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Physiological responses of *Vicia faba* L. to planting density, humic acid rate and phosphorus fertilization levels under drip irrigation system in sandy soil

Ahmed Soliman Mohamed El-Kholy1*, Ragab Mohamed Ali Aly[1], Adel Yossef .Abdelhamid El-Bana[1] and Mohamed Abdelsalam Taha Yasin[1]

Agronomy Department, Faculty of Agriculture, Zagazig University, Zagazig, **Egypt.**

***Correspondence:** ahmedelkholy@zu.edu.eg **Accepted: 25** July 2019 **Published online:** 04 Aug 2019

Two field experiments during winter seasons (2015/2016 and 2016/2017) were conducted to study the influence of three planting densities (190476, 238095 and 285714 plant ha^{-1}.), three humic acid rates (0, 5 and 10 Kg ha^{-1}.) and four phosphorus fertilizer levels (0, 37, 74 and 111 Kg P_2O_5 ha^{-1}) on growth and seed yield of faba bean. The experimental design was a spilt-spilt plot design with three replications. The obtained results revealed that increasing plant density from 190476 to 238095 or 285714 plant ha^{-1} significantly increased plant height and leaf area index (LAI) and decreased each of number of branches and leaves $plant^{-1}$, leaf area (LA), chlorophyll content, plant dry weight at 70, 85 and 100 days after sowing (DAS), net assimilation rate (NAR) and crop growth rate (CGR) at 70-85 and 85-100 DAS. The maximum value of seed yield ha^{-1} was obtained under medium plant density (238095 plant ha^{-1}). Humic acid application (5 or 10 kg ha^{-1}) significantly increased number of branches $plant^{-1}$, LA $plant^{-1}$, LAI, chlorophyll content, plant dry weight at 85 and 100 DAS as well as seed yield. Increasing phosphorus fertilizer levels up to111 kg P_2O_5 ha^{-1} significantly increased number of branches $plant^{-1}$, LA $plant^{-1}$, LAI, chlorophyll content, NAR, CGR and plant dry weight as well as seed yield ha^{-1}.

Keywords: Faba bean, planting densities, humic acid, phosphorus, growth, yield.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the most important winter legume crops for human consumption in Egypt as a protein source and has potential N fixing legume. It is nutritionally important vegetable all over the world, containing 20-36% protein for human and animal consumption. Growth analysis is still simpler and perfect method to estimate the contribution of physiological processes in plant growth and development. The purpose of growth analysis is the determination of the increase in dry matter referred to a suitable basis for photo synthetically active tissue, leaf area and amount of leaf protein (Ali et al., 2004; and Alam and Haider, 2006).

Plant density is an important factor that affects the growth and seed yield of legumes. In this respect, Bakry et al. (2011), Abdallah (2014) and (Salem et al. (2014) found that increasing plant densities significantly increased plant height of faba bean and decreased number of branches and leaves $plant^{-1}$. (Al-Suhaibani et al., 2013) found that increasing plant density increased significantly plant height at 70 and 100 days after plant (DAP), leaf area index at 70 and 100 DAP, relative growth rate (RGR) and net assimilation rate (NAR) at 70 and 100 DAP and total dry weight $plant^{-1}$ ^{at} 100 DAP, however, it significantly decreased number of branches $plant^{-1}$ at 70 and 100 DAP and total dry weight $plant^{-1}$ at 70 DAP. Also, (Gezahegn et al., 2016) recorded a significant increase in leaf area index (LAI) and plant height and a significant decrease in number of branches plant^{-1} due to increasing plant density.

Humus compounds are an important soil component because they improve water holding capacity, pH buffering, and availability of nutrients and reduce the salinity effect (El-Galad et al., 2013). El-Ghamry et al. (2009) found that plant height, number of branches and leaves plant^{-1}, as well as chlorophyll a, chlorophyll b and total chlorophyll content in faba bean leaves significantly increased by application of humic acid (2000 ppm) interacted with amino acid (2000 ppm). Also, Shafeek et al. (2013) indicated that application of humic acid up to 4g L^{-1} to faba bean plants significantly increased plant height, number of leaves plant^{-1} and dry weights of whole plant. Also, increasing humic acid level up to 2g L^{-1} increased significantly number of branches plant^{-1}. Kholdi et al. (2015) recorded a significant increment in chlorophyll content due to the application of humic acid. However, Taha and Osman (2017) cleared that increasing potassium humate up to 70 kg ha^{-1} significantly increased plant height, number of leaves plant^{-1} and canopy dry weight. Leaf content of chlorophyll a + b increased significantly by increasing potassium humate up to 140 kg ha^{-1} of bean plants.

