Pak. J. Bot., 39(2): 485-496, 2007.

DYNAMICS OF FLOWER APPEARANCE, FLOWERING, POD AND SEED SETTING PERFORMANCE AND THEIR RELATIONS TO SEED YIELD IN COMMON BEAN (*PHASEOLUS VULGARIS* L.)

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Abstract

The subject of this study was to determine the temporal distribution of the flowering, pod number and seed per plant, pod and seed setting performance and their relationships to seed yield in common bean (*Phaseolus vulgaris* L.). Field trials were arranged in Randomised Complete Block Design with three replications and carried out at the University of Ondokuz Mayıs, Faculty of Agriculture, during 2002 and 2003 in Samsun, Turkey. Means of studied variables over two years in six common bean genotypes ranged from 37.01 - 60.05 flowers $plant^{-1}$ (NFP), 8.28 - 13.96 pods $plant^{-1}$ (NPP), 16.13% - 29.93% for pod setting ratio (PSR), 2.77 - 6.12 seeds pod^{-1} (NSP), 0.70 - 0.95 unfilled seeds pod^{-1} (NUSP), 76.28% - 90.12% for seed setting ratio (SSR), 16.57 - 67.31 seeds $plant^{-1}$ (NSPP) and 143.7 - 349.5 g m^{-2} for seed yield (SY). Genotypes differed for all examined variables, except for NUSP. All traits varied between years, with the exception of SSR. Positive and strong correlations were found between SY and NFP, NPP, NSPP in both years. NPP, PSR and NSPP reduced drastically in Şahin-90 and Yunus-90 cvs. in 2003 when compared with 2002. Therefore, seed yield of both cultivars were evidently lower in 2003. Regression equations for the relationships between NPP and SY were $Y = 0.383x^2 + 19.349x - 4.5687$ in 2002 and $Y = 0.3035x^2 + 13.749x + 32.084$ in 2003. The highest R^2 values were obtained from the relationship between NPP and SY (R^2=0.9453 in 2002 and R^2=0.9438 in 2003).

Introduction

Reproductive growth in grain crops is initiated by flowering and a period of pod or seed set. The number of pods or seeds that the crop community produces is determined during this period and this number determines, in large part, the final grain yield (Egli, 1998). Flower production and seed set is a key phase in the yield production process, but one that is not well understood (Egli, 2005). Sexual reproductive development is a crucial stage in the life cycle of higher plants as any impairment of the processes involved might have significant implications for the productivity of crop plants and the survival of native species (Black *et al*., 2000). The timing of reproductive events in grain legume crops is modulated strongly by two environmental factors (photoperiod and temperature), and genotypes differ markedly in their relative sensitivity to either or both of these factors (Summerfield & Roberts, 1983). Variation in time to flowering results from differences in sensitivity of genotypes to changes in photo-thermal regimes. This response affects days to maturity, adaptation and yield in diverse environments (Adams *et al*., 1985). Muasya *et al*., (2002a, 2002b) investigated the differences in development of common bean (*Phaseolus vulgaris* L.) crops and pod fractions within a crop.

Although bud or post-flowering abortion of potential reproductive sites occurs naturally in most plants, particularly towards the end of the flowering period, when the maximum number of reproductive organs that can be sustained has been established (Black *et al*., 2000), the intensity of these losses may be influenced both by genotype and environmental conditions during the floral development stage. Further, temporal deterioration of the water status in flower buds is one of the factors causing pollen damage (Tsukaguchi *et al*., 2003).

The distribution of flower and pod production during flowering may be an important determinant of pod and seed number in grain crops (Egli & Bruening, 2005). The abortion rate of flower buds in *Phaseolus vulgaris* depends on the position of the bud within the inflorescence, and flower bud abortion is likely to be selective (Sage & Webster, 1987). Plants probably abort flower buds to adjust seed set. Mungbeans and cowpeas, which bear long pods with many ovules, regulate the production of the number of mature seeds by reducing the seed set in a pod as well as by reducing the fruit set, while *Glycine max* and *Phaseolus lunatus*, which bear short pods with few ovules, responded mostly by reducing fruit set (Osumi *et al*., 1998).

Pechan & Webster (1986) reported that all ovules examined in *P. vulgaris* were fertilized, but they found a discrepancy between the number of ovules fertilized and the final seed number per pod. In addition, Nakamura (1983, 1986) reported that the basal ovules within the ovary of *P. vulgaris* are less likely to mature as seeds. However, these normally aborted ovules develop viable embryos when cultured *In vitro*.

Many studies have examined the effects of genotype and environmental stress on reproductive development and seed yield in *P. vulgaris* L. (Sage & Webster, 1987; Izquierdo & Hosfield, 1987; Monterroso & Wien, 1990; Konsens *et al*., 1991; Ofir *et al*., 1993; Gross & Kigel, 1994; Nakano *et al*., 1998; Suzuki *et al*., 2003; Tsukaguchi *et al*., 2003).

Responses of plants to environmental stress factors may vary depending on plant growth stages. Reproductive organs, mainly flowers, are sensitive to chilling temperature in cool-season legumes (Wery *et al*., 1993). High temperature has also been suggested as a factor that accelerates the ending of the crop cycle (Giulioni *et al*., 1997).

This research aims at increasing insight into the dynamics of flowering, pod and seed setting performance, seed yield potential, and into differences in the relationships between reproductive characteristics and seed yield in common bean (*Phaseolus vulgaris*).

