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# PERCENTAGE OF SOYBEAN LIPIDS IN DIFFERENT CROPS, DENSITIES, AND POSITIONS IN THE PLANT IN SOUTHERN PARÁ

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**Abstract**– The lipid content in soybean grain can be influenced by environmental characteristics, pod positioning, and plant population. However, the objective is to evaluate the percentage of soybean lipids in different plant positions in populations of two crops, in the southern region of the state of Pará. In this sense, two tests were carried out, one in the agricultural year 2018/19 and the other in 2020/21, in Conceição of the Araguaia-PA. The experimental design used in each assay was randomized blocks with three replications. The treatments were arranged in plots sub-sub-sub-Subdivided, being allocated in the plots six cultivars, in the subplots three sowing densities (10; 14; 18 seeds m$^{-1}$) and the sub-sub-two plots sites in the plant (on top and in the bottom third). The characteristic studied was the percentage of lipids. Individual variance analysis was performed and, later, joint analysis of the assays was performed. The highest averages of lipid contents were obtained in the lower third of the plant, with emphasis on the cultivars Ultra 75i77 IPRO, in the density of 18 seeds m$^{-1}$ (24.3% crop 1 and 24.1% in the crop 2). The densities influenced the results, showing significant differences between them and being the best density of (18 seeds m$^{-1}$). When the grains were collected in the lower third of the plant, they showed the highest lipid contents. Crop 1 was affected by the high temperature followed by a water deficit in the grain filling phase, showing that in November in southern Pará you can get summer in the R5.1.

## INTRODUCTION

The crop has soybeans *(Glycine max)*is in great evolution of values and having the price of soybeans in March 2021, 80% higher than the nominal average of March 2021. 2020 (CEPEA, 2021).

Soybeans are the main agro product exported by Pará (50.13%). Between 2010 and 2020, the cultivated area expanded from 85,400 to 603,473,000 hectares, making it the most representative crop in the State (AGÊNCIA PARÁ, 2021).

The lipid content of soybean may vary depending on climatic conditions and cultivars (Lopes *et al*., 2014), levels of fertilization (Korber *et al*., 2017), and the position of the pods in the knots of the main rod (Bellaloui & Gillen, 2010; Sales, 2016).

The identification of the most indicated sowing time for each cultivar would result in better plant development (Faria *et al*., 2018), increments in grain production without changes in agronomic characteristics, and, finally, an increase in lipid yield (Peluzio *et al*., 2014).

Populations of Cruz *et al*. (2016) revealed that plots with the lowest densities (10 Plants m$^{-1}$) produced more than plots with higher plant densities (22 Plants m$^{-1}$). Unlike the results of Camicia *et al*. (2018) which achieved the highest productivity in the density of (18 Plants m$^{-1}$).

Second Barbosa *et al.* (2011), in soybean cultivars cultivated in the State of Tocantins at various sowing times, when the grain filling phase coincides with high temperatures and deficitwater,there is an increase in the oil content of the grains.

Bellaloui *et al.* (2020) evaluated the influence of the use of different population arrangements, agricultural practices, environments, and soybean genotypes on their oil and protein contents, observed the change in the chemical composition of soybean, and justify these changes from the populations of studied plants and climatic factors that occurred during planting.

Concerning the position of the pods in the plant, Bellaloui and Gillen (2010) cultivation under a greenhouse and Filho *et al.* (2019), in soybean cultivation under field conditions, found differences in the percentage of lipids in the different parts of the plant. On the other hand, Sales *et al.* (2016) observed that the grains located in the middle and lower third presented higher lipid content.

Due to the accelerated growth of soybean planting in southern Pará, combined with the scarcity of information on the effects of climatic factors, sowing density, and pod position, on the percentage of lipids of soybean grains in different cultivars, the present study was proposed.

## MATERIALS AND METHODS

The experiments were carried out in the agricultural year 2018/19 and 2020/21, at the Agroecological Experimental Center (CEAGRO), of the Federal Institute of Education, Science and Technology of Pará, Campus Conceição of the Araguaia (8° 18′ 10′′ South e 49° 17′ 02′′ West).

