Estimates of broad-sense heritability for seed yield and yield criteria in faba bean (*Vicia faba* L.)

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Eight faba bean (*Vicia faba* L.) genotypes were grown at lowlands of the west-Mediterranean region of Turkey in order to estimate the broad-sense heritability for plant height, number of stems and pods per plant, seed yield, biological yield, 100-seed weight, days to flowering and maturity. The heritability for plant height, number of stems and pods per plant, seed yield, biological yield, 100-seed weight, days to flowering and maturity were estimated as 83%, 63%, 43%, 62%, 52%, 99%, 97% and 97%, respectively. It was found that seed weight was the least affected trait across changing environmental conditions and followed by days to flowering and maturity. On the other hand, number of pods per plant, biological and seed yields and number of stems per plant were the most affected traits versus environmental conditions.

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Faba bean, *Vicia faba* L., is the only species known in cultivation of section *Faba*. Faba bean was divided two subspecies; *V. faba* subsp. *paucijuga* Murat and *V. faba* subsp. *faba* L. by MAXTED (1995). The taxon *V. faba* subsp. *faba* L. was classified in three variety groups, var. *minor*, var. *equina* and var. *faba* (major). Variety groups were also referred to as tick bean, horse bean or field bean and broad bean (CUBERO 1984; JENSEN 1992; BOND 1995; DUC 1997). Faba bean is grown for dry seeds and is cultivated on nearly 2.5×10^6 ha with a yield of 1504 kg ha^{-1} worldwide. The total cultivated area and yield for dry seeds of faba bean in Turkey is 18×10^3 ha and 1833 kg ha^{-1}, respectively (FAO 2002).

Plant height, number of stems and pods per plant, biological yield, harvest index, 100-seed weight, days to flowering and maturity are the most important characters in faba bean improvement for increasing seed yield due to direct and indirect correlation with seed yield (LOSS and SIDDIQUE 1997). Genotypes by year or environment interactions reduce the association between phenotypic and genotypic values. Also, it may be the cause of poor performance of genotypes for selection from one environment to another, forcing plant breeders to examine genotypic adaptation. Measuring genotype × environment or year interactions are also important to determine an optimum breeding strategy for releasing cultivars with adequate adaptation to target environments (FOX et al. 1997). Many plant breeders consider what might be the ideal plant type for their target area and often construct a crop ideotype. Therefore, estimate of heritability should be determined for applying an optimum breeding strategy. In this study, heritability via variance components and genotype × year interactions for plant height, number of stems and pods per plant, seed yield, biological yield, 100-seed weight, days to flowering and maturity were determined on faba bean genotypes in lowland of the west-Mediterranean region of Turkey.

MATERIAL AND METHODS

The study was carried out at the experimental area of Dept. of Field Crops in Faculty of Agriculture, Akdeniz University, Antalya (30°E, 36°N, 51 m a.s.l.) in the west-Mediterranean region of Turkey. Eight faba bean genotypes were used.

Genotypes were sown in the second week of December and the forth week of November in 2000–2001 and 2001–2002 cropping season, respectively. A randomized complete blocks design with three replications was used in every year. Plots were arranged ten rows of 4 m length with inter- and intra-row spacing of 50 and 10 cm, respectively. The two side rows, one on either side, and 0.25 m length on either side of the plots were discarded as border and thus, the net plot area consisted of two rows of 3.5 m length. Thus 16 square meter areas were evaluated as net plot area, harvested by hand when the crop reached maturity. Nitrogen and phosphorus were applied at a rate of 23 kg ha^{-1} and 60 kg ha^{-1} prior to sowing, respectively.

Plant height was recorded in cm from ground to top of plant with the average of four plants randomly selected in the center of rows prior to maturity. Stems and pods per plant were counted, with the average of four plants randomly selected in the center of rows

prior to maturity. Biological yield was estimated in g per plot with total dry weight of plants in harvest. Seed yield was estimated in kg per ha with total weight of seeds after threshing. The 100-seed weight was recorded in g of the weight of 100 randomly selected seeds from each genotype after threshing. The days to flowering and maturity was estimated as days from sowing time to the day on which at least 50% of the plants in the plot had started to flowering and 100% of plants in the plot had reached maturity, respectively. Consequently, data were analyzed by using MINITAB package software. The form of the analysis of variance and the mean square expectations; the estimates of variance components and the method of determination were used as suggested by Rasmusson and Lambert (1961) and Toker (1998) and shown in Tables 1 and 2, respectively.

