Short communication

Beans Genotypes (*Phaseolus vulgaris* L.) of the Black Group in the Cerrado Environment, Brazil

Guedes POAS[1], Biesdorf EM[2]*, Santos GR[1], Biesdorf Elivelton M[1], Andrade A[1]

[1] Federal Institute of Education, Science and Technology of the State of Mato Grosso, Brazil

[2] Federal University of Viçosa, Av. P. H. Rolfs, s/n, 36570000, Viçosa, MG, Brazil

*Corresponding author: evandromarcospva@hotmail.com

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Abstract

Beans are considered one of the most economically important agricultural crops in Brazil. However, the country is not yet self-sufficient in this crop, importing still about 10% of the beans consumed. The objective of this study was to evaluate the performance of seven black bean cultivars under the soil and climatic conditions of the Brazilian cerrado. The experiment was carried out under a randomized block design, with three replicates. Seven cultivars of black beans were tested: i) BRS Campeiro, ii) BRS 7762 Supremo, iii) BRS Esplendor iv) CNFP 10104, v) CNFP 10793, vi) CNFP 10794 and vii) CNFP 10806). Plant architecture, planting, number of days to flowering and number of days to harvest, as well as the final population of plants, grain yield per plant, yield and weight of 100 grains were evaluated. The varieties tested did not present significant differences in relation to the architecture and the lodging degree. In addition, the number of days to flowering, as well as the number of days to harvest, had little variation among the tested cultivars. However, cultivars CNFP 10104 and CNFP 10793, although they did not show a significant statistical difference compared to the other cultivars in relation to the final population of plants and production per plant, presented the highest yields (kg ha^{-1}) and also the highest values for the Weight of 100 grains. It is concluded that the cultivars CNFP 10104 and CNFP 10793 are those with the greatest potential for use in the soil and climatic conditions of the cerrado of Brazil.

Key words: Evaluation; final population; plant size; production; varieties.

1. Introduction

Beans (*Phaseolus vulgaris* L.) are among the main grain crops produced in Brazil. In the 2016/2017 harvest, the production is estimated at 3 million tons. This is due to the fact that Brazil is able to produce three harvests in the same agricultural year (first-crop beans, second-crop beans and third-crop beans), reaching a total area of 2.9 million hectares [7].

However, the national average productivity is low, approaching 1.2 tons per hectare [7]. In addition, domestic consumption has varied between 3.3 and 3.6 million tonnes between 2010 and 2015, falling to 2.8 million tonnes in 2016, the lowest recorded in history mainly due to the high price increase caused by retraction of the planted area and adverse climatic conditions, resulting in the importation of 10% of its consumption in countries such as Argentina and China.

This scenario is further aggravated by the fact that Brazil and the world are forced to break their food production limits in the face of a global increase in demand. Thus, this context suggests that new strategies be evaluated, new bean cultivars be made available and investigations are being carried out seeking new cultivars for the Brazilian producing regions, notably the region of the Brazilian cerrado, which concentrates the largest area planted with soybeans, maize and cotton from Brazil [22] with the aim of increasing the area planted and reducing production costs in a rational and sustainable management, diverting the areas to the noble production of food.

In this sense, black beans present high potential to increase Brazilian productivity [16], favoring exports and consequently reducing imports from other countries. In addition, black beans naturally present higher productivity potentials than other types of beans [3], are already grown in 21% of the bean production area in Brazil [7] and are in the consumer preference for a large part of the Brazilian market.

The state of Mato Grosso, located in the center of the cerrado biome of Brazil, is the largest producer of corn, soybeans and beef in Brazil [7, 9, 24]. In addition, it is the one with the greatest growth potential of the cultivated area with beans [12]. However, there is a pressing need for research that evaluates and defines cultivars with greater potential for use in the region and adapted to its tropical dry winter climate.

Therefore, the objective of this study was to evaluate the performance of seven bean cultivars of black type (BRS Campeiro; BRS 7762 Supremo; BRS Esplendor CNFP 10104; CNFP 10793; CNFP 10794 and CNFP 10806) in the climate and soil conditions of the cerrado in the southwest at Mato Grosso State, Brazil, and identify which genotypes have the best growing conditions in the region as the region is responsible for most of Brazilian agriculture.