The soil is classified as quartzarenic-neosols (Santos *et al.*, 2018) and has sand or frank sand texture at least 2 m deep and with 85.34% sand. Soil analysis was performed at a depth of 0-20 cm according to Table1.

The predominant climate is tropical with winter drought season (Aw) from Köppen-Geiger, the temperature varies during the year from 20 to 35 °C. The rainy season occurs, nolater, from November to May, and the driest, from June to October, with the annual rainfall index around 2 mil/mm.

Weather data (Figure 1A), obtained through the database of the INMET of the automatic station located in the CEAGRO provided an average every 2 days of accumulated precipitation and average temperature.

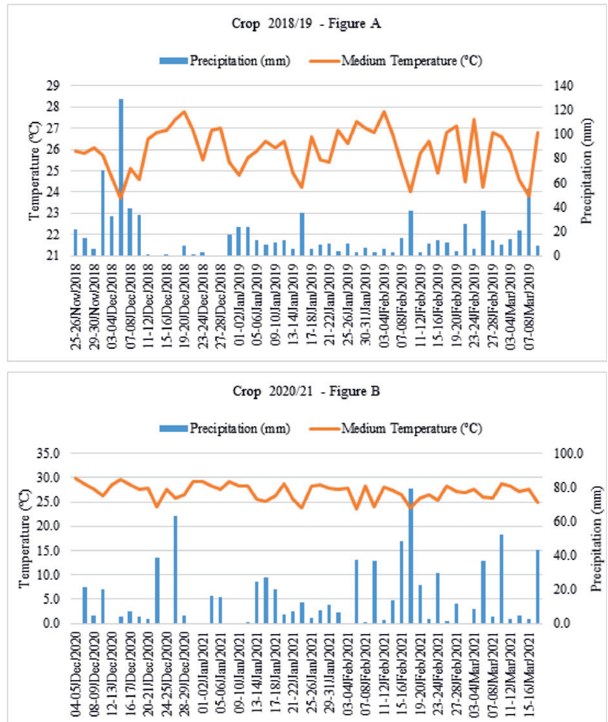


**Fig. 1.** Precipitation médium index (mm) and medium temperature (°C) occurred in the agricultural year 2018/2019 (A) and the agricultural year 2020/21 (B). Medium tabulated every 2 consecutive days. Source: INMET (2022).

The design was randomized blocks (DBC) with three replications, and the treatments are arranged in plots sub-sub-Subdivided, being allocated in the plots six cultivars, in the sub-plots three sowing densities (10; 14; 18 seeds $m^{-1}$) and the sub-sub-plots two sites in the plant (in the upper third and lower third). The experimental plot was composed of four lines of 5 m long, with spacing between the line of 0.45 m and all plots.

**Table 1.** Report of the physical-chemical characteristics of the soil.

| Prof. (cm) | Sand (%) | SB (V) (%) | CTC (T) (cmol/dm3) | Ca | Mg | K | H+Al | Al | MO (%) | P- mel (mg/dm3) | S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-20 | 85.34 | 28.9 | 4.36 | 0.72 | 0.45 | 0.09 | 3.10 | 0.20 | 1.46 | 8 | 1.97 |

*Prof – Depth; SB – Base saturation; MO – Organic matter; CTC – Cation exchange capability.

All evaluated cultivars present molecule resistance of glyphosate groups (RR) e some technology cultivars IPRO (soy intact), which contains resistance to the main insect pests in the order of *Lepidoptera* (Caterpillars) associated with culture. The cultivars were evaluated and the recommendations of their obtainers for the south of Pará (Table 2).

The liming was with dolomític limestone, being performed manually 30 days before planting, applying 2-tonha$^{-1}$. Soil tillage was performed through a conventional leveling grid and manual groove.

The fertilization used was performed next to the sowing, according to the requirements of the crop and according to soil analysis being performed manually, being used 750 kgha$^{-1}$ of simple superphosphate, which corresponds to approximately 150 kgha$^{-1}$ from $P_2O_5$ and 150 kgha$^{-1}$ potassium chloride in the planting groove, which corresponds approximately 90 kg from $K_2O$/ha$^{-1}$ being half the $K_2O$ in planting and another half 15 days after planting. The characteristic studied was the percentage of lipids. Individual variance analysis was performed and, later, joint analysis of the assays was performed.