Phosphorus is a major nutrient, especially for legumes. In spite of the considerable addition of phosphorus to soil, the amount of available for plant is usually low for plant uptake in most tropical soils mainly because of its fixation with Ca in alkaline soil (Fouda, 2017). Edossa Kubure et al., 2016) showed that increasing phosphorus levels significantly increased number of leaves plant^{-1}, plant height and LAI. In Egypt, El-Sobky and Yasin (2017) found that increasing P level from 0 up to 31 kg P_2O_5 fad^{-1} significantly increased number of branches plant^{-1}, while plant height was not affected by P fertilizer levels. However, Woldekiros et al., (2018), observed that increasing P level from zero to 30 then to 60 kg P_2O_5 ha^{-1} significantly increased plant height and shoot dry weight.

Therefore, this investigation was aimed to find out the Impact of plant density, humic acid rates and phosphorus fertilizer levels on growth and seed yield of faba bean under drip irrigation system in sandy soils and the relation between seed yield and vegetative growth traits.

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Research Station, Faculty of Agriculture, Zagazig University at Khattara Region, Sharqia Governorate, Egypt (30°36′N, 32°16′E), during winter seasons of 2015/2016 and 2016/2017. The study investigated three planting densities (190476, 238095 and 285714 plant ha^{-1}.), three humic acid rates (0, 5 and 10 Kg ha^{-1}) and four phosphorus fertilizer levels (0, 37, 74 and 111 Kg P_2O_5 ha^{-1}) on growth and seed yield of faba bean. Each experiment included 36 treatments, which were the combinations of three plant density, three humic acid rates and four phosphorus fertilizer levels. Faba bean was manually planted on both sides of drip line with line spacing of 70 cm and hill spacing 15, 12 and 10 cm for planting densities 190476, 238095 and 285714 plant ha^{-1} respectively. Humic acid was applied as potassium humate-granules (67.25% humic acid, 15.73% fulvic acid, 12.60 % K2O, 1.50 water insoluble and 14.30% moisture) and drilled between both sides of plants in three equal doses, the first one after 20 days after plant (DAS) and the two remaining doses were added at intervals of 15 day time frame between each. Phosphorus was applied as calcium superphosphate fertilizer (12.5 % P_2O_5), where, drilled before sowing under drip lines.

Experimental design

A spilt-spilt plot design with three replications was used, where the plant densities were allocated in the main plots. Humic acid rates were allocated in the sub plots, whereas the sub-sub plots were devoted to the phosphorus fertilizer levels. The soil of the experimental site was sandy loam in texture where it has a particle size distribution of 87.9, 1.55 and 10.55 for sand, silt and clay, respectively. The soil had an average pH of 7.48 and organic matter content of 0.25% and 0.01 of total N. The average available P and K contents were 5.55 and 37.44 ppm, respectively (averaged over the two seasons for the upper 30 cm of soil depth).

General agronomic practices

Faba bean (Giza 3) was planted on fourth and second November in the two seasons, respectively. Each 2nd order sub plot (4.2m × 3m) included 6 drip lines. Plant was made after maize as a preceding crop in both seasons. Nitrogen at level of 48 kg N ha^{-1} added at sowing in form of ammonium sulphaste (20.6% N), and potassium at level of 114 kg K2O ha^{-1} in form of potassium sulphate (48 % K_2O), where, added in two equal doses, the first one drilled before plant under drip lines, and the second was fertigated at 50 DAS. Chemical weed control by using the recommended herbicides and mechanical control by hand hoeing three times were done. Harvesting was practiced on 10th and 15th April in the two seasons, respectively.

Recorded data

Three samples of 10 guarded plants were taken at 70, 85 and 100 days after plant (DAS) from the 2nd drip line of each experimental unit to estimate the following growth parameters:

Vegetative growth characters

1- Plant height (cm).
2- Number of branches plant^{-1}.
3- Number of leaves plant^{-1}.
4- Plant dry weight (g)
5- Chlorophyll content (SPAD reading). The instrument used was a SPAD-502. (Minolta, 1989)
6- Leaf area Leaf area plant^{-1} (cm^2): leaf area was determined by using the disk method according to (Johnson, 1967) Samples of fifty disks (1.2 cm^2) were taken from leaves of the samples and oven dried to calculate the average dry weight relationships. The leaf area per plant was calculated using the following formula:

Leaf area plant^{-1} = (Leaves dry weight * disk area)/ Disk dry weight.

