Environmental effects on phenotypic expression are blunted in greenhouse compared to open field

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Abstract

Two local dry bean populations were used in the study. A total of 432 widely spaced plants (80 x 80 cm) of each population were grown in the greenhouse. Another 500 widely spaced plants (100 x 100 cm) of each population were evaluated in the open field. In the greenhouse grain yield and pod number distributions of population A did not depart from normality. For both traits of population A in the open field, and for both traits of population B either in the greenhouse or in the open field, skewness and kurtosis were significant. Leftward transposition of mean due to positive skewness was accompanied by increased CV values. Although both populations had higher yield and pod number per plant in the open field than in the greenhouse, attributable to less competition, standard deviations increased in higher rates in the open field resulting in higher CV values. Compared to the greenhouse, in the open field CV values of yield and pod number were by 59 and 54% higher for population A, and by 42 and 20% higher for population B. Results revealed a stronger environmental impact on phenotypic expression in the open field, and therefore the greenhouse seemed to ensure conditions under which more objective and reliable selection could be applied.

Media summary

For grain yield and pod number per plant of two dry bean populations less environmental share of phenotypic variance was observed in greenhouse than in open field.

Key words

Genetic variance, Nil-competition, Honeycomb design

Introduction

A basic principle of plant breeding is the multiple-site evaluation and selection, so that breeders are able to cope with the genotype by environment interaction in their attempt to obtain adaptable and stable cultivars. A common practice is also the multiple-site evaluation and the single-site selection, whereas the application of the single-site evaluation and selection is not unusual, for example when any population or F_2 are used as the initial material in a breeding project. In any case, breeders' concern is the control of the environmental effects on phenotypic expression, so that the environmental share in the phenotypic variance decreases, and the chance of obtaining via phenotypes the more promising genotypes increases. Environmental parameters, such as soil heterogeneity, moisture and fertility, uneven depth of sowing, different seed size, as well as climatic fluctuations contribute to variance caused by other than genetic effects. Fasoulas and Fasoula (1995) suggested the honeycomb designs as an effective way to control undesired environmental effects (e.g., widely spaced plants exploit resources according to their genetic potential without being affected by neighbouring plants, and systematic plant arrangement with distances being the same for all plants permit selection at all levels of soil fertility overcoming the detrimental effects of soil heterogeneity). Coefficient of variation (CV) is the most widely used parameter to quantify variability among individual plants of a crop stand (Fasoula and Fasoula 1997; Janick 1999; Tollenaar and Wu 1999; Tokatlidis and Koutroubas 2004). CV represents two kinds of effects, as a consequence of genetic and environmental variance. Therefore, under comparable conditions any increase in CV values of a given entry, results from higher environmental effects. The purpose of the study was to evaluate how essentially different environmental conditions existing in greenhouse and open field affect the degree of environmental variance, in the aim to assess which of them represents more suitable conditions to apply selection in an objective and reliable way.

Methods

Two local dry bean populations were used in the study. These populations concern a famous for bean quality region, located in Western Macedonia, Greece. The first population (A), named by producers "*plaki Prespon*", had been used mainly in the highlands until 1970, and thereafter it was replaced by the second population (B) named "Chrisoupoli", which was assumed more adaptable to lowlands neighbouring "Prespa" lakes in the region. Experimentation was carried out in the Technological Education Institute Farm of Florina, Greece. A total of 432 plants of each population were grown in a greenhouse (sowing date 13 of March 2003), in nonreplicated (NR-0) honeycomb trials (Fasoulas and Fasoula 1995) with plants spaced 80 x 80 cm. Another two NR-0 trials were established on 3rd of May 2003 in the open air (a field adjoining to the greenhouse), each trial containing a total of about 500 plants spaced 100 x 100 cm. Although the 100 x 100 cm density was assumed to approach absence of competition, higher density in the greenhouse was preferred to give the opportunity of including higher total number of plants. Treatments like soil preparation, sowing depth, as well as weed, disease and insect control, irrigation, and fertilisation, were applied carefully to ensure as uniform as possible plant growing conditions. Plants were cut about 140 days after sowing and left to dry about 20 days. Mean grain yield and pod number per plant were calculated. For both traits CV values were also estimated. Skewness and kurtosis of yield and pod number distributions were used to estimate distribution departure from normality.

