Alves *et al*.
Cerrado: Agricultural and Biological Research, 1(2), 30-38, 2024
https://doi.org/10.14295/cerrado.v1i2.618

ORIGINAL RESEARCH PAPER

Performance of soybean cultivars for the Rio Verde region, Goiás, Brazil - 1st season

Willian Nick Alves[1*], Rafael Borges de Assis[1], Cristiano Lima Lobo de Andrade[1,2,3] & Fernando Rodrigues Cabral Filho[1,2,3]

[1]*UniBRAS University Center of Rio Verde, Rio Verde, Goiás, Brazil.*
[2]*Pulveriza Soluções Agrícolas Ltda, Rio Verde, Goiás, Brazil.*
[3]*Goiano Federal Institute, Rio Verde, Goiás, Brazil.*

Article history
Received: April 14, 2024
Revised: May 31, 2024
Accepted: June 14, 2024

*Corresponding Author: Willian Nick Alves, UniBRAS University Center of Rio Verde, Rio Verde, Goiás, Brazil.
Email: nickalvesrv@gmail.com

Abstract: The study of soybean genotypes for different regions of Brazil is of great interest among researchers, rural producers, and seed companies. The experiment was conducted in the municipality of Rio Verde, Goiás, Brazil, in the IF Goiano experimental area. The study aimed to evaluate the adaptation and performance of 10 soybean cultivars in the region. The cultivars were sown and grown under adverse climatic conditions in the field, ensuring that cultural treatments were the same for all cultivars. Vegetative, reproductive, and post-harvest parameters were evaluated. Soybean plants were evaluated at different stages of the growth cycle, with emphasis on the parameters: number of branches, plant height, pod insertion height, and number of reproductive nodes. For post-harvest, grain moisture, thousand-grain weight, and grain weight per plant were evaluated. The data obtained were subjected to analysis of variance (ANOVA) and *Tukey's* test with ($p < 0.05$). Cultivars with different technologies I2X, CE, IPRO, and E showed good production performance aiming for high productivity in the 1st planting. Although for the number of plants per ha^{-1}, the cultivars Tormenta and Supera demonstrated superior results and for productivity the cultivars Ellas Paula, Ellas Dani, Ellas Manu, and HO Guapó obtained greater productivity gains per bag of 60 kg ha^{-1}, generating a mass of a thousand grains exceeding 100 g^{-1} and grain mass per plant exceeding 15 g^{-1}.

Keywords: *Glycine max*; Legumes; Cultivars; Soybean production; I2X, CE, IPRO Technologies.

1. Introduction

Soy [(*Glycine max* (L.) Merrill] originates from the Asian continent and is today the most important crop in the production of processed foods in the world, where it is also used in the pharmaceutical industry and in the agroindustry to produce animal feed rich in protein (Oliveira et al., 2017; Yokomizo et al., 2022). At the end of the 1960s, Brazil had a growing demand for this grain in the domestic market, which led to reflections on making soybeans a large-scale commercial product, however, wheat cultivation was still representative. on Brazilian soil and dominated trade in different regions. In this scenario, soy was considered a second crop, in the production and supply of vegetable protein from agriculture (Jin et al., 2023). However, Brazil had extensive areas for raising poultry and pigs for slaughter in the domestic and foreign markets, this demand was growing and there was a need to produce a greater content of vegetable protein for the production of feed to supply the market the agricultural sector, and thus, soybeans gained greater space and prominence in several regions of the country, presenting the beginning of an important diversity of cultivars of this oilseed grain (Colletti et al., 2020; Toloi et al., 2021; Kraft et al., 2023).

Over the years, research into the production of different soybean cultivars has shown important advances in terms of cultivar types for each region of the country. The development of soybean cultivars adapted to latitudes lower than 30º, practiced in Brazil, was an advance in agriculture as discussed by Rocha et al. (2012). This enabled the expansion of soybean cultivation across a large part of the national territory (Cerutti et al., 2020). Since, Brazil has an extensive territorial area and diverse biomes, Cerrado domain, climate, and solar incidence. In addition to these characteristics, genetic improvement programs have a direct interest in the development of genotypes tolerant to abiotic stresses, present in the most varied environments (Libório et al., 2024). In part, this is due to rural producers with extensive cultivation areas, who are curious about using more than one soybean cultivar in each agricultural harvest. In particular, the soils and climate of the Central-West region present high production with a large number of soybean cultivars cultivated extensively. In the State of Goiás, in the region of the municipality of Rio Verde, Brazil, an important sum of soybean cultivars has proven to be a major player in the agricultural sector, playing an important role in the economy and regional development (Umburanas et al., 2022; Silva et al., 2024).

