Middle East Journal of Agriculture Research
ISSN 2077-4605

Volume : 06 | Issue : 04 | Oct.-Dec. | 2017
Pages:1204-1217

Some Agro-Physiological Studies on Faba Bean

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Received: 28 Sept. 2017 / Accepted: 20 Nov. 2017 / Publication date: 14 Dec. 2017

ABSTRACT

Two field trials were conducted to study the effect of five plant densities i.e., 19, 22.2, 26.6, 33 and 44 plants m^{-2} plant densities which equal to 190, 222, 266, 330 and 440 10^3 plants ha^{-1} on morphological characters, physiological and yield attributes of two faba bean types viz. determinate (FLIP-87 -117 strain) and indeterminate (c.v. Giza-461). The results showed that the indeterminate plants significantly surpassed the determinate plants in plant height at 75 and 90 days from sowing, number of leaves at all growth stages and dry matter accumulation at 45 and 90 days from sowing. Determinate plants possessed greater number of side branches than that of the indeterminate plants, but it was only significant at 90 days from sowing. Greater number of flowers were produced by the indeterminate plants than that of the determinate plants at 75 and 90 days from sowing and although shedding was obvious in both types it was greater in the determinate plants as compared with the indeterminate one at 90 days from sowing. Increasing plant density resulted in reductions in number of leaves, branches flowers and dry matter accumulation per plant of both faba bean types. However, plant height criteria took a reversible magnitude. Moreover, under all rates of plant densities the indeterminate type plants surpassed the determinate plants in all growth characters studied except for number of branches per plant at 90 days from sowing. The indeterminate plant leaves significantly contained greater concentrations of photosynthetic pigments i.e., chl. a, chl. b and carotenoids than those found in the determinate plant leaves. Also, the data showed significant reduction in photosynthetic pigments concentration as planting density increases. Light extinction coefficient (K) values reached their maximum level at 60 days from sowing, then it declined sharply at 75 days from sowing. The data showed that the illumination inside the determinate faba bean canopies was better than the indeterminate plants. (K) values tended to increase as planting density increases, meanwhile, significant interactions were reported between faba bean type as planting density on (K) at all growth stages. Both of determinate and indeterminate faba bean plant leaves reached their maximum expansion at 75 days from sowing reflecting the highest LAI values, then their declined in the subsequent growth stage. The indeterminate faba bean plants significantly surpassed the determinate plants in LAI up to 75 days from sowing. Growth analysis showed that NAR, RGR and CGR reached their maximum rates at (60-75 days growth stage). Faba bean types did not differ significantly in NAR at the early growth stage. The indeterminate plants were able to grow faster with significant CGR values than the determinate plants. The indeterminate faba bean plants surpassed the determinate ones in number of seeds/pod and per plant, 100-seed weight, seed yield per plant and per hectare at all rates of plant density. Seed yield increased with increasing plant densities of both types. The highest seed yield was attained for both types 440 10^3 plants ha^{-1}.

Key words: Determinate, indeterminate faba bean, Physiological, yield attributes.

Introduction

Faba bean crop area in Egypt is about (40,000 hectares), it competes with the main Egyptian winter crops, i.e. wheat and berseem. Faba beans, planted area declined from 45 thousand hectares to 35 thousand hectares between 2008 and 2015, which resulted in reducing total production from 160 to 120 thousand tons between the two mentioned years, i.e., 25% decline in 2015 (Agricultural Economics of Egypt, 2016). So, faba bean cropping area in Egypt is limited and competes with the

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major winter crops area (berseem and wheat). Therefore, faba bean intensification is considered as an approach to increase the productivity per unit area. The narrow row and plant cultivation of faba bean have been found to increase the productivity (Abd El Lateef *et al*., 2014). Increasing plant population density per unit area is an approach to increase faba bean yield (López-Bellido *et al*., 2005).
The dominant faba bean type grown in Egypt is the indeterminate type, however, such type is not suitable for intensification to a certain limit. Recently the magnitude of growing determinate (Topless) type has been attracted the attention of several investigators on legume crops. Determinate faba bean type is a mutation characterized with smaller canopy (Stutzel and Aufuammer, 1991 and Pilbeam *et al.,* 1992) and suitable for narrow culture with high plant population densities than the indeterminate type than the indeterminate faba bean type Pilbeam *et al.,* (1991); Stutzel and Aufuammer (1991); Aguilera and Monrique (1995) and Abd El Lateef *et al*. (2014).

The physiological performance of the determinate faba bean under the high plant population densities is differed from the indeterminate type, due to the growth habit which affect in light extinction coefficient (K); and leaf area index (LAI), Stutzel and Aufuammer (1991), Pilbeam *et al*. (1991). Faba bean variable plant densities can affect differentally the growth, yield and components of various cultivars (Abd Alla and Omran, 2002 and Abdel Latif, 2008). In Egypt, most of the researches deal with the effect of planting density on faba bean physiological performance are condensed on the indeterminate type (Bakry *et al*., 2011). Therefore, the aim of this work is to investigate the effect of plant density on the morphological characteristics, flowering, dry matter accumulation and physiological performance of two faba bean types, i. e. determinate and indeterminate grown with different range of plant population densities.