Materials and Methods

The study was carried out in the experimental area of the Faculty of Agriculture, Ondokuz Mayis University in Samsun (41° 17' N latitude, 36° 19' E longitude, elevation 150 m above sea level), Turkey during 2002 and 2003. Samsun is situated in the north of Turkey and has a humid climate with annual relative humidity of 72% and rainfall of 708 mm.

Monthly total rainfall (mm) and average air temperature (°C) for both years and the long-term period (from 1974 to 2001) are shown in Figs 1 and 2. Monthly total rainfall for each year was significantly different from that for the long-term period (Fig. 1). However, the average air temperature (°C) for the long-term period was similar to those of the 2 years (Fig. 2).

Six common bean genotypes, the registered cultivars Yalova-5, Şahin-90, Karacaşehir-90 and Yunus-90 and the two populations Amerikan Çalı and Iğdır, were used in the study. For growth habit, Yalova-5, Şahin-90, Yunus-90 and Amerikan Çalı were determinate bush, while the rest of the two genotypes were determinate semi-climber.

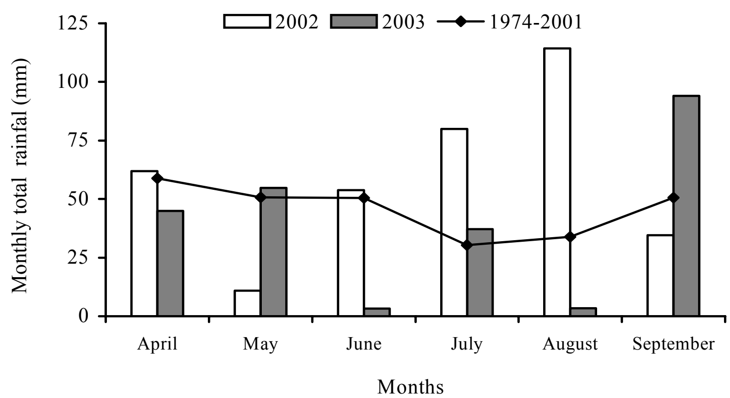

Fig. 1. Monthly total rainfall (mm) in 2002, 2003 and over the long-term period during the common bean growing seasons.

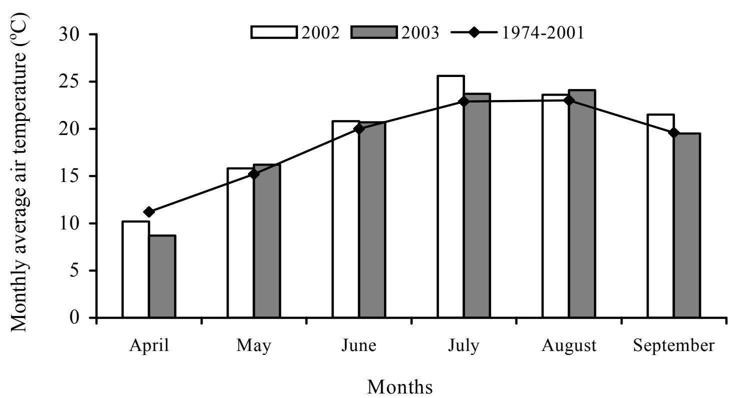

Fig. 2. Monthly average air temperatures (°C) in 2002, 2003 and over the long-term period during the common bean growing seasons.

In both years, the soil texture of the experimental area, which was slightly acidic, very low in phosphorus, rich in potassium and high in organic matter, was heavy clay. Seeds were sown by hand in 4-row plots of 3 m length, with 0.5 m between the rows and 0.1 m between plants. Sowing was performed on May 23 in both years. At planting, nitrogene and phosphorus were applied as Ammonium Sulphate and Triple Super Phosphate @ 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}, respectively. The plots were irrigated after sowing and later on depending on soil water status during the plant growth seasons. Weeds were controlled by hand hoeing when their density increased in the plots.

Five individual plants in 2002 and ten plants in 2003 were randomly selected and labelled in each plot to monitor flowering and pod development throughout the plant growth period. Tagging was done when the first flower buds appeared. The first flower counting started at 42nd and 51th days after sowing in 2002 and 2003, respectively. Then, the number of flowers per plant was counted at 7-day intervals from the first counting to the end of the flowering period. Colored clips were attached to the branches to distinguish the counted flowers from the young floral buds, which would be counted subsequently.

Days from seed sowing to the first flowering and the length of flowering period (days from the first flower to the last flower) were noted. The number of flowers (NFP) and pods per plant (NPP), pod setting ratio (number of pods/number of flowers) (PSR) in the whole plant, number of seeds and unfilled seeds per pod (NSP and NUSP), seed setting ratio (number of all seeds/number of ovules per pod) (SSR), number of seeds per plant (NSPP) and seed yield (SY) were determined in labelled individual plants. Seed and pod setting ratios were expressed as a percentage. All tagged plants were harvested separately to obtain their seed yield per plant.

The experiment was arranged in Randomized Complete Blocks Design with three replications. All data from the two years were subjected to statistical analysis according to the method of analysis of variance (Snedecor & Cochran, 1980). Data were subjected to analysis of variance and correlation coefficients between seed yield and all examined variables were calculated using the TARIST program. Means showing statistical significance were separated using Duncan's multiple range test. The regression analysis was also carried out between seed yield and flowers per plant, pods per plant and seed number per plant for both years separately using the Excel 7.0 package program.