The seeds were treated with fungicides, followed by inoculation of seeds with strains of *Bradyrhizobium japonicum* (500 kgha$^{-1}$). Thinning was performed after the complete emergence of seedlings, leaving the number of plants for each population determined in the treatments.

In the plots in which the number of plants was higher than desired, thinning was performed 15 days after emergence. The first harvest was held on November 25, 2018, and the second was on December 4, 2020.

During the conduction of the two crops, pest and disease control was carried out preventively, during the application via spraying, there were also two applications of foliar fertilizer in the formulation 10;10;10 + micro (Mo 0,5%; Co 1%; Zn 0,5%), during the culture cycle.

The plants were harvested after presenting 95% of the mature pods, i.e., at stage R8 of the Fehr *et al*. (1971). After manual harvesting, the plants were sun-seed to lose moisture and then removed the pods of the upper third and those from the infer for lipid analysis.

Then, the seeds were identified by treatment and then weighed and taken for laboratory analysis for oil extraction in the chemistry laboratory of the Federal Institute of Pará, the campus of Conceição of the Araguaia - Pará.

Oil extraction was carried out with the petroleum ether solvent in a Soxhlet extractor, under conditions of commercial oil procurement, according to the methodology of (AOCS, 1997).

After obtaining the data, the analysis of individual variance was performed and, later, a joint analysis of the assays in which the smallest residual mean square did not differ by more than seven times the highest (Cruz *et al.*,2012), the means of the factors years and cultivars compared by the Scott & Knott (1974) at 5% significance.

## RESULTS AND DISCUSSION

In the joint analysis, a significant interaction was observed between pod site x density x cultivar x crop, and the unfolding was carried out to explain variations in oil content that may be linked to variations in the main effects (Table 3).

The coefficients of variation (CV) obtained vary between (2.45 the 5.06%), showing good accuracy in conducting the experiments according to Gomes (2009). Search for Sales *et al.* (2016) obtained a variation of (CV) between (4.91 the 4.92%).

In general, the averages of lipid contents in Table 4 (upper third and lower third) have always been higher in the highest densities, this is justified because the plants are denser and at least half the plant down, receiving less sunlight. Research by Bellaloui and Gillen (2010) found that the shade

**Table 2.** Description of soybean cultivars for the breeder, degree of maturation, plant density, and date of the crop.

| Cultivate | Breeder | Degree of maturation | Density (Plants/m$^{-1}$) | Planting the crop |
|---|---|---|---|---|
| Bônus 8579 IPRO | BRASMAX | 7.9 | 9 the 16 | 25/10 the 25/11 |
| Ultra 75i77 IPRO | BRASMAX | 7.5 | 16 the 20 | 15/10 the 25/11 |
| Desafio 8473 RR | BRASMAX | 7.4 | 16 the 20 | 25/10 the 25/11 |
| NS 7901 RR | NIDERA | 7.9 | 9 the 14 | 15/10 the 30/11 |
| DM 80i79 IPRO | DOM MÁRIO | 8.0 | 10 the 14 | 01/11 the 25/11 |
| Werma 842 RR | BASF | 8.3 | 9 the 14 | 01/11 the 30/11 |

**Table 3.** Summary of the analysis of variance related to the number of lipids in (%), from six soybean cultivars and with three densities, position of the pods, produced in two 2018/19 and 2020/21 harvests, experiments carried out in Conceição of the Araguaia -Pará.

| Source of Variation | Degree of freedom | Square Medium |
|---|---|---|
| | | Lipids |
| Blocks | 2 | 1.72^NS |
| Crop | 1 | 196* |
| Residue (a) | 2 | 1.03 |
| Cultivars | 5 | 11.42* |
| Cultivars x Crop | 5 | 8.08* |
| Residue (b) | 20 | 0.24 |
| Densities | 2 | 131.6* |
| Density x Cultivate x Crop | 10 | 2.56* |
| Residue (c) | 40 | 0.29 |
| Location in the Plant | 1 | 291.6* |
| Local x Density x Cultivar x Crop | 10 | 2.68* |
| Residue (d) | 82 | 0.35 |
| Medium | | 20.06 |
| CV% (a) | | 5.06 |
| CV% (b) | | 2.45 |
| CV% (c) | | 2.71 |
| CV% (d) | | 2.96 |

* Significant at the level of 5% probability; NS: not significant; by the test F. CV: Coefficient from variance.

does not affect the chlorophyll content in the leaf but increases levels of oleic and linoleic acids.