Materials and Methods

Two field experiments were conducted during the two successive winter seasons at Qalubia governorate, Egypt. The experiments aimed to evaluate the morphological and physiological performance of two faba bean types; i.e. indeterminate type var. Giza 461 and the determinate type (FLIP-87-117 strain) different plant densities. Each experiment included ten treatments which were the combinations of two faba bean types (determinate and indeterminate) sown with five plant densities i.e. 19, 22.2, 26.6, 33 and 44 plants m^{-2}. Different plant densities were achieved by modifying the inter plant spacing sowing (35, 30, 25, 20 and 15 cm to obtain the above-mentioned densities, respectively. The experimental design was split plot design with four replicates where faba bean types were allocated in the main plots and plant density in the sub plots, which randomly distributed in the experimental plots.

The experimental soil was ploughed twice, divided into experimental units each of 10.5 m^2 area 3.5 m long x 3.0 m wide. Faba bean seeds were inoculated with the specific rhizobium strain *R. Leguminosarum* and immediately were sown with the planned density for each experimental plot. Sowing dates were 15^{th} and 20^{th} November in the first and second seasons, respectively. During seed-bed preparation, a uniform application of phosphatic fertilizer at 360 kg ha^{-1} calcium superphosphate (15.5% P_2O_5) was applied. At sowing, a starter dose of nitrogen at 36 kg ha^{-1} was applied in the form of ammonium nitrate (33.5% N). Two weeks later, the plants were thinned at one plant to obtain the required density. Potassium was applied at 115.2 kg K_2O ha^{-1} before the first irrigation.
During the growing seasons four vegetative samples were taken after 45, 60, 75 and 90 days from sowing. Five guarded plants were taken randomly from each experimental unit at each sample to determine the following characters: Plant height (cm), number of branches per plant, number of leaves per plant and total dry weight per plant.

Flowering characteristics: during the growing seasons five plants at each plot were labeled as a representative sample to record the total number of flowers appearing. on the sample plants in each plot during the flowering phase, after 75 and 90 days from sowing.

Growth attributes: during the growing season four vegetative samples were taken from each experimental unit at 45, 60, 75 and 90 days from sowing. Each sample consisted of 5 plants taken at random and the following characters were studied: Leaf area index (LAI) at each vegetative sample was estimated according to (Watson, 1952); relative growth rate (RGR), in (mg/g/day); net assimilation rate (NAR) in (g/m^2/day) and crop growth rate (CGR) in (g/m^2/day) were calculated at the growth stages 45-60, 60-75 and 75-90 days from sowing according to the formula described by

Radford (1967).

Photosynthetic Pigments:

A vegetative leaf sample was taken at 60 days from sowing in each season, the leaves were separated, grounded and the photosynthetic pigments were extracted using 85% aqueous acetone. The concentrations of chl. a, chl. b and carotenoids were calculated according to the formula of Wettestine (1957) in mg/dm^2 fresh weight.

Light extinction coefficient (K):

Light intensity was measured above and under faba bean canopies at noon using Lux-meter at 60, 75 and 90 days for sowing. The light extinction coefficient (K) was determined using the Beer-Lambert equation (Sarmadnia and Koocheki, 1994):- $\text{Ln } I_t/I_o = - k \times LAI$
Where; I_t = amount of the light in the lower part of the canopy (MJ m^{-2} s^{-1}), I_0 = amount of the light in the upper part of the canopy (MJ m^{-2}s^{-1}), k = light extinction coefficient and LAI = leaf area index.

At harvest time, ten plants were randomly taken from each experimental unit and the following characters were studied: Number of pods per plant, number of seeds/pod, number of seeds/plant, 100-seeds weight (g) and seed yield per plant (g).
Three rows of each plot were pulled out to obtain the criteria per square meter and per feddan and left to dry, then threshing was done to obtain: Seed yield (ton/ha), straw yield (ton/ha) and harvest index (%).

The obtained data were subjected to the statistical analysis of the split plot design. Then the homogeneity test was applied using Bartlet's test, then the data were pooled, and the combined analysis was carried out according to Gomez and Gomez (1984). Treatment means were compared using least significant difference test LSD at 5% probability level.

Results and Discussion

Plant height:

Table (1) summarizes the development of faba bean plants at the growth stages after 45, 60, 75 and 90 days from sowing. The data show that the differences between indeterminate and determinate faba bean types were insignificant after 45 and 60 days from sowing. However, .in the subsequent growth stages; i.e., 75 and 90 days the indeterminate type plants were significantly taller than the determinate ones. Such magnitude is mainly due to the growth habit since the determinate plants probably possesses shorter and less number of nodes per stem compared with the indeterminate plants (Pilbeam *et al.,* 1991).

From the same Table (1) the data exhibit that plant height was also affected by plant density at all sampling dates. Faba bean plants. Tended to be taller at when the plant density increased. Such results agree with those obtained by Abd El Lateef *et al*. (2009). However, the interaction between faba bean type and plant density was insignificant. The tallest determinate and indeterminate plants were recorded with the greater plant density while the shortest were with the lower. The obtained results indicated that plant height of both faba bean types was sensitive to the changes in plant population density and the competition was higher at the higher planting density.