2. Material and methods

2. 1 *Local, date and soil*

The experiment was carried out in the experimental area of the Federal Institute of Education, Science and Technology *Campus* São Vicente, in the sector of agriculture, in the year 2012. This area is located in Serra de São Vicente, with geographical coordinates 15° 45 'S and 55° 25’ W. The soil was classified as Dystrophic Red Latosol and the climate of the region was classified as AW by Köeppen classification, tropical rainy season with dry season in winter and rainy season in summer, with average annual precipitation of 2000 mm and average monthly of the temperature is 22.2 ° C [18]. The average local altitude is 800 m and the vegetation cover is the cerrado.

The experimental area was 129.6 m^2 and the soil in the area had the following characteristics in the 0-20 m layer: P (Mehlich-1 Extractor) = 50.5 mg dm^{-3}; Organic matter = 27 g dm^{-3}; PH ($CaCl_2$) = 5.5; K, Ca, Mg, Al and H + Al = 2.9; 29; 12; 0 and 41 mmolc dm^{-3}, respectively, and exchangeable base saturation of 56%.

The meteorological data were monitored throughout the conduction of the experiment. The mean temperature was 26.7 °C while the total precipitation during the experiment period was 99.6 mm. The months of highest rainfall indexes were June and September, which presented values of 33 mm and 40.3 mm, respectively (Figure 1).

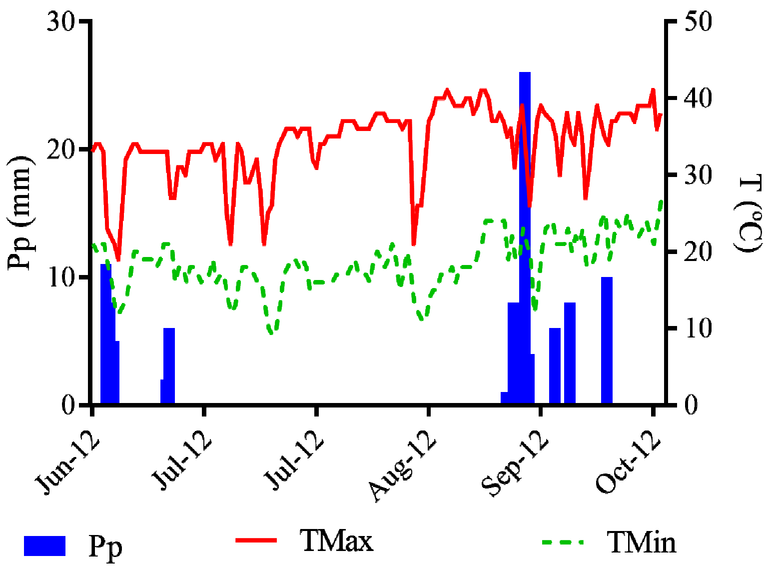

Figure 1. Precipitation (Pp)(mm), maximum (TMax) and minimum (TMin) daily temperature (T)(ºC) of the period between planting and harvesting of the crop in São Vicente da Serra, Mato Grosso, Brazil, 2012.

2. 2 *Experimental design*

The experimental design was a randomized block design (DBC) with seven treatments and three replications. Each experimental unit consisted of four lines of 5.0 m in length, spaced apart by 0.45 m (total area of 9 m^2) with 9 plants per linear meter. Between blocks the spacing was 1.5 m. In order to eliminate the border effect, the two central rows were considered as useful area, scoring 0.45 m from the lateral ends and 0.45 m from the ends of each planting line.

2. 3 *Treatments*

Seven (7) black bean cultivars were tested, being: i) BRS Campeiro; Ii) BRS 7762 Supremo; Iii) BRS Esplendor; Iv) CNFP 10104; V) CNFP 10793; Vi) CNFP 10794 and vii) CNFP 10806.

2. 4 *Implantation of agricultural crops*

The sowing of the cultivars was done manually on July of 2012 with spacing of 0.45 m and planting density of 9 plants per linear meter. Based on the chemical characteristics presented in the soil analysis, the fertilization used in the planting moment was 333.33 kg ha^{-1} of the fertilizer formulation 04-30-10, all applied at the time of sowing for all treatments.