The phenotypic variance, σ_p^2 was determined as following:

$$\sigma_p^2 = \sigma_g^2 + (\sigma_{gy}^2/y) + (\sigma_e^2/ry)$$

where y, g and r are number of year, genotype, and replication, respectively; σ_g^2 and σ_e^2 are components of variance for genotypes and error, respectively. Heritability was estimated as: genotypic variance/phenotypic variance:

$$h^2 = \sigma_g^2/\sigma_p^2.$$

RESULTS AND DISCUSSION

Significant differences between the genotypes were found for all the characters at $p < 0.05$. However, the genotype × year interactions were significant only for number of pods per plant, days to flowering and maturity ($p < 0.05$) in Table 3. Similarly, Flores et al. (1998) found genotype by environment interaction in faba bean and pea crop (*Pisum sativum* L.).

Table 1. *Form of variance analysis and mean square expectations.*

Source	Degree of freedom	Mean square*	Mean square expectation
Replication	$y(r-1)$		
Year	$(y-1)$		
Genotype	$(g-1)$	M_3	$\sigma_e^2+r\,\sigma_{gy}^2+ry\,\sigma_g^2$
Genotype × year	$(g-1)\,(y-1)$	M_2	$\sigma_e^2+r\,\sigma_{gy}^2$
Error	$gy\,(r-1)$	M_1	σ_e^2

* M_1 to M_3 are the observed values of the various mean squares.

Table 2. *Estimates of variance components and method of determination.*

Variance components		Method of determination
Genotype	(σ_g^2)	M_3-M_2/yr
Genotype × year	(σ_{gy}^2)	M_2-M_1/r
Error	(σ_e^2)	M_1

As can be seen in Table 3, the estimated broad-sense heritability were 83%, 63%, 43%, 62%, 52%, 99%, 97% and 97% for plant height, number of stems and pods per plant, seed yield, biological yield, 100-seed weight, days to flowering and maturity, respectively. These findings seem to agree with results reported in chickpea (*Cicer arietinum* L.) by Muehlbauer and Singh (1987). Singh (1991) reported that heritability in pure lines of chickpea were 59%, 70%, 49%, 81%, 89% and 91% for seed yield, plant height, number of pods per plant, days to flowering and maturity and 100-seed weight, respectively. On the other hand, Eser (1976) reported 13% for single plant yield, 25% for number of pods per plant, 78% for seed weight and 30% for plant height narrow-sense heritability in chickpea. She concluded that the seed weight of chickpea was the least influenced trait by environmental conditions. Lumpkin and Mcclary (1994) concluded from different authors that heritability values in pure lines and segregating materials of adzuki bean (*Vigna ungularis* (Willd.) Ohwi and Ohashi) were 84–96% for days to flowering, 26–86% for plant height, 9–87% for pods per plant, 70–99% for seed weight, 44–69% for branches per plant, 99% for days to maturity, 31–50% for seed yield. For 1000-seed weight of common vetch, heritability was determined as 96% by Sabanci and Yildirim (1992). Therefore, they pointed out that 1000-seed weight was less affected than another yield criteria. Our results could also be compared with results of Cowling et al. (1998). They reported from Lesech and Huyghe (1991) that the broad sense heritabilities of lupin (*Lupinus albus* L. var. *albus*) were 91–97% in main stem flowering, 82–92% in main stem height, 76–94% in the seed weight and 45–78% in the seed yield.

The magnitude of heritability was affected by the type of genetic material and yield level of environment due to the fact that the plant height, number of stems and pods per plant, seed yield, biological yield, 100-seed weight, days to flowering and maturity of plants are created by the effects of genes and environment. The most common justification for conducting selection in optimum environments, regardless of the nature of the target environment, was the lower heritability found by Ceccarelli (1994) in low

Table 3. *Results of variance analysis and heritability for plant height (PH), number of stems (S/P) and pods per plant (P/P), seed yield (SY), biological yield (BY), 100-seed weight (SW), days to flowering (DF) and maturity (DM) in faba bean genotypes.*

Sources of variation	Mean squares							
	PH	S/P	P/P	SY	BY	SW	DF	DM
Genotype	504.2**	1.7**	13.8**	2357878**	34.2**	9038.4**	16.6**	223.4**
Genotype × year	84.1^{ns}	0.6^{ns}	188.6**	896243^{ns}	16.4^{ns}	120.9^{ns}	2.4**	7.42**
Error	37.2	0.4	14.6	597973	10.2	60.1	0.3	2.4
Heritability (%)	83	63	43	62	52	99	97	97

*, **; Probability value for test of significance < 0.05 and < 0.01, respectively.

yielding environments. Also, Ceccarelli (1996) reported that lower heritability expected in low input conditions. In addition, Atlin and Frey (1990) concluded that heritability in low yielding environments is lower than high yielding environments in oat (*Avena sativa* L.). Abdelmula et al. (1999) pointed out the lower heritability for faba bean (*Vicia faba* L.) in low yielding environments. Similarly, it was resulted that broad-sense heritability for yield in faba bean was higher in well-watered treatment than drought stress condition (Link et al. 1999). During 2000–2001 and 2001–2002 cropping seasons, rainfall was extremely high in Antalya. Estimated values of the heritabilities in the study were high due to high yielding years.

