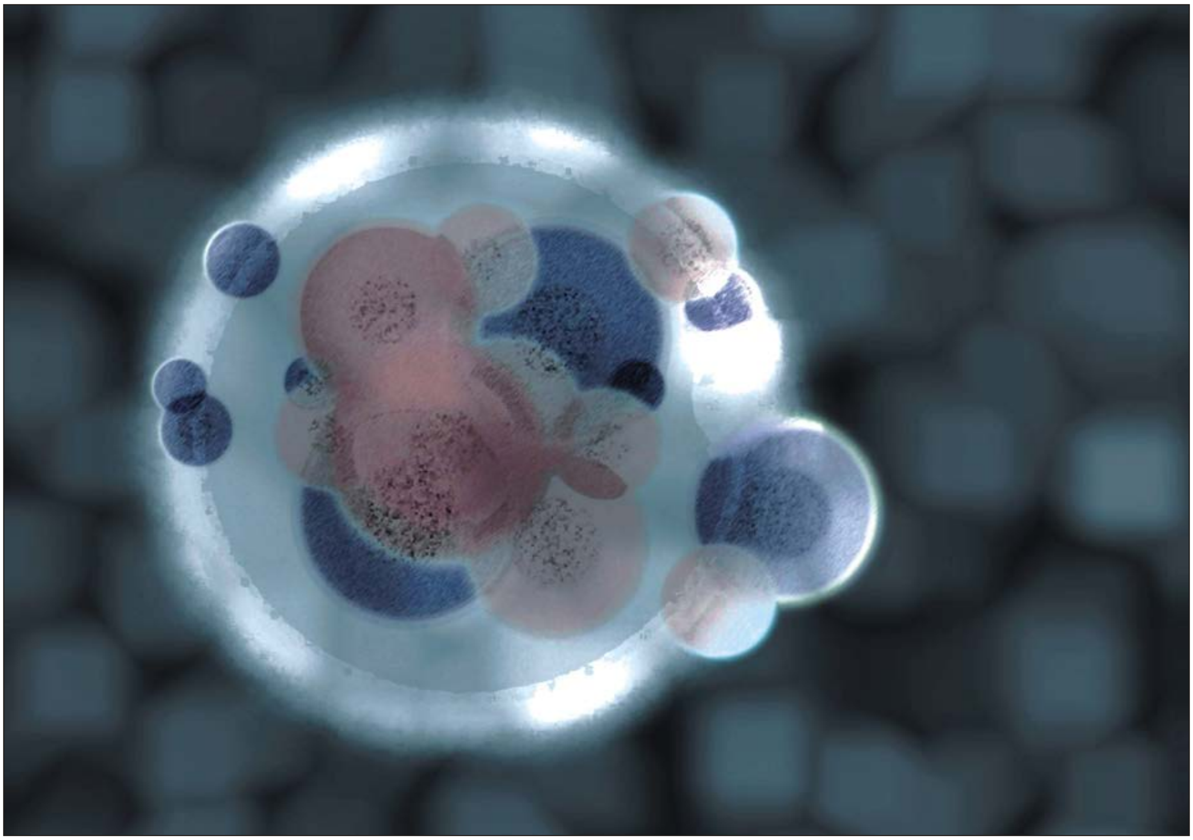

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Correlation and Path Coefficient Analyses of Seed Yield Components in the Sainfoin (*Onobrychis sativa* L.)

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Abstract: The purpose of this research was to evaluate phenotypic correlation coefficients between seed yield and some yield components and to determine the direct and indirect effect of 9 components on seed yield in sainfoin (*Onobrychis sativa* L.). The research was conducted at the Agricultural Research and Experiment Center of Agriculture Faculty, Uludag University in 2000-2003. The field experiments were established in a split plot design with four replications. Seed yield, plant height, raceme number per plant, stem number per m^2, raceme number per m^2, fruit number per raceme, fruit weight per raceme, fruit number per plant, fruit weight per plant and 1000-fruit weight were determined. The data obtained over 3 years were combined. According to results of this research, seed yield was positively and significantly correlated with raceme number per plant (r = 0.266**), fruit number per raceme (r = 546**), fruit weight per raceme (r = 538**), fruit number per plant (r = 0.495**), fruit weight per plant (r = 0.490**) and 1000-fruit weight (r = 0.602**), while seed yield was negative and significantly correlated with stem number per m^2 (r = -0.353**) and raceme number per m^2 (r = -0.305**). Path coefficient analyses revealed that fruit number per plant (2.2757 and 28.50%) had the highest positive direct effect, followed by fruit weight per raceme (1.6989 and 20.74%), on seed yield, while fruit weight per plant showed the highest negative direct effect (-2.3369 and 28.59%).

