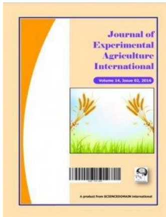

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Influence of Different Population Densities in the Production Performance of Azuki Bean Lines

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JST and JS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MTS, FSO and APVC managed the analyses of the study. Authors LARL and JGC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The demand for azuki beans has increased because of its indication to combat diabetes, composition with high levels of phytochemicals, bioactive and phenolic compounds. However, Brazil still cannot supply its demand for azuki beans. Being more studies on management are needed, to maximize the productivity of this culture. The objective of this study was to evaluate the influence of different population densities in the production performance of azuki beans lines. The experimental design utilized was randomized blocks arranged in 2 x 3 factorial scheme with four replications. The six evaluated treatments were constituted by the combination between two Azuki bean lines, the L1 line (obtained commercially) and line L2 (obtained from a farmer) and three population densities, 500,000 plants.ha^{-1} (with spacing of 0.3 m x 0.2 m), 375,000 plants.ha^{-1} (with spacing of 0.4 m x 0.2 m) and 300,000 plants.ha^{-1} (with spacing of 0.5 m x 0.2 m) (control treatment). The population

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density of 500,000 plants.ha^{-1} provided a higher grain yield when compared to the other population densities, reaching grain yield of 2,223 kg.ha^{-1}. However, we observed the trend that population densities above 500,000 plants.ha^{-1} could have even greater yields.

Keywords: Vigna angularis; row spacing; genotypes; plant population; sowing density.

1. INTRODUCTION

The beans are among the main grain crops produced in Brazil, with an estimated production of 3 million tons for the 2016/2017 harvest. The beans are the main source of protein in the lower income populations due to its low production cost. Moreover, they are cultivated in all Brazilian states due to all its relevance [1].

Beans are a cultivated crop in almost all tropical and subtropical climate countries, with great importance in the constitution of human food, which is related to its low production cost and its nutritional characteristics [2].

Among the genus of beans, the genus Vigna contains about 160 species, where only seven are cultivated. Azuki bean [*Vigna angularis* (Willd.) Ohwi & Ohashi] is highlighted among them, which has its origin in the Asian continent and is widely consumed in China, Japan and Korea, being introduced in Brazil by the Japanese [3].

Several researchers reported the functionalities of the azuki bean, being indicated to combat diabetes due to its hypoglycemic effect. The grains also present high levels of phytochemicals, bioactive and phenolic compounds, which help to promote health and prevent various diseases. In addition, they present higher price than the common bean, increasing the economic return of the crop [4,5,6]. Even though being a food with many functionalities, Brazil still has a low consumption in relation to other countries. However, the product demand is increasing, reaching the demand to outstrip supply in some seasons of the year [7].

Increasing the production of azuki bean is required in order to meet the growing demand, which involves the introduction of genotypes adapted to the growing region. Efforts regarding the efficient management of the crop are also necessary, such as the adequate population density. Despite its great importance, the crop still presents a shortage of this information [8].

With the introduction of new cultivars, there is an increased probability of identifying superior genotypes, adapted to the edaphoclimatic conditions of the region and exhibiting good agronomic characteristics. In this way, it is possible to obtain better options for the cultivation, which will result in greater yield [9].

Adequate population density is fundamental for the efficiency of the production factors and the maximization of the cultivar productive potential, where the scarcity or excess of plants per area is a determining factor for low yield. Therefore, the knowledge of the optimum combination between the population density and the cultivar to be used in each production system is essential for the fully expression of the crop potential. Moreover, this knowledge becomes more relevant in more technical systems [10].

The scarcity of information in the literature regarding lines and population density causes a gap for the proper management of azuki bean. Thus, the objective of this study was to evaluate the influence of different population densities in the production performance of azuki beans lines.