Vegetative growth analysis

1- Leaf area index (LAI): leaf area index was computed by dividing the leaf area per plant by the area of ground occupied by the plant (Watson, 1958)
2. Crop growth rate (CGR g/day)= (W2-W1) / (t2–t1) (Watson, 1967)
3. Relative growth rate (RGR g/g/day) = (Log_e W2-Log_e W1) / (t2–t1) (Radford, 1967)
4. Net assimilation rate (NAR g/cm2/day).NAR = (W2-W1)*(Loge A2-Loge A1) / (A2–A1)*(t2-t1) (Radford, 1967)

C. Seed yield

At harvest time, all plants in the 4th and 5th line were wholly harvested to estimate seed yield ha^{-1}.

Statistical analysis

Data were statistically analyzed according to (Gomez and Gomez, 1984) by using (MSTAT-C, 1989) where statistical program version 2.1 was used for the analysis of variance (ANOVA). A combined analysis was under taken for the data of the two seasons after testing the homogeneity of the experimental errors. Duncan multiple range test was used to compare statistical significant difference (Duncan, 1955). In interaction tables, capital and small letters were used to denote significant differences among columns and rows means, respectively. The combined data of vegetative growth traits and seed yield were computed as suggested by (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Effect of plant density

Vegetative Growth characteristics

Results presented in tables 1 and 2 clear that plant density of 190476 plant ha^{-1} tended to produce the highest values of number of leaves plant^{-1} and plant dry weight at all growth stages, number of branches plant^{-1} at 85 DAS, chlorophyll content at 70 and 100 DAS as well as, LA plant^{-1} at 85 and 100 DAS. Meanwhile, the high plant density of 285714 plant ha^{-1} tended to produce the highest values of plant height. The studied plant densities had no significant effects on number of branches plant^{-1} at 70 and 100 DAS, chlorophyll content at 70 DAS as well as LA plant^{-1} at 70 DAS. The obtained results are in agreement with those reported by Al-Suhaibani et al. (2013) who found that increasing plant density significantly increased plant height at 70 and 100 DAP but significantly decreased number of branches plant^{-1} at 70 and 100 DAP and total dry weight plant^{-1} at 70 DAP.

2- Vegetative growth analysis

All vegetative growth analysis characters presented in table 3 were significantly affected by plant density at all growth stages. The highest RGR, NAR and CGR during two growth period 70-85 and 85 -100 DAS were recorded under low plant density (190476 plant ha^{-1}) without no significant differences with medium plant density (238095 plant ha^{-1}). On the contrary, the high plant density (285714 plant ha^{-1}) recorded the highest LAI without any significant differences with the medium density at 70 and 85 DAS. These results are in agreement with those reported by (Derogar et al., 2014) but (Al-Suhaibani et al., 2013) reported that increasing plant density significantly increased RGR and NAR. However (Gezahegn et al., 2016) recorded a significant increase in LAI.

3- Seed yield

As shown in table 3 the combined analysis of the two seasons indicate that, the medium plant density (238095 plant ha^{-1}) achieved the highest seed yield ha^{-1} as compared to the lower or higher plant densities. Also, no significant differences could be detected between low and high plant density in seed yield ha^{-1}. The decrement in seed yield caused by high plant density (285714 plant ha^{-1}) may be attributed to the competition between plants which increased shading between leaves causing insufficient carbon fixation, increasing respiration rate and intra-plant competition. On the other hand, the reduction in seed yield caused by low plant density (190476 plant ha^{-1}) may be attributed to that the increments in vegetative growth traits could not compensate the reduction occurred in plant population ha^{-1} (Abdallah, 2014).

Effect of humic acid rates

1-Vegetative Growth characteristics

The presented results in tables 1 and 2 indicate that humic acid application had a marked effect on all studied growth characters, except plant height at all stages and number of leaves at 85 and 100 DAP. Application of humic acid at 5 or 10 Kg ha^{-1} significantly increased number of branches $plant^{-1}$ at 70 and 100 DAP, number of leaves at 70 DAS, plant dry weight at 70 and 75 DAS as well as LA $plant^{-1}$ at 70 DAS. Moreover, number of branches $plant^{-1}$ at 85 DAP, chlorophyll content at all growth stages as well as LA $plant^{-1}$ at 85 and 100 DAP showed significant increment due to raising humic acid application up to 10 Kg ha^{-1}. The increase in vegetative growth characters by application humic acid could be referred to its acting as source of plant growth hormones. Also, humic acid stimulate plant growth by the assimilation of major and minor elements, enzyme activation and/or inhabitation, changes in membrane permeability, protein composition and finally activation biomass production (Ulukan, 2008). The obtained results are in accordance with those reported by Kholdi et al. (2015; Fouda, 2017). Also, Taha and Osman (2017) reported significant increments in number of leaves $plant^{-1}$ and plant dry weight of bean plants as well as chlorophyll content due to humic acid application.