Regarding the percentage of soybean lipids and their compensation capacity in the use of space between plants, soybean has been shown to tolerate a wide variation in the plant population, however, there is a difference in the yield of lipids and proteins.

When comparing the oil content, between the thirds of the pods in the plant, within each crop, cultivar, and sowing density, in general, the higher oil content was observed in the grains from the lower third of the plants. However, for cultivars Desafio 8473 RR in crops 1 and 2, in density 14, and Werma 842 RR, in crop 1 in density 14 and crop 2 in density 14, no differences were detected between the thirds.

In the basal region of the plant, the increased availability of blue light may have resulted in increased activity of the omega-6-denaturalize cytosolic enzyme that increased the fatty acid content in grains, mainly oleic and linoleic acids (Khandaker *et al.*, 2015).

These results agree with those obtained by Sales *et al.* (2016) and Bellaloui & Gillen (2010), who found, respectively, the reduction of 4.4 and 4.9% of the grains located in the upper third of the plant, concerning those present in the lower third. Bennett *et al*. (2003) also verified a lower concentration of oil in soybean grains in the epic pods. On the other hand, they disagree with those obtained by Sales *et al.* (2016).

Concerning the harvests 1 (2018/19) and 2 (2020/21), in each third of the pod, cultivar, and density, crop 2 promoted a higher oil content in the grains for most combinations.

The highest temperatures and the lowest precipitation in February and early March, in the grain filling phase, in the harvest 2018/19 (Figure 1B) concerning the harvest 2020/21 (Figure 1A), promoted a differential behavior among cultivars, resulting in a higher oil content in the grains (Table 3), due to the occurrence of biochemical disorders in the biosynthesis of oil (Bellalouiet *al.*, 2020).

These results agree with those obtained by Barbosa *et al.* (2011), Finoto *et al.* (2017), and Carvalho *et al.* (2021), who also observed the effects of high temperatures and water reductions in the increase of oil content in soybean grains. Naoe *et al.* (2020), also had about the isolated and/or associated effect of low water availability and high temperatures on the oil content.

Concerning the average of the densities unfolding within the location level of the pods in the plant, the best averages were in crop 2 and in the lower third, especially all cultivars that did not differ significantly, maintaining the highest percentages. The lower averages were in the upper third of the plant in the harvest 1.

The lowest densities (10 seeds $m^{-1}$), for lipid productivity, observed low data such as Ultra 75i77 IPRO (14.1%), Bônus 8579 IPRO, and Nidera 7901 RR (15.7%), to work closer regionally at the same density as above, obtained 19.9 % that was of Almeida *et al.* (2018) and Prabhakar *et al.* (2018). Leaf expansion is directly related to the photosynthetic capacity of assimilatory tissues, which is higher in smaller densities because self-shading is less intense thus producing a smaller amount of lipids.

Followed by the number in the column, the cultivar Werma 842 RR in all densities in crop 1 showed to come out better even in adverse conditions, showing in its genotype, good characteristics for lipid yield, as well as (Thompson *et al.*, 2015) found cultivars with high lipid yield.

In the lower third of the plant in the density of (18 seeds $m^{-1}$), there was no significant difference in

**Table 4.** Means of the unfolding of the local quadruple interaction of the pod x density x Cultivars x crop, lipid content (%). In two harvests (11/2018 and 12/2020), in two sites in the plant (upper and lower third) and three sowing densities (10;14; 18 $m^{-1}$).