According to the results obtained, seed weight was the least affected trait over years and followed by days to flowering and maturity. Number of pods per plant, biological and seed yields and number of stems per plant were the most affected traits vs environmental conditions.

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REFERENCES

Abdelmula, A. A., Link, W., von Kittlitz, E. et al. 1999. Heterosis and inheritance of drought tolerance in faba bean, *Vicia faba* L. – Plant Breeding 118: 485–490.

Atlin, G. N. and Frey, K. J. 1990. Selecting oat lines for yield in low-productivity environments. – Crop Sci. 30: 556–561.

Bond, D. A. 1995. Faba bean *Vicia faba* (Leguminosae-Papilionoideae). – In: Smartt, J. and Simmonds, N. W. (eds), Evolution of crop plants, 2nd edn. Longman Scientific & Technical, p. 312–316.

Ceccarelli, S. 1994. Specific adaptation and breeding for marginal conditions. – Euphytica 77: 205–219.

Ceccarelli, S. 1996. Adaptation to low/high input cultivation. – Euphytica 92: 203–214.

Cowling, W. A., Huyghe, C. and Swiecicki, W. 1998. Lupin breeding. – In: Gladstones, J. S., Atkins, C. A. and Hamlin, J. (eds), Lupinus as crop plants: biology, production and utilization. CAB International, p. 93–120.

Cubero, J. I. 1984. Taxonomy, distribution and evolution of the faba bean and its wild relatives. – In: Witcombe, J. R. and Erskine, W. (eds), Genetic resources and their exploitation-chickpeas, faba beans and lentils. Martinus Nijhoff/Dr W Junk Publishers, p. 131–144.

Duc, G. 1997. Faba bean (*Vicia faba* L.). – Field Crops Res. 53: 99–109.

Eser, D. 1976. Heritability of some important plant characters, their relationships with plant yield and inheritance of *Ascochyta* blight resistance in chickpea (*Cicer arietinum* L.). – Ankara Üniv. Ziraat Fakültesi Yayinlari, No. 620, Ankara, Turkey.

FAO, 2002. http://www.fao.org./

Flores, F., Moreno, M. T. and Cubero, J. I. 1998. A comparison of univariate and multivariate methods to analyze of G × E interaction. – Field Crops Res. 56: 271–286.

Fox, P. N., Crossa, J. and Ramagosa, I. 1997. Multi-environment testing and genotype × environment interaction. – In: Kempton, R. A. and Fox, P. N. (eds), Statistical methods for plant variety evaluation. Chapman & Hall, p. 117–138.

Jensen, P. C. M. 1992. *Vicia faba* L. – In: van der Maesen, L. J. G. and Somaatmadja, S. (eds), Plant resources of south-east Asia 1. Pulses. Prosea foundation, Bogor, Indonesia, 1990/1992, Pudoc-DLO, Wageningen, the Netherlands, 1990–1992, p. 64–66.

LeSech, L. and Huyghe, C. 1991. Diallel analysis on white lupin: breeding consequences. – Agronomic 11: 719–726.

Link, W., Abdelmula, A. A., von Kittlitz, E. et al. 1999. Genotypic variation for drought tolerance in *Vicia faba* L. – Plant Breeding 118: 477–483.

Loss, S. P. and Siddique, K. H. M. 1997. Adaptation of faba bean (*Vicia faba* L.) to dryland Mediterranean-type environments. I. Seed yield and yield components. – Field Crops Res. 52: 17–28.

Lumpkin, T. A. and McClary, D. C. 1994. Breeding and genetics. – In: Lumpkin, T. A. and McClary, D. C. (eds), Azuki bean: botany, production and uses. CAB International, p. 119–155.

Maxted, N. 1995. An ecogeographical study of *Vicia* subgenus *Vicia*. Systematic and ecogeographical study

on crop genepools. 8. Int. Plant Genet. Resour. Inst., Rome, Italy.

Muehlbauer, F. J. and Singh, K. B. 1987. Genetics of chickpea. – In: Saxena, M. C. and Singh, K. B. (eds), The chickpea. CAB International, p. 99–125.

Rasmusson, D. C. and Lambert, J. W. 1961. Variety × environment interactions in barley variety tests. – Crop Sci. 1: 261–262.

Sabanci, C. O. and Yildirim, M. B. 1992. Estimates of genotype × environment interactions and heritabilities of certain agronomical traits in common vetch (*Vicia sativa* L.). – Turk. J. Agric. For. 16: 797–802.

Singh, M. 1991. Genotypic and phenotypic correlations in plant traits. – Int. Center for Agric. Res. in the Dry Areas, Aleppo, Syria.

Toker, C. 1998. Estimate of heritabilities and genotype by environment interactions for 100-seed weight, days to flowering and plant height in kabuli chickpeas (*Cicer arietinum* L.). – Turk. J. Field Crops 3: 16–20.