2-Vegetative growth analysis:

All vegetative growth analysis traits were significantly increased due to humic acid application (Table 3). The obtained results are in agreement with those obtained by Afifi et al., (2010) who indicated that foliar application with humic acid improved nutrient status and promoted growth. This could be explained that humic acid is rich in both organic and mineral substances which are essential to plant growth and consequently increasing yield quality and quantity (El-Bassiony et al., 2010).

3- Seed yield

The results of the combined analysis of the two seasons recorded a significant increment in seed yield due to humic acid application (5 or 10 kg ha^{-1}) as compared to control treatment (without humic acid application). These results followed the same patterns of the most vegetative growth and growth analysis traits former discussed which stated the superiority of humic acid application on control treatment (Kholdi et al., 2015;El-Guibali et al., 2016 and Fouda, 2017).

Effect of phosphorus fertilizer levels

1-Vegetative Growth characteristics

The results demonstrate in tables 1 and 2 indicate that all studied growth traits, except plant height, exhibited positive and significant response to application of phosphorus. The obtained results clearly showed that, number of branches $plant^{-1}$ at 70 DAS, number of leaves $plant^{-1}$ at all growth stages, chlorophyll content at 70 and 85 DAS as well as, plant dry weight at 70 and 100 DAP were significantly increased by raising phosphorus fertilizer levels up to 74 kg P_2O_5 ha^{-1}. Moreover, the farther increment of phosphorus fertilizer level up to 111 kg P_2O_5 ha^{-1} caused significant increase in number of branches $plant^{-1}$ at 85 and 100 DAS, chlorophyll content at 100 DAS, plant dry weight at 85 DAS as well as, LA $plant^{-1}$ at 85 and 100 DAS. The obtained results are in good connection with those reported by (El-Sobky and Yasin, 2017; Woldekiros et al., 2018). Also, Edossa Kubure et al. (2016) observed that increasing phosphorus levels significantly increased number of leaves $plant^{-1}$, plant height and LAI.

2-Vegetative growth analysis

It is obvious from the presented results in table 3 that increasing phosphorus fertilizer level up to 74 kg P_2O_5 ha^{-1} significantly increased RGR, NAR and CGR at 85-100 DAS. However, LAI at 85 and 100 DAS, RGR, NAR and CGR at 70-85 DAS showed a positive response to raising P fertilizer level up to 111 kg P_2O_5 ha^{-1}. These results are in agreement with those obtained by Mwafy, (1995) and Ahmed and El-Abagy, (2007) who concluded that the highest P application rate produced the most significant values of growth characters including CGR.

Table1; Effect of planting densities, humic acid rates and phosphorus fertilizer levels on plant height, number of branches plant^{-1} and number of leaves plant^{-1} of faba bean at different growth stages (Average of two seasons).

Main effects:	Plant height (cm)			Number of branches plant^{-1}			Number of leaves plant^{-1}		
	70 DAS	85 DAS	100 DAS	70 DAS	85 DAS	100 DAS	70 DAS	85 DAS	100 DAS
D:									
D1	55.90^{b}	83.91^{b}	116.6^{b}	2.900	3.416^{a}	3.762	28.13^{a}	38.75^{a}	43.12^{a}
D2	57.37^{ab}	86.62^{b}	120.1^{ab}	2.662	3.119^{b}	3.511	27.20^{a}	35.08^{b}	39.77^{b}
D3	60.68^{a}	92.20^{a}	126.0^{a}	2.613	2.965^{b}	3.379	24.78^{b}	30.74^{c}	38.39^{b}
F-test	*	**	*	N.S	*	N.S	**	**	**
H:									
H 0	57.92	88.13	121.2	2.650^{b}	3.109^{b}	3.420^{b}	25.95^{b}	35.00	40.21
H 1	58.61	87.72	122.1	2.759^{a}	3.078^{b}	3.573^{a}	26.88^{ab}	34.70	40.42
H 2	57.43	86.88	119.5	2.765^{a}	3.313^{a}	3.659^{a}	27.28^{a}	34.87	40.64
F-test	N.S	N.S	N.S	*	**	*	*	N.S	N.S
P:									
P0	57.75	87.33	120.8	2.635^{b}	3.026^{c}	3.384^{c}	24.75^{c}	32.83^{c}	36.26^{b}
P1	57.84	87.19	120.2	2.700^{b}	3.034^{c}	3.449^{bc}	26.54^{b}	34.26^{b}	40.78^{a}
P2	58.47	88.57	122.0	2.747^{ab}	3.197^{b}	3.588^{b}	27.33^{ab}	36.17^{a}	42.03^{a}
P3	57.89	87.21	120.6	2.817^{a}	3.409^{a}	3.781^{a}	28.19^{a}	36.16^{a}	42.63^{a}
F-test	N.S	N.S	N.S	*	**	**	**	**	**