Results

The effect of years on all variables was significant at the $p<0.05$ or $p<0.01$ level, except for seed setting ratio (Table 1). With the exception of the number of flowers $plant^{-1}$, pod setting ratio and the number of seeds $plant^{-1}$, genotype x year effects were significant for all traits evaluated. These interactions indicate that relative performance of genotypes is dependent upon the conditions of the growing season.

Large differences were found among common bean genotypes for the number of flowers per plant (NFP) ($p<0.01$). NFP varied between 37.01 flowers $plant^{-1}$ in Amerikan Çalı and 60.05 flowers $plant^{-1}$ in Yunus-90. Superior genotype for NFP was Yunus-90, followed by Iğdır (55.93 flowers $plant^{-1}$), Şahin-90 (53.68 flowers $plant^{-1}$) and Karacaşehir-90 (44.95 flowers $plant^{-1}$) (Table 1). Partitioning of NFP into the flowering period showed differences among years and genotypes. Flowering period was two weeks longer in 2002 than 2003 (Figs. 3 and 4). According to data from phenological observations for the both years, the earliest genotypes for days to first flowering (DFF) were Amerikan Çalı (38.00 and 44.67 days) and Yalova-5 (38.33 and 45.33 days), while Karacaşehir-90 was the latest (45.00 and 54.67 days). The length of flowering period ranged from 19.67 to 68.67 days and 26.00 to 61.00 days in 2002 and 2003, respectively (Fig. 5). The shortest and the longest flowering periods, over two years, were recorded in Amerikan Çalı (23.50 days) and Yunus-90 (64.83 days), respectively.

Bean genotypes differed ($p<0.01$) for the numbers of pods per plant (NPP) (Table 1). Yunus-90 was the most productive genotype for NPP (13.96 pods $plant^{-1}$), followed by Karacaşehir-90, Şahin-90 and Iğdır with 12.52, 10.20 and 8.91 pods $plant^{-1}$, respectively. NPP was also significantly different between the years ($p<0.01$).

Karacaşehir-90 had the highest PSR (29.93%) and NSP (6.12 seeds pod^{-1}). When the genotypes were compared with one another for PSR, it was found that more flower buds and/or pod abortion occurred in Iğdır (83.87%), Amerikan Çalı (81.84%) and Şahin-90 (79.75%). Genotypes showed large differences for PSR and NSP among years ($p<0.01$) (Table 1). In 2002, increases in NFP were associated with increases in NPP, but not in 2003 (Table 2).

Table 1. Means of common bean genotypes, years and genotype x year interactions in terms of examined variables and results of analysis of variance.

Genotypes	Number of flowers plant^{-1}			Number of pods plant^{-1}		
	2002	**2003**	**Mean**	**2002**	**2003**	**Mean**
Iğdır	57.98 ns	53.88	55.93ab**	8.15bcd*	9.67bcd	8.91ab**
Yalova-5	46.33	34.24	40.29bc	10.07bcd	6.51d	8.29b
Şahin-90	55.55	51.80	53.68abc	13.75b	6.65d	10.20ab
Karacaşehir-90	42.73	47.16	44.95abc	13.20bc	11.84bcd	12.52ab
Yunus-90	65.73	54.36	60.05a	19.00a	8.93bcd	13.96a
Amerikan Çalı	45.67	28.36	37.01c	8.73bcd	7.83cd	8.28b
Mean	52.33a*	44.97b		12.15a**	8.57b	
	Pod setting ratio (%)			**Number of seeds pod^{-1}**		
	2002	**2003**	**Mean**	**2002**	**2003**	**Mean**
Iğdır	14.53 ns	17.73	16.13b**	3.45c*	3.10cde	3.28c**
Yalova-5	22.81	20.58	21.70ab	3.06cde	2.48f	2.77d
Şahin-90	26.41	14.08	20.25b	3.13cde	2.95de	3.04cd
Karacaşehir-90	32.79	27.07	29.93a	6.17a	6.07a	6.12a
Yunus-90	29.09	18.29	23.69ab	3.06cde	2.74ef	2.90cd
Amerikan Çalı	19.60	16.71	18.16b	4.28b	3.21cd	3.75b
Mean	24.21a**	19.08b		3.86a**	3.43b	
	Number of unfilled seeds pod^{-1}			**Seed setting ratio (%)**		
	2002	**2003**	**Mean**	**2002**	**2003**	**Mean**
Iğdır	1.05a*	0.84ab	0.95ns	75.72e*	78.71cde	77.21c**
Yalova-5	0.66bc	0.75ab	0.71	82.71bcd	77.12de	79.91bc
Şahin-90	0.78ab	0.96ab	0.87	80.29cde	77.20de	78.75bc
Karacaşehir-90	0.97ab	0.42c	0.70	86.49b	93.75a	90.12a
Yunus-90	0.97ab	0.87ab	0.92	76.00e	76.56e	76.28c
Amerikan Çalı	0.86ab	0.69bc	0.77	83.17bc	83.32bc	83.24b
Mean	0.88a*	0.75b		80.73ns	81.11	
	Number of seeds plant^{-1}			**Seed yield (g m^{-2})**		
	2002	**2003**	**Mean**	**2002**	**2003**	**Mean**
Iğdır	28.68ns	21.53	25.11bc**	292.4bc*	230.0bcd	261.2ab**
Yalova-5	19.40	13.74	16.57c	151.6cd	144.6cd	148.1b
Şahin-90	38.42	18.77	28.59bc	349.8b	163.8cd	256.8ab
Karacaşehir-90	69.87	64.76	67.31a	278.4bc	234.4bcd	256.4ab
Yunus-90	51.73	20.60	36.17b	527.6a	171.4cd	349.5a
Amerikan Çalı	39.00	15.35	27.17bc	196.8bcd	90.6d	143.7b
Mean	41.18a**	25.79b		299.4a**	172.4b	

*= Significant at p<0.05, ** = Significant at p<0.01, ns = Not significant

The highest SSR was obtained from Karacaşehir-90 (90.12%). The rest of the genotypes had statistically lower SSR than Karacaşehir-90 (Table 1). NUSP showed negative and significant correlation ($p<0.01$) with SSR in both years (Table 2).