Key words: Sainfoin (*Onobrychis sativa* L.), phenotypic correlation, path coefficient, seed yield, yield components

INTRODUCTION

Sainfoin (*Onobrychis sativa* L.) is an important forage legume for Turkey. It is a native, widely grown perennial legume well adapted to the highland farming system under the dryland conditions of Central and Eastern Anatolia. Sainfoin is a very palatable forage plant and has the advantage of not inducing bloating as an animal feed over alfalfa. It has the advantage of root growth to a greater depth than most annual legumes can achieve. Its roots penetrate through the deeper layers of the soil and supply a great amount of organic matter when plants are under the soil. This organic matter is very important, particulary under dryland conditions due to the difficult of producing large amounts of vegetation (Elçi *et al*., 1995).

It has been reported that Path-Coefficient Analyses (PCA) are more informative and useful than simple correlation coefficients and widely used in crop breeding to determine the nature of relationships between seed yield and some yield components (Kang *et al*., 1983; Williams *et al*., 1990; Gravois and McNew, 1993; Board *et al*., 1997; Samonte *et al*., 1998). Path-coefficient (PC) is a standardized partial regression coefficient that measures the direct influence of one trait upon another and permits the separation of a correlation coefficient into components of direct and indirect effects (Board *et al*., 1997).

In research with sainfoin, Tosun (1988) found significant positive correlation coefficients between seed yield and raceme number per plant (r = 0.72**) and fruit number per raceme (r = 0.57**), negative and significant correlation between seed yield and stem number per m^2 (r = -0.76**). Besides, the researcher determined negative correlations between stem number per m^2 and all components. Tuna (1994) determined positive and significant correlation between seed yield and fruit weight per plant (r = 0.473**). Positive and significant associations of seed yield were observed with 1000-seed weight (Tosun *et al*., 1991), fruit number per plant (Albayrak *et al*., 2003; Avci and Gökkuş, 1997) in common vetch.

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

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MATERIALS AND METHODS

The research was performed at the Agricultural Research and Experiment Station of Agriculture Faculty, Uludag University in 2000-2003. The experimental soil was clayey, non saline, poor in lime and organic matter, rich in potassium and had a neutral pH. Average temperature, relative humidity and precipitation were 15.9°C, 53.7% and 649.2 mm in 2001; 14.9°C, 68.7% and 759.3 mm in 2002; 11.4°C, 66.0% and 364.8 mm in 2003 (January-June); 14.8°C, 68.9% and 698.9 mm in long years (1928-1999) averages, respectively.

The field experiments were established in a split plot design with four replications on 25.11.2000. Five different row spaces (15, 30, 45, 60 and 75 cm) and five different seeding rates (20, 40, 60, 80 and 100 kg ha^{-1}) were used in the experiment. Row spaces and seeding rates were placed main plots and subplots respectively. Plot length was 4 m, plot width ranged from 2.4 to 3 m according to row spaces.

Plots were fertilized with 60 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5 at sowing. In 2001 and 2002 only phosphorus (kg ha^{-1}) was applied.

Seed harvest was performed on July 4th in 2001, June 14th in 2002 and July 3rd in 2003. Plant height (cm), raceme number per plant (number), fruit number per raceme (number), fruit weight per raceme (g), fruit number per plant (number), fruit weight per plant (g), 1000-fruit weight were measured using 10 plants randomly collected from each row. In addition, seed yield (kg ha^{-1}) stem number per m^2 (number) and raceme number per m^2 (number) were also evaluated. The data obtained over 3 years were combined.

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), Sabanci (1996) and Rodriguez *et al.* (2001).