Notes, DAS: Days after sowing, D: planting densities, D1: 190476 plant ha^{-1}, D2: 238095 plant ha^{-1}, D3: 285714 plant ha^{-1}, H: humic acid rates, H0: without application of humic acid, H1: 5 kg humic acid ha^{-1}, H2: 10 kg humic acid ha^{-1}, P: phosphorus fertilizer levels, P0: without application of phosphorus fertilizer, P1: 37 kg P_2O_5 ha^{-1}, P1: 74 kg P_2O_5 ha^{-1}, P3: 111 kg P_2O_5 ha^{-1}. Means with different letters differ significantly according to Least Significant Difference (LSD) test ($P < 0.05$). NS stands for no significant difference, ∗ and ∗∗ denote significance at $P < 0.05$ and $P < 0.01$ levels, respectively.

Table 2; Effect of planting densities , humic acid rates and phosphorus fertilizer levels and on Chlorophyll content (SPAD reading), plant dry weight (g) , Leaf area plant^{-1} (cm2) of faba bean at different growth stages (Average of two seasons).

Main effects:	Chlorophyll content			plant dry weight (g)			Leaf area plant^{-1} (cm^{2})		
	70 DAS	85 DAS	100 DAS	70 DAS	85 DAS	100 DAS	70 DAS	85 DAS	100 DAS
D:									
D1	36.87^{a}	36.32	37.28^{a}	10.36^{a}	16.67^{a}	27.25^{a}	1082	1618^{a}	2247^{a}
D2	34.94^{b}	36.44	37.05^{a}	9.33^{b}	14.83^{b}	24.63^{b}	1118	1534^{a}	2120^{b}
D3	34.38^{b}	35.65	36.08^{b}	9.12^{b}	14.05^{c}	22.08^{c}	971	1384^{b}	1987^{c}
F-test	**	N.S	**	**	**	**	N.S	*	**
H:									
H 0	34.29^{c}	35.44^{c}	36.06^{c}	9.40^{b}	14.65^{b}	21.97^{c}	887^{b}	1462^{b}	1930^{c}
H 1	35.49^{b}	36.24^{b}	36.91^{b}	9.59^{ab}	15.10^{ab}	24.68^{b}	1092^{a}	1441^{b}	2079^{b}
H 2	36.42^{a}	36.74^{a}	37.54^{a}	9.82^{a}	15.80^{a}	27.31^{a}	1193^{a}	1634^{a}	2328^{a}
F-test	**	**	**	*	*	**	**	*	**
P:									
P0	35.17^{b}	35.89^{b}	35.84^{d}	8.40^{c}	13.83^{c}	21.23^{c}	936^{b}	1402^{b}	1807^{c}
P1	35.12^{b}	35.85^{b}	36.46^{c}	9.24^{b}	14.60^{b}	23.36^{b}	1068^{a}	1437^{b}	1898^{c}
P2	35.47^{ab}	36.32^{ab}	37.21^{b}	10.18^{a}	15.09^{b}	26.21^{a}	1078^{a}	1502^{b}	2282^{b}
P3	35.84^{a}	36.50^{a}	37.84^{a}	10.60^{a}	17.20^{a}	27.55^{a}	1145^{a}	1707^{a}	2486^{a}
F-test	*	*	**	**	**	**	*	**	**

Notes, DAS: Days after sowing, D: planting densities, D1: 190476 plant ha^{-1}, D2: 238095 plant ha^{-1}, D3: 285714 plant ha^{-1}, H: humic acid rates, H0: without application of humic acid, H1: 5 kg humic acid ha^{-1}, H2: 10 kg humic acid ha^{-1}, P: phosphorus fertilizer levels, P0: without application of phosphorus fertilizer, P1: 37 kg P_2O_5 ha^{-1}, P1: 74 kg P_2O_5 ha^{-1}, P3: 111 kg P_2O_5 ha^{-1}. Means with different letters differ significantly according to Least Significant Difference (LSD) test ($P < 0.05$). NS stands for no significant difference, ∗ and ∗∗ denote significance at $P < 0.05$ and $P < 0.01$ levels, respectively.