Carvalho et al. (2010), add that the large number of existing soybean cultivars present a formidable diversity in response to environmental factors, which provides excellent adaptability in the most varied regions of Brazil. Among environmental factors, climate is one of the main criteria for a good and satisfactory installation of agricultural cultivars, and the region in which the State of Goiás is located has four types of climates: Am, Aw, Cwa and Cwb, with precipitation average between 1,600 and 1,900 mm and average annual temperature between 19-25 ºC proposed by Köppen-Geiger (1900) (Cardoso et al., 2014; Rubel et al., 2017). Legumes have broad tolerance to climatic factors, determining minimum and maximum limits, within which their existence is possible due to genetics and genetic improvement of resistant and tolerant cultivars (Erofeeva et al, 2021). Choosing a genotype means taking into account the genetic and physiological characteristics of a cultivar for each region, with different types of soil, photoperiod, nutrition, and adaptations to abrupt climatic variations, as when choosing a cultivar not adapted to a given region, it may present difficulties in establishment and development, limiting their productive potential and causing losses to the producer (Meotti et al., 2012).

The experiment carried out in Goiatuba, Goiás and Uberlândia, Minas Gerais, Brazil, Oliveira (2002) observed that the soybean cultivars Msoy 8800, E 313 RCH, DM 339, Celeste, and Garantia showed outstanding production with averages above 3200 kg/ha^{-1} out of 28 cultivars evaluated. The study by Cavalcante et al. (2022) found that different soybean cultivars from the late maturing group recommended and cultivated in the Southwest of Goiás, the cultivar M 7110 presented satisfactory results with greater height, number of nodes and number of pods when compared to other cultivars SYN 13610, 15600, M 6210, 7110 and ICS 7019. However, according to Cerutti et al. (2020), the maximum productive potential of soybean cultivars has not yet been explored.

According to a survey of soybean production in Brazil, in terms of production, planted area, and productivity, in the 22/23 harvest, we had a production of 154,566.3 million tons, a planted area equal to 44,062.6 million hectares and productivity of 3,508 kg/ha^{-1} where the state of Goiás presented a production of 17,734.9 million tons, a planted area equal to 4,547.4 million hectares and productivity of 3,900 kg/ha^{-1} and the State of Mato Grosso, Brazil with the highest soybean production of Brazil with the production of 45,600.5 million tons, planted area equal to 12,086.0 million hectares and productivity of 3,773 kg/ha^{-1} (Conab, 2023).

In addition to the production performance of a soybean cultivar, Carvalho et al. (2010) add in their study on soybean genotypes, that it is desirable that in this crop the cultivars used in planting present a degree of lodging, height of insertion of the first legume and plant that are favorable to mechanized harvesting. With this, the prominent position of soybean cultivation in Brazil, climates, soils, and nutrients, justifies the need for research in order to improve its cultivation and reduce the risk of losses, where due to the extensive cultivation area that Brazil offers. Thus, enabling a great diversity of cultivars. This study aimed to evaluate some productivity parameters in different soybean cultivars in 1st season planting fields in the municipality of Rio Verde, Goiás, Brazil.

2. Material and Methods

2.1. Experimental location

The assay was conducted in an experimental area located in the municipality of Rio Verde, Goiás, Brazil, at geographic coordinates -17.808076 and -50.899117, with an average altitude of 720 m above sea level. The region's climate is classified according to Köppen & Geiger (1928) and Alvares et al. (2013), as Aw (tropical), with rain from October to May and, drought from June to September. The experiment was installed between September and December 2023.

2.2. Soil analysis

The results of chemical analysis of soil samples in the 0-20 cm layer collected in the area of the experiment were: pH 5.19; Calcium (Ca) 5.2, Magnesium (Mg) 1.0, Aluminum (Al) < 0.1, hydrogen (H) + Al 4.4, cation exchange capacity 11.1, in $cmol_c$ dm^{-3}; Potassium (K) 204, Phosphorus (P) 5.3, Sulfur (S) 366, Boron (B) 0.16, Copper (Cu) 0.9, Iron (Fe) 4.5, Manganese (Mn) 11.8, Zinc (Zn) 1.4, in mg dm^{-3}; clay 449, silt 49, and sand 502 g/kg^{-1}, organic matter (OM) 45.6 g/kg^{-1}. Data were taken according to the methodology of the Empresa Brasileira de Pesquisa Agropecuária (Embrapa, 2009). The soil was classified as a Distroferric Red Latosol (Embrapa, 2018), Cerrado phase, with a clayey texture (Santos et al., 2018).

2.3. Soybean cultivars

The cultivars evaluated in the experiment were Supera I2X, Tanque, 72IX74RSF I2X, Tormenta, Ellas Paula IPRO, Ellas Dani I2X, Ellas Manu IPRO, HO Guapó I2X, 78KA42, and 76EA72. Maturation group (MG): 7.3, 7.3, 7.2, 7.4, 7.9, 8.1, 7.6, 7.7, 7.6 and 7.2, respectively.

2.4. Experimental design

The experimental design adopted was a randomized block design (RBD) in strips, being analyzed in an experiment with 10 treatments and 4 replications, with a total of 40 experimental plots.