RESULTS AND DISCUSSION

Simple correlation coefficients among the examined characters are shown in Table 1. Positive relationships existed between seed yield and all its components with the exceptions of the stem number per m^2 and raceme number per m^2 (r = -0.353** and r = -0.305**). Seed yield was positively and significantly correlated with raceme number per plant (r = 0.266**), fruit number per raceme (r = 546**), fruit weight per raceme (r = 538**), fruit number per plant (r = 0.495**), fruit weight per plant (r = 0.490**) and 1000-fruit weight (r = 0.602**). Tuna (1994) observed positive and significant correlation between seed yield and fruit weight per plant in sainfoin. Tosun (1988) determined positive and significant correlation between seed yield and raceme number per plant and fruit number per raceme, negative and significant correlation between seed yield and stem number per m^2. Findings of the present study are in agreement with these results. Several previous studies reported that the correlation between seed yield and fruit number per plant in common vetch was positive and significant, in agreement with our results (Albayrak *et al.*, 2003; Avci and Gökkuş, 1997). Çakmakçi *et al.* (1998), Açikgöz *et al.* (1986) and Orak (1989) determined positive and significant correlation between seed yield and 1000-seed weight in common vetch, in agreement with our results. There was no significant correlation between seed yield and plant height. This result was in accordance with the studies carried out by Gökkuş *et al.* (1996) with common vetch.

Plant height was found to be significantly correlated with stem number per m^2 (r = 0.445**), raceme number per m^2 (r = 0.474**), raceme number per plant (r = 0.540**), fruit number per raceme (r = 0.157**), fruit number per plant (r = 0.183**) and fruit weight per plant (r = 0.114*). Fruit weight per raceme and 1000-fruit weight showed a nonsignificant correlation with plant height (Table 1).

As expected, stem number/m^2 was negatively and significant related with fruit number per raceme (r = -0.502**), fruit weight per raceme (r = -0.598**), fruit number per plant r = -0.461**), fruit weight per plant (r = -0.540**) and 1000-fruit weight (r = -0.577**). Besides, positive and significantly relationships existed between raceme number per m^2 and stem number per m^2 (r = 0.905**)(Table 1). These results were in agreement with the study carried out by Tosun (1988).

Raceme number per m^2 was found to be negatively and significantly correlated with fruit number per raceme (r = -0.418**), fruit weight per raceme (r = -0.500**), fruit number per plant (r = -0.214**), fruit weight per plant (r = -0.319**) and 1000-fruit weight (r = -0.479**) while it was found to be positively and significant correlation with raceme number per plant (r = 0.369**) (Table 1).

Raceme number per plant was positively and significantly correlated with fruit number per raceme (r = 0.364**), fruit weight per raceme (r = 0.348**), fruit number per plant (r = 0.684**), fruit weight per plant (r = 0.601**) and 1000-fruit weight (r = 0.387**).

Positive and significant relationships were found between fruit number per raceme and fruit weight per raceme (r = 0.942**), fruit number per plant (r = 0.878**), fruit weight per plant (r = 0.846**) and 1000-fruit weight (r = 0.712**).

Results indicated that there were positive and significant relationships between fruit weight per raceme and fruit number per plant (r = 0.865**), fruit weight per plant (r = 0.922**) and 1000-fruit weight (r = 0.769**).

Table 1: Correlation coefficients among characters in sainfoin according to averaged over three years

	SY	PH	SN/m^2	RN/m^2	RN/P	FN/R	FW/R	FN/P	FW/P	1000 FW
SY	1.000	0.090^{ns}	-0.353**	-0.305**	0.266**	0.546**	0.538**	0.495**	0.490**	0.602**
PH		1.000	0.445**	0.474**	0.540**	0.157**	0.084^{ns}	0.183**	0.114*	0.031^{ns}
SN/m^2			1.000	0.905**	0.034^{ns}	-0.502**	-0.598**	-0.461**	-0.540**	-0.577**
RN/m^2				1.000	0.369**	-0.418**	-0.500**	-0.214**	-0.319**	-0.479**
RN/P					1.000	0.364**	0.348**	0.684**	0.601**	0.387**
FN/R						1.000	0.942**	0.878**	0.846**	0.712**
FW/R							1.000	0.865**	0.922**	0.769**
FN/P								1.000	0.961**	0.673**
FW/P									1.000	0.716**
1000 FW										1.000

SY: Seed yield, PH: Plant height, SN/m^2: Stem number per m^2, RN/m^2: Raceme number per m^2, RN/P: Raceme number per plant, FN/R: Fruit number per raceme, FW/R: Fruit weight per raceme, FN/P: Fruit number per plant, FW/P: Fruit weight per plant, 1000 FW: Thousand fmit weight.
* significant at the 0.05 probability level, ** significant at the 0.01 probability level, ns: non-significant

Fruit number per plant was found to be significant and positively correlations with fruit weight per plant (r = 0.961**) and 1000-fruit weight (r = 0.673**). It was found positive and significant correlation between fruit weight per plant and 1000-fruit weight (r = 0.716**) (Table 1). These results were in agreement with the study carried out by Yücel (2004) with narbon bean.

