

EFFECTS OF SOWING TIME AND PLANT POPULATION ON THE PRODUCTIVE POTENTIAL AND AGRONOMIC CHARACTERS IN SOY

EFEITO DA ÉPOCA DE SEMEADURA E POPULAÇÃO DE PLANTAS SOBRE O POTENCIAL PRODUTIVO E CARACTERES AGRONÔMICOS EM SOJA

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ABSTRACT: Soy is one of the main cultivated species in the world with great economic expression and high impact on Brazilian agribusiness. The productive potential is expressed due to the genetic constitution of the cultivar and the environment in which it is exposed. The market demands for bean production require the ideal handling of the culture in order to optimize the yield potential of the plant. In this context, the handling of the culture is essential to achieve success when cultivating soy. Plant population influences the agronomic characters and consequently in the grain yield. Thus, this factor needs particular studies for each cultivar. The objective in this study was evaluating the influence of the plant population on the productive potential and agronomic characters in soy, in Uberlândia, Minas Gerais. The experiment was performed in Capim Branco Farm, which belongs to the Federal University of Uberlândia. The study was composed by 15 treatments in a 3x5 factorial scheme, constituted by three cultivars (UFUS 7415, UFUS 7401 and UFUS 6901) and five plant populations (200, 240, 280, 320 and 360 thousand plants ha⁻¹). It was adopted the experimental outlining of randomized complete blocks, with five repetitions. The evaluated characters were: number of days to flowering and maturity (NDF and NDM), plant height at flowering and maturity (APF and APM), number of nodes at flowering and maturity (NNF and NNM), insertion height for the first pod (APV), total number of pods (NVT), thousand grain weight (P1000G) and productivity (PROD). It was noted that plant population didn't interfere in the soy cycle, number of nodes and thousand grain weight. The cultivars UFUS 6901, UFUS 7415 and UFUS 7401 presented better yields in populations of 240, 280 and 320 thousand plants ha⁻¹ respectively.

KEYWORDS: *Glycine max*. Productivity yield. Agronomic components.

INTRODUCTION

The ascension achieved in the last decade by soy brought to the Brazilian agriculture the revolution necessary to put it in highlights and present the productive potential of the country. In the 1960's, soy didn't had economic expression nor visibility when compared to corn, coffee or sugarcane productions, for example (ALVES; TEIXEIRA FILHO; TOLLINI, 1984). However, the most highlighted factor among the ones responsible for such growth is the incessant search for genotypes which are superior and adapted to many geographic regions.

The fitotechnic works in the final stage of improvement make it easier to make recommendations to producers and collaborate to the success and development of the released genotype. The amplitude of the sowing calendar of soy is extensive and varies according to the region and the cultivar. The locations where the developed

cultivar will be commercialized must be similar to the region where the pre-release tests are performed.

So, as in any agricultural activity, the productivity is affected by many variables. The definition of the plant population to be used in the tillage has one of the lowest costs to the producer, when compared to adopting technologies to elevate the productive potential of the cultivars.

The set of cultural handlings required by soy culture is diverse; the plant population combined to the spacing between the lines cause expressive changes in the tillage, such as gathering of dry matter, presence of weeds, bedding and disease dissemination (BALBINOT JUNIOR et al., 2015; VITORINO et al., 2017). There's direct influence in these variables, due to intraspecific competition for water, light and nutrients (HEIFFIG et al., 2006; BALBINOT JUNIOR et al., 2015).

The population can vary between 200 and 500 thousand plants ha⁻¹ and due to the array and plasticity of the culture there is a possibility of

altering the grain yield (TROGELLO; GALVÃO; SEDIYAMA, 2016). Genotypes with elevated bedding rates are recommended to populations of 200 to 250 thousand plants ha⁻¹ and resistant genotypes, 300 thousand plants ha⁻¹ (EMBRAPA, 2011).

Büchling et al. (2017) conducted research with the purpose of evaluating the response of nine soy genotypes in different population densities, in the southern region of the country and observed that there were no discrepant values regarding grain yield, thus, correlating this performance in the culture and plasticity of the plant.

On the other hand, Cruz et al. (2016) reported that the increment of bean productivity according to the increase of sowing density, although they utilized distinct plant spacing arrays. These authors, alongside Vasquez et al. (2014) stated that the linear increase in the bean productivity due to the sowing density referred to the number of pods per plant and weight of produced beans.

