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Research Article

Effect of plant density on growth and yield attributes of common bean (*Phaseolus vulgaris* L.) genotypes

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Abstract

Common bean (*Phaseolus vulgaris* L.) is an economically significant seed crop in tropical regions. With the objective of studying the effect of plant density on growth and yield characteristics of common bean, four common bean varieties ('GLP190S', 'NITU', 'ECOPALM021' and 'NUA99') collected from IRAD-Cameroon and four plant spacing distances (10 cm x 10 cm, 15 cm x 15 cm, 20 cm x 20 cm and 30 cm x 30 cm) corresponding respectively to four plant density (121, 49, 36 and 16 plants/m^2) were evaluated for twelve quantitative traits in a randomly completed block design with three repetitions. ANOVA and correlation analysis were performed. Means values of each trait from the ANOVA analysis was submitted to the Tukey test at 5% probability level. The effect of variety was significant for all the twelve studied traits except the number of seed per plant. Pod length, plant height, number of seeds per pod and 100 seed weights were not affected by plant density while the numbers of seeds per plant, number of pods per plant, biological and seed yield were significantly affected by plant density. Interaction effect of plant variety and plant density on seed yield, biological yield, number of pods per plant and collar diameter was significant. No positive correlation was found between plant density and any of the studied traits. Leaf width, collar diameter, number of functional leaves and number of pods per plant inversely correlated with plant density. At the lowest plant density (16 plant/m^2), seed yield and biological yield correlated poorly with related quantitative traits comparing to higher plant densities. From all the studied varieties, only 'ECOPALM021' showed the seed yield not affected by plant density. This study also showed that the higher seed yield and important biological yield was at 16 plants/m^2 plant density.

Keywords: agro-morphological traits; common bean; plant density; plant spacing; seed yield; yield components

Introduction

Common bean (*Phaseolus vulgaris*) is a warm season annual legume crop grown primarily for its protein. This legume was first domesticated in Central and Southern America and is now widely cultivated in the tropics, subtropics and temperate regions (Gepts and Debouck, 1991; Burle *et al.*, 2010). It has a broad commercial importance (Caicedo *et al.*, 1999). World over, common bean is grown over an area of about 28.78 million hectares with an annual production of about 23.14 million tons that feeds around 300 million people in the tropics and 100 million people in Africa (FAO, 2013). This crop is one of the predominantly top pulse

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crops grown in Cameroon. Being a protein rich food 16% to 33% (Vidigal-Filho *et al.*, 2011), it plays an important role in human nutrition, principally in developing countries. Common bean grains are also a good source of iron, zinc and aromatic amino acids that include lysine, leucine, isoleucine, aspartic acid and glutamic acid (Buruchara *et al.*, 2011; Carrasco-Castilla *et al.*, 2012). Common bean has considerable variation in growth habit, qualitative and quantitative traits (Onwueme and Sinha, 1991). Due to the fact that this crop is grown in widely diverse cropping systems, commercial yields are very variable and can fall below the genetic potential of the crop (Graham and Ranalli, 1997). The use of various population densities in plants is largely due cultivar growth habits, cropping systems, availability and cost of seed to be sown (Singh and Gutierrez, 1990).

Plant spatial pattern is an important agronomic factor, having a great influence on growth and development of any crop and therefore is likely to affect grain yield (Olsen *et al.*, 2012). Plant density is considered a vital factor in obtaining higher seed yield. Air temperature, solar radiation, moisture, fertility, photosynthesis, respiration and transpiration are elements required by plants for their nutrition, growth and yield performance. A dense population may have limitations for the maximum availability of these factors. As for example, there is usually competition for sunlight generates within a plant community (Cayón *et al.*, 2004). It is then necessary to determine the optimum density of plants for obtaining maximum yield. Seed yield increase is a major concern for common bean producers. Determining the optimal plant population density in order to obtain optimal yield is therefore a major agronomic goal. For any crop species, an optimum plant population density exists for maximum economic yield and this varies with cultivar and environment (Bruns and Abbas, 2005). At harvest, farmers are experiencing an inconsistency in yield because of the use of various plant densities in common bean production. Sowing at a seed spacing that results in optimal plant population density may reduce seed costs and lodging (Boquet and Walker, 1980).