Results indicated that plant height, stem number per m^2, raceme number per plant, fruit weight per raceme, fruit number per plant and 1000-fruit weight showed positive direct effect on seed yield whereas there was negative direct effects of raceme number per m^2, fruit number per raceme and fruit weight per plant on seed yield. Path coefficient analyses revealed that fruit number per plant (2.2757 and 28.50%) had the highest positive direct effect, followed by fruit weight per raceme (1.6989 and 20.74%), on seed yield (Table 2). This result was in agreement with the studies carried out by Çakmakçi *et al*. (1998), Yilmaz and Can (1998) with common vetch.

Fruit weight per plant and fruit number per raceme showed the highest negative direct effect (-2.3369 and -1.3851, respectively). On the other hand, fruit weight per plant showed a large positive indirect effect (2.1868 and 26.75%) through fruit number per plant whereas fruit number per plant had a large negative indirect effect (-2.2456 and 28.12%) through fruit weight per plant on seed yield (Table 2). If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be reason of correlation. In such situations, the indirect causal factors must be considered simultaneously (Singh and Chaudhary, 1977).

Because the direct effect of plant height on seed yield was positive and low (0.0015 and 0.08%), this trait should not be considered as the choice of selection characters for seed yield component studies in sainfoin (Table 2).

The direct effect of stem number per m^2 on seed yield was positive and high (0.6176 and 11.21%). Correlation coefficient can be negative but the direct effect may be positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed, i.e., Restrictions are to be imposed to nullify the undesirable indirect effects to make use of the direct effect (Singh and Chaudhary, 1977). The path coefficient value of stem number per m^2 was found to be the result of the strong positive indirect effect of stem number per m^2 via fruit weight per plant (1.2623 and 22.90%).

The direct effect of raceme number per m^2 on seed yield was negative and high (-0.7030 and 16.91%). The path coefficient value of raceme number per m^2 was found to be a consequence of the strong negative indirect effect of raceme number per m^2 via fruit weight per raceme (-0.8488 and 20.42%), followed by fruit number per plant (-0.4868 and 11.71%) (Table 2).

The direct effect of 1000-fruit weight on seed yield was positive (0.4023 and 6.06%). The path coefficient value of 1000-fruit weight was found to be the result of the strong negative indirect effect of 1000-fruit weight via fruit weight per plant (-1.6738 and 25.23%), followed by fruit number per raceme (-0.9860 and 14.86%) (Table 2). Results of the present study are in general agreement with the results of several previous studies (Albayrak, 2004; Çakmakçi *et al*., 1998; Yilmaz and Can, 1998; Sabanci, 1996) with common vetch.

Path coefficient and correlation analyses have been widely used in many crop species to understand or clarify the nature of the complex interrelationships among traits and to identify sources of variation in yield, which can be utilized to develop selection characters or improve the seed yield with agricultural practices.

The data obtained from this study could be useful for sainfoin breeders and seed producers concerned with increasing seed yield. According to the results of the correlation analyses significant and positive correlations between seed yield and raceme number per plant, fruit number per raceme, fruit weight per raceme, fruit number per plant, fruit weight per plant and 1000-fruit weight were determined. Path coefficient analyses revealed that plant height, stem number per m^2, raceme number per plant, fruit weight per raceme, fruit number per plant and 1000-fruit weight represent a direct positive effect on seed yield in

Table 2: Phenotypic path coefficient showing direct and indirect effects of different components on seed yield according to averages of three years