2.5. Planting system and cultural treatments

The planting system used was direct planting in straw. A five-row seed-fertilizer equipped with a horizontal disc system was used to distribute the seeds. The spacing between lines used was 0.45 m, with a strip of 10 lines 30 m long. The planting system adopted was direct planting, with the previous planting being corn in the 2023 harvest. Fertilization was carried out in the planting furrow, using the same amount of fertilizer 400 kg ha^{-1} with commercial formulation 4-30-16. Pest, disease, and weed controls were carried out as necessary.

2.6. Vegetative parameters

Between 30 and 50 days after sowing, the number of plants per hectare and the flowering date of the cultivars were evaluated (Table 1).

Table 1. Parameters in number of days to flowering and harvest date of cultivars, harvest 2023/24, in the municipality of Rio Verde, GO, Brazil.

Cultivar	Days/flowering	Harvest date
Supera I2X	37	02/29/2024
Tanque	37	02/29/2024
72ix74RSF	37	02/29/2024
Tormenta	37	02/29/2024
Ellas Paula	45	03/09/2024
Ellas Dani	53	03/09/2024
Ellas Manu	40	03/09/2024
Ho Guapó	40	03/09/2024
Stine 78KA42	40	03/09/2024
Stine 76EA72	37	02/24/2024

Source: Authors, 2024.

During the reproductive period (harvest), two plants per plot were evaluated, verifying the following characteristics: number of branches (NB); plant height (PH), and pod insertion height on the main stem (IVHMS) expressed in centimeters (cm); the number of nodes in the first insertion (NNI), and number of reproductive nodes in the main stem (NRN); the number of pods (NP); grain moisture (GM) expressed as a percentage (%); mass of thousand grains (MTG) and mass of grains per plant (MGP) (Pelúzio et al., 2006; Meotti et al., 2012). To determine the reproductive parameter, two lines with 2^2 per repetition (2 lines of 2 meters) were collected, where the number of total pods per plant was evaluated. The difference between MTG values was determined by genotype for each cultivar as described by Blanc et al. (2018).

2.7. Statistical analysis

The means of the analyzed data were subjected to analysis of variance (ANOVA), and when differences were observed between the results of the cultivars, *Tukey's* test was applied with probability ($p < 0.05$). The statistical software SISVAR®, (Ferreira, 2019) was used in this study.

3. Results

3.1. Plant population per hectare^{-1}

Among soybean cultivars, the Tormenta genotype demonstrated the highest number of plants per ha^{-1} with 260 thousand plants ha^{-1}, followed by Supera with 248 thousand plants per ha^{-1}. The lowest number of plants was observed for the HO Guapó genotypes with 93 thousand plants per ha^{-1} (Figure 1).

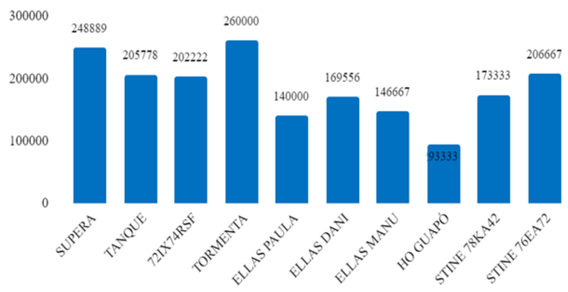

Figure 1. Plant population per hectare^{-1}, in the 2023/24 harvest, in the municipality of Rio Verde, GO, Brazil. Source: Authors, 2024.

3.2. Morphological parameters

Among the flowering dates, only the Ellas Dani cultivar differs from the other cultivars evaluated, with a difference of 16 days, and the other cultivars with 37 days (Table 1). In the evaluations of the first pod, and number of reproductive nodes, no difference was observed between the cultivars. In Table 2, the cultivar Ellas Paula presented NB = 8 higher than the other cultivars, for PH Tormenta with 127 and Ellas Paula with 123 cm presented the best results among the cultivars evaluated. The IVHMS index of Ellas Manu with 6.5 followed by Supera with 6.3 cm, NNI the cultivars 72IX74RSF, Ellas Manu, and Stine 76EA72 presented a value of 2.5, did not differ statistically, however with results superior to the other cultivars, while for NRN the best results were observed for Ellas Paula and HO Guapó with 20.8.

Table 2. Number of branches (NB) (nº), plant height (AH) (cm), pod insertion height (IVHMS) (cm), insertion node number (NNI) (nº), and number of reproductive nodes on the main stem (NRN) (nº), at the time of harvest.

Cultivar	NB	AH	IVHMS	NNI	NRN
Supera I2X	5.3	108.5	6.3	2.0	17.0
Tanque	4.3	99.8	5.8	2.3	17.8
72IX74RSF	3.0	110.5	6.1	2.5	18.8
Tormenta	5.5	127.8	6.1	2.3	15.3
Ellas Paula	8.0	123.3	5.0	1.5	20.8
Ellas Dani	6.3	117.5	5.3	2.3	19.3
Ellas Manu	7.3	108.3	6.5	2.5	19.5
HO Guapó	6.0	89.3	5.3	2.3	20.8
Stine 78KA42	1.3	81.8	4.8	1.5	16.5
Stine 76EA72	2.8	101.3	6.5	2.5	19.0

Source: Authors, 2024.