Number of branches/plant:

Table (1) shows the number of branches/plant after 45, 60, 75 and 90 days from sowing as affected by faba bean type, row and plant spacings. The data indicated that the differences between faba bean types in number of branches were insignificant at 60 and 75 days from sowing. However, at 90 days from sowing the determinate plants formed more significant number of branches per plant as compared with indeterminate plants. Such increase in number of branches at 90 days is resulted due to the growth habit where faba bean plants flowered after 75 days from sowing. Consequently, the

determinate plants began to form new side branches which increased as the plants advanced in the age. These results agree with those of Heath *et al*. (1994) who indicated that determinate faba bean possessed more side branches than the indeterminate. Significant differences in number of branches per plant were recoded due to planting density. Lower plant density resulted in significant increase in number of branches per plant after 60 and 75 days from sowing. The greatest number of branches was formed with the planting density of 19 plants m^{-2} at all sampling dates. The interaction between faba bean type and plant density was insignificant in all sampling dates. Coelho and Pinto (1989) note that the faba bean displays great plasticity in response to variations in plant density. Also, the duration of the vegetative period and the weather conditions during vegetative growth are of great importance for the compensatory capacity of faba beans, since they affect the number of stems per plant. In a longer growing season and given optimum growing conditions, plants grown at low density can effectively compensate for deficiencies with respect to those grown at high densities, by fully developing a larger number of side branches. The obtained results are in agreement with those obtained by Abd El Lateef *et al*. (2005) in determinate mungbean. Yucel (2013) found that the plant density had a significant effect on plant height, branches number $plant^{-1}$.

Table 1: Effect of faba bean type and planting density on plant height, No. of branches and leaves at different sampling dates (Average of two seasons).

Faba bean type (A)	No. of plants m^{-2} (B)	Plant height (cm)				No. of branches				No. of leaves			
		Days				Days				Days			
		45	60	75	90	45	60	75	90	45	60	75	90
Indeterminate	44	20.1	43.9	67.3	85.1	1.9	2.6	2.5	2.4	13.5	20.4	28.2	27.1
	33	19.4	36.8	60.9	80.5	2.1	2.8	3.3	2.3	13.5	25.7	32.3	33.2
	26.6	19.3	33.9	55.4	77.6	2.4	3.3	3.3	3.1	11.7	23.4	28.8	35.5
	22.2	19.6	33.1	56.2	75.3	2.0	3.0	3.3	3.4	11.8	21.7	35.8	42.6
	19	18.1	26.8	55.4	61.8	2.4	3.1	4.2	3.3	12.4	22.9	38.2	36.8
Mean		19.3	34.9	59.0	76.1	2.2	3.0	3.3	2.9	12.6	22.8	32.7	33.0
Determinate	44	20.5	38.6	55.2	69.1	1.7	1.8	3.2	3.2	8.8	17.2	24.7	27.3
	33	19.3	34.6	52.3	63.9	1.9	2.9	3.4	3.3	10.4	21.0	24.1	24.2
	26.6	19.3	33.8	52.5	61.7	1.8	3.2	4.1	4.0	10.1	23.6	30.0	21.7
	22.2	17.7	31.0	48.1	58.8	2.3	2.8	3.8	4.1	10.2	21.2	26.7	26.6
	19	18.6	29.6	51.1	54.3	2.3	3.2	3.5	4.3	10.4	20.4	30.5	28.1
Mean		19.1	33.5	51.8	61.6	2.0	2.8	3.6	4.9	10.0	20.7	27.2	25.6
Mean for plant density	44	20.3	41.3	61.3	77.1	1.8	2.2	2.9	4.1	11.2	18.8	26.5	27.2
	33	19.3	35.7	56.6	72.2	2.0	2.8	3.4	2.8	11.9	23.4	28.2	28.7
	26.6	19.3	33.8	53.9	69.6	2.1	3.2	3.7	3.6	10.9	23.5	29.4	28.6
	22.2	18.7	32.1	52.2	67.1	2.2	2.9	3.6	3.7	10.7	21.5	31.2	34.6
	19	18.4	28.2	53.2	58.0	2.4	3.2	3.9	3.8	11.4	21.6	34.2	32.4
Mean		19.2	34.2	55.4	68.8	2.1	2.9	3.5	4.3	11.2	21.8	29.9	29.3
LSD at 0.05 A		NS	NS	2.1	3.2	NS	NS	NS	1.0	0.4	1.4	1.5	2.3
LSD at 0.05 B		1.2	1.4	2.1	2.4	NS	0.3	0.2	NS	NS	NS	2.6	NS
LSD at 0.05 AxB		NS	NS	NS	NS	NS	NS	NS	NS	NS	3.1	3.7	5.6

Number of leaves/plant:

Data presented in Table (1) show that the indeterminate plants produced significant greater number. of leaves/plant than the determinate plants. The superiority of the indeterminate in number of leaves $plant^{-1}$ may be due to the indeterminate plants were taller than the determinate plants and the growth continued after flowering. Similar results were obtained by Stutzel and Aufhammer (1991).

Fewer number of leaves were formed at 60, 75 and 90 days from sowing as plant density increased. Similar magnitude was recorded for the interaction between faba bean type plant density which resulted in significant effect on number of leaves plant^{-1} at 60, 75 and 90 days from sowing date. Such significance expresses the complex interference between the two factors.