Table3. Effect of planting densities , humic acid rates and phosphorus fertilizer levels on Leaf area index (LAI), Relative growth rate (RGR g/g/day), Net assimilation rate (NAR g/cm2/day), Crop growth rate (CGR g/day) and seed yield of faba bean at different growth stages (Average of two seasons).

Main effects:	Leaf area index (LAI)			RGR (g/g/day)		NAR (g/cm^2/day)		CGR (g/day)		Seed yield (ton ha^{-1})
	70 DAS	85 DAS	100 DAS	70 -85 DAS	85-100 DAS	70 -85 DAS	85-100 DAS	70 -85 DAS	85-100 DAS	
D:										
D1	2.062^{b}	3.083^{b}	4.280^{c}	0.190^{a}	0.310^{a}	42.85^{a}	69.95^{a}	0.439^{a}	0.716^{a}	3.837^{b}
D2	2.663^{a}	3.653^{a}	4.978^{b}	0.166^{ab}	0.311^{a}	37.35^{ab}	70.07^{a}	0.382^{ab}	0.718^{a}	4.145^{a}
D3	2.776^{a}	3.957^{a}	5.680^{a}	0.153^{b}	0.236^{b}	34.39^{b}	53.12^{b}	0.352^{b}	0.544^{b}	3.874^{b}
F-test	**	**	**	*	*	*	*	*	*	*
H:										
H0	2.061^{b}	3.446^{b}	4.516^{c}	0.151^{b}	0.228^{b}	33.92^{b}	51.22^{b}	0.347^{b}	0.525^{b}	3.663^{b}
H1	2.615^{a}	3.433^{b}	4.855^{b}	0.168^{ab}	0.303^{a}	37.73^{ab}	68.29^{a}	0.386^{ab}	0.699^{a}	4.103^{a}
H2	2.825^{a}	3.814^{a}	5.567^{a}	0.191^{a}	0.327^{a}	42.94^{a}	73.62^{a}	0.440^{a}	0.754^{a}	4.091^{a}
F-test	**	*	**	**	**	**	**	**	**	**
P:										
P0	2.196^{b}	3.259^{b}	4.236^{c}	0.157^{b}	0.224^{c}	35.33^{b}	50.42^{c}	0.362^{b}	0.516^{c}	3.469^{d}
P1	2.571^{a}	3.414^{b}	4.849^{b}	0.160^{b}	0.275^{b}	36.10^{b}	62.19^{b}	0.370^{b}	0.637^{b}	3.832^{c}
P2	2.593^{a}	3.562^{b}	4.962^{b}	0.166^{b}	0.318^{ab}	37.31^{b}	71.55^{ab}	0.382^{b}	0.733^{ab}	4.167^{b}
P3	2.641^{a}	4.022^{a}	5.869^{a}	0.196^{a}	0.326^{a}	44.04^{a}	73.36^{a}	0.451^{a}	0.751^{a}	4.340^{a}
F-test	*	**	**	**	**	**	**	**	**	**

Notes, DAS: Days after sowing, D: planting densities, D1: 190476 plant ha^{-1}, D2: 238095 plant ha^{-1}, D3: 285714 plant ha^{-1}, H: humic acid rates, H0: without application of humic acid, H1: 5 kg humic acid ha^{-1}, H2: 10 kg humic acid ha^{-1}, P: phosphorus fertilizer levels, P0: without application of phosphorus fertilizer, P1: 37 kg P_2O_5 ha^{-1}, P1: 74 kg P_2O_5 ha^{-1}, P3: 111 kg P_2O_5 ha^{-1}. Means with different letters differ significantly according to Least Significant Difference (LSD) test ($P < 0.05$). NS stands for no significant difference, ∗ and ∗∗ denote significance at $P < 0.05$ and $P < 0.01$ levels, respectively.

3- Seed yield

The results of the combined analysis of the two growing seasons exhibited gradual increment in seed yield with each increase in P fertilizer level up to the highest studied level (111 kg P_2O_5 ha^{-1}). Such positive effects were observed throughout the most vegetative growth traits. In addition it was confirmed significant at all growth stages. Then, phosphorus application rate of 111 kg P_2O_5 ha^{-1} gave the highest seed yield ha^{-1} which followed by 74 kg P_2O_5 ha^{-1}, while the lowest seed yield ha^{-1} was given when no phosphorus was added. Such results stated the vital role of phosphorus fertilization in improving the productivity of faba bean (El-Gizawy and Mehasen, 2009;El-Aref et al., 2012 and Edossa Kubure et al., 2016)

Effect of interactions

A- Interaction between plant density and humic acid rates

From the presented results in Table 4 it could be included that number of leaves plant^{-1} at 100 DAS, LA plant^{-1} at 100 DAS, NAR at 85-100 DAS and CGR at 85-100 DAS showed no significant response to humic acid rates under the low plant density. On the other hand, the aforementioned traits showed significant response to raising humic acid rates up to 5 kg ha^{-1} when the medium plant density was applied and up to 10 kg ha^{-1} when high plant density was used. The obtained results exhibit the important role of humic acid application under the higher plant density, where the plants suffered from competition on light and nutrients.

