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Variation in leaf traits, yield and yield components of faba bean in response to planting dates and densities

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ABSTRACT

Although faba bean (*Vicia faba* L.) is a rich source of protein and forage yet its yield is low in Pakistan. Planting time and density are the two major factors affecting faba bean yield. The objective of this study was to evaluate the effect of planting dates and densities on the leaf traits, yield and yield components of faba bean at New Developmental Farm, NWFP Agricultural University, Peshawar. Faba bean was planted on 8 dates from 20 September to 27 December at two-week interval at four planting densities of 150,000, 300,000, 450,000 and 600,000 plants ha^{-1}. Planting dates significantly affected days to 50% flowering, pods plant^{-1}, leaves plant^{-1} , leaf area (LA), leaf weight (LW), specific leaf area (SLA) and specific leaf weight (SLW), while planting densities significantly affected days to 50% flowering, LA, SLW, pods plant^{-1}, and 100 grains weight. Crop planted on September 20 or October 4 took maximum days to 50% flowering (64), produced more pods plant^{-1} (21.8), heavier grains (66.13 g), more and heavier leaves plant^{-1}. Planting density of 450,000 plants ha^{-1} improved yield and yield components, and further increase in planting density decreased leaf traits, pods plant^{-1} and grain yield. It may be concluded that faba bean can be planted up to October 4 at 450,000 plants ha^{-1} to obtain maximum yield in the study area.

INTRODUCTION

Faba bean (*Vicia faba* L.) is a rich source of protein and used for feed, soap making, green vegetable, salad and forage (Daur et al., 2008). In spite of its numerous advantages, the yield in Pakistan is low. Yield is the product of proper growth, development, source sink relationship and assimilates partitioning to the leaf for efficient light interception, grains and other plant parts. Planting time is crucial in many farming systems because early or late sowing in the growing season expose the crop to drought, adverse temperature, pests and diseases attack. Planting after October decreased dry matter production and yield of faba bean (Berhe, 1998; Rajender *et al*., 1993, Sliman, 1993, McDonald *et al*., 1994; Kurmawanshi *et al*., 1994). Late sowing increases the severity of insect and disease attack (Sahile *et al*., 2008; McDonald *et al*., 1994). Plant density is another important factor determines growth, development and yield (McRae *et al*., 2008; Hassan and Khaliq, 2008; McMurray, 2004; Mathews *et al*., 2008). However, maintenance of optimum planting density is always a big problem to the farmers. Sub-standard plant density result in high weeds infestation, poor radiation use efficiency and low yield, while dense plant population on the other hand cause lodging, poor light penetration in the canopy, reduce photosynthates production due to shading of lower leaves and drastically reduce the yield (Lemerle *et al*., 2006; Lemerle *et al*., 2004;Vassilev, 1998; Jettner *et al*., 1998a &b). Salih (1992) reported that seed yield was highest at 499,000 plant ha^{-1} compared with 333,000 or 667,000 plants ha^{-1}. Rajender *et al*., (1993) concluded that thicker density of 330,000 plants ha^{-1} produced higher seed yields than thin density. Mathews *et al*., (2008) concluded that optimum plant density was 200,000 to 240,000 plants ha^{-1}, while Armstrong *et al*., (2008) reported increase in yield up to 800,000 plants ha^{-1}. The present research was conducted to evaluate response of faba bean planted on different dates at various planting densities under agro-climatic condition of Peshawar, Pakistan.

MATERIAL AND METHODS

The experimental site is located at 34.01^0 N latitude, 71.35^0 E longitude, and at an altitude of 350 m above sea level in Peshawar valley. Peshawar is located about 1600 km North of the Indian Ocean and has the continental type of climate. Soil texture is clay loam, low in organic matter (0.87 %), extractable phosphorus (6.57 mg kg^{-1}), exchangeable potassium (121 mg kg^{-1}), alkaline (pH 8.2) and calcareous in nature (Amanullah *et al*., 2009). Average air temperature recorded during faba bean growing season was 23.2,17.5,13.6,10.2,11.1 15.6, 24.4 and 31.4 in October, November, December, January, February, March , April and May respectively (Table 1).

Table 1: Average air temperature during growing season of faba bean from October 1999 to May 2000.

