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DENSITY AND PLANTING DATE INFLUENCE PHENOLOGICAL DEVELOPMENT ASSIMILATE PARTITIONING AND DRY MATTER PRODUCTION OF FABA BEAN

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Abstract

Phenological development determines the period of vegetative and reproductive growth, assimilate partitioning and dry matter production. Planting time and density are the major factors affecting phenological development, assimilate partitioning and yield of faba bean. The aim of this study was to evaluate the effect of planting date and plant density on phenological development, assimilate partitioning and yield of faba bean. Faba bean was planted on eight dates from September 20 to December 27, 1999 with 14 days interval maintaining 4 density (150,000, 300,000, 450,000, 600,000 plants ha^{-1}) at New Developmental Farm, NWFP Agricultural University, Peshawar. Planting dates and population density significantly affected days to flowering, days to maturity, grains pod^{-1}, plant height and grain yield ha^{-1}. However, days to emergence and maturity were only affected by planting date. Crop planted on September 20 took minimum days to emergence (5 days) and maximum days to flowering (57.6), maturity (204), produced more grains pod^{-1} (3.4) and taller plants (176.9 cm). Crop planted on October 4, 1999 produced maximum grain yield (4153 kg ha^{-1}). Plant density of 450,000 plants ha^{-1} took maximum days to flowering (54.2), more grain pod^{-1} (3.2) and produced maximum grain yield (2498 kg ha^{-1}), while population density of 600,000 plants ha^{-1} produced tallest plants (146.3 cm). It can be concluded that faba bean can be planted up to October 4 at 450,000 plants ha^{-1} to obtain maximum yield.

Introduction

Faba bean (*Vicia faba* L.) is considered as the rich source of low cost protein and carbohydrate (Daur *et al*., 2008). However, the yield of faba bean in Pakistan is very low in spite of its numerous advantages. Yield is the product of balanced phenological development; efficient source sink relationship and proper assimilate partitioning to the grains and other plant parts. Planting time and density are the two major factors affecting phenological development, source sink relationship and assimilate partitioning of faba bean. Planting time is crucial in many farming systems to avoid frost, drought, pests or diseases, which may occur early or late in the growing season. The research results revealed that days to flowering, maturity and dry matter production of faba bean decreased with delay in planting after October 30 (Berhe, 1998; Rajender *et al*., 1993, Sliman, 1993, McDonald *et al*., 1994; Kurmawanshi *et al*., 1994). Late sowing may result in severe insect and disease attack (Sahile *et al*., 2008; McDonald *et al*., 1994).

Plant density is a major determinant of proper plant development, growth and dry matter accumulation (McRae *et al*., 2008; Hassan & Khaliq, 2008; McMurray, 2004; Mathews *et al*., 2001). Thin plant density may result in low yield, more weeds infestation and poor radiation use efficiency, whereas dense plant density can cause lodging, less light penetration in the crop canopy, reduce photosynthetic efficiency and reduce the yield drastically (Vassilev, 1998; Jettner *et al*., 1998a &b; Lemerle *et al*., 2004; Lemerle *et al*., 2006). Salih (1992) planted *Vicia faba* at 333000, 499000 and 667000 plants ha^{-1} and reported that seed yield was highest at 499000 plants ha^{-1}. Further increase in plant density decreased seed yield. Rajender *et al*., (1993) concluded that dense canopies (330,000 plants ha^{-1} produced significantly higher seed yields than sparse densities. Singh *et al*., (1992) observed tallest plants with dense canopy, while Mathews *et al*., (2008) concluded that optimum plant density was 200,000-240,000 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 study the effect of planting dates and population density on the phenological development, assimilate partitioning and grain yield of faba bean.

Materials and Methods

Experiment was conducted at New Developmental Farm, KPK Agricultural University, Peshawar during 1999-2000. The experimental farm is located at 34.01^{o} N latitude, 71.35^{o} E longitude 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 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), and alkaline (pH 8.2) and is 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 the month of 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.