2. MATERIALS AND METHODS

2.1 Site Location

The experiment was performed in the experimental field of the Agricultural Sciences Center of the Federal University of Alagoas (CECA/UFAL), located in the municipality of Rio Largo-AL (09°28'02"S, 35°49'43"W). According to [11], the soil is classified as argisolic cohesive yellow Latosol of medium-clayey texture. According to the Köppen climate classification, the climate of the municipality is type As, rainy tropical climate with dry summer, with annual average temperature and rainfall respectively between 24 to 26°C and 1300 to 1600 mm [12].

2.2 Experimental Design and Treatments

The experimental design utilized was randomized blocks arranged in 2 x 3 factorial scheme with four replications. The six evaluated treatments were constituted by the combination between two Azuki bean lines, the L1 line (obtained commercially) and line L2 (obtained from a farmer) and three population densities, 500,000 plants.ha^{-1} (with spacing of 0.3 m x 0.2 m), 375,000 plants.ha^{-1} (with spacing of 0.4 m x 0.2 m) and 300,000 plants.ha^{-1} (with spacing of 0.5 m x 0.2 m) (control treatment). The area was divided in four blocks with a total of 24 experimental plots. Each plot was constituted by 4 rows of 5 m length, with 75 plants per row, totaling an area of 6 m^2 for the density of 500,000 plants.ha^{-1}, 8 m^2 for the density of 375,000 plants.ha^{-1} and 10 m^2 for the density of 300,000 plants.ha^{-1}. The useful area for data collection was defined as the two central rows, discarding the first six and the last six plants of each end.

2.3 Soil Properties and Sowing Date

Initially, composed soil sampling was carried out prior to the preparation of the experimental area in the 0-20 cm layer in order to characterize the chemical properties of the soil. The results exhibited pH = 5.7, organic matter = 1.67%, Na = 38 ppm, P = 13 ppm, K = 83 ppm, Ca = 2.6 meq/100 mL, Mg = 1.8 meq/100 mL, Al = 0.04 meq/100 mL, H+Al = 4.0 meq/100 mL, sum of bases (SB) = 4.8 meq/100 mL, cation exchange capacity = 8.8 meq/100 mL, base saturation (V) = 54.4%, Fe = 236 ppm, Cu = 0.37, Zn = 1.79 ppm, and Mn = 11.40 ppm.

Soil preparation was carried out with harrowing and no soil correction was required. Chemical basic fertilization with 30 kg.ha^{-1} of N and 30 kg.ha^{-1} of P_2O_5 was performed at sowing time.

The sowing procedure was carried out manually on 02/June/2013, where 300 seeds were distributed per plot. Three seeds were distributed evenly every 0.20 m and thinning was not performed, remaining 15 plants per linear meter. The weed control was done through manual weeding (hoeing), with a total of two operations during the crop cycle. The maximum and minimum daily temperatures and precipitation were recorded during the experiment (Fig. 1).

During the crop cycle, irrigation was performed whenever the crop presented water stress, even if the experiment was implemented in the rainy season, irrigation was necessary due to the summer periods. The azuki bean harvest began at 78 days after sowing and was performed in three stages in view of the uneven maturity of the pods. The remaining harvest followed an interval of 7 days, being the last harvest performed at 92 days after sowing. The harvest was done collecting 126 plants, which is the useful area of each plot.

2.4 Evaluated Parameters

In order to evaluate the productive performance of the lines, the following traits were evaluated: number of pods per plant (NVP), in unit; length of pod (COV), in cm; number of seeds per pod, (NSV) in unit; weight of one hundred seeds (PCS) in g; weight of pods without grains (PC) in kg.ha^{-1} and grain yield (RG) in kg.ha^{-1}.

2.5 Statistical Analysis

The results of the experiment were submitted to analysis of variance and when statistical significance was reached, the means of the treatments were submitted to the Tukey test (P = 0.05), using the Minitab 17 computational application [13].