		Average temperature			
Month	Period	Max.	Min.	Mean Temperature	Monthly Mean Temperature
October	1-15	31.8	15.3	23.6	
	16-31	31.0	15.0	23.0	23.3
November	1-15	26.9	10.9	18.9	
	16-30	25.1	7.1	16.1	17.5
December	1-15	24.8	5.2	15.0	
	16-31	22.3	2.2	12.3	13.6
January	1-15	16.3	1.8	9.1	
	16-31	20.6	2.2	11.4	10.2
February	1-15	17.7	3.3	10.5	
	16-29	20.9	2.7	11.8	11.1
March	1-15	25.0	2.0	13.5	
	16-31	25.9	9.0	17.4	15.5
April	1-15	31.6	12.8	22.2	
	16-30	35.5	17.8	26.7	24.4
May	1-15	39.4	19.6	29.5	
	16-31	41.5	24.9	33.2	31.4

Experimentation

Experiment was conducted in randomized complete block design with split-plot arrangement using four replications during 1999-2000. The crop was planted at 14 days interval on 8 dates from 20th September to 27th December using four plant densities (150,000, 300,000, 450,000 and 600,000 plants ha^{-1}) at New Developmental Farm, NWFP Agricultural University, Peshawar. Dates were allotted to main plots while planting densities were allotted to subplots. A plot size of 3.5x2.4m having 6 rows 3.5m long was used. Row to row distance of 40 cm was maintained. The desired densities were maintained by varying plant to plant distance for each density. Prior to sowing the field was thoroughly prepared. Nitrogen and phosphorus were applied in the form of diammonium phosphate (DAP) at 100 kg ha^{-1} having 18% N and 46% P_2O_5. Irrigation, hoeing and other cultural practices were uniformly followed for all treatments. Data was recorded on days to 50% flowering, number of leaves $plant^{-1}$, leaf area $plant^{-1}$, leaf weight $plant^{-1}$, specific leaf area (SLA) $plant^{-1}$, specific leaf weight (SLW) $plant^{-1}$, number of pods $plant^{-1}$ and grain yield.

Days to 50% flowering

Days to 50% flowering were counted from the date of planting till 50% flowering were developed on plants in each subplot.

Leaves plant^{-1}

Number of leaves $plant^{-1}$ data was recorded by counting number of leaves in 5 randomly selected plants in each sub-plot.

Leaf area plant^{-1}

Leaf area $plant^{-1}$ was recorded by selecting 5 plants at random from each subplot. Five leaves from each plant were selected and passed through leaf area measuring machine. Leaf area was multiplied by the total number of leaves in 5 plants.

Leaf weight plant^{-1}

Leaves of the 5 plants were sun-dried for 2 weeks and dry weight was recorded with an electric balance and averaged.

Specific leaf area plant^{-1}

Specific leaf area for 5 selected plants was calculated by using the formula; SLA= LA / LW, where LA is the leaf area and LW is leaf dry weight.

Specific leaf weight plant^{-1}

Specific leaf weight (SLW) $plant^{-1}$ was calculated by using the formula, SLW=LW/LA

Number of pods plant^{-1}

For number of pods $plant^{-1}$, 5 plants were randomly selected and tagged from each subplot, their pods were counted and averaged.

100 grain weight

Hundred grains were randomly picked from each treatment and weighed with electronic balance.

Grain yield

For grain yield two central rows of each subplot were harvested, sun-dried, threshed, cleaned and weighed with an electronic balance.

$$\text{Yield (kg per ha)} = \frac{\text{Grain weight (g)}}{\text{Number of rows (2)} \times \text{R-R Distance (0.4)} \times \text{Row length (3.5 m)}}$$

Statistical Analysis

The data recorded were statistically analyzed according to RCB design with split plot arrangements and Least Significant Difference (LSD) Test was employed upon obtaining significant F-values (Snedecor & Cochran 1980).

RESULTS AND DISCUSSION

Days to 50% flowering

Statistical analysis of the data revealed that planting date (D), planting density (P) significantly affected days to 50% flowering, while D x P interaction showed no significant effect (Table 2). Crop planted on September 20 took maximum days to flowering (63.7), thereafter days to flowering enhanced and minimum days to flowering (52.6) were noted for crop planted on November 29. The variation in days to flowering might be due to variation in air temperature experienced by the crop (Pandey, 1982). Thin plant density (150,000) took more days to flowering (60.5) compared with thick plant density (600,000).

Table 2: Days to 50% flowering of faba bean as affected by planting dates and plant density.