The HO Guapó cultivar showed a statistical difference with a result of 135 for NP, differing between the other cultivars. For GM Ellas Dani demonstrated the highest grain moisture with 16% among the other cultivars, for the MTG parameter the cultivars Supera, Tanque, 72IX74RSF, and Ellas Paula presented superior results (164, 166, 176, and 176 g^{-1}) respectively, among the other cultivars, however, did not differ from each other according to the *Tukey* test ($p > 0.05$), whereas for the MGP parameter, HO Guapó showed better performance with 57 g^{-1} differing between the other cultivars (Table 3).

Table 3. Number of pods per plant (NP) (nº), grain moisture (GM) (%), thousand-grain mass (MTG) (g^{-1}), grain mass per plant (MGP) (g^{-1}).

Cultivar	NP	GM%	MTG	MGP
Supera I2X	67bc	11c	164a	18cd
Tanque	65bc	12bc	166a	20cd
72IX74RSF	73bc	11c	176a	19cd
Tormenta	50c	12bc	157ab	15d
Ellas Paula	109b	14ab	176a	35b
Ellas Dani	96bc	16a	159ab	31bc
Ellas Manu	105bc	12bc	157ab	34b
HO Guapó	135a	11c	160ab	57a
Stine 78KA42	79bc	11c	121c	27bcd
Stine 76EA72	66bc	12bc	143b	23bcd

Means followed by different letters in the column differ from each other using the *Tukey's* test with 5% probability. Source: Author 2024.

3.3. Post-harvest productivity parameters

In the parameter productivity per hectare^{-1} (Figure 2), five cultivars presented average productivity between 80-89 bags of 60 kg/ha^{-1}, while the other cultivars evaluated presented lower average productivity between 63-79 bags of 60 kg/ha^{-1}, however, the evaluated genotypes showed no statistical difference between them.

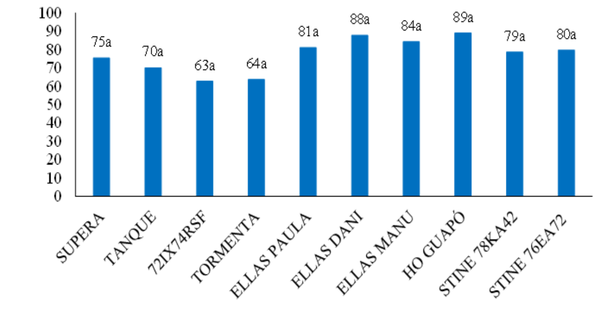

Figure 2. Productivity of soybean bags of 60 kg per hectare^{-1}. Source: Authors, 2024.

4. Discussion

Several studies verifying adaptability in different soybean cultivars corroborate our findings for the ten genotypes evaluated for the Cerrado area, in the Center-West region of Brazil, in the Southwest Goiás microregion.

The flowering period between the cultivars did not differ significantly. This is due to well-established cultivars for the Cerrado region with a good photoperiod. The flowering period is discussed by Jiang et al (2011), who discusses the sowing time, which is extremely important, because according to these researchers late sowing results in early flowering, reducing the cycle and plant height. The shorter the duration of exposure of plants to long photoperiods, the earlier the flowering will be when the plant is still small. These changes in the morphology and architecture of the plant can compromise grain production. In the study by Pelúzio et al. (2006) in two sowing seasons in a Cerrado area in the south of the State of Tocantins, Brazil, the researchers did not observe major variations in the flowering period for the 1st season between 42-51 days and the 2nd season between 44-52 days for 10 cultivars (M-Soy 8866, BRS Tracajá, M-Soy 9350, 98C81, M-Soy 8870, MGBR Garantia, M-Soy 9001, M-Soy 108, BRS Sambaíba and DM Nobre), the authors still argue that the long youthfulness of cultivars used combined with the photoperiodic conditions of the central region of Brazil, present a constant in this morphological parameter, favoring the vegetative development of soybean.

In our study, the cultivars had tall plants. This parameter was also observed by Tessele et al. (2017) where they found greater plant height for the cultivars Nidera 7338 IPRO and Agroeste 3610 IPRO with values of 119.09 and 116.75 cm. Still in this study, researchers did not find plant heights lower than 94 cm when evaluating 12 cultivars in Marechal Cândido Rondon, State of Paraná, Brazil, in the 2013/14 harvest. Marchiori et al. (1999) discuss the interference in plant height depending on the crop cycle, where cultivars sown outside the recommended period have lower averages, corroborating our results.