Common bean genotypes varied in the number of seeds per plant (NSPP). The highest NSPP was obtained from Karacaşehir-90 (67.31 seeds plant^{-1}) and the other genotypes were not statistically different from one another. Means of 2002 and 2003 for NSPP were statistically different (Table 1). NSPP positively and significantly correlated ($p<0.01$) with NPP, PSR and NSP for both years (Table 2).

Table 2. Correlations among all examined variables in common bean genotypes in 2002 and 2003.

Variables	Years	2	3	4	5	6	7	8
1. Number of flowers $plant^{-1}$	2002	0.582^{*}	-0.089	-0.498^{*}	-0.005	-0.394	0.122	0.742^{**}
	2003	**0.132**	**-0.329**	**0.089**	**0.186**	**-0.068**	**0.178**	**0.526***
2. Number of pods $plant^{-1}$	2002		0.737^{**}	-0.047	0.082	-0.123	0.584^{*}	0.875^{**}
	2003		**0.501***	**0.556***	**-0.247**	**0.462**	**0.627****	**0.559***
3. Pod setting ratio (%)	2002			0.410	0.111	0.200	0.671^{**}	0.455
	2003			**0.494***	**-0.465**	**0.486***	**0.664****	**0.524***
4. Number of seeds pod^{-1}	2002				0.202	0.607^{**}	0.652^{**}	-0.178
	2003				**-0.680****	**0.899****	**0.905****	**0.426**
5. Number of unfilled seeds pod^{-1}	2002					-0.627^{**}	0.204	0.269
	2003					**-0.893****	**-0.680****	**-0.226**
6. Seed setting ratio (%)	2002						0.308	-0.380
	2003						**0.833****	**0.337**
7. Number of seeds $plant^{-1}$	2002							0.543^{*}
	2003							**0.660****
8. Seed yield (g $plant^{-1}$)	2002							
	2003							

* = Significant at p<0.05, ** = Significant at p<0.01

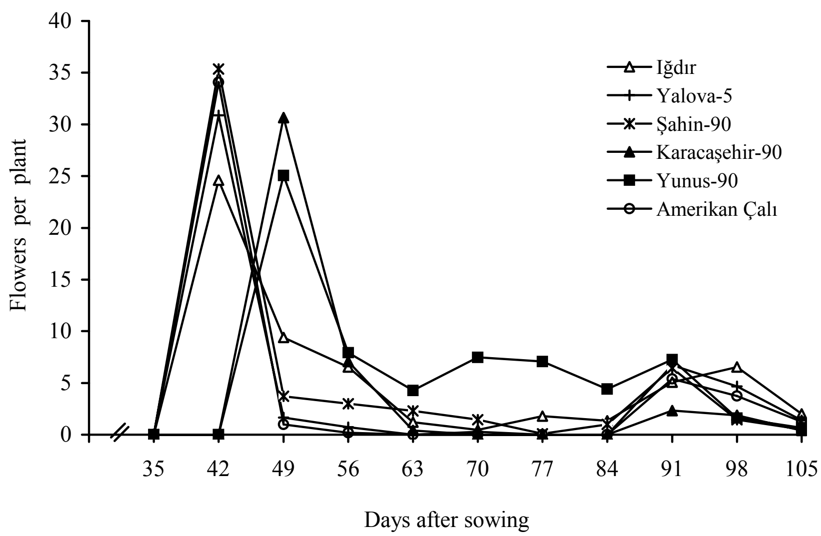

Fig. 3. Temporal distribution of flower production per plant within the flowering period in common bean genotypes in 2002 (DAS: Days after sowing)

Statistical analysis revealed a high significance for genotypes, years and genotype x year interaction regarding seed yield (SY). SY ranged from 143.7 g m^{-2} (Amerikan Çalı) to 349.5 g m^{-2} (Yunus-90). Amerikan Çalı and Yalova-5 were the low yielding genotypes in terms of SY (Table 1). SY was positively and significantly ($p<0.05$ or $p<0.01$) associated with NFP, NPP and NSPP in both years (Table 2). Regression equations for the relationships between SY and NPP, were $Y = 0.383x^2 + 19.349x - 4.5687$ in 2002 and $Y = 0.3035x^2 + 13.749x + 32.084$ in 2003. NPP gave the highest R^2 values with SY ($R^2 = 0.9453$ in 2002 and $R^2 = 0.9438$ in 2003) (Fig. 6).