A major factor influencing optimal seed spacing for any particular environment is the genotype. There is very little information about the study of genotype-density relation in common bean. The effect of plant density on growth and yield attributes in common bean could vary due to varietal features. Thus, the correlation between seed yield and yield components under diverse planting density is essential to understand the basis mechanism of yield-plant density relationship and could help in optimizing plant density for improving yield of common bean. The present study aims to investigate the influence of different plant densities on growth and yield attributes on four common bean varieties in order to select the optimum planting pattern for cultivation of this crop.

Materials and Methods

Plant material and study site

Four varieties of common beans named 'GLP190S', 'NITU', 'ECOPALM021' and 'NUA99', obtained from IRAD (Institute of Agricultural Research for Development) in Cameroon were used for the study. The experiment was carried out at the Research and Teaching Farm of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang, located in the Western Region of Cameroon. The experimental site is located at 5° 20' N latitude and 10° 05' E longitude and at a mean altitude of 1407 m above the sea level. Here, the annual rainfall ranges from 1800 to 2000 mm with an average annual air temperature and relative humidity of 20.50 °C and 76.80%, respectively.

Experimental design

The experiment was in factorial format based on randomized completed block design with three replications and was carried out in 2017/2018 cropping season. The factors of experiment included four levels of plant densities: 16 plants/m^2 (30 cm x 30 cm), 36 plants/m^2 (20 cm x 20 cm), 49 plants / cm^2 (15 cm x 15 cm) and 121 plants /m^2 (10 cm x 10 cm) as shown in Table 1 and four varieties of common beans ('GLP190S', 'NITU', 'ECOPALM021' and 'NUA99').

Plant cultivation, data collection and analysis

Ploughing was carried out two weeks before the experiment and on a total area of 185.5 m^2. Three blocks were used and each consisted of a total area of 56.25 m^2. Blocks were separated each other by 2 m. Each block consisted of 16 experimental units of 1 m^2 each. The distance between each experimental unit was 0.7 m. Prior to sowing, the experiment plot was watered several times for maximum soil moisture. Sowing at each of the density level was carried out in each experimental unit on December 27th 2017. Two seed were sown per hill and thinning was carried out two weeks from sowing, leaving only the most vigorous plant from the two. Fertilizers consisted of poultry manure and NPK (20-10-10). The former was incorporated during ploughing at a concentration of 180 kg/ha. Three weeks after sowing, the later was applied at the rate of 100 kg/ha. During plant growth period, ordinary agronomic practices including watering and weeding were done regularly. Data were collected during growth and at maturity periods. They were collected from the four middle plants of each experimental unit. All the twelve agro-morphological traits data that are presented in Table 2 were collected. Seed yield and related quantitative traits were analyzed using XLSTAT version 2014. Data from each cultivar were separately subjected to analysis of variance. When variance analysis showed statistical significance, Tukey test was applied at 5% probability to determine differences among means. These were done using the same XLSTAT software computer program.

Table 1. List of plant spacing and density used for this study in common bean genotypes

Treatment	Plant spacing (centimeters between plants and rows)	Plant density (plants / m^2)
T1	10 x 10	121
T2	15 x 15	49
T3	20 x 20	36
T4	30 x 30	16

Table 2. List of agronomic quantitative traits used for this study in common bean genotypes

No	Traits	Description
1	Collar Diameter	Mean stem diameter of the twelve selected plants at ten weeks
2	Plant height	Mean height of twelve selected plants at eight weeks
3	Leaf length	Mean length of the twelve selected leaves at eight weeks
4	Leaf width	Mean width of the twelve selected leaves at eight weeks
5	Number of functional leaves	Mean number of functional leaves of the twelve selected plants at eight weeks
6	Pod length	Mean length of the twelve selected pods in each plant at eight weeks
7	Pod per plant	Total number of pods per plant counted per selected plants at the time of harvest
8	Seed per pod	Mean number of seeds of the selected pods in each selected plant at harvest
9	Seed per plant	Mean number of seeds of the twelve selected plant at harvest
10	100 seed weight	Weight of 100 seeds of each of the twelve selected plant at harvest
11	Biological yield	Total weight of shoots of the twelve selected plants at ten weeks
12	Seed yield	Total weight of all the seeds per plant of the twelve selected plants at harvest