2. 5 *Crop management*

The control of weeds was carried out using mechanical force tools for manual use. Pest control was performed with imidacloprid (1 g L^{-1}) at a dose of 250 g ha^{-1} only when monitoring indicated the level of economic damage, according to the official recommendation for culture [10] at 15 days after emergence and 45 days after the emergency. N fertilization was carried out with 60 kg ha^{-1} of nitrogen, divided in two stages (at 15 days after emergence as well as at 30 days after emergence), in the form of urea (45% N).

2. 6 *Evaluated parameters*

The plant architecture (PA) was evaluated through an index scale adapted from Embrapa Meio-Norte, in which the index 1 (one) means that the plant has an erect architecture, while index 2 (two) and 3 (three) signify semi-erect and prostrate sizes, respectively (Table 1), plant lodging (LP) by adaptation of the scale notes proposed by Embrapa [10] (Table 1); number of days to flowering (NDF) and number of days to harvest (NDH), which were evaluated through daily visits to the experimental area with the objective of evaluating the number of days needed between emergencies up to 50% +1 of the plants in the useful area of each plot with at least one open flower and 50% +1 of the plants in the useful area of each plot at the collection point, respectively.

Table 1. Classification of bean plant architecture and lodging of bean plants. São Vicente da Serra, Mato Grosso, Brazil, 2017.

Index	Type	Description
1	Erect	Main and secondary branches short, with the insertion of the secondary branches forming a right angle with the main branch.
2	Semi-erect	Main and secondary branches short, with the insertion of the secondary branches approximately perpendicular to the main branch. Usually they do not touch the ground.
3	Prostrate	Main and long secondary branches, with the lower secondary branches touching the soil and tending to support themselves in vertical supports.
	lodging of bean plants	
1	All or almost all standing plants (+ 95%);	
3	All or almost all slightly lodged plants or up to 25%;	
5	All plants moderately inclined or 25% to 50% of lodged plants;	
7	All plants strongly inclined or 50% to 80% of lodged plants;	
9	Over 80% of lodged plants.	

Source: Adapted from Embrapa [10].

In addition, the final population of plants (POP) was evaluated by counting the number of plants that produced in the useful area of each plot at the time of harvest;

Production per plant (PP), evaluated through the evaluation of the quantity of grains per plant in the average observed in each plot after correction to 13% of humidity; yield (PROD), which was obtained through the total grains produced by cultivating, correcting for 13% moisture (wet basis) and relating to one hectare; Weight of 100 grains (100SW) (g) by random selection of 100 grains of each plot and weighed on a precision scale and corrected for 13% moisture (wet basis).

2. 7 *Statistical analysis*

The results were submitted to analysis of variance, established by the degree of freedom of the residue equal to or greater than 12, according to the rules of the analysis. When statistical significance was reached, the means of the treatments were submitted to the Tukey test (P = 0.05) using the Assistat Version 7.7 program.

3. Results and discussion

Plant architecture (PA) was not affected (P = 0.01) by cultivation in the cerrado environment of the State of Mato Grosso (Table 2). Despite this, differences in behavior were observed among the evaluated cultivars. The cultivars BRS Campeiro, BRS Esplendor, CNFP 10793 and CNFP 10794 presented semi-erect architecture to the prostrate, while cultivars BRS 7762 Supremo, CNFP 10104 and CNFP 10806 presented behavior ranging from erect to semi-erect (Figure 2A).

In this sense, according to Menezes Júnior et al. [15] and Mendes et al. [14], the current trend of modern agriculture is that new cultivars have erect and greater tolerance to lodging because, in this way, it is expected to obtain a physiologically more efficient plant and, above all, that facilitates the cultural treatments and allows the harvest mechanized. In addition, an erect plant can minimize the incidence of diseases, especially *Sclerotinia sclerotiorum* (Lib.), increase the technological quality of the grain and reduce crop losses [6].

Therefore, considering that cultivars BRS 7762 Supremo, CNFP 10104 and CNFP 10806 showed upright behavior, these are the ones potentially with the best response to the use in the agricultural areas of the cerrado of the State of Mato Grosso, Brazil.