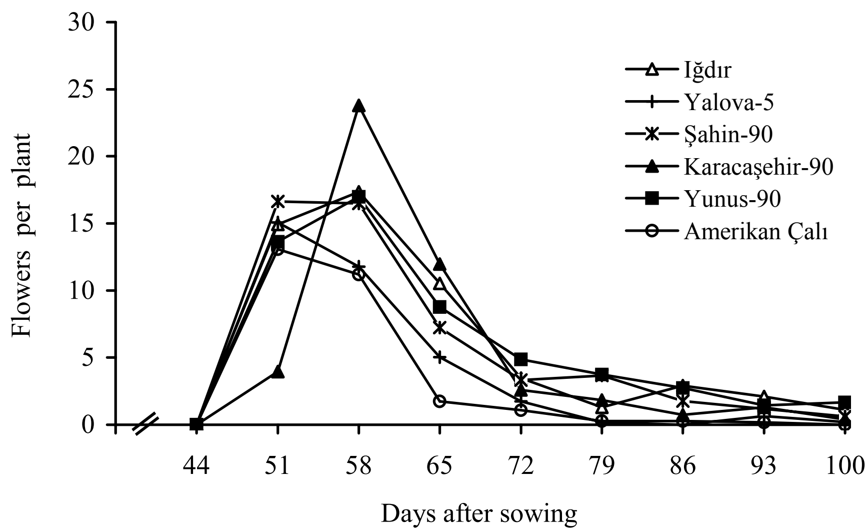

Fig. 4. Temporal distribution of flower production per plant within the flowering period in common bean genotypes in 2003 (DAS: Days after sowing)

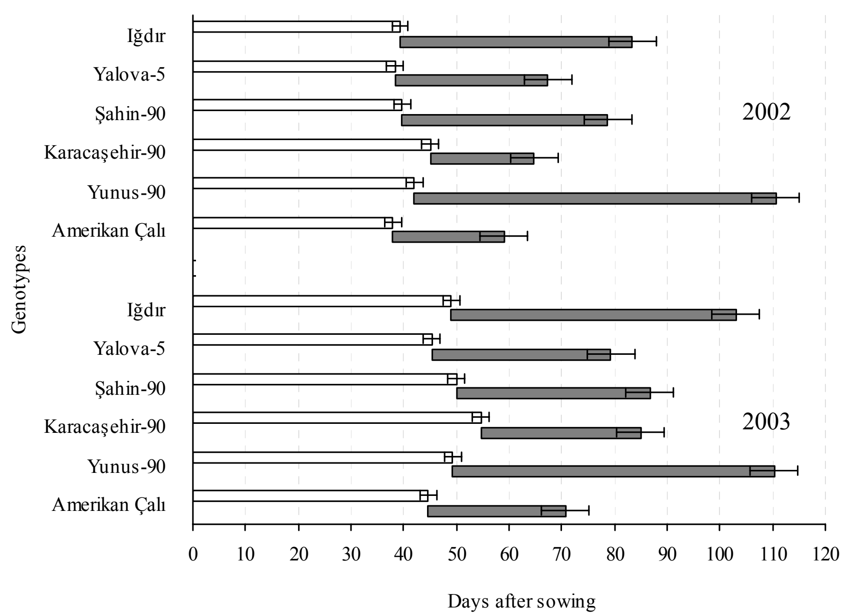

Fig. 5. Days from sowing to the first flowering (□) and the length of flowering periods (■) in common bean genotypes in 2002 (upper) and 2003 (lower). Horizantal bars represent standard error of the mean.

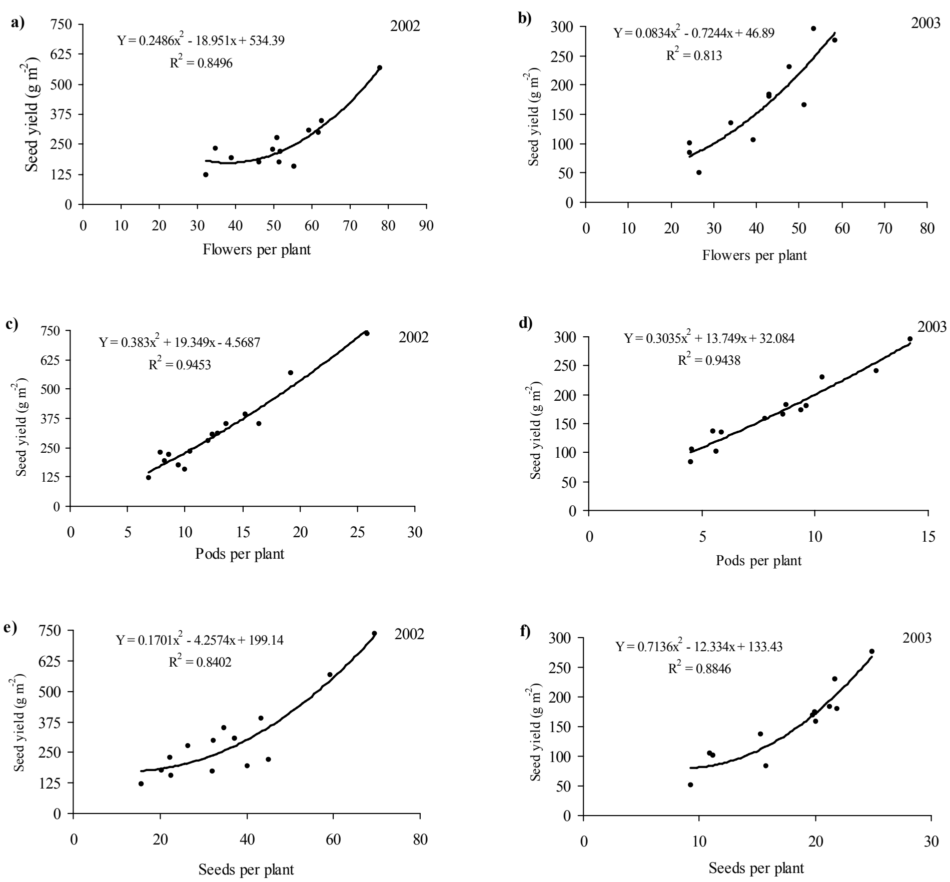

Fig. 6. The relationships between seed yield and flowers per plant (a, b), pods per plant (c, d), and seeds number per plant (e, f) in 2002 (on the left side) and 2003 (on the right side).