Results

Effect of plant density

Table 3 presents the effect of plant variety and plant density on seed yield and its related components in common bean plants. For the four plant varieties studied, eight out of the twelve studied quantitative traits were affected by plant density for 'GLP090' variety. Six out of twelve for 'ECAPALM021' and five out of twelve for 'NITU' and 'NUA-99' varieties (Table 3). This table and Fig. 1 showed that the maximum biological yield is obtained with the lowest plant density (16 plants /m2) for all studied varieties. The same trend was observed for seed yield only for 'GLP090' and 'NITU' varieties. The seed yield of 'ECAPALM021' was not affected by the spacing pattern (Table 3)

As can be seen in Table 4, there were large differences between cultivars for all quantitative traits studied except the number of seed per pod. Results from the analysis of variance (Table 4) showed that the effect of plant density was significant at 0.1% probability level for collar diameter, leaf width, number of functional leaves, number of pod per plant and biological yield; at 1% for the number of seed per plant and seed yield and at 5% for leaf length. Significantly, plant densities did not affect the number of seeds per pod, 100 seed weight, pod length and plant height (Table 4). Comparison of mean between plant spacing treatments showed that the highest seed yield, biological yield and the number of functional leaves was obtained at a plant spacing of 30 cm x 30 cm corresponding to a plant density of 16 plants /m^{2} (Figure 1). ANOVA results showed no interaction between plant variety and plant density for most of the measured quantitative traits (Table 4). The interaction variety x plant density was significant for collar diameter, number of pods per plant, biological yield and seed yield (Table 4).

Table 3. Effect of plant variety and plant density on seed yield and its related components in common bean plants

Genotype	Plant spacing (cmx cm)	Plant density (plants /m^{2})	Collar Diameter	Plant height	Leaf length	Leaf width	Number of functional leaves	Pod length	Pod per plant	Seed per pod	Seed per plant	100 seed weight	Biological yield	Seed yield
'GLP 190S'	10 ×10	121	6.08^{b}	32.79^{a}	7.30^{ab}	5.16^{b}	9.33^{b}	14.02^{a}	4.83c	4.08 ^{a}	20.17^{c}	63.08^{a}	13.85^{b}	12.42^{b}
	15 ×15	49	6.09^{b}	30.92^{a}	7.68^{ab}	5.71^{ab}	10.67^{b}	14.30^{a}	8.33b	4.50^{a}	24.75^{bc}	55.90^{a}	12.66^{b}	13.67 ^{b}
	20 ×20	36	6.67^{b}	29.67^{a}	8.28^{a}	6.18^{a}	10.92^{b}	14.31^{a}	9.25b	4.58^{a}	29.83^{b}	61.45^{a}	14.81^{b}	18.37^{a}
	30 ×30	16	7.17^{a}	30.21^{a}	7.18^{b}	5.63^{ab}	14.58^{a}	13.67^{a}	11.25^{a}	4.17^{a}	39.08^{a}	61.49^{a}	20.93^{a}	23.99^{a}
			*	ns	*	*	*	ns	***	ns	**	ns	***	**
'NITU'	10 ×10	121	5.17^{b}	29.75^{a}	7.03^{a}	5.28^{a}	6.25^{a}	14.92^{a}	5.17c	4.58^{a}	15.92^{b}	60.89^{a}	13.03^{b}	9.72^{b}
	15 ×15	49	5.00^{b}	28.04^{a}	7.24^{a}	5.06^{a}	7.50^{a}	14.47^{a}	6.67^{b}	4.33^{a}	16.00^{b}	58.31^{a}	11.47^{b}	9.22^{b}
	20 ×20	36	5.67^{a}	28.08^{a}	7.51^{a}	5.51^{a}	7.17^{a}	14.70^{a}	7.42^{b}	4.25^{a}	19.25^{ab}	62.40^{a}	10.75^{b}	12.13^{a}
	30 ×30	16	5.83^{a}	26.54^{a}	7.43^{a}	5.97^{a}	7.92^{a}	14,50^{a}	8.83^{a}	4.33^{a}	22.33^{a}	60.80^{a}	16.15^{a}	13.28^{a}
			*	ns	ns	ns	ns	ns	**	ns	*	ns	***	*
'ECAPAL M021'	10 × 10	121	6.67^{b}	35.29^{a}	6.38^{a}	4.38^{c}	8.66^{b}	12.32^{b}	6.42^{b}	3.92^{a}	28.59 ^{a}	55.31^{a}	17.27^{b}	15.35^{a}
	15 × 15	49	6.69^{b}	35.75^{a}	6.46^{a}	4.72^{bc}	10.17^{ab}	13.78^{a}	6.75^{b}	4.25^{a}	32.75^{a}	54.98^{a}	19.74^{ab}	17.62^{a}
	20 × 20	36	7.83^{ab}	36.83^{a}	6.99^{a}	5.45^{b}	12.50^{a}	12.59^{b}	10.17^{a}	4.08^{a}	34.42^{a}	54.56^{a}	21.83^{a}	19.87^{a}
	30 × 30	16	7.08^{a}	34.29^{a}	7.03^{a}	5.77^{a}	11.75^{ab}	12.43^{a}	12.25 ^{a}	4.09 ^{a}	30.33^{a}	53.90^{a}	20.50^{a}	16.49^{a}
			***	ns	ns	***	*	**	***	ns	ns	ns	***	ns
'NUA-99'	10 × 10	121	6.75^{b}	38.82^{a}	6.44^{a}	4.89^{a}	9.83^{b}	13.40^{a}	10.50^{a}	4.25^{a}	38.58^{a}	58.55^{a}	18.18^{b}	25.12^{a}
	15 × 15	49	7.33^{b}	37.83^{a}	6.92^{a}	5.53^{a}	10.67^{ab}	13.47^{a}	8.25^{a}	4.42^{a}	30.83^{a}	56.12^{ab}	18.61^{b}	17.21^{bc}
	20 × 20	36	6.67^{b}	33.83^{a}	6.77^{a}	5.40^{a}	8.92^{b}	13.17^{a}	8.67^{a}	4.17^{a}	27.83^{a}	47.64^{b}	15.47^{b}	13.08^{c}
	30 × 30	16	8.53^{a}	36.73^{a}	7.03^{a}	5.75^{a}	13.42^{a}	13.18^{a}	12.26^{a}	4.50^{a}	37.06^{a}	56.70^{ab}	22.73^{a}	20.26^{ab}
			***	ns	ns	ns	**	ns	ns	ns	ns	*	***	***