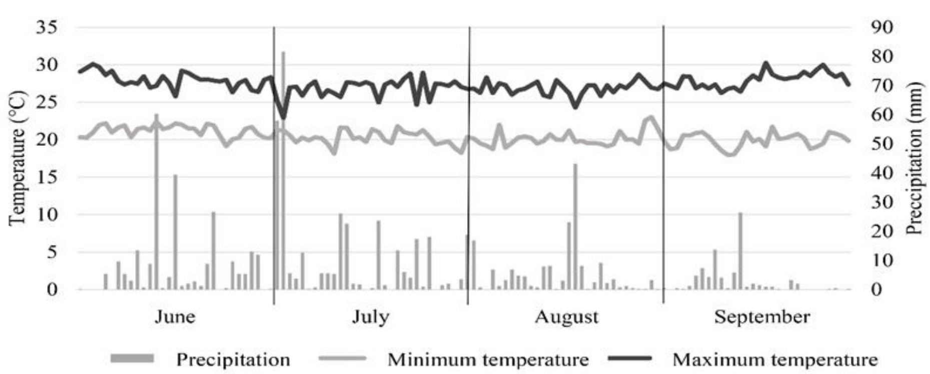

Fig. 1. Daily records of maximum temperature, minimum temperature and precipitation during the experiment, from June to September 2013, in the municipality of Rio Largo-AL

3. RESULTS AND DISCUSSION

The traits length of pod, number of seeds per pod and weight of one hundred seeds presented significant differences between the lines at the probability level (P = 0.01) by the F-test and grain yield at the probability level (P = 0.05) by the F-test. In the same way, population densities had a significant effect on the lines for the variable grain yield at the probability level (P = 0.05) by the F-test, respectively. It is worth noting that the interaction between lines x population densities did not present a significant difference by the F-test at probability level (P = 0.05) for all evaluated traits (Table 1).

For the number of pods per plant, no differences were observed between lines and the population densities, with an overall mean of 9.2 (Table 2). Regarding the agronomic performance of the lines, whereas [14] obtained an average of 8.09. This difference can be related to temperature, where the experiment of the present study was installed in a warmer region when compared to that utilized by [14]. Moreover, azuki bean presents better development in higher temperatures [8]. In relation to the population densities, the results of the present study differ from the results of other studies, where the population density of 500,000 plants.ha^{-1} did not show any difference between the others population densities regarding the number of pod per plant, disagreeing with [15,10,16], which observed decreasing number of pod per plant as the population density was increased in common bean, indicating that the azuki bean supports higher population densities.

The trait weight of pods without grains did not differ between the lines and nor between the population densities, presenting general mean of 895 kg.ha^{-1} (Table 2). It can be very important for the farmer, being a source of organic matter for the soil and feed for ruminant animals. Studies reported the relevance of organic matter in the soil, which improves the physical and chemical

Table 1. Summary of analysis of variance and coefficients of variation for the evaluated traits at 92 days after planting in the influence of different population densities on two lines of azuki bean, Rio Largo-AL, 2014

FV	QM					
	NVP	COV	NSV	PCS	PC	RG
Lines (L)	0.20ns	1.31**	2.43**	4.22**	26811.52ns	1120664.34*
Population densities (DP)	14.80ns	0.02ns	0.28ns	0.25ns	186366.17ns	1009765.67*
Interaction L x DP	2.39ns	0.03ns	0.42ns	0.46ns	133468.90ns	111348.27ns
Blocks	4.40	0.45	0.18	0.29	119868.91	305364.25
Residue	4.83	0.09	0.24	0.14	91113.39	223412.29
CV	23.87	2.70	5.96	4.55	33.73	25.68

*ns, ** e * Not significant at (P = 0.05) probability, significant at (P = 0.01) probability, significant at (P = 0.05) probability, respectively, by the F-test. [1/] number of pods per plant (NVP) in unit; length of pod (COV) in cm; number of seeds per pod (NSV) in unit; weight of one hundred seeds (PCS) in g; weight of pods without grains (PC) in kg.ha^{-1} and grain yield (RG) in kg.ha^{-1}*