Discussion

Common bean (*Phaseolus vulgaris* L.) is a self-pollinating food grain legume. Days to first flowering and the length of flowering period vary depending on cultivars and environmental conditions in common bean (Adams *et al*., 1985; Wallace *et al*., 1991). The days between sowing and flowering and between sowing and pod harvesting decreased with delays in sowing date. However, the harvest duration was prolonged (Wang-BingLiang *et al*., 2004).

Although plants produce many flowers, only a limited number of them develop into pods. A large proportion of flowers or young pods are abscissed by the effects of different factors. Izquierdo & Hosfield (1987) reported that average reproductive abscission was 48%, the tendency being more marked in determinate bush types than in indeterminate types. Abscission ratio of reproductive organs throughout the flowering and pod setting periods ranged from 48% to 82% in common bean (Tanaka & Fujita, 1979; Izquierdo & Hosfield, 1981). Yaman (1994) reported that the number of flowers varied from 21.23 to 52.40 flowers plant^{-1} for planting dates and 34.12 to 43.87 flowers plant^{-1} for common bean cultivars. Our results for NFP were in agreement with Yaman (1994), and also Helvacıoğlu & Şehirali (2001) who stated that NFP was found between 21.5 and 49.3 flowers plant^{-1} in *P. vulgaris*.

Abortion-inducing factors appear to be important in the green bud stage of ontogeny and in early stages of fruit/embryo development in *P. vulgaris* (Sage & Webster, 1987). Post fertilization fruit-set may be reduced by embryo abortion (Gross & Kigel, 1994). Suzuki *et al*., (2003) found that abnormal pods occurred along with failure of fertilization at high temperatures in snap bean. However, even with successful fertilization, abnormal pods appeared with poor ovule development. Similar results were observed in the field when air temperatures exceeded 28°C. In common bean plants exposed to high temperature of 32/27°C (day/night) for 5 d at anthesis, a reduction in pod and seed numbers occurred as a result of increased abscission of flower buds, flowers and young pods, and the failure of fertilization and seed development (Ofir *et al*., 1993). In contrast, Nakano *et al*., (1998) reported that flowers, which have already opened, and immature pods, were not heat-sensitive in the common bean.

Monthly total rainfall in June, July and August in 2002 was higher than that in the same period in 2003 (Fig. 1). Rainfall during the pod development and maturing stage caused reflowering in all plants and prolonged flowering period in 2002 (Fig. 3). Therefore, vegetative growth of the plants was better and the total number of flowers produced by plants in 2002 (52.33 flowers plant^{-1}) was higher ($p<0.05$) than that in 2003 (44.97 flowers plant^{-1}) (Table 1).

Stressful conditions such as high temperature or moisture deficiency can reduce yield due to reduction in one or more of the reproductive components. Beans are particularly susceptible to drought during flowering, with significant flower and pod abortion occurring when water shortage occurs at this time (Graham & Ranalli, 1997). Water deficit delayed leaf appearance, but hastened flowering and seed fill (Nunez-Barrios, 1991). In the present study, all plots were irrigated to prevent water stress during the drought periods. For that reason, there was no water stress that prevented pod setting or promoted flower and pod abortion during the flowering period in the both years. Thus, variation among common bean genotypes for NPP and PSRs could be attributed primarily to the genotypical differences. In soybean, similar result has been stated that the cultivar variation in abortion is frequently related to flower production and apparently not to any intrinsic difference in the abortion process (Egli, 2005).

Results for NSPP found in the present study were similar to that of Çakmak *et al*., (2001), and Helvacıoğlu & Şehirali (2001) who stated that NSPP varied between 21.3 and 118.8 seeds plant^{-1}.

The longest flowering periods, in average of two years, were found in Yunus-90 (64.83 days), Iğdır (49.00 days) and Şahin-90 (37.83 days). Yalova-5 and Amerikan Çalı were the earliest for the first flowering time in both years (Fig. 5). Decreases in the number of flowers opened at successive counting periods were lower in Yunus-90, Şahin-90 and Iğdır when compared the others (Figs. 3 and 4). They also had high 100-seed weight (not shown in tables). The temporal distribution of flower and pod production plays a role in determining when the reproductive sink reaches its maximum rate of assimilates utilization. If all flowers on a plant were pollinated on the same day, the pods would probably develop nearly simultaneously and assimilate utilization would increase rapidly to its maximum level. If flowers developed over a longer period, utilization would increase much more slowly as successive pods reached the stage where their assimilate use was maximum. In this case, developed pods using assimilate at the maximum rate would coexist with flowers and immature pods using very little assimilate, which could lead to abortion of flowers or small pods (Egli, 2005).

