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Path Coefficient and Correlation Analysis Between Seed Yield and Its Affecting Components in Common Vetch (*Vicia sativa* L.)

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Abstract

The study was held to evaluate relationships between seed yield (SDY) and its affecting components in common vetch (*Vicia sativa* L.) genotypes. It was analyzed the direct and indirect effects of the components on SDY using simple correlation and path coefficient analyses over the three consecutive growing seasons data. Field trials were performed in the research areas of the GAP International Agricultural Research and Training Center (GAP IARTC) in Diyarbakir, Turkey, during the 2008–09, 2009–10, and 2010–11 growing seasons with winter sowings. The experimental design was a randomized block design with three replications. Results from simple correlation analysis showed that pod numbers per plant (PNP) was significantly ($P < 0.05$) and positively correlated with SDY. The remaining yield component traits were highly significantly ($P < 0.01$) positively correlated with seed yield. In addition, path coefficients analysis showed that only biological yield (BLY) (3.7455 and 55.76%) and straw yield (SWY) (-3.0385 and 45.34%) had the strongest direct effects on seed yield. However, days to physiological seed maturity (DSM), pod numbers per plant (PNP), seed numbers per pod (SNP), harvest index (HTI) thousand seed weight (TSW) did not have any direct effects on seed yield. These five traits indirectly affected SDY, especially via BLY and SWY. Based on these results, we concluded that BLY should be used as the primary selection criterion for improving seed yield in common vetch.

Keywords: Common vetch (Vicia sativa L.), correlation coefficient analysis, seed yield, yield components, path coefficient analysis

Adi Fiğ (*Vicia sativa* L.) Genotiplerinde Tohum Verimi ve Verim Kompenentleri Arasındaki İlişkilerin Path ve Korelasyon Analizi ile Tespiti

Özet

Bu çalışma, adi fiğ (*Vicia sativa* L.) genotiplerinde tohum verimi ve tohum verimine etki eden özellikler arasındaki ilişkilerin değerlendirmesi amacıyla ele alınmıştır. Araştırmada tohum verimi ve verim kompenentleri arasındaki ilişkiler, basit korelasyon analizi ile belirlenirken, incelenen özelliklerin tohum verimi üzerindeki doğrudan ve dolaylı etkileri ise path analizi ile belirlenmiştir. Araştırma, Diyarbakır GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi Müdürlüğü deneme alanlarında 2008-09, 2009-10 ve 2010-11 ekim sezonlarında kışlık olarak tesadüf blokları deneme desenine göre üç tekrarlamalı olarak yürütülen tarla denemelerinden elde edilen gözlem verilerine dayanmaktadır. Yapılan korelasyon analiz sonucuna göre, bitkide bakla sayısı (PNP) özelliği ile tohum verimi (SDY) arasında 0.05 düzeyinde olumlu ilişki saptanırken, incelenen diğer tüm özellikler ile tohum verimi arasında 0.01 düzeyinde önemli ve olumlu ilişki saptanmıştır. Path analiz sonucuna göre ise, tohum verimim üzerinde en yüksek doğrudan etkisi bulunan özellikler biyolojik verim (BLY) (3.7455 ve 55.76%) ve saman verimi (SWY) (-3.0385 ve 45.34%) özellikleri olurken, fizyolojik olum gün sayısı (DSM), bitkide bakla sayısı (PNP), baklada tane sayısı (SNP), hasat indeksi (HTI) ve bin tane ağırlığı (TSW) özelliklerinin tohum verimi (SDY) üzerinde herhangi bir doğrudan etkileri saptanmamıştır. Bu beş özelliğin tohum verimi üzerinde etkileri dolaylı ve özellikle biyolojik verim ve saman verimi özellikleri üzerinden olmuştur. Araştırma bulgularına göre;

adi fiğde tohum verimini artımak amacıyla yapılacak ıslah çalışmalarında biyolojik verim özelliği başlıca seleksiyon kriteri olarak kabul edilmelidir.