Results

Although population B had higher yield and pod number means than population A (Table 1), the two populations, more or less, responded the same to different environmental conditions (Fig. 1, 2). Both exhibited higher mean values in the open field than in the greenhouse, either for grain yield per plant or pod number per plant. This difference could be mainly attributed to less plant-to-plant interference for environmental inputs, due to less competition resulting from lower density in the open field. However, in the open field standard deviations increased in higher rates compared to means, and consequently the CV values increased (Fig. 1, 2). Distribution skewness and kurtosis of population A were not significant under the greenhouse conditions for both yield and pod number per plant. On the other hand, under the open field conditions, skewness and kurtosis were positive and significant, because of high number of plants accumulated on the left side of distribution, and accompanied by higher CV values (Fig. 1). Compared to the greenhouse, in the open field CV values of population A were by about 59 and 54% higher for yield and pod number, respectively. Higher CV values in the open field showed that environmental impact on phenotypic variance of population A was greater in the open field than in the greenhouse. The same impact was observed in case of population B. Although skewness and kurtosis of yield distribution were significant under either greenhouse or open field conditions (Table 1), CV increased by 42% in the open field (Fig. 2). Similarly, skewness and kurtosis of pod number distribution were significant under either greenhouse or open field conditions (Table 1), but CV increased by 20% in the open field (Fig. 2).

Table 1. Statistical parameters of the two populations (A, B) for grain yield and pod number including: number of plants harvested (n), mean value ($\bar{x}$), standard deviation (s.d.), skewness and kurtosis.

Population/Site		n	$\bar{x}$	s.d.	skweness	kurtosis
			Grain yield (g/plant)			
A	Greenhouse	418	129.3	52.53	-0.084	-0.026
	Open field	406	182.5	118.1	0.741 ***	0.583 **
B	Greenhouse	427	139.0	69.23	0.580 ***	0.430 *
	Open field	431	195.0	138.0	0.361 **	-0.768 ***
			Number of pods per plant			
A	Greenhouse	418	70.72	26.36	-0.019	0.151
	Open field	406	121.9	70.03	0.614 ***	0.315
B	Greenhouse	427	81.85	40.75	0.740 ***	0.872 ***
	Open field	431	128.3	76.83	0.259 *	-0.415 *

* P<0.05, ** P<0.01, *** P<0.001

Although distribution of a population is expected to be normal, usually deviates from normality because of the environmental effects. As environmental effects become stronger, CV increases. The more the CV increases the more the distribution skews leftwards (Fasoula and Fasoula 1997). The fact that under lower density used in the open field both populations had greater means is an evidence that stronger plant-to-plant interference for use of environmental resources existed under higher density in the greenhouse. Consequently, in the greenhouse, even if one particular parameter of the environmental variance was stronger, total environmental variance was lower. Actually, under comparable conditions, less plant-to-plant interference for use of resources is expected to result in lower CV values (Fasoula and Fasoula 1997; Tollenaar and Wu 1999; Tokatlidis and koutroubas 2004). Kyriakou and Fasoulas (1985) compared the performance of a rye population under dense stand (15 x 15 cm) and under nil-competition (90 x 90 cm). Under nil-competition the grain yield distribution was normal, while under dense stand, although mean yield per plant was by 7.5 times lower (15 g), CV was by 1.6 times higher (53%), causing mean and mode of distribution to be transposed leftwards. Generally, there is a negative relationship between plant density and plant-to-plant uniformity, and therefore CV decreases as density decreases, until the plant-to-plant interference for use of resources becomes minimum (Fasoula and Fasoula 1997; Janick 1999). Therefore, increased environmental impact on the phenotypic expression of either grain yield per plant or pod number per plant was obvious in the open field. Higher environmental fluctuations under the open field conditions, such as air temperature and moisture, caused stronger environmental effects on phenotypic expression. Furthermore, plants in the open field were battered by hail on 25^{th} of May, adding another environmental parameter in phenotypic variance. Results indicated that greenhouse conditions ensure better environmental control and seem to be more suitable to apply selection in the aim to identify the superior genotypes. Comparatively stronger environmental effects under the open field conditions lead in a more biased selection.

