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Abstract: The purpose of this research was to evaluate phenotypic correlation coefficents between seed yield per plant and some yield components, and to determine the direct and indirect effect of 6 components on seed yield per plant in narbon bean (*Vicia narbonensis* L.) lines. The research was conducted in the area of the Field Crops Research Training Center of the University of Çukurova, in Adana, Turkey, in the 1996/97 and 1997/98 crop years. The randomized complete blocks design with 3 replications was used. Positive and statistically significant ($p<0.05$) relationships were determined between seed yield per plant and days to flowering, number of pods per plant, number of seeds per plant, harvest index, and 1000-seed weight. There was a negative and significant correlation between seed yield and plant height. Path coefficient analyses indicated that the number of seeds per plant (0.6338), 1000-seed weight (0.3176), harvest index (0.1275), days to flowering (0.1041), and the number of pods (0.0729) had a positive direct effect on seed yield in the narbon bean. The results of this study indicate that number of seeds per plant, 1000-seed weight, days to flowering, number of pods per plant and harvest index affected seed yield per plant and it was concluded that these characters should be considered as significant selection criteria in narbon bean breeding for yield under the regional conditions of Çukurova.

Key Words: Narbon bean (*Vicia narbonensis* L.), phenotypic correlation coefficient, path coefficient, seed yield, yield components

Koca Fiğde (*Vicia narbonensis* L.) Tane Verim Komponentlerinin Korelasyon ve Path Analizi

Özet: Bu araştırmada, koca fiğ'de (*Vicia narbonensis* L.) tane verimi ve verimle ilgili özellikler arasındaki ikili ilişkiler ile bitki başına tane verimini etkileyen doğrudan ve dolaylı etkiler saptanmıştır. Araştırma, 1996/97 ve 1997/98 ürün yıllarında Çukurova Üniversitesi, Adana/Türkiye'de yürütülmüş. Araştırma, tesadüf blokları deneme desenine gore 3 tekrarlamalı olarak planlanmıştır. Bitki başına tane verimi ile çiçeklenme süresi, bitki başına bakla sayısı, tane sayısı, hasat indeksi, 1000 tane ağırlığı arasında istatistiki olarak ($p<0.05$) düzeyinde önemli ve olumlu ilişkiler saptanmıştır. Tane verimi ile bitki boyu arasında ise önemli ve olumsuz bir ilişki saptanmıştır. Path analizi sonuçlarına gore; bitki başına tane verimine doğrudan katkıyı, bitki başına tane sayısı (0.6338), 1000 tane ağırlığı (0.3176), hasat indeksi (0.1275), çiçeklenme süresi (0.1041) ve bakla sayısı (0.0729) yapmıştır. Araştırma sonucunda, bitki başına tane sayısı, 1000 tane ağırlığı, çiçeklenme süresi, bakla sayısı ve hasat indeksinin, bitki başına tane verimi üzerine etkili özellikler olduğu ve bölge koşullarında yapılacak ıslah çalışmalarında, bu özelliklerin önemli seleksiyon kriterleri olarak dikkate alınması gerektiği sonucuna varılmıştır.

Anahtar Sözcükler: Koca fiğ (*Vicia narbonensis* L.), fenotipik korelasyon, path analizi, tane verimi, verim komponentleri

Introduction

Vetches are an important source of protein and have a major role in animal nutrition, and it is essential to know the relationship between yield and its components in vetch breeding programs.

Determining seed and hay yield components will provide important benefits in vetch breeding studies in the future. However, simple correlation coefficients between yield and yield components may not give satisfactory results. On the other hand, in practice, selection criteria will contribute to selection based on direct effects. Path coefficient analyses have been used to evaluate selection criteria in several crops. This technique is useful in determining the direct influence of one variable on another, and also separates the correlation coefficient into its components of direct and indirect effects (Rodriguez et al., 2001).