Dry matter accumulation (g)/plant:

Data presented in Table (2) show significant differences between faba bean types at 45 and 90 days from sowing in the total dry weight plant^{-1}. It is clear that the indeterminate type plant accumulated more dry matter than the of determinate type. While, the differences were insignificant after 60 and 75 days from sowing. The superiority of the indeterminate faba bean plants may be due to the indeterminate plants possessed taller canopy with higher number of leaves. However, the determinate plants possessed more side branches, they did not compensate the amount of the dry matter accumulated by the indeterminate plants. These results, are in agreement with those of Stutzel and Aufhammer (1991); Stutzel *et al.* (1994) and Abd El Lateef *et al*. (2014). They indicated that dry matter production was generally higher in the indeterminate cultivars than in the determinate faba bean. From the same Table, the results indicate that dry matter accumulation was significantly affected by plant density. It can be noticed that successive increases in dry matter plant^{-1} were reported as plant density decreased. The greatest dry matter accumulation was occurred at 19 plants m^2 at all sampling dates. Similar findings were reported by López-Bellido *et al.,* 2005. The interaction between faba bean type and row spacing insignificant, on dry matter plant^{-1} at 90 days from sowing. The highest plant dry matter plant^{-1} was recorded under at 19 plants m^2 and the lowest at 44 plants m^{-2} respectively, in both determinate and indeterminate types.

Table 2: Effect of faba bean type and planting density on dry matter (g plant-1) and No. of flowers plant-1 at different sampling dates (Average of two seasons).

Faba bean type (A)	No. of plants m^{-2} (B)	Dry matter g/plant				No. of flowers/plant	
		Days				Days	
		45	60	75	90	75	90
Indeterminate	44	2.65	6.35	12.08	20.07	18.03	15.40
	33	3.02	7.73	12.17	22.62	26.37	24.83
	26.6	3.25	7.85	12.55	24.92	26.30	24.37
	22.2	4.70	8.97	12.55	26.19	25.37	24.30
	19	2.70	7.53	13.38	28.25	29.30	25.90
Mean		3.27	7.69	12.55	24.41	25. 0	22.96
Determinate	44	2.98	6.42	11.52	17.04	22.60	15.63
	33	1.90	6.85	11.97	19.18	23.20	16.37
	26.6	2.46	7.45	13.08	20.02	26.50	16.03
	22.2	2.37	7.50	12.62	21.22	26.03	24.60
	19	2.32	7.07	13.59	23.68	30.17	26.83
Mean		2.09	7.06	12.53	20.23	25.70	19.89
Mean for plant density	44	2.23	6.39	11.80	18.55	20.32	15.52
	33	2.28	7.30	12.07	20.90	24.79	20.60
	26.6	3.09	7.90	12.82	22.47	26.40	20.20
	22.2	2.14	8.24	12.59	23.70	25.70	24.45
	19	2.81	7.30	13.44	25.97	29.74	26.37
Mean		2.51	7.38	12.55	22.32	25.40	21.43
LSD at 0.05 A		0.48	NS	NS	1.14	0.53	1.33
LSD at 0.05 B		NS	NS	NS	0.9	2.24	1.41
LSD at 0.05 AxB		NS	NS	NS	NS	3.2	2.42

Number of flowers/plant:

Table (2) shows the data of number of flowers formed by faba bean types grown under different row and plant spacing at 75 and 90 days from sowing. The indeterminate faba bean significantly exceeded the determinate type in number of f1owers plant^{-1} at 75 and 90 days from sowing in addition the highest plant density significantly reduced the number of flowers formed compared with the other plant densities at 75 and 90 days from sowing. These results are generally in accordance with those obtained by Barry and Storey (1979) and Quagliotti *et al.* (1994). The interaction (faba bean type x plant density) was significant at 75 and 90 days from sowing. The data of the interaction effect of both faba bean types under different plant densities indicate that flower shedding was greater under the severs plant competition conditions (44 plants m^{-2}). Several researchers explained the phenomena of faba bean flower shedding and attributed it to the inadequate supplies of assimilate to meet the demands of each reproductive sink, Unkovich *et al*. (2010) reported that While flowering over an extended period in indeterminate crops means that developing flowers and pods are subject to a broader range of climatic conditions, some of which may cause abortion of reproductive parts, it also means that aborted flowers or seeds may be compensated for by later formed flowers.

Photosynthetic pigments chl. a, chl. b and carotenoids:

Photosynthetic pigments of both faba bean types at the different plant densities at 60 days from sowing are presented in Table (3). Indeterminate faba bean leaves contained significant greater chl. a, chl. b and carotenoids than found in the determinate leaves. Plant density insignificantly affected photosynthetic pigments content in faba bean leaves. In general, as plant density increased insignificant reduction in chl. a, chl. b and carotenoids occurred in faba bean leaves. Such reduction in photosynthetic pigments under high plant density may be due to the increase in competition for environmental such as nutrients and light in addition, no significant interactions between faba bean type and plant density were reported.

Leaf area index (LAI):

The results in Table (3) show that faba bean leaves reached their maximum expansion at 75 days from sowing either for the determinate or the indeterminate types, then' it declined sharply at 90 days from sowing. In general, LAI values exhibit insignificant differences between indeterminate and determinate types at 45 and 90 days from sowing (Table, 2). However, indeterminate type plant surpassed the determinate plants in LAI criteria after 60 and 75 days from sowing. In other words, the indeterminate type plants could expand and cover greater land area more than occurred by the determinate plants at these growth stages. In this respect, some investigators reported that the indeterminate faba bean type produced higher LAI than the determinate type, Pilbeam *et al.* (1991), Stutzel *et al.* (1992) and Silim and Saxena (1992).