The observed variation in behavior, notably for BRS Esplendor and CNFP 10793 varieties, suggests that these varieties are sensitive to the environmental conditions of the growing region. The probable explanation for this is that in the region of this experiment, during this time of year, there is a great thermal amplitude and this can, according to Teixeira et al. [27], directly affect the physiology of bean plants. According to these authors, with high humidity, temperatures and / or organic material, the bean plant presents greater vegetative development, provoking alterations in the architecture, and may even alter the behavior of erect to prostrate in some occasions, as those verified in this experiment.

Similar results were observed by Collicchio et al. [6], which found architectural variation of common bean plants when they were sown between October and November in the southeastern region of Brazil, at which time there are higher temperatures and rainfall in the region.

In addition, it is pointed out that there is a significant difficulty in performing the visual evaluation of the plant architecture and subsequent classification in an index scale. This is particularly difficult when the evaluation is performed in a small number of plants, that is, the procedure is more coherent when considering families.

Table 2. Summary of variance analysis (ANOVA) for the plant architecture (PA), lodging of plants (LP) number of days to flowering (NDF) number of days to harvest (NDH), and the final population of plants (POP), grain yield per plant (PP), yield (PROD) and weight of 100 grains (100SW).

FV	GL	PA	LP	NDF	NDH	POP	PP	PROD	100SW
		(index)	(index)	(days)	(days)	(individuals)	(g)	(kg ha^{-1})	(g)
Block	2	0.75	0.73	1.20	2.08	1.93	1.21	2.27	3.42
Treatments	6	1.42	0.42	3.95	1.87	0.43	6.79	23.2**	17.68*
Residue	12								
CV (%)		37.84	12.48	10.90	5.22	12.48	15.64	15.24	17.54

** significant at the 1% level (P =0.01); GL, degree of freedom.

No significant difference was observed between the varieties tested in relation to the lodging index of the plants (Table 2). However, there was a great variance among the evaluated varieties, especially for the varieties BRS Esplendor and CNFP 10793, which presented lodging rates lower than two up to values higher than eight, suggesting that they are varieties that can be influenced by the interaction with the environment (Figure 2B).

Comparing the behavior of the varieties BRS Esplendor and CNFP 10793 in relation to the plant architecture and the lodging index, it was observed that these were the two varieties that presented the most variation in relation to the architecture (Figure 2A), indicating that the alteration of bean plant architecture, bypassing the erect toward the prostrate, considerably increases the risk of lodging (Figure 2B) such as were also those which have a greater tendency to lodging.

In fact, Teixeira et al. [27], evaluating the degree of heritability of the bean plant architecture in the southeastern Brazil, verified that the alteration of the erect architecture to prostrate of common bean plants affects the length of the internodes of the plants and this increases the risk of lodging. Also according to the same authors, the length of the internode had the best value between the estimated mean components and the components of the variance for the selection of erect bean plants.

Furthermore, the lodging of BRS splendor and CNFP 10793 plants may be related to the high incidence of winds that occurs in the region of implantation of the experiment at the time of the experiment year, since Gardiner et al. [11] explains that the increase in lodging occurrence in common bean plants depends on average wind speed and intermittence and wind turbulence.

In this context, there are two sets of plant and environmental parameters [1] involved in the lodging process: those that force the plant and those that resist movement. That is, according to Cleugh et al. [5], the drag force of the wind that acts on the plant depends on the exposed area, the drag coefficient and the square of the local wind speed. The drag coefficient, in turn, depends on the plant architecture and the ability of the leaves to become rationalized in order to reduce their silhouette area.