| | Upper Third | | | | | |
|---|---|---|---|---|---|---|
| | Crop1 | | | Crop2 | | |
| Cultivar | 10 | 14 | 18 | 10 | 14 | 18 |
| Ultra 75i77 IPRO | 14.1bIIB3 | 19bIA1 | 19.3bIIA1 | 18.7aIC3 | 20.1bIIB1 | 21.4bIA1 |
| Bônus 8579 IPRO | 15.7bIIC2 | 18.3bIB1 | 19.5bIIA1 | 21.5aA1I | 21.4bIIA1 | 21bIA1 |
| DM 80i79 IPRO | 16.4bIIB2 | 16.8bIIB2 | 18.4bIIA2 | 18.5bC3I | 20.4bIB1 | 21.6bIA1 |
| Nidera 7901 RR | 15.7aIIB2 | 17bIIA2 | 16.5bIIA3 | 19.5bA3I | 20.6bIA1 | 20bIA2 |
| Desafio 8473 RR | 16bIIB2 | 19.2aIIB1 | 19.6bIA1 | 20.2aA2I | 20.9bIA1 | 20.2bIA2 |
| Werma 842 RR | 17.5bIIB1 | 19.3aIA1 | 18.6bIA2 | 17.3bB4I | 19.9aIA1 | 19.1bIA3 |
| Medium | 16 | 18 | 18.7 | 19.3 | 20.5 | 20.5 |
| | Lower Third | | | | | |
| | Crop1 | | | Crop2 | | |
| Cultivar | 10 | 14 | 18 | 10 | 14 | 18 |
| Ultra 75i77 IPRO | 16.5aIIB4 | 21.9aIB1 | 24.3aIA1 | 19.6aIC2 | 21.5aIB2 | 24.1aIA1 |
| Bônus 8579 IPRO | 22.1aIC1 | 19.8aIIB2 | 23.2aIA2 | 22aIB1 | 22.4aIB1 | 23.7aIA1 |
| DM 80i79 IPRO | 18.6aIIB3 | 19.5aIIB2 | 22.3aIIA1 | 20.1aIC2 | 21.7aIB2 | 23.6aIA1 |
| Nidera 7901 RR | 16.5aIIC4 | 20.1aIIB2 | 23.1aIA2 | 21.4aIB1 | 22aIB1 | 23.8aIA1 |
| Desafio 8473 RR | 19.7aIIB2 | 20.1aIIB2 | 22.4aIA1 | 20.9aIB1 | 22.5aIB1 | 23.3aIA1 |
| Werma 842 RR | 18.7aIC3 | 19.8aIIB2 | 21.4aIA1 | 19aIB2 | 20.8aIA2 | 20.5aIA1 |
| Medium | 18.7 | 20.2 | 22.1 | 20.5 | 22 | 23.1 |

1. The average unfolding of the pod site, within each level of density, cultivar, and crop, followed by the lowercase letter in the line belongs to the statistically homogeneous group, at 5% significance by the Scott-Knott test.
2. Average crop unfolding, within each pod site level, density, and cultivar, followed by the Roman numeral in the line belongs to the statistically homogeneous group, at 5% significance by the Scott-Knott test.
3. Averages of the density unfolding, within each level of the pod, cultivar, and crop site, followed by the capital letter on the line belong to the statistically homogeneous group, at 5% significance by the Scott-Knott test.
4. The average of the unfolding of the cultivars, within each level of pod site, density, and crop, followed by the number in the column belongs to the statistically homogeneous group, at 5% significance by the Scott-Knott test.

cultivars, showing satisfactory lipid content, the same resemble studies of Cruz *et al*. (2016) and Almeida *et al.* (2018). The higher accumulation of dry mass in the highest densities is associated with the higher number of plants per area, and not necessarily with the higher production of photoassimilates.

The cultivars Ultra 75i77 IPRO, Bônus 8579 IPRO, and DM 80i79 IPRO were obtained in the two crops with the highest density the highest significant averages of lipids in the upper third, and in the lower third, there was no significant difference, showing that the lipid content in the lower third will be higher in the highest density, because due to the increase in leaf area and photosynthetic rate, it results in a higher carbon availability (C), leading to an increase in lipid content.

## CONFLICT OF INTEREST

There is no conflict of interest between the authors. all authors contributed directly to the article.

## CONCLUSION

1. High temperatures combined with water stress in the grain filling phase cause biochemical disturbances in lipid biosynthesis, increasing production.
2. At higher densities, soybean cultivars tend to have higher lipid yields in the lower third.

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