Yield increases generally result from increases in total number of pods per plant, especially large yield increases. The upper limits on the number of seeds per pod and seed size are genetically confined; however, these two components can still fluctuate enough to produce sizable yield increases. NPP, PSR and NSPP were drastically reduced in Şahin-90 and Yunus-90 cvs. in 2003 when compared with 2002. Therefore, seed yield of both cultivars were evidently lower in 2003. Although Karacaşehir-90 had higher NSPP when compared with the others, Yunus-90 and Şahin-90 were not statistically different from small-seeded Karacaşehir-90 for seed yield due to their large seeds (Table 1). Plant seed yield was found to be 7.30 and 15.98 g $plant^{-1}$ in common bean by Çakmak *et al*., (1999) and Anlarsal *et al*., (2000). Our results for the relationships between SY and some variables were similar to Subhadrabandhu *et al*., (1978) who stated that plant seed yield correlates with the number of flowers $plant^{-1}$, pod setting ratio and seed number pod^{-1}. Seed yield of pinto beans (*Phaseolus vulgaris* L.) ranged from 262 to 378 g m^{-2} and 167 to 356 g m^{-2} in 1994-95 and 1995-96, respectively (Dapaah *et al*., 1999).

Some practices, including fertilisation, proper row spacing and planting rate, irrigation, and weed control are all attempts to reduce the amount of floral and pod abortion and thus increase yields. Under field conditions, it is not always possible to eliminate the negative effects of uncontrolled factors on flower and pod occurrence or abscission, and pod or seed setting.

Dapaah *et al*., (1999) found that the number of pods per plant was consistently and strongly correlated with seed yield in both years. Large differences were found among common bean genotypes in occurrence of reproductive organs such as flowers, pods, seeds, and their abscission in the present study. Correlation and regression analysis showed that NPP, NFP and NSPP were the main determinants on seed yield among all examined variables (Table 2 and Fig. 6). Therefore, selection of common bean genotypes that compensate for seed yield losses from abscission of flower buds, flowers and young pods may contribute to stable seed yield under stressful conditions. New common bean genotypes should be considered for their potential expression of reduced abscission and higher yields. In addition to yield related characteristics, flowering, pod and seed setting performance should be considered as selection criteria in common bean breeding programmes.

General characteristics of flower production, flower and pod abortion, and pod and seed set in common beans are well known. However, they have generally not been into models to provide a better understanding of the determination of pod and seed number per unit area or per plant. Detailed studies in the future on modeling the dynamics of flowering, pod and seed setting, and reproductive success in common bean could be helpful to explain unknown complex systems at these critical growth periods.

Acknowledgement

The author wishes to thank Gregory T. Sullivan of the University of Ondokuz Mayıs, Samsun-TURKEY, for his critical reading of the manuscript.

References

Adams, M.W., D.P. Coyne, J.H.C. Davis, P.H. Graham and C.A. Francis. 1985. Common bean (*Phaseolus vulgaris* L.). In: *Grain Legume Crops*. (Eds.): R.J. Summerfield, E.H.Roberts, Collins, London, pp. 433-476.

Anlarsal, A.E., C. Yücel and D. Özveren. 2000. The determination of seed yield and yield components in some bean (*Phaseolus vulgaris*) cultivars and correlations between these characters under the Çukurova conditions. *Turk. J. Agric. Forestry,* 24: 19-29. (Abstract in English).

Black, V.J., J.A. Roberts and C.A. Stewart. 2000. Impact of ozone on the reproductive development of plants. *New Phytol*., 147: 421-447, *Tansley Review,* No. 115.

Çakmak, F., N. Azkan, O. Kaçar and N. Çöplü. 1999. Determination of agronomic characters and seed yield potential of some dry bean lines. *Proceedings of the 3rd Field Crops Congress of Turkey* (15-18 November 1999), Vol. III, 354-359, Adana, Turkey. (Abstract in English).

Çakmak, F., O. Kaçar, N. Çöplü and N. Azkan. 2001. Determination of agronomic characters and seed yield potential of some dry bean lines in Bursa ecological conditions. *Proceedings of the 4th Field Crops Congress of Turkey* (17-21 September 2001), 353-358, Tekirdağ, Turkey. (Abstract in English).

Dapaah, H.K., B.A. McKenzie and G.D. Hill. 1999. Effects of irrigation and sowing date on phenology and yield of pinto beans (*Phaseolus vulgaris* L.) in Canterbury, New Zealand. *New Zealand J. of Crop and Hort. Sci.,* 27: 297-305.

Egli, D.B. 1998. *Seed biology and the yield of grain crops*. CAB International, Wallingford, UK.

Egli, D.B. 2005. Flowering, pod set and reproductive success in soya bean. *J. Agronomy & Crop Sci.,* 191: 283-291.

Egli, D.B. and W.P. Bruening. 2005. Temporal profiles of pod production and pod set in soybean. *Eur. J. Agron.* 24: 11-18.

Giulioni, L., J. Wery and F. Tardieu. 1997. Heat stress-induced abortion of buds and flowers in pea: is sensitivity linked to organ age or to relations between reproductive organs? *Ann. Bot.,* 80: 159-168.

Graham, P.H. and P. Ranalli. 1997. Common bean (*Phaseolus vulgaris* L.). *Field Crops Res.,* 53: 131-146.

Gross, Y. and J. Kigel. 1994. Differential sensitivity to high temperature of stages in the reproductive development of common bean (*Phaseolus vulgaris* L.). *Field Crops Res.,* 36: 201-212.

Helvacıoğlu, İ.A. and S. Şehirali. 2001. The effects of different nitrogen fertilizers and doses on yield and yield components of dwarf beans (*Phaseolus vulgaris* L. var. *nanus* Dekapr.). *Proceedings of the 4th Field Crops Congress of Turkey* (17-21 September 2001), 391-395, Tekirdağ, Turkey. (Abstract in English).