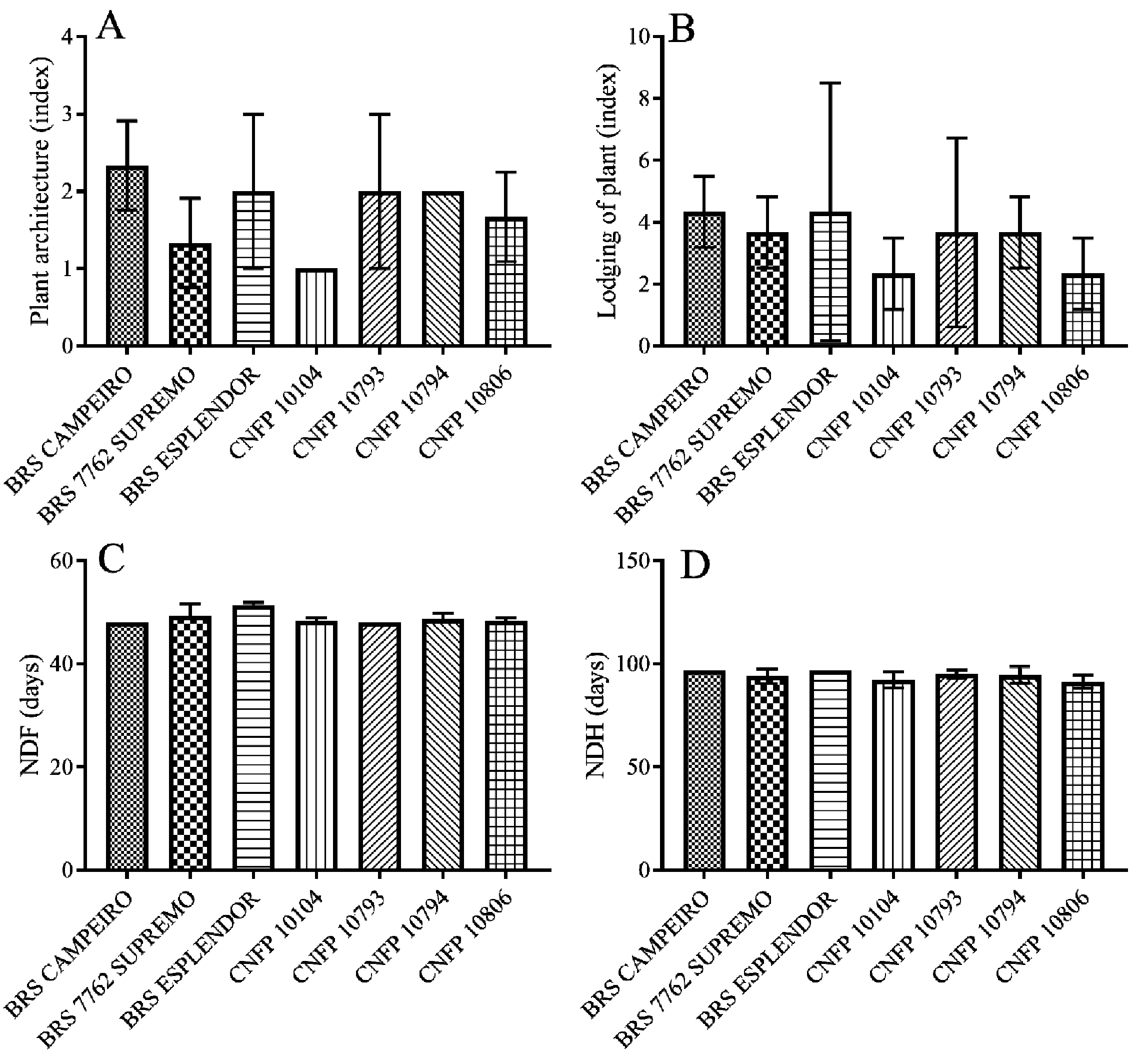

Figure 2. Averages of plant architecture (PA), lodging (LP), number of days to flowering (NDF) and number of days to harvest (NDH) of cultivars tested under cerrado environment in Brazil. Means followed by the same letter between columns do not differ significantly by the Tukey test (P = 0.05).

The number of days to flowering (NDF) and number of days to harvest (NDH) did not show differences among bean varieties studied (Table 2). According to Buratto et al. [2], the search for early varieties has been the goal of many breeding programs. Precocity is defined as the ability of plants to complete their cycle, in a period less than that considered normal or average (80-90 days for common bean) [8]. Among the characteristics associated with precocity, the number of days from emergence to flowering (NDF) has been the most used by researchers [29].

Thus, by the results presented, the genotypes have the same cycle length ranging between 48 to 50 days until the emergence of full flowering, and 95 to 100 days from emergence to the crop (Figures 2C and 2D). Therefore, the genotypes presented a statistically common cycle to that found in the other Brazilian regions. Buratto et al. [2], evaluating the adaptability and stability for grain yield in early common bean cultivars and lines in different locations, observed that there is a difference between bean genotypes in relation to precocity, but this precocity may be detrimental to productivity.