In other studies, such as Barros et al. (2003) where they verified the effect of sowing time on different cultivars, the researchers did not find a plant height lower than 50 cm. Pelúzio et al. (2006) found that, for different soybean cultivars, plant heights greater than 50 cm could result in production losses during mechanized harvesting. Still in this study, the cultivar BRS Tracajá had a plant height of 61 cm, when planted in December (2nd season). In other regions such as the State of Minas Gerais, Brazil, Carvalho et al. (2010) found different soybean cultivars adapted to the Southwest region in an experiment with a plant height of 51 cm, with the highest value being 113 cm. The lowest is 62 cm for the microregion of Lavras-MG and an average variation of 79 cm, the largest being 101 cm, and the lowest plant height is 64 cm for the microregion of Itutinga-MG. The authors also add that the genotypes with the highest plant height were DM Vitória and Emgopa 314 with 106 and 103 cm, respectively.

According to Carvalho et al. (2010), planting soybean cultivars poorly adapted to certain regions can harm the good development of the plant, favoring the occurrence of weeds and losses in mechanized harvesting. This theory corroborates Cartter & Hartwig (1967) where values considered suitable for plant height for mechanized harvesting are between 60-120 cm.

The insertion height of the first vegetable in our study showed lower insertion, varying between 4-6 cm insertion for the cultivars Stine 78KA42, Ellas Manu, and Stine 76EA72, respectively. Results superior to ours were described by Tessele et al. (2017) found an average height of insertion of the first vegetable among 12 cultivars for the southern region of Brazil between 17.25 cm for cultivar Nidera 6909 IPRO and 22.22 cm for cultivar Nidera 7300 IPRO; and by Carvalho et al. (2010) where they found an average result of 18 cm for the Itutinga microregion and between 15-36 cm in Lavras - MG, higher for the varieties tested in our study, however, the cultivars evaluated in this study are for the Southwest region of Brazil, and were applied for comparison purposes only.

According to Medina (1994) and Tessele et al. (2017) plant height and especially the insertion height of the first legume are among the morphological factors that most influence losses and purity of grains with mechanized harvesting. According to Marcos Filho (1986), a good soybean cultivar must have a height of insertion of the first legume between 10 and 12 cm, for a good harvest to occur. However, this parameter is greatly influenced by the environment, such as humidity, light, and photoperiod (Sediyama, 1972). In our results, insertion may have been influenced by factors such as rainfall and long photoperiod, extending the vegetative period, as Tessele et al. (2017) obtained good rainfall and photoperiod indexes with insertion superior to ours.

The number of pods per plant, mass of one thousand grains, and mass of grains per soybean plant evaluated in the ten cultivars for the Cerrado in our study presented higher averages when compared to other studies. The number of pods obtained from twelve cultivars adapted and not adapted to Southern Brazil, evaluated by Tessele et al. (2017) found average values between 28.06 and 49.41. Mass of 100 seeds between 11.05-16.64 g^{-1} and productivity between 1767.64-4397.48 kg ha^{-1}. According to Anselmo et al. (2011), the difference in productivity between soybean cultivars and planting areas can be explained by the photoperiodic sensitivity of soybeans and the different responses in different production environments (edaphoclimatic conditions), however, showing the great potential of these cultivars.

Soybean production is a very complex characteristic (controlled by several genes and which suffer from environmental influence), where the yield depends on several factors, such as the number of legumes per plant and the grain mass (Peixoto et al., 2000). Our production averages showed no statistical difference between cultivars. However, highlights for the cultivars Ellas Paula, Ellas Dani, Ellas Manu, and OH Guapó should be measured with an average value between 81-89 kg ha^{-1} for the 60 kg bag per ha^{-1}. Encouraging results were obtained with average grain production ranging between 3467-4370 kg ha^{-1} for ten soybean cultivars in the 1st season and between 2646-3603 kg ha^{-1} 2nd season in the southern region of the State of Tocantins, Brazil, between the periods 2003/04 and 2004/05 by Pelúzio et al. (2006). Carvalho et al. (2010) also obtained good productivity indices in two microregions of Itutinga and Lavras for different soybean cultivars in the Southeast region, State of Minas Gerais, Brazil, with the variation of 54% with averages between 2314-3575 kg ha^{-1} in the harvests 2006/07 and 2007/08, in grain yield for the cultivars Emgopa 314 and Monsoy 8001, respectively. This variation was higher in Lavras with 93% and an average of 3553 kg ha^{-1} for the UFV cultivar.

These authors also add that the different genotypes must be tested in different Brazilian regions, due to the adaptability of these materials to their vegetative, reproductive, and post-harvest parameters, which are intimately influenced. Asfaw et al. (2009) and Meotti et al. (2012) complement that production results in different environmental conditions, around 80% of this variation is generally caused by the environment, while only 10% of the variation occurs due to the effects of genotypes and the genotype x environment interaction.