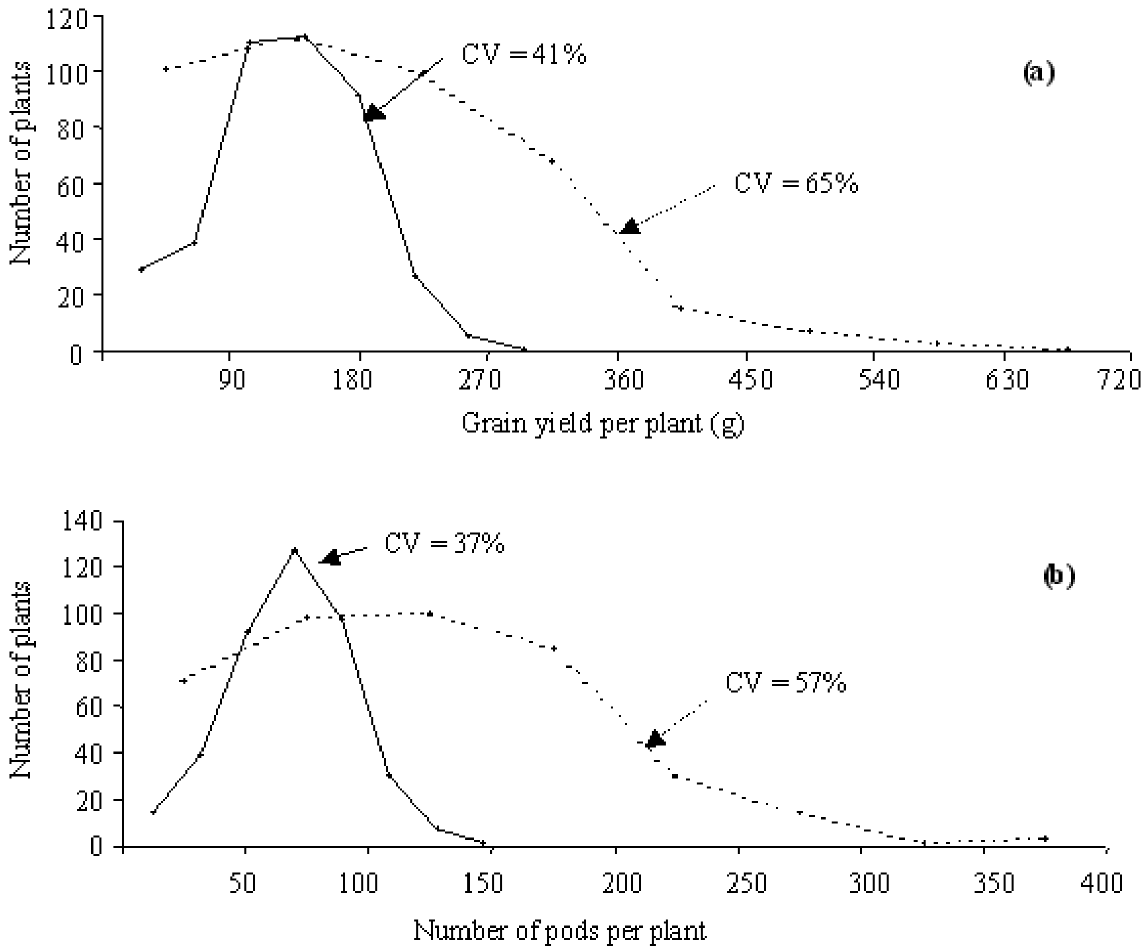

Figure 1. Yield (a) and pod number (b) distribution of population A in the greenhouse (continuous line) and in the open field (dotted line). CV=coefficient of variation.

Conclusion

Results indicated that for selection purposes in dry bean populations the density of 100 x 100 cm is preferable than that of 80 x 80 cm, when less plant-to-plant interference for use of resources is sought to eliminate the competition's detrimental impact. Grain yield and pod number CV values, as well as their frequency distributions, evidenced that environmental effects on phenotypic expression are stronger in the open field. On the other hand, environmental confusing effects decreased under the greenhouse conditions. Therefore, in the greenhouse the risk of obtaining inferior genotypes is blunted and selection within a population may be applied in a more objective and reliable way.