From Table (3), it is clear that significant effects were observed due to density at all growth stages studied Leaf area index values at the higher plant densities tended to be the greatest and gradually decreased as they increased. The interaction between faba bean type x plant density after 45 days from sowing was significant indicating no clear magnitude resulted from these interactions at successive growth stages studied.

The obtained results of LAI at the different growth stage indicate that both determinate and indeterminate faba bean gave similar LAI values at the peak leaf expansion periods (60 and 75 days from sowing). Also, higher plant density resulted in higher LAI values. Several investigators came to similar conclusions on where they found for longer growing season, together with optimum growing conditions, may lead to the fuller development of a larger number of side branches at low plant densities, LAI and dry matter values are similar to those recorded at high plant densities, López-Bellido *et al*. (2005).

Table 3: Effect of faba bean type and planting density on LAI, Light Extinction Coefficient (K) and Photosynthetic pigments (mg/dm2) at different sampling dates (Average of two seasons).

Faba bean type (A)	No. of plants m^{-2} (B)	LAI				Light Extinction Coefficient (K)			Photosynthetic pigments mg/dm2 at 60 DAS		
		DAS				DAS					
		45	60	75	90	60	75	90	Chl. a	Chl. b	Carotenoids
Indeterminate	44	2.92	5.59	9.7	5.02	1.16	0.38	0.30	6.62	1.82	2.19
	33	1.77	3.95	8.99	3.49	2.09	0.90	0.41	6.91	2.09	2.70
	26.6	1.83	4.1	7.67	3.05	2.54	0.35	0.48	6.91	2.83	2.75
	22.2	1.38	3.57	6.39	2.74	2.71	0.38	0.51	7.38	2.87	3.03
	19	1.15	3.04	5.25	2.6	2.85	0.45	0.70	7.53	3.39	3.23
Mean		1.81	4.05	3.72	3.38	2.27	0.34	0.48	7.07	2.6	2.78
Determinate	44	2.43	4.73	6.41	3.8	1.16	0.31	0.51	6.25	1.52	1.81
	33	2.10	3.54	8.22	3.62	2,29	0.36	0.53	6.27	1.90	2.25
	26.6	1.58	3.21	6.15	3.2	2.58	0.42	0,67	6.47	2.49	2.30
	22.2	1.12	2.64	4.97	2.63	2.87	0.46	1.21	7.10	2.64	2.91
	19	1.23	2.62	3.93	2.50	3.60	0.53	1.54	7.19	2.91	3.11
Mean		1.69	3.35	3.09	3.15	2.5	0.41	0.89	6.66	2.29	2.51
Mean for plant density	44	2.69	5.18	5.27	4.42	1.16	0.27	0.41	6.43	1.68	2.02
	33	1.94	3.75	8.61	3.56	2,20	0.32	0.48	6.59	1.99	2.41
	26.6	1.71	3.66	6.91	3.13	2.56	0,39	0.58	6.69	2.66	2.50
	22.2	1.26	2.61	5.69	2.69	2,79	0.42	0.86	7.24	2.76	2.90
	19	1.19	2.83	5.54	2.55	3.23	0.49	1.12	7.36	3.16	3.10
Mean		1.76	3.71	3.41	3.27	2.39	0,38	0.69	6.86	2.45	2.61
LSD at 0.05 A		NS	0.45	0.4	NS	0.19	0.05	0.16	0.19	0.23	NS
LSD at 0.05 B		0.31	0.57	0.57	NS	0.21	0.03	0.08	NS	NS	NS
LSD at 0.05 AxB		0.44	NS	NS	NS	NS	NS	0.11	NS	NS	NS

Light extinction coefficient (K):

The light extinction coefficient (K) which expresses the amount of light extinction along biological canopy, it is expressed as the term (K). Data in Table (3) show significant differences in (K) values between determinate and the indeterminate plants at 60, 75 and 90 days from sowing. The determinate faba bean plants showed better Illumination circumstances than that reported by the indeterminate ones at the three sampling dates. Moreover, the data also show that K values tended to reach the peak values at the early growth stages (60 days), then it decreased at 75 days and became slightly greater at 90 days from sowing. The fluctuations in K at the studied growth stages could be attributed to the canopy development where at the early growth stages, the arrangement of the plants permits light penetration along the canopy freely more than the at subsequent stages. Meanwhile, it is worthy to notice that the data of K sharply contrasted with LAl values (Table, 2) where the later were smaller at 60 days and reached the peak at 75, days from sowing, then it decreased at 90 days. In this respect, some investigators reported that the determinate type plants intercept more K than the indeterminate type (Stutzel and Aufhammer, 1991 and Stutzel *et al*., 1994) while, Silim and Saxena (1992) reported the opposite. On the other hand, other investigators did not find any significant differences between the determinate and the indeterminate type in the average of light extinction coefficient (K), Pilbeam *et al.* (1991). Growth is usually limited by competition between plants for

solar radiation, when environmental conditions are favorable. In Mediterranean conditions, individual plant growth may be limited by lack of rainfall, particularly at high plant densities, while competition for radiation is low (Loss *et al*., 1998).