Still regarding increased productivity, cultivars not adapted to certain regions, according to Nidera (2015), present poor production results. This was observed in the study by Tessele et al. (2017) where researchers found very low productivity rates in soybean cultivars not adapted to the southern region of Brazil for the standards of the evaluated cultivars, especially for NS7209 IPRO and NS 7338 IPRO. This low productivity index may possibly be related to the High maturation group for this region. As described by Penariol (2000) and Rodrigues et al. (2001) the displacement of a cultivar with a high maturity group to a high latitude region extends the cycle of this cultivar due to its response to the photoperiod as it is a short-day crop.

5. Conclusion

It is concluded that the ten soybean cultivars cultivated in the Brazilian Cerrado area, Central-West region, and Southwest microregion for the municipality of Rio Verde, Goiás, Brazil, the soybean cultivars with different technologies I2X, CE, IPRO, and E present good performances of production aiming at high productivity versus environmental factors where cultivars with an earlier cycle and super early cycle are recommended.

Although for the number of plants per ha^{-1}, the cultivars Tormenta and Supera demonstrated superior results and for productivity the cultivars Ellas Paula, Ellas Dani, Ellas Manu, and HO Guapó obtained greater productivity gains per bag of 60 kg ha^{-1}, generating a mass of a thousand grains exceeding 100 g^{-1} and grain mass per plant exceeding 15 g^{-1}.

6. Acknowledgement

Thanks to the Goiano Federal Institute, Rio Verde, Goiás, Brazil, and the AgroFort Gestão de Compras Ltda Group, Santa Helena de Goiás, Goiás, Brazil. We also thank the partners and collaborators Agroeste, Ellas Genética, HO Genética, and Stine, Brazil.

7. References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. L. M., & Sparovek, G. (2014). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22(6), 711-728. DOI 10.1127/0941-2948/2013/0507

Anselmo, J. L., Andrande, J. A. C., Lazarini, E., Costa, D. S., & Leal, A. J .F. (2011). Estabilidade e adaptabilidade de genótipos de soja na região dos Chapadões. *Científica*, 39(1-2), 69-78.

Barros, H. B., Peluzio, J. M., Santos, M. M., Brito, E. L.,

& Almeida, R. D. (2003). Efeitos das épocas de semeadura no comportamento de cultivares de soja, no sul do Estado do Tocantins. *Revista Ceres*, 50(291), 565-572.

Blanc, R. B., & Júnior, C. V. (2018). Avaliação de produtividade de cultivares de soja em Pinhão - PR. *Tech & Campo*, 1(1), 77-89. https://www.revista.camporeal.edu.br/index.php/tech/article/view/186

Cardoso, M. R. D., Marcuzzo, F. F. N., & Barros, J. R. (2014). Classificação climática de Köppen-Geiger para o estado de Goiás e o Distrito Federal. *Acta Geográfica*, 8(16), 40-55. DOI: 10.5654/actageo2014.0004.0016

Carter, J. L., & Hartwig, E. E. (1967). The management of soybean. *In*: Norman, A. G. (Ed.). The soybean. New York: Academy, 162-221 p.

Carvalho, E. R., Rezende, P. M., Ogoshi, F. A., Botrel, É. P., Alcantara, H. P., & Santos, J. P. (2010). Desempenho de cultivares de soja [*Glycine max* (L) Merrill] em cultivo de verão no sul de Minas Gerais. *Ciência e Agrotecnologia*, 34(4), 892-899. https://doi.org/10.1590/S1413-70542010000400014

Cavalcante, W. S. S., Silva, N. F., Teixeira, M. B., Rodrigues, E., Neto, G. Z., Cabral Filho, F. R., & Andrade, C. L. L. (2022). Productive performance of soybean cultivars grown in southwest Goiano. *Research, Society and Development*, 11(17), e181111738881. http://dx.doi.org/10.33448/rsd-v11i17.38881

Cerutti, P. H., Santos, M., Muniz, A. T., Rodrigues, A. R., Carbonari, L. T. S., 7 Schwarzer, P. A. (2020). Desempenho de cultivares de soja em diferentes ambientes de cultivo. *Nativa*, 8(3), 390-396. https://doi.org/10.31413/nativa.v8i3.9521

Colletti, A., Attrovio, A., Boffa, L., Mantegna, S, & Cravotto, H. (2020). Valorization of by-products from soybean (*Glycine max* (L.) Merr.) processing. *Molecules*, 25(9), 2129. https://doi.org/10.3390/molecules25092129

Embrapa (2018). Sistema brasileiro de classificação de solos. 5ª Edição, Revista e ampliada, Brasília, DF, Brasil, 356 p.

Embrapa (2009). Empresa Brasileira de Pesquisa Agropecuária. Soja - BRSMG 752S. Available in: https://www.embrapa.br/documents/1355202/1529289/BRSMG752S_convencional.pdf/f6ad20ed-1799-4b12-a26a-2fbe5038ec89 Access in June 13, 2024.