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

Experimentation: To study phenological development and assimilate partitioning of faba bean an 8 x 4 factorial experiment was conducted in randomized complete block design with split-plot arrangement using four replications during the winter season 1999-2000. The crop was planted on 8 dates from 20th September to 27th December with 14 days interval using four plant densities (150,000, 300,000, 450,000 and 600,000 plants ha^{-1}) at New Developmental Farm, NWFP Agricultural University, Peshawar. Planting dates were allotted to main plots while populations 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 population was maintained by varying plant to plant distance for each population. Prior to sowing the field was thoroughly prepared. Nitrogen and phosphorus were applied in the form of 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 emergence, days to flowering, days to maturity, number of grains pod^{-1}, plant height and grain yield. Days to emergence were calculated from the date of sowing to the date when first plant emerged in each treatment. Days to flowering data was recorded when first flower was noticed on the plant in each subplot. Days to maturity data was recorded by counting days from sowing to the date when 85% of the plants matured in each subplot. To record number of grains pod $^{-1}$ data, ten plants were randomly selected from each subplot, their pods were taken and number of grains were counted and their average was calculated. Heights of the ten randomly selected plants were measured from the base to the tip of the plant with the help of measuring tape and were averaged for recording plant height. For grain yield data, two central rows were harvested, dried, threshed, cleaned, weighed and converted into grain yield ha^{-1}.

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 emergence: Statistical analysis of the data revealed that planting dates (D) significantly affected days to emergence (Table 2), while plant density (P) and interaction between DxP showed non significant effect on days to emergence. Crop planted on September 20 took minimum days to emergence (5.0). Days to emergence decreased with delay in planting and crop planted on December 27 took maximum days to emergence (19.0). Mean values for the population density showed that all the four populations included in the experiment took equal number of days to emergence (9.8). The enhanced emergence in case of early in September and October compared with November/ December may be due to high temperature which enhanced emergence of early planting.

Days to flowering: Planting dates (D) and plant density (P) significantly affected days to flowering (Table 3), while DxP interaction showed non significant effect on days to flowering. Crop planted on September 20, took maximum days to flowering (57.6). Days to flowering enhanced with delay in planting and minimum days to flowering (49.2) were taken by crop sown on November 29.Thereafter, further delay in planting increased days to flowering. This variation in days to flowering might be due to variation in temperature experienced by the crop. Similar results were also reported by Pandey (1982). Maximum days to flowering (54.2) were taken by 150,000 plants ha^{-1}, while minimum days to flowering (52.5) were taken by 600,000 plants ha^{-1}. The interaction between DxP revealed that maximum days to flowering (58.5) were taken by 150,000 plants $ha^{-1,}$ planted on September 20 and minimum days to flowering (48.0) were taken by 600,000 plants ha^{-1} planted on November 29.

Days to maturity: Analysis of the data revealed that planting dates (D) significantly affected days to maturity, while plant density (D) and DxP interaction showed non significant effect on days to maturity (Table 4). Crop planted on September 20, took maximum days to maturity (204). Days to maturity decreased with delay in planting and minimum days to maturity (131) were taken by crop sown on December 27. This reduction in days to maturity in case of late planting may be due to unfavorable photoperiod and high temperature that forced the crop to windup the life cycle rapidly at the cost of reduction in yield and yield components. These findings agree with Pandey (1982) who found that days to maturity decreased with delay in sowing. Mean values for density showed that almost equal non significant days to maturity were recorded for all plant density.

Grains pod^{-1}: Statistical analysis of data revealed that planting dates (D), plant density (P) and their interaction had significant effect on number of grains pod^{-1} (Table 5). Crop planted on September 20 produced maximum grains pod^{-1} (3.4). As the sowing was delayed, reduction in number of grains pod^{-1} started and minimum grains pod^{-1} (2.4) were recorded from December 27 planted crop This decrease in grain pod^{-1} with delayed sowing may be due to shorter grains filling duration and poor pod formation in late sowing. Mean values for density revealed that low plant density of 150,000 plants ha^{-1} produced maximum grains pod^{-1} (3.2). Grains pod^{-1} showed inverse relationship with increased plant density and minimum number of grains pod^{-1} (2.6) were recorded at 600,000 plants ha^{-1}. The interaction between DxP showed that maximum grains pod^{-1} (3.5) were recorded at 150,000 plants ha^{-1}, planted on September 20, while minimum grains pod^{-1} (1.9) were recorded at 600,000 plants ha^{-1}, planted on December 27. Similar results were reported by Selim & EI-Seessy (1991) and Jasinska & Kotecki (1995) who demonstrated that grains pod^{-1} decreased with increasing plant density.