Net Assimilation Rate, NAR (g/m^2/day):

Data in Table (4) show that faba bean plant types did not show significant difference in NAR except at the growth stage of (60-75) days from sowing. However, significant effects due to row spacings were reported at the three growth stages studied. Reducing plant led to insignificant increase in NAR at the growth stages (45-60) and (60-75) days from sowing. Meanwhile, as plant density became fewer significant increase in NAR was reported. Moreover, as faba bean plants advanced in the NAR decreased. The interaction between faba bean type and plant density were insignificant at all growth stages. Such results indicate the biological stress resulted from higher plant density was obvious with the determinate faba bean plants more than the indeterminate plants. These results are in contrast with those obtained by Shalaby and Mohamed (1978), they found reduction in NAR as plant spacing increased from 10 to 25 cm.

Table 4: Effect of faba bean type and planting density on growth attributes (NAR, RGR and CGR) at different sampling dates (Average of two seasons).

Faba bean type (A)	No. of plants m^{-2} (B)	NAR (g/m2/day)			RGR (mg/g/day)			CGR (mg/g/day)		
		45-60 days	60-75 days	75-90 days	45-60 days	60-75 days	75-90 days	45-60 days	60-75 days	75-90 days
Indeterminate	44	4.89	5.8	4.89	39.45	47.15	36.79	14.53	28.4	34.3
	33	5.05	6.87	5.05	43.45	50.6	40.25	11.32	28.2	32.3
	26.6	5.67	7.23	5.67	47.79	51.67	44.22	11.3	26.2	29.3
	22.2	6.73	7.68	6.73	50.37	54.29	47.12	9.61	25.0	28.6
	19	7.39	7.75	7.39	56.11	57.24	47.74	7.78	20.9	23.1
Mean		5.95	7.06	5.95	4745	52.19	43.22	10.91	25.7	29.5
Determinate	44	4.98	5.24	4.34	36.0	41.34	30.17	12.83	24.5	25.4
	33	5.27	5.61	4.82	38.15	44.04	32.17	9.35	22.4	23.0
	26.6	5.92	7.00	5.43	40.22	47.09	37.74	9.05	20.3	19.5
	22.2	6.08	8.11	5.81	43.2	49.15	36.87	7.78	19.4	18.3
	19	6.57	8.2	6.28	46.56	52.77	37.75	7.43	16.2	16.7
Mean		5.76	6.83	5.34	40.83	46 88	34.93	9.29	20.6	20.6
Mean for plant density	44	4.94	5.5	3.43	37.73	44.25	33.48	13.68	26.5	39.9
	33	5.16	6.24	3.97	40.8	47.32	36.51	10.34	25.3	27.7
	26.6	5.80	7.12	4.22	44.0	49.38	39.48	10.18	23.3	24.4
	22.2	6.41	7.90	4.79	46.78	51.72	41.99	8.7	22.2	23.4
	19	6.98	7.98	5.65	50.38	55.01	43.93	7.61	18.5	19.9
Mean		5.86	6.95	4.41	44.14	49.53	39.08	10.1	23.2	25.1
LSD at 0.05 A		NS	NS	0.35	4.3	4.5	4.5	1.2	0.99	2.07
LSD at 0.05 B		NS	NS	NS	NS	NS	NS	1.12	NS	NS
LSD at 0.05 AxB		NS	NS	NS	NS	NS	NS	NS	NS	NS

Relative growth rate, RGR (mg/g/day):

Significant effects on RGR were reported due to faba bean type, at the growth stages of 45-60, 60-75 and 75-90 days from sowing Table (4). In general, faba bean plants reached their maximum

RGR at the growth stage of 60-75 days from sowing and decreased in the further stage 75-90 days from sowing. Greater RGR values were reported by indeterminate plants compared with the determinate plants. In addition, successive increases in RGR were reported as plant density decreased at the three growth stages mentioned. meanwhile no significant interactions were reported by the plant type and plant density.

Crop growth rate, CGR (g/m^2/day):

Data in Table (4) show significant effects due to faba bean type, and plant density on CGR at the three growths stages 45-60, 60-75 and 75-90 days from sowing. Indeterminate faba bean possessed the ability to grow more rapidly than the determinate plants with significant rate at the three growth stages. Also, as plant density became greater faba bean plants tended to grow faster with high significant rates. The data clearly show that both faba bean types reached their peak CGR at 60-75 days from sowing, and then they declined. The interaction between faba bean type and plant density was significant at all growth stages. The interaction between faba bean type and plant density was insignificant at all sampling periods.

The obtained results show that the highest CGR value was reported at 44 plants m^{-2}. Meanwhile the data of CGR are parallel to those obtained on DM, LAI, NAR, RGR criteria in the peak growth stage. The obtained results are in harmony with those obtained by Shalaby and Mohamed (1978) and in contrast with those obtained by Coelho and Pinto (1989). Also, Stutzel and Aufhammer (1992) reported greater CGR in the indeterminate than the determinate faba bean but not affected by plant distribution. In this respect, the behavior of other growth indices in response to variation in plant density is generally linked to the dry matter and LAI values attained over the various crop stages. Polign and Uggenti (1989) report different LAR, NAR and relative growth rate (RGR) values for different botanical types (mayor, equina and minor). With regard to plant density, Singh *et al*. (1992) and Tuttobene and Vagliasindi (1995) detected an increase in crop growth rate (CGR), when sowing rate was increased, while Singh *et al*. (1992), and in some cases, El-Zahab *et al*. (1981) observed a decrease in RGR and NAR values. However, Coelho and Pinto (1989) failed to find any significant difference in NAR for the different densities studied.