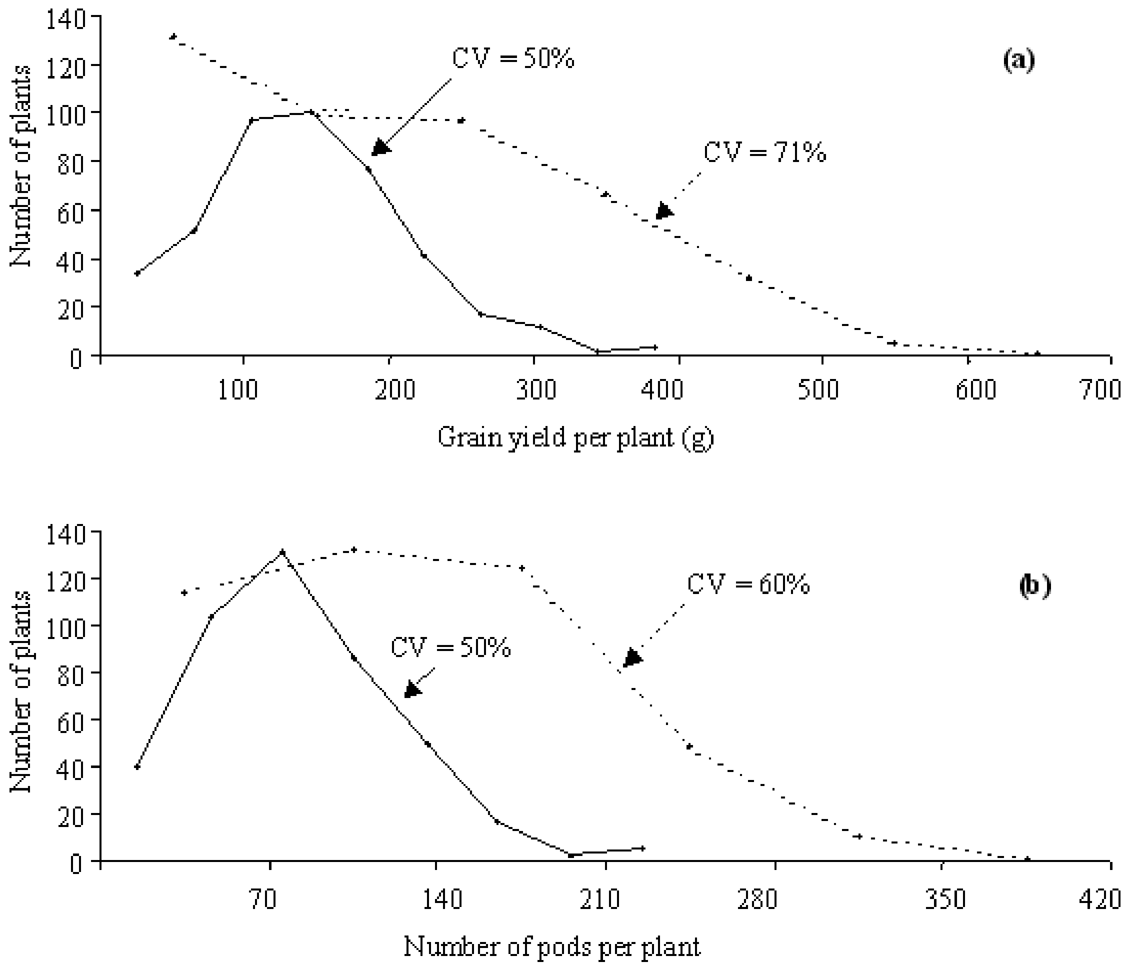

Figure 2. Yield (a) and pod number (b) distribution of population B in the greenhouse (continuous line) and in the open field (dotted line). CV=coefficient of variation.

References

Fasoula DA and Fasoula VA (1997). Competitive ability and plant breeding. In Plant Breeding Reviews (Ed. J Janick) 14, 89-138.

Fasoulas AC and Fasoula VA (1995). Honeycomb selection designs. In Plant Breeding Reviews (Ed. J Janick) 13, 87-139.

Janick J (1999). Exploitation of heterosis: Uniformity and stability. In: The Genetics and Exploitation of Heterosis in Crops. pp. 319-333. Madison, WI. USA: ASA, CSSA, CSSA.

Kyriakou DT and Fasoulas AC (1985). Effects of competition and selection pressure on yield response in winter rye (*Secale cereale* L.). Euphytica, 34, 883-895.

Tokatlidis IS and Koutroubas SD (2004). A review of maize hybrids' dependence on high plant populations and its implications for crop yield stability. Field Crops Research, in press.

Tollenaar M and Wu J (1999). Yield improvement in temperate maize is attributable to greater stress tolerance. Crop Science 39, 1597-1604.