	Population (000 plants ha^{-1})				
Planting date	150	300	450	600	Mean
Sep 20, 1999	64.50	64.50	63.25	62.75	63.69a
Oct 4, 1999	64.00	64.00	63.25	62.50	63.44a
Oct 18, 1999	64.00	64.00	63.25	62.50	63.33a
Nov 1, 1999	61.00	60.75	59.25	58.00	59.75c
Nov 15, 1999	57.25	56.75	55.50	56.50	55.50d
Nov 29, 1999	54.00	53.25	52.00	51.25	52.62e
Dec 13, 1999	57.25	57.00	56.75	55.50	56.62d
Dec 27, 1999	61.75	61.00	60.50	59.50	60.69b
Mean	60.47a	60.09a	59.25b	58.56c	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Number of Leaves Plant^{-1}

Planting date (D) significantly affected leaves per plant^{-1}, while planting density (P) and interactions between D x P showed non significant effect on leaves plant^{-1} (Table 3). More leaves plant^{-1} (40.2) were recorded for crop planted on 20 September, while fewer leaves plant^{-1} (26.2) were recorded from crop planted on 27 December. The interactions between D x P showed that maximum leaves plant^{-1} (40.2) were recorded from crop planted on 20 September at 150,000 plants ha^{-1}, while minimum leaves plant^{-1} (24.2) were recorded on 13 December planted at 600,000 plants ha^{-1}. Eearly planting date produced more leaves plant^{-1} due to longer vegetative growth compared with late planting where high temperature forces the crop to complete its life cycle in shorter time (Singh et al. (1992).

Table 3: Number of leaves plant^{-1} of faba bean as affected by planting date and population density

Planting Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sept.	40.25a	36.25 b	33.25 b-g	31.00 c-j	35.19a
04 Oct.	32.25 c-i	33.50 b-f	34.75 bc	36.50 ab	34.25ab
18 Oct.	33.75 b-f	34.00 b-e	34.25 bcd	34.25 bcd	34.06ab
01 Nov	30.25 e-l	31.00 c-j	33.50 b-f	32.75 b-h	31.88abc
15 Nov.	29.25 h-l	29.25 h-l	29.50 g-l	30.50 d-k	29.63bcd
29 Nov.	30.00 f-l	27.75 j-m	29.00 h-l	28.50 i-l	28.81cd
13 Nov.	29.25 h-l	27.50 j-m	26.75 klm	24.25 m	26.94cd
27 Dec.	26.50 l-m	26.50 l-m	27.50 j-m	24.50 m	26.25d
Mean	31.43a	30.71a	31.06a	30.28a	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Leaf area plant^{-1}

Analysis of data revealed that D, P and D x P interactions significantly affected leaf area per plan^{-1}t (Table 4). Maximum leaf area (1617.7 cm^2) was recorded for crop sown on 20 September, while lowest leaf area (943.7) cm^2 was observed from 27 December. Maximum leaf area (459.2 cm^2) was recorded at 450,000 plants ha^{-1}, while lowest leaf area (1270.3 cm^2) was recorded at 150,000 plants ha^{-1}. Regarding D x P interactions, maximum leaf area (1715.7 cm^2) was recorded from 20 September planted at 450,000 plants ha^{-1}, while lowest leaf area (855.0 cm^2) was recorded from 27 December planted at 150,000 plants ha^{-1}. Broader leaves from early sowing may be due to the longer vegetative growth period which resulted in longer and wider leaves.

Table 4: Leaf area plant^{-1} (cm^2) of faba bean as affected by planting date and population density

Planting Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	1446 e-j	1648 ab	1716 a	1662 ab	1618 a
04 Oct.	1395 i-l	1494 d-g	1674 ab	1538 cd	1525 ab
18 Oct.	1393 i-l	1556 cd	1604 bc	1530 cde	1520 ab
01 Nov.	1363 j-m	1477 d-i	1483 d-h	1507 def	1459 abc
15 Nov.	1296 mno	1424 f-k	1428 f-k	1411 g-l	1390 bc
29 Nov.	1267 no	1336 lmn	1401 h-l	1374 j-m	1344 cd
13 Dec.	1144 p	1218 op	1341 k-n	1165 p	1217 d
27 Dec.	855 s	966.3 qr	1028 q	889.5 rs	934.8 e
Mean	1270 b	1390 a	1459 a	30.28 a	1384 a

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Specific leaf area plant^{-1}