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The correlation between yield components and the partitioning of the correlation coefficient into its components of direct and indirect effects have been extensively studied. Negative and significant associations of seed yield were observed with days to flowering, podding and maturity in the narbon bean (Siddique et al., 1996); plant height, and days to flowering in common vetch (Anlarsal et al., 1999); plant height in the faba bean (Bakheit and Mahdy, 1988); and plant height, mean stem length and days to flowering in common vetch (Sabancı, 1996).

Positive and significant associations of seed yield were observed with 1000-seed weight in common vetch (Tosun et al., 1991); the number of primary branches, flowers, seeds, and pods per plant in the faba bean (Sindhu et al.,1985); number of pods per plant, number of seeds per pod and 100-seed weight in the faba bean (Nigem et al., 1990); number of pods per plant in common vetch (Sabancı, 1996); and number of branches per plant, number of pods per plant, number of seeds per pod, 1000-seed weight and seeds per plant in the mung bean (Kumar et al., 2002). Tosun et al (1991) found a positive and significant correlation between 1000-seed weight and 2 components, pod number and seed number per pod, in common vetch.

Negative and significant associations of days to flowering were observed with plant height in common vetch (Anlarsal et al., 1999). Positive and significant associations of days to flowering were found in the case of plant height in common vetch (Sabancı, 1996). There was a positive and significant correlation between pod numbers per plant with 1000-seed weight (Tosun et al., 1991).

Seed yield has been reported to be influenced by the number of pods per plant, number of seeds per pod and 100-seed weight in the faba bean (Sindhu et al., 1985; Bakheit and Mahdy, 1988; Nigem et al., 1990); the pod numbers per plant and the number of seeds per pod in common vetch (Anlarsal and Gülcan, 1990); and number of pods in the mung bean (Kumar et al., 2002).

The objectives for this study were (a) to estimate correlation coefficients for phenotypic characters between seed yield and seed yield components, and (b) to evaluate the relative contribution of each component to seed yield using path coefficent analyses.

Materials and Methods

Sixteen lines of Narbon bean provided by ICARDA were used as genetic materials. The trial was arranged with 3 replications in the randomized complete black (RCB) design under the lowland conditions of the University of Çukurova Research Area in the 1996/97 and 1997/98 crop years. Each plot contained 4 rows 4 m in length and 0.3 m apart. Plots were fertilized with 30 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} at sowing. The research area had sandy loam type texture and was classified as class I land capability. The Çukurova region, in southern Turkey, has a typical coastal Mediterranean climate. Climatic data related to the research location are shown in Table 1.

The data obtained over 2 years were combined and subjected to variance analyses in RCB design measurements and observations of examined characters were performed 10 ten plants chosen randomly from the mid-row of each plot. The following were observed and measured: days to flowering (days), plant height (cm), number of pods (numbers), number of seeds per plant (numbers), harvest index (%), seed yield per plant (g), and 1000-seed weight (g). Days to flowering was recorded as the time from sowing 50% flowering. Plant height was measured before harvesting and other characters were measured at or after harvest.

The data used were obtained from a previous study, carried out in the 1996/97 and 1997/98 crop years (Yücel, 2001).

The simple phenotypic correlation coefficients among all observed components were first calculated by the Tarist statistical program and then they were separated into direct and indirect effects via path coefficient analyses as suggested by Anlarsal and Gülcan (1989), Sabancı (1996) and Rodriguez et al. (2001). In path analysis, seed yield per plant was the dependent variable and the other characteristics were considered as independent variables in Figure 1.

Results and Discussion

Simple correlation coefficients among the examined characters are shown in Table 2. Positive and significant relationships were found statistically between days to flowering and the other components number of seeds per plant (r = +0.212*), harvest index (r = +0.235**), and seed yields per plant (r = +0.340**). Days to flowering

Table 1. Meteorological data for Adana province for 1996, 1997, 1998 and the long term[1].