Thereby, the elevated variability of soy genotypes and release of new cultivars, it becomes a relevant matter the need to invest in studies that prioritize the fitotechnic handling of soy culture, due to the wide options of plant population.

Thus, the present study aimed to evaluate the influence of the plant population on the productive potential and agronomic characters in soy, in Uberlândia, Minas Gerais.

MATERIAL AND METHODS

The study was conducted in the experimental station Capim Branco Farm, altitude 843m, latitude 18° 53'19''S, longitude 48° 20'57''W, owned by the Federal University of Uberlândia (UFU), located in the municipality of Uberlândia, Minas Gerais.

There were evaluated three cultivars of conventional soy developed by the Program for Soy Improvement and Genetic Studies from UFU (PMEGS), UFUS 7415 (early and semideterminate growth, UFUS 7401 (early and determinate growth) and UFUS 6901 (early and indeterminate growth) and 5 plants populations (200, 240, 280, 320 and 360 thousand plants ha⁻¹) in factorial scheme (3 x 5), sowed in October in the 2016/2017 crop. It was adopted the experimental outlining of randomized complete blocks, with five repetitions. The portions were constituted by four 5 m long lines of soy plants with spacing of 0.50 m between them. The used area was composed by 2 central rows, eliminating 0.5 m from the extremities, making 4 m² for each plot.

The experiment was implanted in an area characterized as Dystrophic Dark Red Latosol with clayey texture. A sample composed of soil was collected in the depth between 0 and 20 cm and was chemically analyzed. The soil preparation occurred conventionally with plowing once and harrowing twice. Afterwards, it was made the fertilizing of the sowing with 400 kg ha⁻¹ of the NPK 02-28-18 formulation.

The cultural handling, weeding, pest and disease control were performed whenever necessary, in conformity with recommendations to soy culture. (EMBRAPA, 2013).

Based on the useful area in the portion, the following agronomic characters were evaluated:

- a) Number of days to flowering (NDF): corresponds to the number of days between emerging (VE) and flowering (R1) in 50% of the used portion;
- b) Number of days to maturity (NDM): corresponds to the number of days between emerging (VE) and complete maturation (R8) in 50% of the used portion;
- c) Plant height at flowering (APF): distance, in centimeters, between the soil surface and the apical extremity;
- d) Plant height at maturity (APM): distance, in centimeters, between the soil surface and the apical extremity;
- e) Number of nodes at flowering (NNF): obtained by counting all nodes on the main haste at flowering;
- f) Number of nodes at maturity (NNM): obtained by counting all nodes on the main haste at maturity;
- g) Insertion height for the first pod (APV): distance, in centimeters, between the soil surface and the insertion of the first pod;
- h) Total number of pods (NVT): after harvesting, it was realized an accounting on the number of pods with 1, 2, 3 and 4 beans, and afterwards it was obtained the NVT, by summing up all pods;
- i) Thousand grain weight (P1000G): after grain processing the weight of one thousand grains was determined according to the methodology proposed by the Seed Analysis Rule (BRASIL, 2009);
- j) Grain productivity (PROD): calculated based on the evaluation of mass of grains provided in the used area, extrapolated to kg ha⁻¹ and corrected to 13% humidity, according to the formula:

$$PF = PI \times \frac{(100 - UI)}{(100 - UF)}$$

In which:

PF: Corrected weight in the grains sample;
 PI: Initial weight of the grains sample;
 UI: Initial humidity in the grain sample;
 UF: Final humidity (13%) in the grain sample

Except for NDF, NDM and PROD, all characters were measured in five plant samples in the used portion at random.

The statistical analyses were performed in the Program for Genetics and Statistics – *Programa Genes* (CRUZ, 2012) and the regression analyses in the software SigmaPlot version 11.

RESULTS AND DISCUSSION

The number of days to flowering, which comprehends the vegetative cycle in a plant, is distinct between the cultivars, due to their particular sensibility to the photoperiod, which is specific in each cultivar (MATSUO; FERREIRA; SEDIYAMA, 2015). In the present study, the vegetative cycle (NDF) varied between 31 (UFUS 6901) and 37 days (UFUS 7401) and the complete cycle (NDM) from 93 (UFUS6901) to 103 days (UFUS 7415) (Table 1). It was noted that, predominantly, the vegetative cycles were similar in all plant populations, except by UFUS 6901, which presented an inferior vegetative cycle that all the others in the population of 200 thousand plants ha⁻¹.