Table 2. Mean comparison of lines and population densities for the evaluated traits in azuki bean, Rio Largo-AL, 2014

Lines	NVP[2/]	COV	NSV	PCS	PC	RG
L1	9.11 a	11.59 a[1/]	8.70 a	8.74 a	928.14 a	2056 a
L2	9.29 a	11.13 b	8.06 b	7.91 b	861.29 a	1624 b
Mean	9.20	-	-	-	894.71	-
Population densities	**NVP**	**COV**	**NSV**	**PCG**	**PC**	**RG**
500,000 plants.ha^{-1}	7.64 a	11.32 a	8.57 a	8.17 a	1065 a	2223 a
375,000 plants.ha^{-1}	9.83 a	11.33 a	8.19 a	8.52 a	848 a	1780 ab
300,000 plants.ha^{-1} [3/]	10.13 a	11.42 a	8.38 a	8.29 a	771 a	1520 b
Mean	9.20	11.35	8.38	8.32	895	-

[1/] Means followed by the same letter in the column do not differ from each other by the Tukey test at (P = 0.05) probability. [2/] number of pods per plant (NVP) in unit; length of pod (COV) in cm; number of seeds per pod (NSV) in unit; weight of one hundred seeds (PCS) in g; weight of pods without grains (PC) in kg.ha^{-1} and grain yield (RG) in kg.ha^{-1}. [3/] control treatment

characteristics of the soil, reduces water and wind erosion (due to the protection caused by mulching), maintenance of soil temperature, and prevents infestation of invasive plants [17]. On the other hand, the supply of this biomass to animals in the form of hay in times of scarcity is an alternative to guarantee the food security of herds in the regions of tropical climate. Legume haying is efficient in the conservation of the forage, being able to be used as a feed alternative [18,19]. Thus, farmers could use this biomass to boost their incomes.

The population densities did not have a significant effect on pod length, number of seeds per pod and weight of one hundred seeds, which had a mean respectively of 11.35 cm, 8.38 units and 8.32 g (Table 2). This indicates that even with increased competition at higher densities, the amount of photoassimilates translocated and stored as carbohydrates in the bark of the pod and in the grains were not altered, enabling the maintenance of the specific quantity and weight of the grains, i.e., the maintenance of the physiological quality of the grains [10].

The results of these traits are similar to those found by [15,10], which studied the effects of different sowing densities and observed a non-significant effect for number of seeds per pod and weight of one hundred seeds. Furthermore, this indicates that these traits are little influenced by the population density, being them more related to the cultivar. Therefore, the evaluated lines had a significant effect on the length of pod, number of seeds per pod and weight of one hundred seeds, being the line L1 with the best results for these traits.

For the grain yield, the sources of variation lines and population densities presented significant effect, where the L1 line obtained the highest grain yield with 2,056 kg.ha^{-1} (Table 2). This exhibits the superiority of its genetic makeup, which provided a better agronomic performance for the region, being L1 the most suitable for cultivation. Regarding the population densities, the density of 500,000 plants.ha^{-1} presented the highest grain yield with 2,223 kg.ha^{-1}, but not statistically different from the density of 375,000 plants.ha^{-1}. However, a grain yield response tendency was observed in relation to the population densities, because the increase in density also increases yield in the studied treatments, being this a consequence of the non-significant effect of density on the number of pods per plant, number of seeds per pod and weight of one hundred seeds, which are yield components [15,8]. Thus resulting in a higher grain yield, requiring studies with larger population densities of azuki bean.

4. CONCLUSION

The L1 line presented the highest grain yield when compared to L2. Considering that this trait is more important for farmers, the L1 line is the most recommended for cultivation.

The population density of 500,000 plants.ha^{-1} exhibited higher productivity in relation to the other population densities, being this agronomically recommended to the farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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