Months	Years	Highest temperatures (ºC)	Lowest temperatures (ºC)	Average temperatures (ºC)	Average relative humidity (%)	Total rainfall (mm)
	1996	23.7	11.1	16.2	62.0	13.6
November	1997	22.3	11.5	15.4	74.7	107.3
	Long term*	22.6	10.6	15.1	63.0	67.2
	1996	17.7	9.4	12.7	77.0	122.5
December	1997	15.2	7.4	10.7	79.3	177.8
	Long term	16.8	6.8	11.1	66.0	118.1
	1997	16.2	5.4	9.2	68.0	38.0
January	1998	14.2	4.5	8.5	69.6	46.4
	Long term	14.5	5.0	9.9	66.0	111.7
	1997	14.4	3.1	8.0	68.0	67.0
February	1998	17.2	4.4	9.9	63.9	6.30
	Long term	16.0	5.9	10.4	66.0	92.0
	1997	16.6	4.9	10.2	65.0	19.4
March	1998	17.0	6.6	11.3	71.7	92.9
	Long term	19.2	8.0	13.1	66.0	67.9
	1997	19.5	9.3	14.2	73.0	104.4
April	1998	24.7	12.3	18.2	68.7	56.2
	Long term	23.5	11.6	17.1	69.0	51.4
	1997	29.0	16.3	22.6	68.0	20.1
May	1998	27.4	16.5	21.6	70.5	32.9
	Long term	28.2	15.3	21.4	67.0	46.7

* The long term averages of 40 years of records
1: Data colleceted from Adana Meteorological station

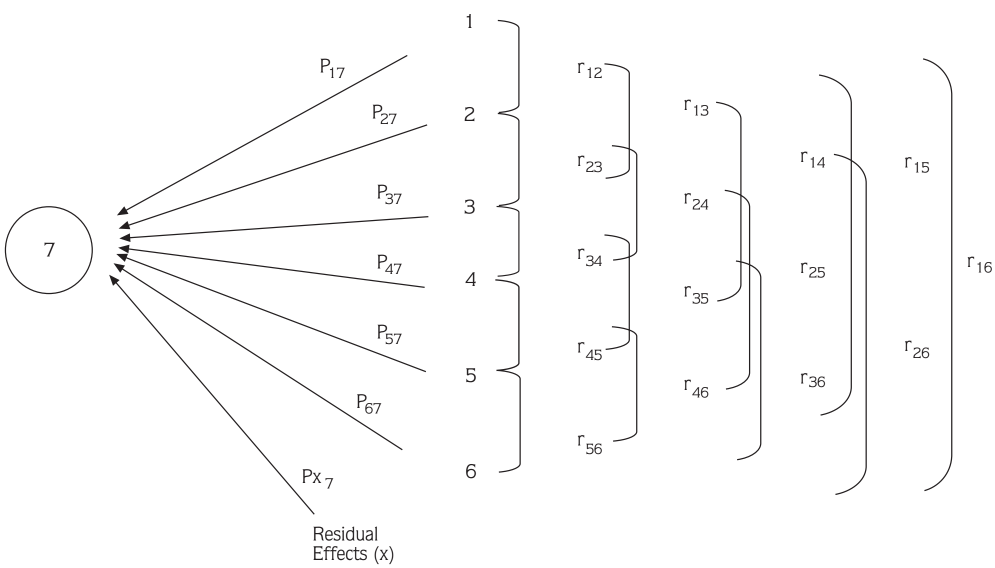

Figure 1. Path diagram showing interrelationships among traits 1 to 7. The residual variable (x) is the undetermined portion, $\sqrt{1-R^2}$. P and r indicate direct path coefficients and correlation coefficients, respectively.
1) Days to flowering 2) Plant height 3) Number of pods $plant^{-1}$
4) Number of seeds $plant^{-1}$ 5) Harvest index 6) 1000-seed weight 7) Seed yield $plant^{-1}$

Table 2. Phenotypic correlation coefficients of seed yield components in the narbon bean (n = 96).