Yield

Number of pods/plant:

From table (5), it is clear that no significant differences between the determinate and the indeterminate types as well as plant density and their interaction. Insignificant reduction in the number of pods per plant was given as plant density increased and the greatest reduction was recorded at 44 plants m^{-2}. It is worthy to note that pod-set percent (relatively to number of flowers initiated at 75 days) of the indeterminate and the determinate faba bean type plants were 40.6 and 41.5% respectively. Under the highest plant density and higher severe plant competition (44 plants m^{-2}) it seems that the determinate plants could tolerate flower shedding and the percent of pod set was (49%) as compared with for the indeterminate plants (31.1 %). Such results indicate that determinate faba bean plants seems to be favorable for sowing with higher densities than the indeterminate plants. Furthermore, although the number of pods formed were lower under the highest plant density but in terms of unit area the determinate plants could compensate such reduction. The obtained results are in harmony with those obtained by Pilbeam *et al*. (1991) and Silim and Saxena (1992). Pilbeam *et al*. (1991) report that high plant densities also reduce the number of pods per stem as well as the number of pods per plant. Adisarwanto and Knight (1997) found a strong correlation between seed yield and number of pods per plant for different densities.

Number of seeds per pod and per plant:

Data presented in table (5), show that the indeterminate plants significantly exceeded the determinate ones in number of seeds per pod. Increasing plant density significantly increased number of seeds per pod at compared with the lowest density. The interaction between faba bean type and

plant density was insignificant. Similar magnitude was reported on number of seeds per plant due to faba bean type (table 5). Greater number of seeds was produced by indeterminate faba bean plants compared with determinate type because of the higher number of seeds per pod formed for the indeterminate type. Successive increase in number of seeds/plants were seen as row or plant density decreased. Significant interaction between faba bean type x plant density) was reported. Such results are in agreement with those obtained by EL- Deeb (1982) and Amer *et al.* (1992). Moreover, several investigators reported that within any given faba bean cultivar, number of seeds per pod shows a relatively stable response to variations in sowing date or plant density (Stringi *et al*., 1986; Graf and Rowland, 1987; Salih, 1989; Coelho and Pinto, 1989 and López-Bellido *et al.,* 2005). Also. Dahmardeh *et al.* (2010) showed that some characters were markedly affected by plant density, except plant height, height of the lowest pods of surface, 100 seeds weight, number of pods per plant and number of seed per pod. Increasing plant density from 12.5 to 20 plants m^{-2} significantly increased economical yield and biological yield.

Table 5: Effect of faba bean type and planting density on yield and yield components characters(Average of two seasons).

Faba bean type (A)	No. of plants m^{-2} (B)	No. of pods/plant	No. of seeds/pod	No. of seeds/plant	Seed yield g/plant	100-Seed weight (g)	Seed yield ton/ha	Straw yield ton/ha	HI %
Indeterminate	44	7.3	3.2	16.0	16.0	72.9	3.74	5.06	35.0
	33	9.4	3.2	22.4	17.9	75.0	3.54	3.62	39.3
	26.6	10.1	3.2	24.0	21.3	75.4	3.30	4.01	44.2
	22.2	11.9	3.5	24.6	23.0	75.0	3.17	3.34	42.7
	19	12.8	3.7	25.7	25.1	74.0	2.96	3.19	45.5
Mean		10.3	3.6	22.5	20.7	74.4	3.34	3.84	41.3
Determinate	44	8.7	2.6	16.0	9.0	73.3	3.15	2.88	35.4
	33	9.5	2.7	17.6	12.3	73.4	2.94	3.22	38.0
	26.6	9.9	2.7	21.7	14.8	74.0	2.53	2.69	40.5
	22.2	11.1	2.9	23.7	16.1	76.4	2.32	2.38	42.3
	19	11.8	3.0	24.3	18.5	74.0	2.19	2.28	44.9
Mean		10.2	2.7	20.7	14.1	75.2	2.63	2.69	40.2
Mean for plant density	44	8.0	2.9	15.7	12.5	73.1	3.45	3.98	35.2
	33	9.3	3.0	20.0	15.1	74.2	3.24	3.41	38.7
	26.6	10.0	3.1	22.8	16.5	74.7	2.92	3.36	42.3
	22.2	11.5	3.2	24.2	19.5	75.7	2.75	2.88	42.5
	19	12.3	3.4	25.0	21.8	74.0	2.57	2.74	45.2
Mean		10.2	3.1	21.6	17.4	74.3	2.99	3.26	40.8
LSD at 0.05 A		NS	0.2	0.8	1.8	0.5	0.77	0.15	NS
LSD at 0.05 B		NS	0.2	2.0	NS	2.0	0.95	NS	NS
LSD at 0.05 AxB		NS	NS	2.8	3.5	NS	NS	NS	NS

100-seed weight:

Data in table (5), show that 100-seed weight (gm) of the indeterminate type were significantly heavier than that of the determinate type. Meanwhile, plant density significantly affected 100-seeds weight. Similar findings on 100-seed weight were reported by Barry and Storey (1979) who found that 100 seed weight were not affected by changes in density or less changed and Bakry *et al.* (2011) came to a similar conclusion.