Table 1. Vegetative and complete cycle of three soy cultivars sowed in October in Uberlândia/MG, harvest 2016/2017.

Cultivar	NDF					
	Plant population (one thousand plants ha ⁻¹)					
	200	240	280	320	360	Mean
UFUS 7415	33.60 ab	35.0 a	34.40 a	32.20 a	34.00 a	34.64
UFUS 6901	31.60 b	33.80 a	37.20 a	35.40 a	35.80 a	34.76
UFUS 7401	36.20 a	33.20 a	33.40 a	35.60 a	37.40 a	35.16
CV (%)	7.33					
DMS	3.89					
Cultivar	NDM					
	Plant population (one thousand plants ha ⁻¹)					
	200	240	280	320	360	Mean
UFUS 7415	100.40	103.20	100.80	96.60	99.20	100.64 a
UFUS 6901	93.80	97.40	96.60	95.80	97.00	96.12 b
UFUS 7401	101.80	98.00	101.00	99.00	102.00	100.36 a
CV (%)	3.02					
DMS	2.03					

Means followed by letters, in vertical, do not differ statistically between themselves by the Tukey test at 5%. NDF and NDM: Number of days to flowering and maturity, respectively.

Regarding the number of days to maturity, it was reported that the most precocious cultivar was UFUS 6901 in all plant populations, except in 240 and 320 thousand plants ha⁻¹. UFUS 6901 stood out among the cultivars from PMEGS by its precocity (96 days) (Table 1) presenting great potential to the seed market. However, it was not possible to find a regression which could explain the biological phenomena of the cultivar during the performance of its vegetative cycle. According to Silva et al. (2015), there's a demand by cultivars with precocious cycle, because they make possible to the producer to use the area for a fast harvest or even as a mean to treat an area against diseases.

Plant height in flowering and maturity are relevant characters in studies about soy, because they are related with the bean productivity and production components (NAVARRO JUNIOR; COSTA, 2002; ORMOND et al. 2015).

Ruled by many genes, plant height is a quantitative character which is influenced by the genetic constitution of the cultivar and also by environmental effects (SEDIYAMA; TEXEIRA; BARROS, 2009). Soy plants expressed linear increase in height in function of the increment in plant population in the evaluation of flowering and maturity (APF and APM) (Figure 1), this behavior was also observed by Linzmeyer Junior et al. (2008) and Mauad et al. (2010).

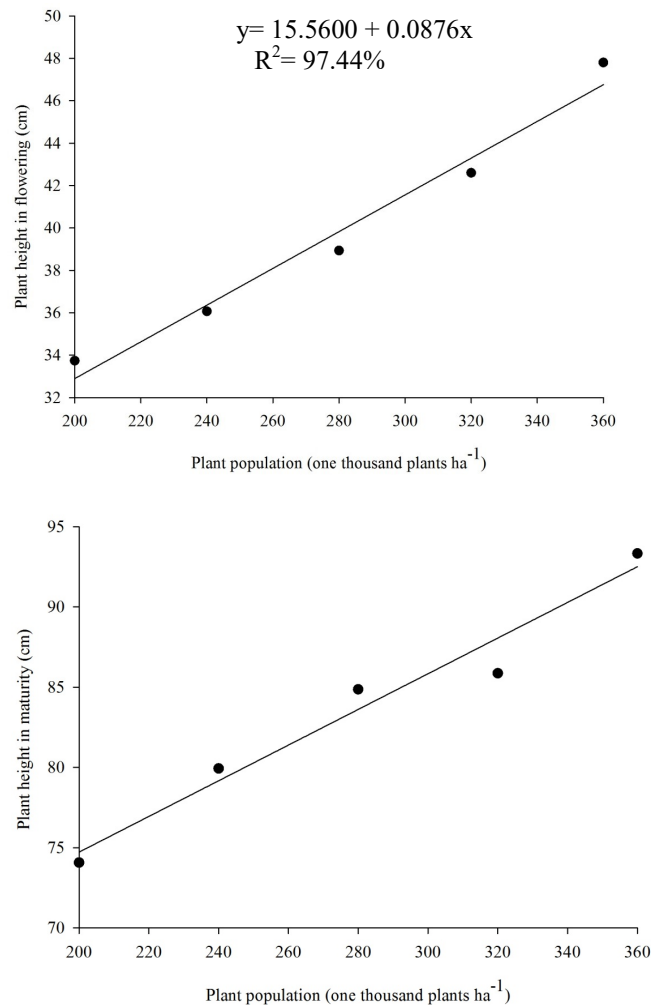


Figure 1. Plant height in flowering and maturity (APF and APM) for three soy cultivars sowed in October, in function of the plant population in the 2016/2017 harvest.