^{df}: degree of freedom; *: significant at 5% probability threshold; **: significant at 1% probability threshold; ***: significant at 0.1% probability threshold; ^{ns}: not significant

Table 4. Analyses of variance (F ratios) on yield and related components for the plant variety, plant density and their interaction

	Variety (df = 3)			Density (df = 3)			Variety x Density (df = 9)		
Trait	**F**	**P**	**Sign.**	**F**	**P**	**Sign.**	**F**	**P**	**Sign.**
Collar Diameter (mm)	40.160	0	***	19.900	0	***	2.384	0.014	*
Plant height (cm)	27.042	0	***	1.747	0.159	NS	0.699	0.708	NS
Leaf length (cm)	8.920	0	***	3.097	0.023	*	0.737	0.464	NS
Leaf width (cm)	3.197	0.025	*	8.057	0	***	1.273	0.255	NS
Number of functional leaves	15.786	0	***	8.697	0	***	1.584	0.123	NS
Pod length (cm)	29.340	0	***	1.973	0.078	NS	1.447	0.171	NS
Number of pods per plant	5.728	0	***	14.850	0	***	1.898	0.042	*
Number of seed per pod	2.283	0.081	NS	0.613	0.607	NS	1.108	0.359	NS
Number of seed per plant	19.591	0	***	3.884	0.003	**	2.646	0.007	**
100 Seed weight (g)	8.733	0	***	1.712	0.166	NS	1.797	0.072	NS
Biological yield (g / plant)	22.349	0	***	10.983	0	***	2.277	0.025	*
Seed yield (g / plant)	16.360	0	***	4.466	0.008	**	10.983	0	***

[df]: degree of freedom; *: significant at 5% probability threshold; **: significant at 1% probability threshold; ***: significant at 0.1% probability threshold; [ns]: not significant