There was no significant statistical difference between the varieties studied in relation to the final population of plants (POP) (Table 2). In fact, there was a high coefficient of variation for each variety tested, probably due to the high occurrence of weeds in the area (Figure 3A). Despite this, these results disagree with those obtained by Souza et al. [26], which found effects of plant populations (100 to 400 thousand plants) on the yield of common bean cvs. Pearl and Carioca. Despite this, it is emphasized that the population of all the varieties found in this work was in agreement with what is recommended for the culture (163 thousand to 300 thousand) [25].

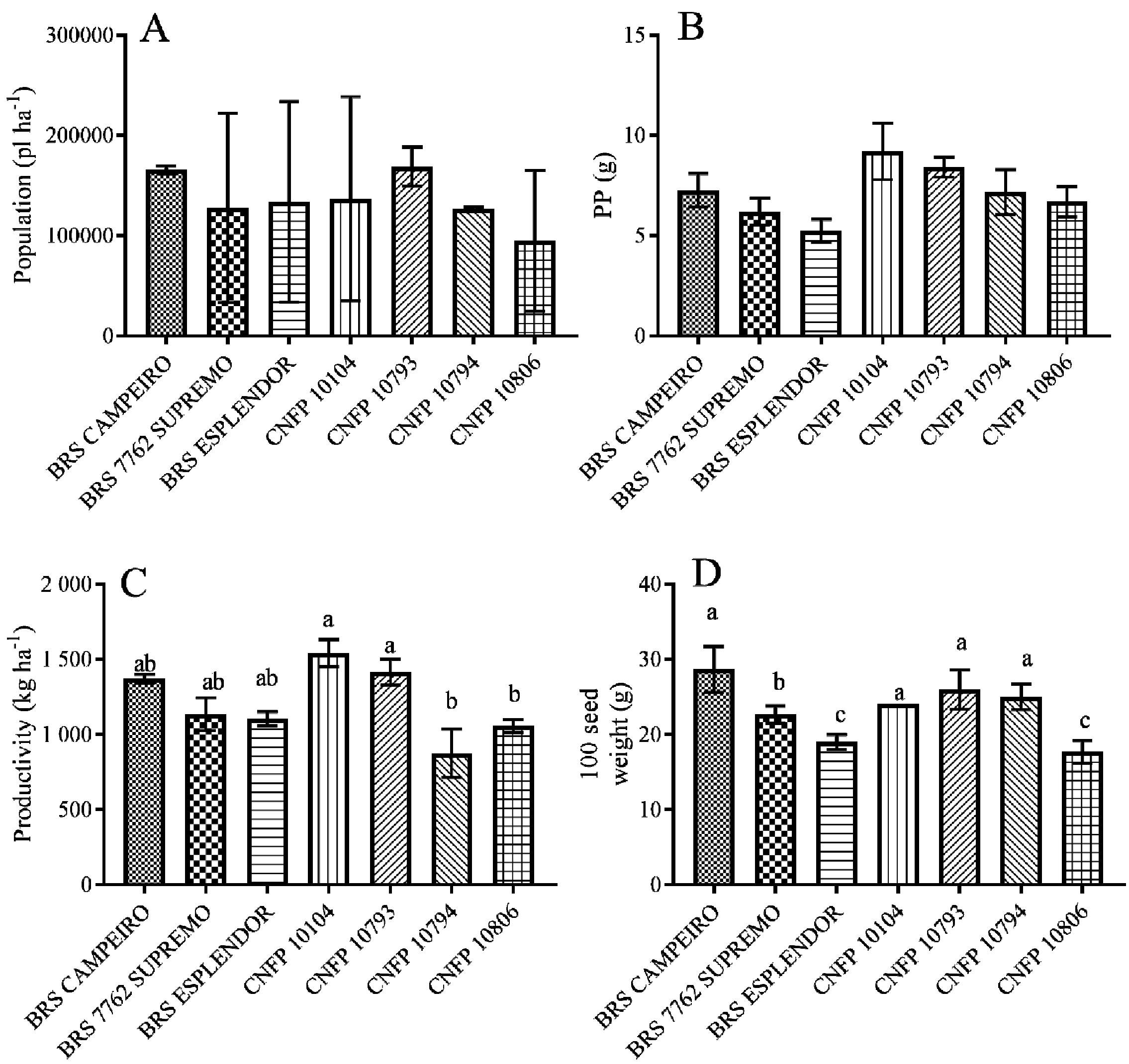

Figure 3. Mean of final plant population (POP), grain yield per plant (PP), grain yield (PROD) and weight of 100 bean grains as a function of cultivars tested in cerrado environment, Brazil. Means followed by the same letter between columns do not differ significantly by the Tukey test (P = 0.05).