In the end of the vegetative cycle of soy, it is essential to measure plant height, once it is influenced by the growth type. Cultivar UFUS 7415, which has semideterminate growth, although

presenting average height above the other cultivars in flowering (45.37 cm), didn't had the greater height in maturity (74.31 cm) (Table 2).

Table 2. Plant height in flowering and maturity in soy and insertion height of the first pod, sowed in October in Uberlândia/MG.

Cultivar	APF	APM	APV
UFUS 7415	45.37 a	74.31 b	13.46 a
UFUS 6901	37.64 b	97.30 a	14.30 a
UFUS 7401	36.55 b	79.16 b	15.76 a
CV (%)	15.79	11.78	34.95
DMS	4.28	6.69	3.35

Means followed by letters, in vertical, do not differ statistically between themselves by the Tukey test at 5%. APF and APM: Plant height at flowering and maturity, respectively; APV: Insertion height of the first pod.

Cultivar UFUS 6901 grew 2.5 times in comparison to its height in flowering and achieved the greatest final height (Table 2). This behavior can

be attributed to the fact that the plant presents indeterminate growth, which happens in plants which continue to grow and produce nodes after

flowering. Furthermore, there are reports in literature stating that plants which indeterminate growth type have a great final height, in general (EMBRAPA, 2011).

Mechanized harvest makes it easy to remove the beans from the field in the final stage of the cycle, but if performed incorrectly, it may imply in money loss to the producer, being considered tolerable a loss of up to 60 kg ha⁻¹ (SILVEIRA; CONTE, 2013). The height in the Brazilian cultivars varies from 50 to 90 cm, which contributes to minimize loss during harvesting (SEDIYAMA; OLIVEIRA; SEDIYAMA, 2016). Cultivars from PMEGS, UFUS 7415, UFUS 6901 and UFUS 7401 obtained values near to the expected recommendation range (74.31 cm, 97.30 cm and 79.16 cm, respectively) (Table 2).

Sediyama; Teixeira; Reis (2005) and Rocha et al. (2012) mentioned that the ideal insertion height of the first pods nearly 15 cm, but due to the technology invested in harvesters, the minimum height is 10 cm. Cultivars from PMEGS fit the required standards (Table 2). The insertion height of the first pod (APV) didn't present discrepant alteration related to cultivars UFUS 7415, UFUS 6901 and UFUS 7401, which reached heights of 13.46, 14.30 and 15.76, respectively (Table 2). This

fact can be explained by the positive correlation between APM and APV exhibited in several studies (ALMEIDA et al., 2010; NOGUEIRA et al; 2012; LEITE et al., 2015).

Costa (2013) evaluated experimental soy portions with fewer plants by meter, and it was possible to observe inferior results in plant height and insertion height of the first pod. On the other hand, Balbinot Junior et al. (2015) and Gomes et al. (2017) reported that regardless of the type of plant growth and population, there were no differences in plant height and insertion height of the first pod, when submitted to four different plant stands.

The number of nodes in soy has a direct association in the formation of the foliar canopy in plants, and consequently the volume of green matter (MARTINS et al., 2011). The number of nodes in flowering (NNF) remained the same for the three cultivars used in this study. On the other hand, cultivar UFUS 7415, in maturity (NNM) didn't remain average, reducing to 13.88 nodes (Table 3). Martins et al. (2011) commented that in their study realized in the municipality Santa Maria/RS in different agricultural years that, from the appearing of two consecutive nodes and on it is possible to estimate the total number of nodes on the vegetable.

Table 3. Number of nodes in flowering (R1) and reproductive (R8) in soy, sowed in October in Uberlândia.