Dates (D) significantly affected specific leaf area (SLA), however, P and interactions between D x P showed non-significant effect (Table 5). Maximum SLA plant^{-1} (45.3cm^{2}g^{-1}) was recorded on 27 December planting date, while lowest SLA plant^{-1} (22.7cm^{2}g^{-1}) was recorded from 04 October. Leaf thickness mainly contributes to leaf weight and leaf thickness is directly proportional to light duration. Total light received by 27 December planted crop was comparatively less than early planted crop, thus leaf weight decreased and resulted in high SLA. Maximum SLA (29.03 cm^{2}g^{-1}) was recorded at 600,000 plants ha^{-1}, while minimum SLA of 26.36 cm^{2}g^{-1} was recorded at 150,000 plants ha^{-1}. For interaction between D x P, maximum SLA plant^{-1} was recorded (48.460 cm^{2}g^{-1}) for crop sown on 27 December at 150,000 plants ha^{-1}. Lowest SLA (21.02 cm^{2}g^{-1}) was recorded for 04 October planted crop at 150,000 plants ha^{-1}.

Table 5: Specific leaf area plant^{-1} (cm^2 /g) of faba bean as affected by sowing date and population density

Planting Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	21.31	24.62	27.32	27.00	25.06 c
04 Oct.	21.02	22.29	24.81	22.61	22.68 c
18 Oct.	21.09	23.60	24.27	23.21	23.04 c
01 Nov.	21.78	23.47	23.31	23.69	23.06 c
15 Nov.	21.55	24.03	24.38	23.28	23.31 c
29 Nov.	21.99	23.18	24.01	23.77	23.24 c
13 Nov.	33.72	43.55	29.69	44.33	37.83 b
27 Dec.	48.46	44.86	43.50	44.35	45.29 a
Mean	26.36 c	28.70 ab	27.66 bc	29.03 a	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Leaf weight plant^{-1}

Sowing date (D) significantly affected leaf weight plant^{-1}, while plant density and interactions between D x P showed no significant effect Table 6). Heavier leaves plant^{-1} (67.23g) were recorded for crop planted on 04 October, thereafter leaf weight decreased as sowing was delayed. Reduction in leaf weight might be due to the fact that late sowing decreased both total dry matter and leaf weight (Sliman, 1993).

Table 6: Leaf weight plant^{-1} (g) of faba bean as affected by planting date and population density

Planting date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	67.90	66.93	62.95	62.05	64.96ab
04 Oct.	66.40	67.00	67.50	68.03	67.23a
18 Oct.	65.07	66.03	67.33	66.48	66.22a
01 Nov.	62.70	62.95	63.74	63.68	63.27abc
15 Nov.	60.10	59.25	58.73	60.68	59.69bc
29 Nov.	57.60	57.62	57.84	57.78	57.71c
13 Nov.	37.20	31.39	34.52	29.95	33.26d
27 Dec.	16.865	21.575	24.585	20.18	20.80e
Mean	54.22a	54.09a	54.65a	53.60b	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Specific leaf weight Plant^{-1}

Specific leaf weight plant^{-1} was significantly affected by D and P, while interaction between D x P was non-significant (Table 7). Maximum SLW per plant^{-1} (0.044 gcm^{-2}) was recorded on 0.04 October, while lowest SLW plant^{-1} (0.022 gcm^{-2}) was recorded for crop sown on 27 December. Similarly maximum SLW plant^{-1} (0.042 g cm^{-2}) was recorded at 150,000 plants ha^{-1} and lowest SLW plant^{-1} (0.037 g cm^{-2}) was recorded at 450,000 plants ha^{-1}. As regards interactions between D x P, maximum SLW plant $^{-1}$ (0.048 gcm^{-2}) was recorded for crop sown on 04 October at 150,000 plants ha^{-1}, while lowest SLW (0.021 gcm^{-2}) was recorded for 27 December sowing at 150,000 plants ha^{-1}.

Table 7: Specific leaf weight plant^{-1} (g cm^{2}) of faba bean as affected by sowing date and population density

Planting Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	0.047	0.041	0.037	0.037	0.040 ab
04 Oct.	0.048	0.045	0.040	0.044	0.045 a
18 Oct.	0.048	0.043	0.042	0.043	0.044 a
01 Nov.	0.046	0.043	0.043	0.042	0.044 ab
15 Nov.	0.046	0.042	0.041	0.043	0.043 ab
29 Nov.	0.046	0.043	0.041	0.042	0.043 ab
13 Dec.	0.033	0.026	0.033	0.025	0.029 b
27 Dec.	0.021	0.022	0.023	0.023	0.022 bc
Mean	0.042 a	0.039 ab	0.037 ab	0.038 ab	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Number of Pods plant^{-1}