Association between plant density, yield and related components

Collar diameter, leave width, number of functional leaves and the number of pods per plant decreased with increasing plant density (Table 5). Using combined estimates data, variation in yield attributes (seed and biological yield) was positively and completely explained by collar diameter, plant height, number of functional leaves, number of pods per plant, and number of seeds per pod (Table 5). These yield attributes were however negatively correlated with pod length (Table 5). Separate correlations between individual plant values of yield and related components of yield were calculated for the different plant density essayed. One additional significant correlation (between biological yield and leaf length) was detected which did not show up in the combined estimate correlations. At the lowest plant spacing, the number of significant associations between yield and related quantitative components was significantly reduced (Table 5). At this density, seed yield was positively correlated with both the number of seeds per pod and the number of functional leaves while the biological yield was positively correlated with both the number of functional leaves and the number of pods per plant. There was no association between seed yield and the number of functional leaves at the highest plant density. Whether in the combined estimates or in the different plant density studied, there was no association between yield attributes and leaf width, number of seed per pod and 100 seed weight (Table 5).

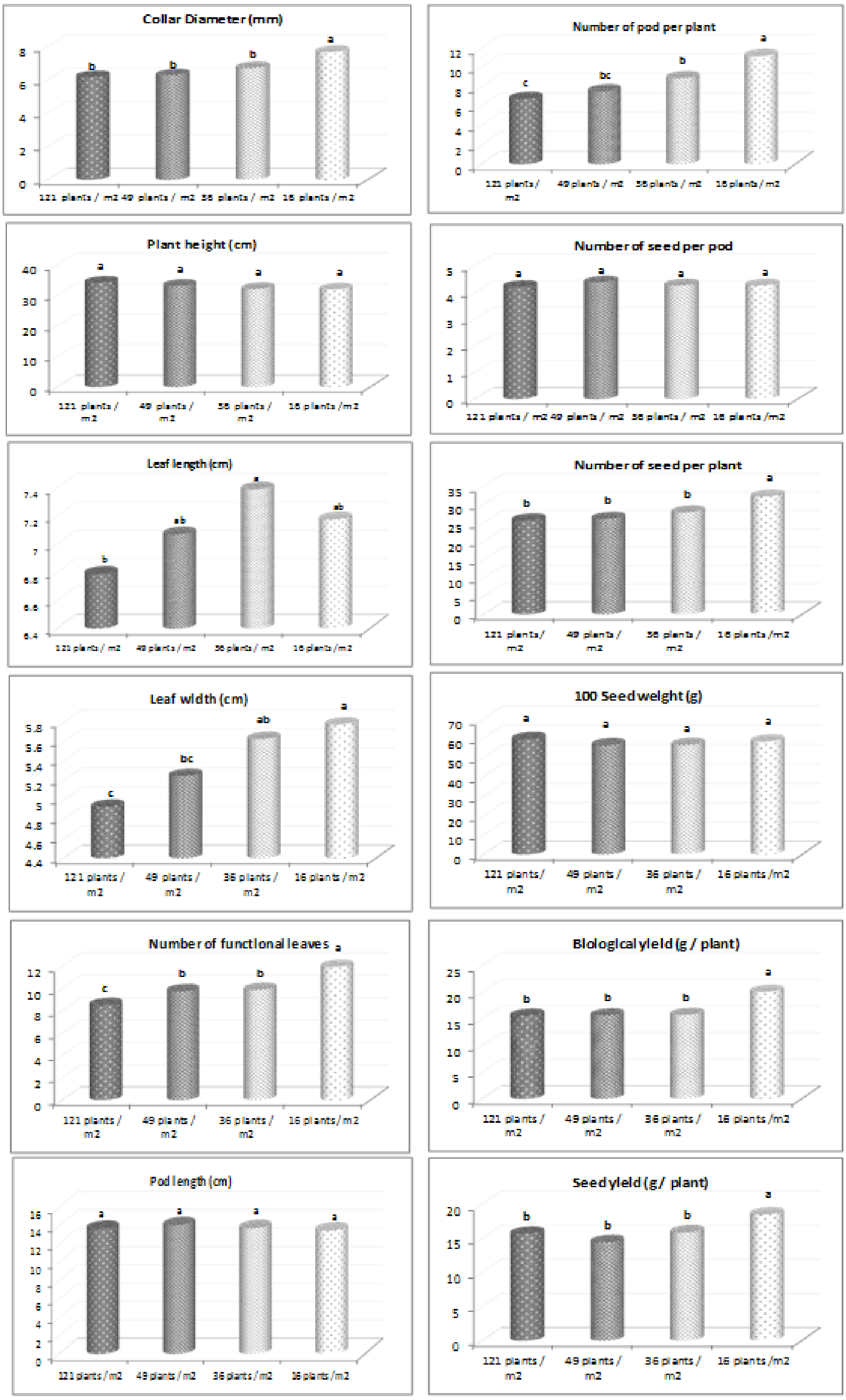

Figure 1. Growth attributes and yields components as affected by plant density. For each trait, same letter indicates no significant difference

Table 5. Pearson correlation coefficients for plant density, yield components and related quantitative traits in common bean

Plant density and yield attributes	Traits and combined estimates		Plant density			