Cultivar	NNF	NNM
UFUS 7415	9.85 a	13.88 b
UFUS 6901	9.27 b	16.25 a
UFUS 7401	9.32 ab	15.84 a
CV (%)	8.47	10.58
DMS	0.58	1.10

Means followed by letters, in vertical, do not differ statistically between themselves by the Tukey test at 5%. NNF and NNM: Number of nodes at flowering and maturity, respectively.

Formation and development of pods are decisive in soybean production, since the amount of pods depends on the number of fertilized eggs. The racemose inflorescence that soy has presents between 8 and 40 flowers and 75% of the flowers may not bear fruits, even though, the production of pods may be up to 400 per plant (NOGUEIRA et al., 2009; SEDIYAMA; OLIVEIRA; SEDIYAMA, 2016).

From another point of view, Peixoto et al. (2002) pointed out that this character (NVT) isn't satisfactory to ensure soy productivity potential, because the pod bear one to five seeds and most cultivars bore pods with two or three seeds. It was not possible to adjust a regression model for the

cultivars UFUS 7415 and UFUS 7401 that could explain biologically its behavior for character NVT (Table 4 and Figure 2).

The increase in plant population for the cultivar UFUS 6901 responded inversely proportional to the number of pods per plant (NVT) (Table 4). Machado (2017) discussed that it was observed a reduction in the number of pods per plant as long as plant populations increased. According to Heiffig (2002), the number of pods per plant is the component of grain yield which is mostly influenced by plant population. These results are in accordance to those obtained by Tourino et al. (2002) and Cruz et al. (2016).

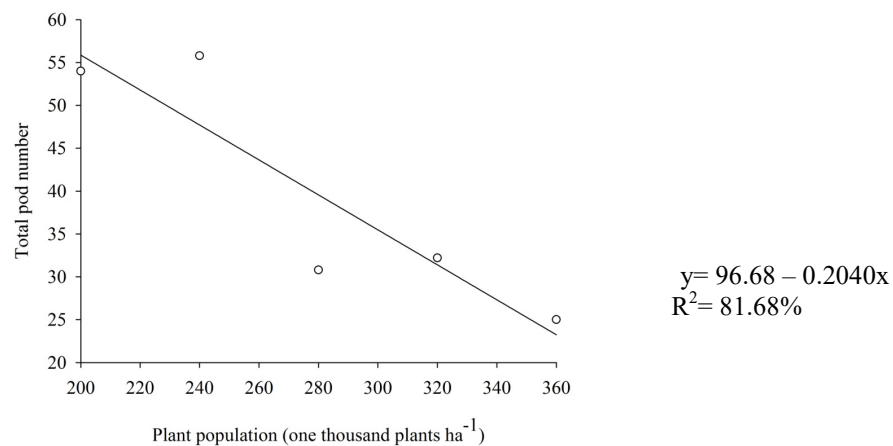


Figure 2. Total pod number (NVT) of cultivar UFUS 6901, sowed in October for harvest 2016/2017.

Table 4. Number of pods, thousand grain weight and soy productivity in kg ha⁻¹, sowed in October for harvest 2016/2017.

NVT						
Cultivar	Plant population (one thousand plants ha ⁻¹)					Média
	200	240	280	320	360	
UFUS 7415	50.60 a	62.24 a	42.48a	54.51 a	41.24a	50.21
UFUS 6901	54.08 a	55.80 a	30.72 a	32.12 b	24.90 a	39.52
UFUS 7401	37.56 a	26.36 b	35.68 a	37.04 ab	30.64 a	33.45
CV (%)	28.24					
DMS	17.66					
P1000G						
Cultivar	Plant population (one thousand plants ha ⁻¹)					Média
	200	240	280	320	360	
UFUS 7415	165.00	175.50	172.50	173.50	173.75	172.05 a
UFUS 6901	173.50	174.75	176.00	173.75	179.75	175.55 a
UFUS 7401	174.75	172.75	170.25	171.00	177.00	173.15 a
CV (%)	4.68					
DMS:	5.53					
PROD						
Cultivar	Plant population (one thousand plants ha ⁻¹)					Média
	200	240	280	320	360	
UFUS 7415	2816.40 a	3067.00 a	3715.51 a	3345.50 a	3686.46 a	3326.18
UFUS 6901	2990.59 a	3166.36 a	2176.99 b	2295.82 b	2389.98 b	2603.95
UFUS 7401	2143.18 a	2279.34 a	2717.58 b	3533.30 a	3157.50 ab	2766.18
CV (%)	22.43					
DMS	990.73					

Means followed by letters, in vertical, do not differ statistically between themselves by the Tukey test at 5%. NVT: Total pod number; P1000G: thousand grain weight; PROD: Grain productivity.

