the number of grains per pod (NGV). Afterwards, the parcel was collected and tracked to then determine the mass of a thousand grains (MMG) and productivity (PROD). All grain dough has been adjusted to 13% moisture.

3.5 Statistical Analysis

The data obtained were submitted to the analysis of variance and the means were compared by Scott Knott's test at the 5% probability level, using the Sisvar software (FERREIRA, 2019).

4 RESULTS AND DISCUSSION

He observed that there was a significant effect on only three variables: productivity (PROD), number of pods per plant (NVP) and plant population (POP). In this study, no significant difference was identified in total plant height, insertion height of first pod and number of grains per pod, indicating that these variables are strongly related to the genetic characteristics of the plants, and little changed by management (Table 1).

<table>
<thead>
<tr>
<th>FV</th>
<th>GL</th>
<th>Medium Square of Residue</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>ALT</td>
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<tr>
<td>Block</td>
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<tr>
<td>Treatment</td>
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<tr>
<td>CV (%)</td>
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</tr>
<tr>
<td>Error</td>
<td>9</td>
<td>0.3694</td>
</tr>
</tbody>
</table>

ALT (cm): plant height, ALTV (cm): insertion height of the first pod, NVP: number of pods per plant, NGV: number of grains per pod, NGP: number of grains per plant, MMG (g): mass of one thousand grains, PROD (kg ha⁻¹): productivity of soybean grains, POP: final plant population, depending on different populations.

* significant and ns not significant by F-test at 5% probability level. CV: coefficient of variation.

Source: Authors (2023).

It was observed in Figure 2 that plant populations influenced the number of pods per plant. The population of 250,000 plants was the one that provided the greatest number of pods, remaining 30.1% above the average of the values obtained in the largest populations. The number of pods per plant has decreased in the largest populations.
Figure 2. Number of pods per plant (NVP) of soybeans depending on different populations.  
Source: Authors (2023)

According to Mauad (2010), this result may be related to the fact that at higher seeding densities, there is a greater competition for light, and lower availability of photoassimilates, causing the plant to decrease the number of branches and producing fewer nodes (where the reproductive buds are developed), providing smaller branches, fewer potential nodes and, as a consequence, fewer pods per plant.

The increase in the number of pods is one of the most important mechanisms for soybean plasticity (BALBINOT JUNIOR et al., 2015). In the smallest plant populations, soybean cultivation tends to increase its yield components, compensating for empty spaces, causing a single plant to produce enough pods to compensate for the lack of other plants in the area (DERETTI et al., 2022).

The final soybean plant populations suffered a reduction at the end of the cycle of 16.5; 7.6; 5.7 and 6.0%, respectively, to the sowing densities of 200, 250, 300 and 350 thousand ha⁻¹ seeds, which were established at the sowing of the crop (Fig. 3).

Figure 3. Final population of plants as a function of sowing density.  
Source: Authors (2023)
The plant population per hectare is defined by line spacing and plant spacing, and can be used to exploit the productive potential of soybean cultivation. Different densities can promote vegetative growth and plant productivity, and can also directly influence the foliar area, impacting the efficiency of light capture for photosynthesis (MORO et al., 2021). Another important factor is the final plant population, which depends directly on the sowing density, germination power, and survival rate of plants.

Sowing density can influence plant growth, having an effect on interspecific and intraspecific competition, and can even alter plant morphology due to its high phenotypic plasticity. This phenotypic plasticity makes it possible to compensate for low populations, with increased production per plant, presenting more productive nodes, branches and pods per plant, thus maintaining the productive ceiling with lower populations (BÜCHLING et al., 2017).

The use of high sowing densities in soybeans leads to an increase in costs with seeds, besides favoring bedding, presenting no advantages, since the response in productivity with the increase in plant density is practically zero, since the use below recommended, can favor the growth of weeds and cause losses at the time of harvest (SOUZA, 2010).

The highest productivity of soybeans was obtained in the sowing density of 250 thousand ha$^{-1}$ seeds (Fig. 4). The productivity value obtained was 21.9% higher than that obtained with the lowest density of seeds and 20.7% higher than that obtained in the higher densities. The use of 250,000 seeds represents an economy of 16.7% and 28.6% in the number of seeds spent in sowing, when one compares the densities of 300 and 350,000 seeds.

![Figure 4. Soybean Productivity (PROD) in different populations. Source: Authors (2023)](image)

Higher yields with lower densities were obtained by Tourino et al. (2002). The authors explain that this fact occurred due to a better spatial distribution of plants, thanks to changes in their architecture, having greater closing of the lines between lines, and improving weed control.

Productivity of grains from the highest to the lowest densities may be related to good climatic conditions, represented by the good distribution of rainfall during the crop cycle (Fig. 1), favoring plant development, taking into account what Balbinot Junior et al., (2015), that the reduction of plants per hectare may not be interesting in environments not conducive to the growth and development of the crop. Also, it may be related to the increase in number of pods per plant, and number of grains per individual, causing the plant to increase its productive
capacity, at several different densities, confirming its great phenotypic plasticity, compensating for the low densities with the increase of branches (DERETTI et al., 2022).

The recommendation of the company that owns the cultivar is 300,000 plants per hectare, but according to the results, the greatest productivity was with planting 250,000 plants per hectare. This increase in productivity is mainly due to the greater use of sunlight, the absorption of water and nutrients present in the soil.

In relation to the cost of production, the amount of seeds spent per hectare was calculated. Each bag of soybean seeds with treatment costs on average 350 reais, and the seed bag comes with a total of 140,000 seeds, so, in the treatment with 200,000 seeds per hectare, used 1.42 bags; 250,000, 1.78 bags; 300,002.14 bags and 350,002.5 bags of seeds. Thus, as is observed in Figure 5, the more seeds, the higher the cost of production.

![Figure 5](image.png)

**Figure 5.** Cost per hectare for the quantity of seeds used.  
**Source:** Authors (2023)

With the soybean bag costing on average 160 reais in the year 2022, one can notice in figure 6, the amount of bags needed to cover the cost of the seeds.

![Figure 6](image.png)

**Figure 6.** Cost of bags per hectare depending on different populations  
**Source:** Authors (2023)
It was observed that in the population of 250,000 plants, it spent 0.78 bags less than in the population of 300,000 plants, but produced 15.56 extra bags, an increase of 18.79% in relation to the witness, having an excellent return.

5 CONCLUSIONS

Sowing density interferes with the number of pods per plant and the productivity of soybeans.

The density of 250,000 ha$^{-1}$ seeds was the one that brought about the highest productivity of soybeans and the lowest cost in sowing.

REFERENCES