	Trait	Combined estimates	10 cm x 10 cm (121 plants/m^2)	15 cm x 15 cm (49 plant /m^2)	20 cm x 20 cm (36 plants /m^2)	30 cm x 30 cm (16 plants /m^2)
Plant density (Plant /m^2) with	Collar diameter	-0.36*				
	Plant height	0.17^{ns}				
	Leaf length	-0.22^{ns}				
	Leaf width	-0.40**				
	Number of functional leaves	-0.37**				
	Pod length	0.04^{ns}				
	Pod per plant	-0.48***				
	Seed per pod	-0.09^{ns}				
	Seed per plant	-0.16^{ns}				
	100 seed weight	0.15^{ns}				
	Biological yield	-0.04^{ns}				
	Seed yield	-0.13^{ns}				
Seed yield (g / plant) with	Collar diameter	0.50***	0.72**	0.74**	0.67*	0.11^{ns}
	Plant height	0.51***	0.82**	0.72**	0.59*	0.26^{ns}
	Leaf length	-0.07^{ns}	-0.23^{ns}	-0.28^{ns}	0.05^{ns}	0.09^{ns}
	Leaf width	0.06^{ns}	-0.07^{ns}	-0.06^{ns}	0.09^{ns}	-0.10^{ns}
	Number of functional leaves	0.63***	0.41^{ns}	0.43^{ns}	0.75**	0.82**
	Pod length	-0.29*	-0.46^{ns}	-0.41^{ns}	-0.26^{ns}	0.09^{ns}
	Pod per plant	0.66***	0.77**	0.35^{ns}	0.80**	0.51^{ns}
	Seed per pod	-0.02^{ns}	-0.13^{ns}	-0.13^{ns}	0.28^{ns}	0.05^{ns}
	Seed per plant	0.96***	0.99***	0.96***	0.91***	0.95***
	100 seed weight	0.11^{ns}	-0.14^{ns}	-0.16^{ns}	0.35^{ns}	0.10^{ns}
	Biological yield	0.64***	0.76**	0.66*	0.74**	0.34^{ns}
Biological yield (g / plant) with	Collar diameter	0.59***	0.66*	0.52ns	0.82**	0.51^{ns}
	Plant height	0.64***	0.81**	0.81**	0.71**	0.38^{ns}
	Leaf length	-0.24^{ns}	-0.04^{ns}	-0.63*	-0.27^{ns}	0.23^{ns}
	Leaf width	-0.19^{ns}	0.07^{ns}	-0.53^{ns}	-0.15^{ns}	-0.27^{ns}
	Number of functional leaves	0.53***	0.83***	0.01^{ns}	0.69*	0.65*
	Pod length	-0.46**	-0.37^{ns}	-0.18^{ns}	-0.71**	-0.41^{ns}
	Pod per plant	0.46**	0.73**	-0.14^{ns}	0.44^{ns}	0.62*
	Seed per pod	-0.08^{ns}	-0.03^{ns}	0.02^{ns}	-0.29^{ns}	0.12^{ns}
	Seed per plant	0.64***	0.73**	0.61*	0.76**	0.45^{ns}
	100 seed weight	-0.06^{ns}	-0.14^{ns}	0.01^{ns}	0.02^{ns}	-0.43^{ns}
	Seed yield	0.64***	0.76**	0.66*	0.74**	0.34^{ns}