B- Interaction between plant density and phosphorus fertilizer levels

Results pertaining to vegetative growth analysis during 85-100 DAS and seed yield during the combined analysis as influenced by the interaction between plant density and phosphorus fertilizer levels are presented in Table 4. The obtained results indicate that LAI showed a significant positive response to increasing plant density up to 285714 plant ha^{-1} under different levels of applied phosphorus, while, it did not show any response to varying plant density when no phosphorus was added. NAR and CGR presented significant response to raising phosphorus fertilizer level up to 111 kg P_2O_5 ha^{-1} under the medium plant density. On the other hand, this response did not observed under low or high plant densities.

Table 4; Interaction effect of planting densities & humic acid rates, planting densities & phosphorus fertilizer levels and humic acid rates & phosphorus fertilizer levels

D:	Humic acid rate (H)			Phosphorus fertilizer level				H:	Phosphorus fertilizer level			
	H0	H1		P0	P1	P2	P3		P0	P1	P2	P3
	No. leaves plant at 100 DAS			Leaf area index (LAI) at 100 DAS					RGR (g/g/day) at 85-100 DAS			
D1	A 44.90a	A 42.56a	A 41.88a	A 3.900a	A 4.504b	A 4.111c	A 4.606c	**H0**	A 0.252a	A 0.166b	A 0.257a	A 0.237b
D2	B 37.90b	A 42.24a	AB 39.16a	B 4.184a	B 4.796ab	B 4.942b	A 5.990b	**H1**	B 0.192a	AB 0.297a	A 0.349a	A 0.373a
D3	AB 37.84b	B 36.45b	A 40.87a	C 4.626a	BC 5.249a	B 5.833a	A 7.011a	**H2**	B 0.229a	A 0.363a	A 0.349a	A 0.363a
	LA plant^{-1} at 100 DAS			NAR (g/cm^2/day) at 85-100 DAS								
D1	A 2137a	A 2307a	A 2296ab	A 53.71a	A 70.49a	A 78.10a	A 77.52a	**H0**	A 56.66a	A 37.26b	A 57.71a	A 53.26b
D2	B 2016a	AB 2016a	A 2240b	C 47.31a	BC 58.34a	AB 81.49a	A 93.12a	**H1**	B 43.09a	AB 67.63a	A 78.50a	A 83.97a
D3	C 1636b	B 1880b	A 2447a	A 50.24a	A 57.73a	A 55.05a	A 49.45b	**H2**	B 51.51a	A 81.67a	A 78.44a	A 82.85a
	NAR (g/cm^2/day) at 85-100 DAS			CGR (g/day) at 85-100 DAS								
D1	A 63.71a	A 73.72a	A 72.43a	A 0.550a	A 0.722a	A 0.80a	A 0.794a	**H0**	A 0.582a	A 0.382b	A 0.591a	A 0.545b
D2	B 44.10a	A 94.82a	A 71.27a	C 0.484a	BC 0.597a	AB 0.83a	A 0.954a	**H1**	B 0.441a	AB 0.693a	A 0.804a	A 0.860a
D3	B 45.86a	B 36.34b	A 77.15a	A 0.515a	A 0.591a	A 0.56a	A 0.506b	**H2**	B 0.528a	A 0.836a	A 0.803a	A 0.848a
	CGR (g/day) at 85-100 DAS			Seed yield (ton ha^{-1})								
D1	A 0.652a	A 0.755a	A 0.742a	B 3.544a	B 3.595b	A 4.005b	A 4.155a	**H0**	B 3.303a	B 3.429b	B 3.582b	A 4.339a
D2	B 0.452a	A 0.971a	A 0.730a	C 3.412a	B 4.144a	AB 4.499a	A 4.524a	**H1**	C 3.643a	B 4.052a	A 4.466a	AB 4.250a
D3	B 0.470a	B 0.372b	A 0.790a	C 3.451a	BC 3.757b	B 3.948b	A 4.342a	**H2**	C 3.461a	B 4.015a	A 4.454a	A 4.433a