Yield components	Plant height	Number of pods plant^{-1}	Number of seeds plant^{-1}	Harvest index	Seed yield plant^{-1}	1000-seed weight
Days to flowering	-0.344**	-0.086 ns	0.212*	0.235**	0.340**	0.151 ns
Plant height	-	0.134 ns	-0.295**	-0.580**	-0.500**	-0.393**
Number of pods plant^{-1}	-	-	0.649**	0.211*	0.478**	-0.038 ns
Number of seeds plant^{-1}			-	0.557**	0.821**	0.064 ns
Harvest index				-	0.661**	0.283**
Seed yield plant^{-1}					-	0.442**

ns: non-significant; * Significant at 5% level of P; ** Significant at 1% level of P.

was positively correlated with seed yields per plant and is in accordance with Sindhu et al. (1985) but not with Siddique et al. (1996) or Anlarsal et al. (1999). In contrast to Siddique et al. (1996) and Anlarsal et al. (1999), seed yields of the lines of the later flowering increased, because the plants were affected by low temperatures during the bloom stage in the first experimental year. This situation is related to environmental conditions rather than genotypic reasons. Since low temperature delays days to flowering, hay yield increases, and seed yield and yield components decrease (Açıkgöz, 2001). There were negative and significant correlations between days to flowering and plant height (-0.344**), in agreement with Anlarsal et al. (1999) but not with Sabancı (1996). The reason why the plants height decreased was the unsuitable weather conditions.

Plant height was negatively and significantly correlated with the number of seeds per plant (r = -0.295**), harvest index (r = -0.580**), 1000-seed weight (r = -0.393**) and seed yield per plant (r = -0.500**). These results were in agreement with the studies carried out by Bakheit and Mahdy (1988) with the broad bean, and Sabancı (1996) with common vetch. Plant height increased because of warm and rainy weather conditions in the growing period in the second experiment year and so plants tend to lodge. This caused the yield and yield components to decrease. As a result, a shorter plant type is an important breeding objective in the narbon bean in the warm and rainy conditions of Çukurova.

Positive and significant correlations between pod numbers per plant and the other yield components, number of seeds per plant (r = +0.649**), harvest index (r = +0.211*), and seed yields per plant (r = +0.478**) were found. There were positive and significant correlations between pod numbers per plant and seed yield per plant. These results were in accordance with the results reported by Sindhu et al. (1985), Nigem et al. (1990) and Kumar et al. (2002). There were negative and non significant correlations between pod numbers per plant and 1000-seed weight (-0.038 ns), and this result is not in agreement with the results of Tosun et al. (1991).

Positive and significant correlations between number of seeds per plant and the other yield components, harvest index (r = +0.557**) and seed yield per plant (r = +0.821**) were found, in agreement with Kumar et al. (2002). There was no significant correlation between number of seeds per plant and 1000-seed weight (0.064 ns).

Harvest index was found to be significantly correlated with seed yield per plant (r = +0.661**) and 1000-seed weight (r = +0.283**). There were significant correlations between 1000-seed weight with seed yield per plant (r = +0.442**). These results were in accordance with Sindhu et al. (1985), Nigem et al. (1990), Tosun et al. (1991) and Anlarsal et al. (1999).

Figure 1 shows the path coefficient analyses. The direct and indirect effects of seed yield components on seed yield are shown in Table 3 and the direct effects and their percentages are in bold and underlined.

Path coefficient analyses (Table 3) revealed that number of seeds per plant (0.6338 and 77.23%) had the highest positive direct effect, followed by 1000-seed weight (0.3176 and 70.95%), on seed yield per plant. Similar results were reported by other researchers (Sindhu et al., 1985; Bakheit and Mahdy, 1988; Nigem et al., 1990).