Plant height: Plant height was significantly affected by planting dates (D), plant density (P) and DxP interaction (Table 6). Early planted crop (September 20) attained maximum plant height of 176.9 cm. Plant height linearly decreased with delayed sowing and minimum plant height of 87.4 cm was recorded from December 27 planted crop. This reduction in plant height with delay in sowing time might be due to the fact that the months of September and October were more conducive for plant growth and development and the early planted crop may have more time for absorbing nutrients from the soil, attaining proper vegetative growth, efficient light utilization and development of more photosynthates than late planted crop (Bae *et al*., 1985). Crop planted at 600,000 plants ha^{-1} resulted in maximum plant height of 146.3 cm, followed by crop planted at 450,000 plants ha^{-1} attaining plant height of 136.4 cm, while 150,000 plants ha^{-1} produced shortest plants. Interaction between DxP revealed that maximum plant height of 195.9 cm was attained by 600,000 plants ha^{-1}, sown on September 20, while minimum plant height of 78.70 cm was attained by 150,000 plants ha^{-1} sown on December 27. The tallest plant at thick plant density might be due to competition among plants for light which consequently increased plant height (Selim & EI. Seessy, 1991; Jasinska & Kotecki, 1995).

Table 2. Days to emergence of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep. 20, 1999	5.00	5.00	5.00	5.00	5.00f *
Oct. 4, 1999	6.00	6.00	6.00	6.00	6.00ef
Oct. 18, 1999	6.00	6.00	6.00	6.00	6.00ef
Nov. 1, 1999	6.75	6.75	6.75	6.75	6.75e
Nov. 15, 1999	9.00	9.00	9.00	9.00	9.00d
Nov. 29, 1999	12.00	17.00	12.00	12.00	13.25c
Dec. 13, 1999	15.00	15.00	15.00	15.00	15.00b
Dec. 27, 1999	19.00	19.00	19.00	19.00	19.00a
Mean	9.84	9.84	9.84	9.84	

LSD (0.05) value for planting dates = 1.270

Means followed by similar letters are non significant at 0.05 level of probability according to LSD test.

Table 3. Days to flowering of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep. 20, 1999	58.50	57.50	57.25	57.00	57.56a
Oct. 4, 1999	57.00	56.75	56.00	55.00	56.19b
Oct. 18, 1999	56.50	56.50	53.00	54.75	55.69b
Nov. 1, 1999	53.25	52.50	52.50	51.00	52.31d
Nov. 15, 1999	51.75	51.25	51.00	50.50	51.12e
Nov. 29, 1999	50.00	49.75	49.25	48.00	49.25f
Dec. 13, 1999	52.25	51.25	51.50	50.75	51.44de
Dec. 27, 1999	54.25	54.25	53.50	52.75	53.69c
Mean	54.19a	53.72ab	53.25b	52.47c	

LSD (0.05) value for planting dates = 0.8878

LSD (0.05) value for population = 0.5514

Table 4. Days to maturity of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep. 20, 1999	204.50	204.25	204.00	204.75	204.37 a
Oct. 4, 1999	196.25	196.00	196.25	196.75	196.31 b
Oct. 18, 1999	184.25	184.50	185.00	185.25	184.75 c
Nov. 1, 1999	173.50	174.00	174.50	174.00	174.00 d
Nov. 15, 1999	146.75	161.75	162.00	162.50	158.25 e
Nov. 29, 1999	150.50	150.50	151.00	151.25	150.81 f
Dec. 13, 1999	140.75	141.00	141.25	142.00	141.25 g
Dec. 27, 1999	131.00	131.25	131.50	131.75	131.37 h
Mean	162.94	167.90	168.19	168.53	

LSD (0.05) value for planting dates = 3.921

Means followed by similar letters are non significant at 0.05 level of probability according to LSD test.