	Path Coef.	(%)		Path Coef.	(%)
PH vs seed yield	$r = 0.090^{ns}$		FW/R vs seed yield	r = 0.538**	
Direct effect	0.0015	0.08	Direct effect	1.6989	20.74
Indirect effect via SN/m^2	0.2751	15.97	Indirect effect via PH	0.0001	0.002
Indirect effect via RN/m^2	-0.3334	19.35	Indirect effect via SN/m^2	-0.3692	4.51
Indirect effect via RN/P	0.0592	3.44	Indirect effect via RN/m^2	0.3512	4.29
Indirect effect via FN/R	-0.2171	12.60	Indirect effect via RN/P	0.0381	0.47
Indirect effect via FW/R	0.1425	8.27	Indirect effect via FN/R	-1.3041	15.92
Indirect effect via FN/P	0.4155	24.11	Indirect effect via FN/P	1.9677	24.02
Indirect effect via FW/P	-0.2661	15.44	Indirect effect via FW/P	-2.1541	26.29
Indirect effect via 1000 FW	0.0127	0.74	Indirect effect via 1000 FW	0.3093	3.78
SN/m^2 vs seed yield	r = -0.353**		FN/P vs seed yield	r = 0.495**	
Direct effect	0.6176	11.21	Direct effect	2.2757	28.50
Indirect effect via PH	0.0007	0.012	Indirect effect via PH	0.0003	0.003
Indirect effect via RN/m^2	-0.6360	11.54	Indirect effect via SN/m^2	-0.2846	3.56
Indirect effect via RN/P	0.0037	0.07	Indirect effect via RN/m^2	0.1504	1.88
Indirect effect via FN/R	0.6954	12.62	Indirect effect via RN/P	0.0750	0.94
Indirect effect via FW/R	-1.0154	18.42	Indirect effect via FN/R	-1.2156	15.22
Indirect effect via FN/P	-1.0488	19.03	Indirect effect via FW/R	1.4689	18.39
Indirect effect via FW/P	1.2623	22.90	Indirect effect via FW/P	-2.2456	28.12
Indirect effect via 1000 FW	-0.2320	4.21	Indirect effect via 1000 FW	0.2706	3.39
RN/m^2 vs seed yield	r = -0.305**		FW/P vs seed yield	r = 0.490**	
Direct effect	-0.7030	16.91	Direct effect	-2.3369	28.59
Indirect effect via PH	0.0007	0.017	Indirect effect via PH	0.0002	0.002
Indirect effect via SN/m^2	0.5588	13.44	Indirect effect via SN/m^2	-0.3336	4.08
Indirect effect via RN/P	0.0404	0.97	Indirect effect via RN/m^2	0.2246	2.75
Indirect effect via FN/R	0.5793	13.94	Indirect effect via RN/P	0.0659	0.81
Indirect effect via FW/R	-0.8488	20.42	Indirect effect via FN/R	-1.1714	14.13
Indirect effect via FN/P	-0.4868	11.71	Indirect effect via FW/R	1.5660	19.16
Indirect effect via FW/P	0.7465	17.96	Indirect effect via FN/P	2.1868	26.75
Indirect effect via 1000 FW	-0.1925	4.63	Indirect effect via 1000 FW	0.2881	3.53
RN/P vs seed yield	r = 0.266**		1000 FW vs seed yield	r = 0.602**	
Direct effect	0.1096	2.38	Direct effect	0.4023	6.06
Indirect effect via PH	0.0008	0.017	Indirect effect via PH	0.0000	0.0007
Indirect effect via SN/m^2	0.0208	0.45	Indirect effect via SN/m^2	-0.3563	5.37
Indirect effect via RN/m^2	-0.2591	5.63	Indirect effect via RN/m^2	0.3365	5.07
Indirect effect via FN/R	-0.5039	10.95	Indirect effect via RN/P	0.0424	0.64
Indirect effect via FW/R	0.5908	12.84	Indirect effect via FN/R	-0.9860	14.86
Indirect effect via FN/P	1.5565	33.82	Indirect effect via FW/R	1.3063	19.69
Indirect effect via FW/P	-1.4048	30.53	Indirect effect via FN/P	1.5307	23.07
Indirect effect via 1000 FW	0.1556	3.38	Indirect effect via FW/P	-1.6738	25.23
FN/R vs seed yield	r = 0.546**				
Direct effect	-1.3851	17.56			
Indirect effect via PH	0.0002	0.003			
0.003 Indirect effect via SN/m^2	-0.3101	3.93			
Indirect effect via RN/m^2	0.2940	3.73			
Indirect effect via RN/P	0.0399	0.51			
Indirect effect via FW/R	1.5996	20.28			
Indirect effect via FN/P	1.9973	25.32			
Indirect effect via FW/P	-1.9765	25.05			
Indirect effect via 1000 FW	0.2864	3.63			

sainfoin, but fruit number per plant and fruit weight per raceme were of greater importance than the others. The consideration of these characters can contribute to the success of breeding studies in the sainfoin in the Marmara region. Fruit weight per plant showed a large positive and highest indirect effects through fruit number per plant on seed yield.

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