Izquierdo, J.A. and G.L.A. Hosfield. 1981. A collection receptable for field abscission studies in common bean. *Crop Sci.,* 21: 622-625.

Izquierdo, J.A. and G.L.A. Hosfield. 1987. Flower, pod and leaf abscission of dry beans (*Phaseolus vulgaris* L.). *Agro Ciencia,* 3: 105-115.

Konsens, I., M. Ofir and J. Kigel. 1991. The effect of temperature on the production and abscission of flowers and pods in snap bean (*Phaseolus vulgaris* L.). *Ann. Bot.,* 67: 391-399.

Monterroso, V.A. and H.C. Wien. 1990. Flower and pod abscission due to heat stress in beans. *J. American Soc. Hort. Sci.,* 115: 631-634.

Muasya, R.M., W.J.M. Lommen and P.C. Struik. 2002a. Differences in development of common bean (*Phaseolus vulgaris* L.) crops and pod fractions within a crop (I. Seed growth and maturity). *Field Crop Res*., 75: 63-78.

Muasya, R.M., W.J.M. Lommen and P.C. Struik. 2002b. Differences in development of common bean (*Phaseolus vulgaris* L.) crops and pod fractions within a crop (II. Seed viability and vigour). *Field Crop Res.,* 75: 79-89.

Nakamura, R.R. 1983. *Reproductive capacity and kinship in Phaseolus vulgaris L*. Ph.D. Dissertation. Yale University, New Haven, Connecticut, USA.

Nakamura, R.R. 1986. Maternal investment and fruit abortion in *Phaseolus vulgaris*. *American J. Bot.,* 73: 1049-1057.

Nakano, H., M. Kobayashi and T. Terauchi. 1998. Sensitive stages to heat stress in pod setting of common bean (*Phaseolus vulgaris* L.). *Japanese J. Tropical Agric.,* 42: 78-84.

Nunez-Barrios, A. 1991. *Effects of soil water deficits on dry beans (Phaseolus vulgaris L.) at different growing stages*. Ph.D. Thesis, Michigan State University.

Ofir, M., Y. Gross, F. Bangerth and J. Kigel. 1993. High temperature effects on pod and seed production as related to hormone levels and abscission of reproductive structures in common bean (*Phaseolus vulgaris* L.). *Scientia Hort.,* 55: 201-211.

Osumi, K., K. Katayama, L.U. de la Cruz and A.C. Luna. 1998. Fruit bearing behavior of 4 legumes cultivated under shaded conditions. *JARQ, Japan Agric. Res.,* 32: 145-151.

Pechan, P.M. and H.E. Webster. 1986. Flower and pod set of *Phaseolus vulgaris* under controlled environment conditions. *Hort. Science,* 21: 989-991.

Sage, T.L. and B.D. Webster. 1987. Flowering and fruiting patterns of *Phaseolus vulgaris* L. *Botanical Gazete,* 148: 35-41.

Snedecor, G.W. and W.G. Cochran. 1980. *Statistical Methods*. 7th Edition, The Iowa State University Press, USA.

Subhadrabandhu, S., M.W. Adams and D.A. Ricosky. 1978. Abscission of flowers and fruits in *Phaseolus vulgaris* L. I. Cultivar differences in flowering pattern and abscission. *Crop Sci.,* 18: 893-896.

Summerfield, R.J. and E.H. Roberts. 1983. Environmental regulation of flowering in faba beans, chickpeas, and lentils. In: *Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s, ICARDA, Syria*. (Eds.): M.C. Saxena, S. Varma.

Suzuki, K., M. Shono and Y. Egawa. 2003. Occurrence of abnormal pods and abscission of flowers at high temperatures in snap bean. *Research Highlights JIRCAS*, 46-47, 2002.

Tanaka, A. and K. Fujita. 1979. Growth, photosynthesis and yield components in relation to grain yield of the field bean. *Journal of the Faculty of Agriculture Hokkaido Univ.,* 59: 145-238.

Tsukaguchi, T., Y. Kawamitsu, H. Takeda, K. Suzuki and Y. Egawa. 2003. Water status of flower buds and leaves as affected by high temperature in heat-tolerant and heat-sensitive cultivars of snap bean (*Phaseolus vulgaris* L.). *Plant Production Sci.,* 6: 24-27.

Wallace, D.H., P.A. Gniffke, P.N. Masaya and R.W. Zobel. 1991. Photoperiod, temperature and genotype interaction effects on days and nodes required for flowering of bean. *J. American Hort. Sci.,* 116: 534-543.

Wang-BingLiang, Zhu-ShuZhu, Zhu-QinMei and Xu-Min. 2004. Effects of seeding date and cultivar on pod setting ability of dwarf bean (*Phaseolus vulgaris* var. *humilis*). *Acta Agriculturae Shanghai,* 20: 80-83.

Wery, J., O. Turc and J. Lecoeur. 1993. Mechanisms of resistance to cold, heat and drought in cool-season legumes, with special reference to chickpea and pea. In: *Breeding for Stress Tolerance in Cool-Season Food Legumes*. (Eds.): K.B. Singh, M.C. Saxena. ICARDA, pp. 271-291.

Yaman, M. 1994. The effect of different planting dates on yield and flower drops in dry bean cultivars. *Proceedings of the Field Crops Congress of Turkey* (25-29 April 1994), Agronomy Section, Vol I, pp. 325-327, İzmir, Turkey. (Abstract in English).

(Received for publication 14 November 2006)