*: significant at 5% probability threshold; **: significant at 1% probability threshold; ***: significant at0.1% probability threshold; ^{ns}: not significant

Discussion

This study involved two factors: plant varieties ('GLP090S', 'NITU', 'ECOPLALM021' and 'NUA99') and planting densities (16, 36, 49 and 121 plants per m^2) and their interaction on common bean growth and yield. Genotypes 'GLP190S' and 'NITU' produced the highest yield at the lowest plant density (16 plant / m^2 plant density while 'NUA99' exhibited the highest seed yield at the lowest plant density (121 plant /m^2). Seed yield of the genotype 'ECOPLALM021' was not affected by plant density. These results Imply that the yield response of common bean to plant density significantly vary with genotypes as also shown by Rahman and Hossain (2011) in soybean. In all four varieties, yield contributing traits such as collar diameter, number of functional leaves and number of pod par plant decreased with increasing plant density and the highest seed yield was obtained at the lowest plant density.

With regard to the effect of plant density on plant vegetative growth, sowing plants at a higher rate of plant density at 121 plants per m^2 or at lower rate of plant density of 16 plants per m^2 did not affected plant height. This no association between plant density and plant height may be due to plant varieties used that were all erects. Our results differ from those of Tuarira and Moses (2014), Kazemi *et al.* (2012) and Seif *et al.* (2016) who found a positive association between plant density and plant elongation in common bean. Meanwhile, less plant density at the rate of 16 plants /m^2 increased significantly the number of functional leaves and collar diameter. The augmentation of these growth variables at low plant density is likely due to the lowest competition between plants for water, space, carbon dioxide and nutrients required for growth. This is highly expected since plants at lower density receive more solar radiation with increase photosynthetic activities that consequently affect positively plant growth. These results are consistent with previous studied on common bean by Seif *et al.* (2016) and on cowpea by Smith and Porter (1989).

In general, plant density did not correlate significantly with seed yield. However, sowing seeds at the lowest density rate of 16 plants per m^2 increased significantly seed yield compared to sowing at rates 36, 49 and 121 plants per m^2. Such augmentation of seed yield at the lower population density may be due to the efficient utilization of growth resources such as large quantities of nutrients, sunlight and water for each plant and this is likely to produce more pods that will reach the maturity stage without falling off and consequently will produced important seed yield. These results are similar to those obtained on beans by Jafroudi *et al.* (2007) and Seif *et al.* (2016). We found the absence of any significant differences among plant densities for number of seeds per pod and 100-seed weight. This suggests that competition was not plain enough to impose any changes on these components of yield. Previous study in common bean by Kazemi *et al.* (2012), Seif *et al.* (2016) and Goulden (1976) also found no significant differences for seed weight and number of seed per pod between distinct plant densities treatments. The correlation analysis showed that plant height, the number of functional leaves, and biological yield positively and significantly ($p = .0002, .0000$ and $.0000$, respectively) correlated with seed yield, (Table 5). This result indicates that the biomass production contributes more to seed yield. Similar observations were found in soybean by Matsuo et al. (2018). The number of pod per plant in this study increased as a result of an Increase in plant spacing or a decrease in plant density (Table 5) and this agrees with previous reports of Adam and Weaver (1998), Board *et al.* (1990) and Jafroudi *et al.* (2007) on common bean. Among the yield components, the seed yield was significantly and positively correlated only with the number of pods (Table 5), indicating that stable pod production is essential for stable seed yield.

Conclusions

For each crop production system, there is an optimum population density that maximizes seed yield. The results of this research show that density has an effect on growth and yield component of common bean. As the population density increases, tiny collar diameter, small number of functional leaves and a smaller number of pods per plant were observed. At the lowest population density of 16 plant /m^2, seed yield and biological yield correlated poorly with related quantitative traits comparing to higher population densities. Higher seed yield and important biological yield was at 16 plants / m^2 population density. Seed yield was not affected by plant density for 'ECOPALM021' genotype. These results show that density is an important factor in the cultivation of common bean genotypes, affecting significantly growth and yield attributes.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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