Dates (D), P and interactions between DxP significantly affected pods plant^{-1}

(Table 8). More pods plant^{-1} (21.8) was recorded for crop sown on 20 September, while fewer pods plant^{-1} (4.9) were recorded from 27 December. Early planted crop more efficiently utilized the nutrient, water and radiation for longer duration that resulted in more pods compared with late planted crop (Tay, 1992). For planting density maximum number of pods plant $^{-1}$ (13.9) were recorded at 450,000 plants ha^{-1}, while lowest pods plant $^{-1}$ (12.0) were recorded at 600,000 plants ha^{-1}. As regards interactions between D x P, more pods plant^{-1} (24.2) were recorded from crop sown on 20 September planted at 450,000 plants ha^{-1}, while fewer pods plant^{-1} (3.7) were recorded at 600,000 plants ha $^{-1}$ sown on 27 December.

Table 8: Number of pods plant^{-1} of faba bean as affected by planting date and population density

Planting Date Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	19	20	24	23	21 a
04 Oct.	17	18	20	23	19 b
18 Oct.	14	18	18	16	16 c
01 Nov.	16	16	20	14	17 c
15 Nov.	7	10	9	7	8 d
29 Nov.	6	9	8	5	7 de
13 Dec.	5	7	6	4	6 ef
27 Dec.	4	6	5	4	5 f
Mean	11 d	13 b	14 a	12 c	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

100 grain weight

Planting dates, planting densities and interactions between D x P significantly affected 100 grain weight (Table 9). Crop planted on 20 September produced heavier grains (66.1 g), while lighter grains (58.7 g) were recorded from 1 November. Early planted crop efficiently utilized the nutrient, water and radiation for longer duration that resulted in heavier grains compared with late planted crop (Tay, 1992). Thin density (150,000 plants ha^{-1}) produced heavier grains (63.2 g) compared with thick density (150,000 plants ha^{-1}) which produced lighter grains (61.0 g). The lighter grains at thick density may be due to tough competition for soil moisture, nutrients and radiation for photosynthates production (Jasinska and Kotecki, 1995).

Table 9: Grain yield (kg) of faba bean as affected by planting date and population density.

Sowing Date	Planting densities (000 plants ha^{-1})				Mean
	150	300	450	600	
20 Sep.	371 d	412 c	440 ab	429 bc	413 a
04 Oct.	380 d	418 bc	456 a	429 bc	421 a
18 Oct.	285 g	336 e	373 d	313 f	327 b
01 Nov.	188 i	244 h	295 fg	179 ij	226 c
15 Nov.	108 mno	141 kl	160 jk	155 k	141 d
29 Nov.	104 no	122 lmn	129 lm	103 no	114 de
13 Dec.	102 no	110 mn	109 mn	859 op	102 de
27 Dec.	50 q	54 q	67 pq	61 q	58 e
Mean	198 c	230 b	254 a	219 bc	

Means of the same category followed by different letters are significantly different at 5% level of probability using LSD test.

Grain yield

Dates (D), P and interaction between D x P significantly affected grain yield (Table 10). Planting up to 4 October produced higher yield, thereafter yield decreased as planting was delayed and lowest yield (58.2 kg) was recorded for crop sown on 27 December. The high yield from early planted crop might be due to the fact that early planted crop had longer period for vegetative growth and better utilization of water and nutrients. Moreover late sown crops produced less pods plant^{-1} and hence resulted in low yield. The low yield might be due to cold weather during December-January which hindered the normal growth, photosynthetic and rhizobial activities and the crop did not produce enough leaf area to intercept most of the incoming radiations and convert them to chemical energy through photosynthesis. Moreover, the reduction in yield in late planted crop may be due to poor growth, shorter grain filling duration and maturity period, less number of fruiting nodes and pods plant^{-1} and minimum grains pod^{-1} (Berhe, 1998 and Sahile *et al*., 2008). Thin density (150,000 plants ha^{-1}) produced lowest grain yield which increased with increase in density up to 450,000 plants ha^{-1}, thereafter further increase in density did not increase grain yield. Interaction between D x P revealed that maximum yield was recorded at 450,000 plants ha^{-1} sown on 4 October, while minimum grain yield was recorded 150,000 plants ha^{-1} planted on n 27 December. The dense plant density may cause more lodging, less light penetration in the crop canopy and reduced photosynthetic efficiency that resulted in low grain yield (Mathews *et al*., 2008 and Lemerle *et al*., 2006).

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