Ferreira, D. F. (2019). Sisvar: A computer analysis system to fixed effects split plot type designs. *Brazilian Journal of Biometrics*, 37(4), 529-535. https://doi.org/10.28951/rbb.v37i4.450

Ferreira, L. L., Carvalho, I.R., Lautenchleger, F., Martins, T. S., Carvalho, P. R. V., Amaral, G. C. L., Campos, J. N., Fernandes, M. S., Silva, J. G., & Loro, M. V. (2022). Soybean seedling performance in different seed treatments. *Agronomy Science and Biotechnology*, 8, 1-11. https://doi.org/10.33158/ASB.r149.v8.2022

Jiang, Y., Wu, C., Zhang, L., Hu, P., Hou, W., Zu, W., & Han, T. (2011). Long-day effects on the terminal inflorescence development of a photoperiod-sensitive soybean [*Glycine max* (L.) Merr.] variety. *Plant Science*, 180, 504-510.

Jin, H., Yang, X., Zhao, H., Song, X., Tsvetkov, Y. D., Wu, Y., Gao, Q., Zhang, R., & Zhang, J. (2023). Genetic analysis of protein content and oil content in soybean by genome-wide association study. *Frontiers in Plant Science*, 14. https://doi.org/10.3389/fpls.2023.1182771

Júnior, A. A. B., Procópio, S. O., Debiasi, H., Franchini, J. C., & Panison, F. (2015). Semeadura cruzada em cultivares de soja com tipo de crescimento determinado. *Semina Ciências Agrárias*, 36(3), 1215-1226. https://doi.org/10.5433/1679-0359.2015v36n3p1215

Kraft, E., Alexandre, D., Oliveira Filho, L. C. I., Baretta, C. R. D., Klauberg-Filho, O., & Baretta, D. (2023). Is there a relationship between enchytraeids diversity and community with soybean (*Glycine max* L.) productivity in no-till system in subtropical soils of Brazil? *Annals of Applied Biology*, 183(2), 159-169. https://doi.org/10.1111/aab.12843

Köppen, W., & Geiger, R. (1928). Klimate der Erde. Gotha: Verlag Justus Perthes. Wall-map 150 cm x 200 cm.

Köppen, W. (1936). Das geographisca System der Klimate. *In*: Köppen, W., & Geiger, G. I. C., (Eds.). Handbuch der Klimatologie, Berlin: Gebr, Borntraeger, 1-44.

Libório, I. F., Campos, C. N. S., Santana, D. C., Oliveira, I. C., Oliveira, J. L. G., Teodoro, L. P. R., Baio, F. H. R., Theodoro, G. F., & Teodoro, P. E. (2024). Boron fertilization improves the agronomic performance of soybean genotypes in the Brazilian Cerrado. *Agriculture*, 14(1), 27. https://doi.org/10.3390/agriculture14010027

Marchiori, L. F. S., Câmara, G. D. S., Peixoto, C. P., & Martins, M.C. (1999). Desempenho vegetativo de cultivares de soja [*Glycine max* (L.) Merrill] em épocas normal e safrinha. *Scientia Agricola*, 56(2), 383-390.

Marcos Filho, J. (1986). Produção de sementes de soja. Fundação Cargill, Campinas, 1986. 86 p.

Medina, P. F. (1994). Produção de sementes de cultivares precoces de soja, em diferentes épocas e locais do Estado de São Paulo. Tese de Doutorado pela

Universidade de São Paulo, Piracicaba, São Paulo, Brasil, 173 p.

Meotti, G. V., Benin, G., Silva, R. R., Beche, E., & Munaro, L. B. (2012). Épocas de semeadura e desempenho agronômico de cultivares de soja. *Pesquisa Agropecuária brasileira*, 47(1), 14-21. https://doi.org/10.1590/S0100-204X2012000100003

Meotti, G. V., Benin, G., Silva, R. R., Beche, E., & Munaro, L. B. (2012). Épocas de semeadura e desempenho agronômico de cultivares de soja. *Pesquisa Agropecuária Brasileira*, 47(1), 14-21. https://doi.org/10.1590/S0100-204X2012000100003

Nidera. (2015). Nidera Sementes. Catálogo de produtos Sul. Available in: <http://www.niderasementes.com.br/biblioteca_visualizar_arquivo_pdf.aspx?id=23#page/1>. Access in: 06 June 2024.

Oliveira, A. M. S. (2002). Estabilidade fenotípica de 28 cultivares de soja em solos de cerrado do Brasil Central. Dissertação de Mestrado em Fitotecnia e Melhoramento vegetal pela Universidade Federal de Uberlândia, Uberlândia, Minas Gerais, Brasil, 90 p.

Pelúzio, J. M., Fidelis, R. R., Almeida Júnior, D., Barbosa, V. S., Richter, L. H. M., Silva, R. R., & Afférri, F. S. (2006). Desempenho de cultivares de soja, em duas épocas de semeadura, no sul do estado do Tocantins. *Bioscience Journal*, 22(2), 69-74.