Table 5. Grains pod^{-1} of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep. 20, 1999	3.50a	3.45ab	3.35abc	3.12d-g	3.35a
Oct. 4, 1999	3.25b-e	2.97f-j	2.87h-l	2.72k-n	2.95b
Oct. 18, 1999	3.25b-e	3.05e-h	3.00f-j	2.70lmn	3.00b
Nov. 1, 1999	3.17c-f	3.02f-i	2.92g-k	2.82i-m	2.98b
Nov. 15, 1999	3.00f-j	2.92g-k	2.87h-l	2.80j-m	2.90bc
Nov. 29, 1999	3.00f-j	2.57n-q	2.45pq	2.37q	2.60d
Dec. 13, 1999	3.27bcd	2.87h-l	2.67l-o	2.47opq	2.82c
Dec. 27, 1999	2.92g-k	2.65m-p	2.15r	1.90s	2.40e
Mean	3.17a	2.94b	2.79c	2.61d	

LSD (0.05) value for planting dates = 0.1163, LSD (0.05) value for population = 0.07222
LSD (0.05) value for interaction = 0.2043

Table 6. Plant height (cm) of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep. 20, 1999	157.47efg	170.20c	184.15b	195.85a	176.92a
Oct. 4, 1999	152.00fg	160.10de	169.95c	184.30b	166.59b
Oct. 18, 1999	139.50hi	133.12i	165.27cd	183.50b	155.35c
Nov. 1, 1999	142.55h	132.17i	150.25g	158.55d-f	145.88d
Nov. 15, 1999	104.25mno	108.90k-n	116.40jk	123.42j	113.24e
Nov. 29, 1999	98.57opq	102.10nop	110.00klm	115.67k	106.58f
Dec. 13, 1999	91.02qrs	94.02qr	105.87l-o	113.22kl	101.03g
Dec. 27, 1999	78.70t	85.50st	89.22rs	96.20pqr	87.40h
Mean	120.51d	123.26c	136.39b	146.34a	

LSD (0.05) value for planting dates = 4.642, LSD (0.05) value for population = 2.699
LSD (0.05) value for interaction = 7.633
Means followed by similar letters are non significant at 0.05 level of probability according to LSD test.

Table 7. Grain yield (kg ha^{-1}) of faba bean as affected by planting dates and plant density.

Planting date	Population (000 plants ha^{-1})				Mean
	150	300	450	600	
Sep 20, 1999	3690.17c	3448.20cd	4349.11ab	4258.03ab	3936.38b
Oct 4, 1999	3734.50c	4127.66b	4486.61a	4262.48ab	4152.81a
Oct 18, 1999	2812.51f	3326.68de	3691.96c	3093.74ef	3231.22c
Nov 1, 1999	1856.24h	2408.92g	2921.37f	1760.71hi	2236.81d
Nov 15, 1999	1044.64klm	1374.10jk	1516.06ij	1492.85ij	1356.91e
Nov 29, 1999	1013.39lmn	1204.46jkl	1271.39jkl	1008.03lmn	1124.31f
Dec 13, 1999	996.44lmn	1066.96klm	1061.60klm	858.92mno	996.00f
Dec 27, 1999	505.37p	553.59op	683.92nop	616.07op	589.74g
Mean	1956.66c	2188.82b	2497.75a	2168.85b	

LSD (0.05) value for planting dates = 193.6, LSD (0.05) value for population = 119.8
LSD (0.05) value for interaction = 338.8
Means followed by similar letters are non significant at 0.05 level of probability according to LSD test.

Grain yield: Significant differences in grain yield were observed due to planting dates (D), plant density (P) and DxP interaction (Table 7). Crop planted on October 04 produced highest grain yield of 4153 kg ha^{-1}, followed by September 20 planted crop producing 3936 kg grains ha^{-1}, while lowest grain yield of 589.7 kg ha^{-1} was recorded for December 27 planted crop. The high yield from early planted crop might be due to the fact that early planted crop had sufficient longer vegetative period 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} and severe insect and disease attack (Berhe, 1998; Sahile *et al*., 2008).

Low plant density of 150,000 plants ha^{-1} produced lowest grain yield of 1957 kg ha^{-1}. Grain yield increased linearly with increase in plant density and reached the highest grain yield of 2498 kg ha^{-1} at density of 450,000 plants ha^{-1}. Thereafter further increase in plant density decreased grain yield. Interaction between DxP showed that highest grain yield of 4487 kg ha^{-1} was recorded from 450,000 plants ha^{-1} planted on October 04, while minimum grain yield of 505.4 kg ha^{-1} was recorded from 150,000 plants ha^{-1} planted on December 27. The dense plant population 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; Lemerle *et al*., 2006). It can be concluded that faba bean can be planted up to October 4 at 450,000 plants ha^{-1} to obtain maximum yield.

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