It is known that the number of pods and the number of grains are defined by the time of flowering on soy (KNEBEL et al., 2006). Lima et al. (2009) stated that the photoperiod interfered in the amount of flowers in the flowering period, affecting the number of pods, diverging from the results of the present work, in which both environments presented similar means. Furthermore, egg fertilization problems or lack of nutrients destined to fill the beans are reflected in empty pods (LIMA et al., 2009).

The definition of culture productivity is related to production components of the plants, being these: number of pods, number of seeds per pod and grain weight (DALCHIAVON; CARVALHO, 2012). Bezerra et al. (2016) clarified that seeds with greater mass in ideal conditions became better nurtured plants, being consequently more productive and Fonseca et al. (2016) affirmed that the weight of one thousand seeds is relevant to calculate sowing density and its uniform distribution. Sedyama; Oliveira; Sedyama (2016) pointed out that the average seed weight of soy for industrial purposes may vary between 12 and 20 g per 100 seeds.

The mass of soy seeds is originated from photosynthetic activity and photoassimilated translocation to grains during the filling period, which indicates that different plant populations do not generate variation difference in the thousand grain weight (P1000G) (Table 4) (KNEBEL et al., 2006). Similar results were achieved by Procópio et al. (2013) and Procópio et al. (2014) when testing plant populations that also didn't found differences in seed mass.

Grain productivity is the most desired character in field researches and its result depends on a variety of genetic, environmental and handling factors, thus, researches are a necessity for correct and efficient recommendations to soy plant populations.

Cultivar UFUS 7401 incremented linearly its production with the elevation of plant population (Figure 3). Seus (2011) working with population density of soy cultivars in meadow soil obtained results which were similar to those in this work and Gomes et al. (2017) in Boa Vista/RR evaluated soy productivity in four population densities (10, 14, 18 and 22 plants m⁻¹), in Embrapa Experimental Fields, and reported that the increase in plants per row reflected in the increase of grain productivity.

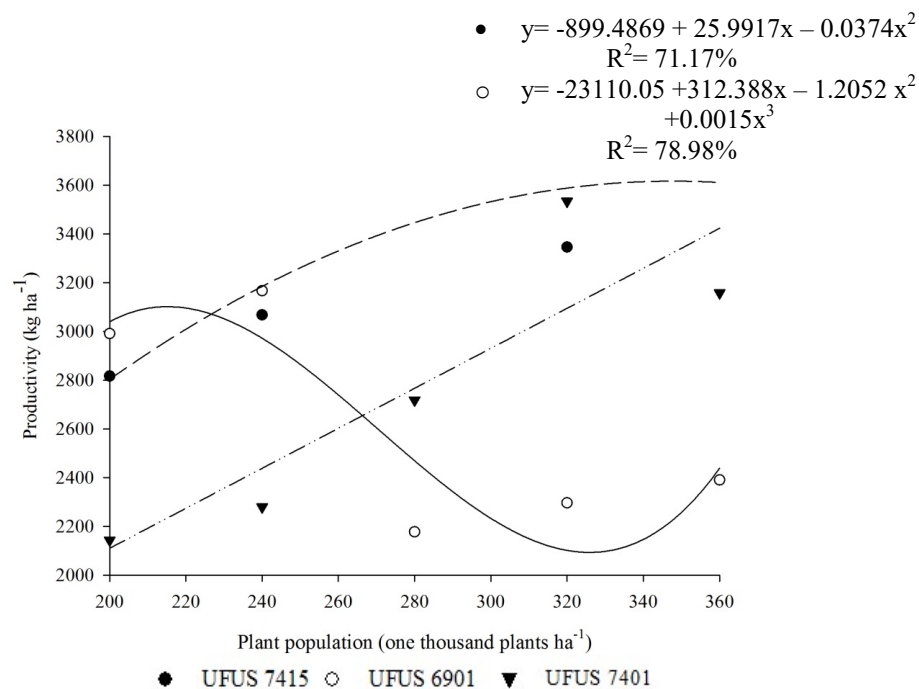


Figure 3. Soy productivity (kg ha⁻¹) of cultivars from PMEGS sowed in Uberlândia.