Penariol, A. (2000). Soja: cultivares no lugar certo. *Cultivar*, 16, 31-32.

Procópio, S. O., Júnior, A. A. B., Debiasi, H., Santos, J. C. F., & Panison, F. (2013). Plantio cruzado na cultura da soja utilizando uma cultivar de hábito de crescimento indeterminado. *Revista de Ciências Agrárias – Amazonian Journal of Agricultural and Environmental Sciences*, 56(4). https://btcc.ufra.edu.br/index.php/ajaes/article/view/1135

Procópio, S. O., Júnior, A. A. B., Debiasi, H., Franchini, J. C., & Panison, F. (2014). Semeadura em fileira dupla e espaçamento reduzido na cultura da soja. *Revista Agro@mbiente On-Line*, 8(2), 212-221. http://revista.ufrr.br/index.php/agroambiente/article/view/1469

Rambo, L., Costa, J. A., Pires, J. L. F., Parcianello, G., & Ferreira, F. G. (2004). Estimativa do potencial de rendimento por estrato do dossel da soja, em diferentes arranjos de plantas. *Ciência Rural*, 34(1), 33-40. https://doi.org/10.1590/S0103-84782004000100006

Rao, M. S. S., Mullinix, B. G., Rangappa, M., Cebert, E., Bhagsari, A. S., Sapra, V. T., Joshi, J. M., & Dadson, R. B. (2002). Genotype x environment interactions and yield stability of food-grade soybean genotypes. *Agronomy Journal*, 94, 72-80. https://doi.org/10.2134/agronj2002.7200

Rodrigues, O., Didonet, A. D., Lhamby, J. C. B., Bertagnolli, P. F., & Luz, J. D. (2001). Resposta quantitativa do florescimento da soja à temperatura e ao fotoperíodo. *Pesquisa Agropecuária Brasileira*, 36(3), 431-437.

Rubel, F., Brugger, K., Haslinger, K., & Auer, I. (2017). The climate of the European alps: Shift of very high resolution Köppen-Geiger climate zones 1800-2100. *Meteorologische Zeitschrift*, 26(2), 115-125. DOI 10.1127/metz/2016/0816

Santos, H. G., Jacomine, P. K., Anjos, L. H. C., Oliveira, V. Á., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Araújo Filho, J. C., Oliveira, J. B., & Cunha, T. J. F. (2018). Sistema brasileiro de classificação de solos. Brasília, DF: Embrapa, 5ª Edição, Revista e ampliada, Brasil.

Silva, W. B., Menezes Filho, A. C. P., Reis, M. N., Soares, S. L., Bertan, I., Godoi, C. R. C., Ferreira, M. C., Cavalcante, A. K., Ferreira, J. C. S., & Ventura, M. V. A. (2024). Adaptability and stability of soybean [*Glycine max* (L.) Merrill] strains in Central-West Brazil. *Brazilian Journal of Science*, 3(7), 1-16. https://doi.org/10.14295/bjs.v3i7.594

Tessele, A., Kreinchinski, F. H., Albrecht, L. P., Albrecht, A. J. P., & Lorenzetti, J. B. (2017). Desempenho de cultivares de soja intacta em Marechal Cândido Rondon, Oeste Paranaense. *Scientia Agraria Paranaensis*, 16(2), 200-205. http://dx.doi.org/10.18188/1983-1471/sap.v16n1p200-205

Toloi, M. N. V., Bonilla, S. H., Toloi, R. C., Silva, H. R. O., & Nääs, I. A. (2021). Development indicators and soybean production in Brazil. *Agriculture*, 11(11), 1164. https://doi.org/10.3390/agriculture11111164

Umburanas, R. C., Kawakami, J., Ainsworth, E. A., Favarin, J. L., Anderle, L. Z., Dourado-Neto, D., & Reichardt, K. (2022). Changes in soybean cultivars released over the past 50 years in southern Brazil. *Scientific Reports*, 12, 508. https://doi.org/10.1038/s41598-021-04043-8

Yokomizo, G. K. I., Arias, C. A. A., Silva Neto, S. P., & Santos, I. C. (2022). Desempenho de cultivares de soja no cerrado do Amapá quanto a estabilidade e adaptabilidade. *Cientific@*, 9(1), 1-11. https://doi.org/10.37951/2358-260X.2022v9i1.5930

Funding Information

Not applicable.

Author’s Contributions

Willian Nick Alves: project design, writing the study, field and laboratory experiments, writing the article, publication. *Rafael Borges de Assis*: technical assistant for research, field analysis, and agricultural spraying. *Cristiano Lima Lobo de Andrade*: co-supervisor, planting, harvesting, laboratory analysis, statistical analysis. *Fernando Rodrigues Cabral Filho*: study supervisor, first corrections, post-evaluation corrections, statistical analysis, and experimental monitoring.

Ethics

Not applicable.