The yield per plant (PP) did not present a statistically significant difference between the studied varieties, that is, all varieties studied had the same grain yield per plant. Contrary results were obtained by Ribeiro et al. [23] which, when evaluating the effects of lineage versus environment interaction on grain yield components in beans, noticed a significant difference between the varieties. According to these authors, the occurrence of high-temperature air in the lower reproductive period contributes to establishing the number of grains per pod because the beans are very sensitive to the air temperature in the flowering period. Therefore, the possible cause of the insignificance (P =0.05) among the cultivars tested in relation to grain production per plant is due to the high temperatures, added to the low rainfall rates that occurred in the region of this experiment at the time of cultivation.

Nevertheless, the grain yield varieties studied varied from 875 kg ha^{-1} to 1542 kg ha^{-1} with a significant difference between the varieties tested (Table 2). In fact, the varieties with higher grain yield were CNFP 10104 and CNFP 10794, while the lowest yields were CNFP 10794 and CNFP 10806 (Figure 3C).

Similar results were observed by Pereira et al. [20] which, evaluating new black bean cultivars in cerrado conditions, they noted that the variety of black beans CNFP 10104 showed high yield potential, yield stability, grain with excellent cooking properties and moderate resistance to anthracnose.

Furthermore, even higher results were observed by Carvalho et al. [4], when testing the performance of bean genotypes of the commercial black grown in the winter-spring season in Jaboticabal, São Paulo, Brazil, noticed that the productivity of the CNFP 10794 variety reached values of 3245 kg ha^{-1}, that is, higher than those observed in this study.

However, according to Vieira et al. [28] up to 87% of bean roots are located in the first 0.10 m, giving it high sensitivity to water shortage and compression. Therefore, although the soil does not show visible signs of compaction, the decline in the monthly values of rainfall in the region during the experiment (Figure 1) may have directly affected the productivity of all varieties analyzed, especially CNFP 10794 and 10806 CNFP, which were those most affected. This behavior allows to deduce that CNFP 10794 and CNFP 10806 are less suitable by the environmental conditions of the Brazilian cerrado region and the varieties CNFP 10104 and CNFP 10794 are those most favorable to the cultivation in the region.

The weight of 100 grains presented a statistically significant difference among the varieties tested (Table 2). In this context, the weight of 100 grains is a characteristic that varies according to the cultivar and is considered of great importance for the consumer market, being a feature strongly influenced by the environment [21,19]. That is, the cerrado environment, given its low humidity conditions and high daytime temperatures, significantly affected ($P < .01$) the tested cultivars. The cultivars BRS Campeiro, CNFP 10793, CNFP 10794 and CNFP 10104 were those with greater weight of 100 grains suggesting that they would probably be more vigorous when using their seeds, because according to Oliveira et al. [17], the size of seed in legumes can be used as a parameter for selecting lineages with higher seedling vigor.

In this context, Guimarães et al. [13] checking which stage of development and nitrogen levels in more adequate coverage for early cultivars of bean in southwest Goias, Brazil, noted that the weight of 100 grains showed significant differences among cultivars and significant interaction between cultivar and applied nitrogen (N) dose. That is, confirming that there is a difference in response between bean varieties due to changes in the growing environment.

4. Conclusion

The cultivars CNFP 10104 and CNFP 10793 are those with the greatest potential for use in the cerrado edaphoclimatic conditions in the southwest of the State of Mato Grosso, Brazil. Therefore, it is suggested that these genotypes are those that are better able to contribute to the increase of the area planted with beans in Brazil and possibly as lineages in a breeding program.

Nevertheless, the genotypes CNFP 10793 and CNFP 10806 are not recommended for cultivation in the Brazilian Cerrado because they were highly sensitive to the climate and soil conditions of the region and thus provide low grain yields.

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