In the population of 320 plants ha⁻¹ cultivars UFUS 7415 and UFUS 7401 obtained grain yield superior to 3300 kg ha⁻¹ (Table 4). Although, the population of 280 thousand plants ha⁻¹ favored the

grain yield for cultivar UFUS 7415 (3715.51 ha⁻¹), offering to the seed market a viable cost-effective option by adopting smaller plant populations. Giraldi (2016) and Büchling et al. (2017) observed

in their field studies a productivity response similar to the one in the present work.

Andrade et al. (2016) evaluated the development of soy cultivated in conventional and crossed planting in different population densities and confirmed that the treatments behaved in a homogeneous fashion towards the stipulated factors, without reporting increments in yield with the increase of plant stands. Balbinot Junior et al. (2015) also didn't report effects in grain productivity, when submitted to two sowing densities in soy, in Londrina/PR. This behavior may be explained by the plasticity of soy culture, keeping productivity uniform towards discrepant agricultural managements (RITCHIE, 1996; BALBINOT JUNIOR et al., 2015).

The state of Minas Gerais achieved the mark of 3480 kg ha⁻¹ of soy in the harvest 2016/2017, while the national productivity obtained 3364 kg ha⁻¹ (CONAB, 2018). Such yields are close to the cultivars from the improvement program from UFU. Thus, the performance of conventional soy cultivars, when sowed in October, presented the

ability the cultivars have to compete in the agricultural market.

CONCLUSIONS

Plant population influenced in agronomic characters and productivity potential of soy cultivars, except for the populations of 200 and 240 thousand plants ha⁻¹ didn't influence in the grain yield of cultivars UFUS 7415, UFUS 7401 and UFUS 6901.

The population of 280 thousand plants ha⁻¹ provided high grain productivity for cultivar UFUS 7415.

UFUS 7401 obtained its best yield in the population of 320 thousand plants ha⁻¹.

The cultivar UFUS 6901 reached its highest yield in the population of 240 thousand plants ha⁻¹.

ACKNOWLEDGMENT

To the Coordination of Personal Improvement in Higher Education (CAPES) for conceding a scholarship.

RESUMO: A soja é uma das principais espécies cultivadas no mundo, com grande expressão econômica e alto impacto no agronegócio brasileiro. O potencial produtivo é expresso devido à constituição genética da cultivar e ao ambiente em que está exposta. As demandas do mercado para a produção do grão requerem o manuseio ideal da cultura, a fim de otimizar o potencial de rendimento da planta. Nesse contexto, o manejo da cultura é essencial para obter sucesso no cultivo da soja. A população de plantas influencia os caracteres agrônomicos e, conseqüentemente, no rendimento de grãos. Assim, esse fator necessita de estudos específicos para cada cultivar. O objetivo deste estudo foi avaliar a influência da população de plantas no potencial produtivo e nos caracteres agrônomicos da soja, em Uberlândia, Minas Gerais. O experimento foi realizado na Fazenda Capim Branco, pertencente à Universidade Federal de Uberlândia. O estudo foi composto por 15 tratamentos em esquema fatorial 3x5, constituído por três cultivares (UFUS 7415, UFUS 7401 e UFUS 6901) e cinco populações de plantas (200, 240, 280, 320 e 360 mil plantas ha⁻¹). Foi adotado o delineamento experimental de blocos completos casualizados, com cinco repetições. Os caracteres avaliados foram: número de dias para o florescimento e maturidade (NDF e NDM), altura da planta no florescimento e maturidade (APF e APM), número de nós no florescimento e maturidade (NNF e NNM), altura de inserção da primeira vagem (APV), número total de vagens (NVT), peso de mil grãos (P1000G) e produtividade (PROD). Observou-se que a população de plantas não interferiu no ciclo da soja, número de nós e peso de mil grãos. As cultivares UFUS 6901, UFUS 7415 e UFUS 7401 apresentaram melhores rendimentos nas populações de 240, 280 e 320 mil plantas ha⁻¹, respectivamente.

PALAVRAS-CHAVE: *Glycine max*. Rendimento de produtividade. Componentes agrônomicos.

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