Table 3. Phenotypic path coefficient showing direct and indirect effects of different components on seed yield plant^{-1}.

Yield components	Days to flowering (days)		Plant height (cm)		Number of pods plant^{-1}		Number of seeds plant^{-1}		Harvest index (%)		1000-seed weight (g)	
	Path Coef.	%	Path Coef.	%	Path Coef.	%	Path Coef.	%	Path Coef.	%	Path Coef.	%
Days to flowering (days)	**0.1041**	**29.51**	0.0304	8.62	-0.0062	1.77	0.1341	38.03	0.0300	8.50	0.0478	13.57
Plant height (cm)	-0.0358	6.88	**-0.0884**	**17.20**	0.0097	1.87	-0.1870	35.99	-0.0739	14.22	-0.1248	24.02
Number of pods plant^{-1}	-0.0089	1.64	-0.0118	2.17	**0.0729**	**13.40**	0.4115	75.63	0.0269	4.94	-0.0121	2.22
Number of seeds plant^{-1}	0.0220	2.68	0.0261	3.18	0.0473	5.77	**0.6338**	**77.23**	0.0710	8.65	0.0204	2.49
Harvest index (%)	0.0245	3.70	0.0513	7.75	0.0154	2.32	0.3529	53.37	**0.1275**	**19.29**	0.0898	13.57
1000 seed weight (g)	0.0157	3.50	0.0348	7.77	-0.0028	0.62	0.0408	9.11	0.036	8.05	**0.3176**	**70.95**

Residual effect = 0.331

The direct effect of days to flowering on seed yield per plant was positive and its values were 0.1041 and 29.51%. The path coefficient value of days to flowering was found to be the result of a strong indirect effect via seed yield per plant (0.1341 and 38.03%), followed by 1000-seed yield (0.0478 and 13.57%).

The direct effect of plant height on seed yield per plant was negative and low (-0.0884 and 17.20%). The path coefficient value of plant height was found to be the result of the strong negative indirect effect of plant height via number of seeds per plant (-0.1870 and 35.99%), followed by 1000-seed weight (-0.1248 and 24.02%).

The direct effect of pod numbers per plant on seed yield per plant was positive (0.0729 and 13.40%), confirming the results of Anlarsal and Gülcan (1990), Sindhu et al. (1985), Kumar et al. (2002) and Bakheit and Mahdy (1988). The high path coefficient value of pod numbers per plant was found to be the result of the strong positive indirect effect of pod numbers per plant via number of seeds per plant (0.4115 and 75.63%).

The direct effect of harvest index on seed yield per plant was positive (0.1275 and 19.29%). The high path coefficient value of harvest index was found to be a consequence of the strong indirect effect of harvest index via number of seeds per plant (0.3529 and 53.37%), followed by 1000-seed weight (0.0898 and 13.57%).

The direct effect of 1000-seed weight on seed yield per plant was positive and high (0.3176 and 70.95%). The highest path coefficient of 1000-seed weight was found to be the result of the positive indirect effect of 1000-seed weight via number of seeds per plant (0.0408 and 9.11%), followed by harvest index (0.036 and 8.05%). These results are in agreement with the findings published before (Sindhu et al., 1985; Bakheit and Mahdy,1988; Nigem et al., 1990).

Conclusions

In the studied characters, the direct and indirect effects of the number of seeds per plant, 1000-seed weight, days to flowering, harvest index and pod number per plant on seed yield per plant were positive and high, but the first 2 characters were of greater importance than the others. The consideration of these characters can contribute to the success of breeding studies in the narbon bean in the Çukurova region. Furthermore, according to the results of the correlation analyses a significant and negative correlation between seed yield per plant and plant height was determined. Short narbon bean species should be preferred, because the tall varieties tend to lodge in the region. A positive and significant correlation was found between the days to flowering and seed yield, and the days to flowering affected seed yield positively. However, late flowering lines should be preferred in cold temperatures for seed yield .

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