Notes, DAS: Days after sowing, D: planting densities, D1: 190476 plant ha^{-1}, D2: 238095 plant ha^{-1}, D3: 285714 plant ha^{-1}, H: humic acid rates, H0: without application of humic acid, H1: 5 kg humic acid ha^{-1}, H2: 10 kg humic acid ha^{-1}, P: phosphorus fertilizer levels, P0: without application of phosphorus fertilizer, P1: 37 kg P_2O_5 ha^{-1}, P1: 74 kg P_2O_5 ha^{-1}, P3: 111 kg P_2O_5 ha^{-1}. LA plant^{-1}: leaf area plant^{-1}, NAR: Net assimilation rate, CGR, crop growth rate, RGR: relative growth rate. Means with different letters differ significantly according to Least Significant Difference (LSD) test ($P < 0.05$), capital and small letters were used to denote significant differences among columns and rows means, respectively.

Table 5; Simple correlation coefficients and their significance levels between seed yield and vegetative growth traits (data averaged over two seasons)

Traits	Number of days after sowing			Traits	Number of days after sowing	
	70	85	100		70 - 85	85 - 100
Plant height	0.024^{ns}	-0.008^{ns}	-0.020^{ns}	RGR	0.160^{ns}	0.417**
No. branches $plant^{-1}$	0.170^{ns}	0.172^{ns}	0.307**	NAR	0.160^{ns}	0.416**
No. leaves $plant^{-1}$	0.275**	0.051^{ns}	0.332**	CGR	0.160^{ns}	0.416**
Chlorophyll content	0.167^{ns}	0.375**	0.257**			
Plant dry weight	0.282**	0.332**	0.500**			
LA $plant^{-1}$	0.229*	0.101^{ns}	0.471**			
LAI	0.272**	0.172^{ns}	0.397**			

Sample size (n) = 108, *,** and NS indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order

Under low and medium plant densities seed yield ha^{-1} showed positive increment to raising phosphorus fertilizer level up to 74 kg P_2O_5 ha^{-1}, while under the high plant density it showed positive increment to raising phosphorus fertilizer level up to 111 kg P_2O_5 ha^{-1}.

C- Interaction between humic acid rates and phosphorus fertilizer levels

The offered results in Table 4 indicated that, RGR, NAR and CGR showed no significant response to varying phosphorus fertilizer levels when no humic acid was added. On the other direction, under the application of 5 or 10 kg H.A ha^{-1} the aforementioned traits showed significant and positive response to increasing phosphorus fertilizer level up to 37 kg P_2O_5 ha^{-1}. Furthermore, seed yield ha^{-1} showed significant response to raising phosphorus fertilizer level up to 111 kg P_2O_5 ha^{-1} under without humic acid application, while it exhibited positive response to increasing phosphorus fertilizer level up to 74 kg P_2O_5 ha^{-1} under humic acid application (5 or 10 kg H.A ha^{-1}). The obtained results reveled that humic acid application not only increased seed yield and growth analysis of faba bean but also lead to more solubility to phosphorus in the soil leading to minimizing the added rates from phosphorus to the soil (El-Galad et al., 2013;Sarwar et al., 2014)

Correlation coefficient between seed yield and vegetative growth traits

Results in table 5 showed that at 70 DAS, seed yield ha^{-1} was significantly positively correlated with number of leaves $plant^{-1}$, plant dry weight, LA $plant^{-1}$ and LAI while at 85 DAS while, seed yield ha^{-1} was significantly positively correlated with chlorophyll content and plant dry weight. Furthermore, all vegetative growth traits with the exception of plant height, showed significant correlation with seed yield ha^{-1} (Table 5).

Concerning the correlation between seed yield ha^{-1} and vegetative growth analysis, the obtained results showed that LAI at 70 and 100 DAS presented significant correlation with seed yield ha^{-1}. Also, RGR, NAR and CGR were significantly positively correlated with seed yield ha^{-1} during 85-100 DAS while during 70-85 DAS showed no significant correlation with seed yield ha^{-1}. Finally, it could be concluded that plant dry weight and LAI at 100 DAS as well as RGR, NAR and CGR were the most effective traits on final seed yield ha^{-1}.

CONCLUSION

The obtained data showed that seed yield ha^{-1} was significantly positively correlated with vegetative growth traits (number of branches $plant^{-1}$, number of leaves $plant^{-1}$, chlorophyll content, plant dry weight, LA $plant^{-1}$, LAI, RGR, NAR and CGR), and seed yield can be increased by increasing related growth traits through sowing faba bean in density of 190476 plant ha^{-1}, application of 5 kg humic acid ha^{-1} and 74 kg P_2O_5 ha^{-1} or 111 kg P_2O_5 ha^{-1}.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Authors participate in collecting, analyzing data and writing this study. All authors read and approved the final version.

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