Seed yield per plant:

Data in table (5) show that the indeterminate faba bean seed yield per plant (gm) significantly surpassed that of the determinate type. Increasing plant density increased seed yield per plant and the lowest seed yield per plant was produced at 44 plants m^{-2} while the greatest yield was obtained at 19 plants m^{-2}. Similarly, the interaction between faba bean type and plant density was significant. The superiority of the indeterminate faba bean type in seed yield per plant could be attributed to their its greater photosynthetic area, more dry matter accumulated, greater number of seeds per pod and per plant. The obtained results are in harmony with those obtained by López-Bellido *et al.* (2005). Idris (2008) indicated that increasing plant spacing increased number of pods per plant and consequently gave the highest seed yield.

Harvest index (HI%):

Data in table (5), show insignificant differences between the determinate and the indeterminate faba bean types or plant density and their interaction in harvest index. As row or plant spacings increased HI was increased to reach the maximum values at lowest plant density. Such results did not agree with those obtained by Pilbeam *et al.* (1991) who found that indeterminate plants had greater HI than the determinate plants due to their greater canopy. Also, he found that HI decreased with increasing plant density, since high densities increased total dry matter rather than seed yield. Determinate cultivars displayed a lower HI, although their response to varying density was identical to that of indeterminate cultivars (Stutzel and Aufhammer, 1992).

Straw yield ton/ha:

Indeterminate faba bean significantly exceeded the determinate type in straw yield per ha (ton) as shown in Table (5). The data showed also significant effects due to row or plant spacings. On contrast to other yield components, plant density increased straw yield per hectare. The highest straw yield was obtained for both faba bean types at 44 plants m^{-2}. The interaction between faba bean type and plant density was. The straw yield increase of the indeterminate faba bean type may be due to its greater height and larger canopy compared with the determinate ones. Also, the high straw yield of both indeterminate and determinate plants under the highest densities may be mainly due to the increase in plant population densities in these treatments. In this respect, some investigators mentioned that increasing plant density by closer spacing increased significantly the straw yield per feddan, Abd El Lateef *et al*. (2005).

Seed yield ton/ha:

Data in Table (5) show clearly that seed yield ton/ha of the indeterminate faba bean type significantly exceeded the determinate one regardless plant density. Planting faba bean at 44 plants m^{-2} resulted in producing the highest seed yield per hectare, meanwhile the lowest seed yield per hectare was obtained at 19 plants m^{-2}. The interaction between faba bean type and plant density was insignificant. The differences in the yield of the indeterminate type plant at 44, 33, 26.6 and 22.2 plants m^{-2} were insignificant indicating that it is favorable to increase the density up to 44 plants m^{-2}. On contrast, the determinate faba bean type gave its higher yield at 44, 33, and 26. Plants m^{-2} which was significantly superior than the other densities. Such results indicate that the determinate faba bean plant give their potential yield at higher density than the indeterminate one. Several investigators reported higher increase in seed yield by increasing faba bean plant population Abd El Lateef *et al*., 2014. Also, Pilbeam *et al*. (1990) reported that the optimum density for determinate varieties was higher than that for the indeterminate varieties. In addition, (Stutzel and Aufhammer, 1992) indicated that at the same plant density, seed yield is lower in determinate than in indeterminate cultivars (Stutzel and Aufhammer, 1992). Also, Abd El Lateef *et al*. (2014) came to similar conclusion. Moreover Unkovich *et al*. (2010) reported that determinate crops generally have higher harvest indices as most crop resources are diverted to grain production once flowering has commenced. In contrast, for indeterminate crops, such as most legumes and oilseeds, concurrent vegetative and

reproductive growth is maintained, resulting in competition for resources between vegetative and reproductive sinks (Pate and Armstrong, 1996), and flowering occurs over an extended period during which flowers and pods may be subjected to a range of climatic stresses. Yucel (2013) found that the plant density had a significant effect on pods number plant^{-1}, seed number plant^{-1}, seed weight plant^{-1}, 100-seed weight and seed yield ha^{-1} in both seasons. Increasing plant density from 11 to 44 plants m^{2} significantly decreased branches number plant^{-1}, pods number plant^{-1}, seeds number plant^{-1}, seed weight plant^{-1} and 100-seed weight, however, plant height significantly increased. The highest seed yield ha^{-1} was obtained at 22 plants m^{-2} density. Dergar *et al*. (2014) found that the maximal and minimal grain yields were obtained for density 12 plants m^{-2} and density 8 plants m^{-2} with averages of 487.49 and 369.69 g m^{-2}, respectively.

Conclusion

It could be concluded form this study that the indeterminate type of faba bean plants out yielded the determinate type at all plant density treatments thus, planting the indeterminate faba bean type is favorable. Under the conditions of this study. Moreover, the determinate type plants could be used as a genetic source in plant breeding programs.

Acknowledgment

The authors wish to present this work to the soul of the late Professor Dr M.S. Zidan for his role in carrying out this work.

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