Anahtar Kelimeler: Adi fiğ (*Vicia sativa* L.), korelasyon analizi, tohum verimi, verim komponentleri, path analizi

Introduction

Common vetch (*Vicia sativa* L.) is one of the most heavily cultivated annual legume forage species in Turkey and globally. It is typically cultivated for forage, seeds, and green manure (Cakmakcı et al., 2003). Common vetch is a legume and it increases soil nitrogen content. It contributes to disease prevention for crops that are subsequently rotated (Ayed et al., 2001; Caballero et al., 2001). Common vetch is highly palatable and high in protein content, and reduces the likelihood of bloating in ruminants. Moreover, following seed harvest, the remnant straw is a valuable source of roughage (Acıkgoz, 2001). A major problem for animal husbandry in Turkey, and especially the Southeastern Anatolia Region, is the shortage of high-quality roughage (Sayar et al., 2010). To address this shortage, plant breeders have worked to develop improved cultivars from different forage crops species (Sayar et al., 2013).

Understanding the relationship between yield and yield components, in advance of initiating a plant breeding program, contributes to both the efficacy and efficiency of the program (Anlarsal and Gulcan, 1989). Yield components have direct and indirect effects on yield. Simple correlation analysis is insufficient to fully describe the complexity of these relationships (Acıkgoz ve Tekeli, 1980; Cakmakcı ve ark., 1998). The path coefficient or partial regression analysis method is more effective than simple correlation analysis for revealing the interactions of these traits (Sabancı, 1996; Kara ve Akman, 2007).

The path coefficient analysis method was initially used by Dewey and Lu (1959) in crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.). This method has also been applied to other crops. Although Acıkgoz and Tekeli (1980) suggested seeds per panicle and seed weight traits as primary selection criteria to improve seed yield (SDY) in smooth bromegrass (*Bromus inermis* Leyss.), Seker and Serin (2004) suggested stem counts and fertile stem counts as the most important selectable traits in this forage grass. On the other hand, Yucel (2004) used path analysis in narbon vetch (*Vicia narbonnesis* L.) to determine that SDY was affected by days to flowering, number of seeds per plant (SNP), number of pods per plant (PNP), one thousand seed weight (TSW), and harvest index (HTI). Turk et al. (2008) proposed harvest index (HTI) and biological yield (BLY) to be the primary selection criteria to improve SDY in narbon vetch.

The objective of the study was to reveal clear relationships between seed yield and its affecting components to determine true selection criteria for seed yield in common vetch (*Vicia sativa* L.) genotypes. For this reason, it was determined simple correlation coefficients and direct and indirect effects based on path coefficients using field trial data collected from twenty common vetch genotypes over the 2008-09, 2009-10, and 2010-11 growing seasons.

Materials and Methods

Plant materials of the study were twenty common vetch genotypes, consisting of 7 cultivars and 13 promising lines. The cultivars were Alınoglu-2001, Dicle, Gorkem, Kralkızı, Kubilay-82, Ozveren and Uludag. The five promising lines, IFVS-715, IFVS 2427, IFVS 2541, IFVS 3091, and IFVS 3889, were provided by the International Center for Agricultural Research in Dry Areas, Aleppo, Syria (ICARDA). An additional four promising lines, GAP 2604, GAP 2490, GAP 61721, and GAP 59998, were obtained from the Eastern Mediterranean Agricultural Research Institute, Adana, Turkey. Line-22 was provided by the Cukurova University Agriculture Faculty Field Crops, Adana, Turkey. The remaining three promising lines, D-71, D-72, and D-135, were obtained from the GAP International Agricultural Research and Training Centre (GAP IARTC), Diyarbakır, Turkey.

This study was conducted during three consecutive growing seasons (2008-2009, 2009-2010, and 2010-2011) in the experimental fields of the GAP International Agricultural Research and Training Centre (GAP IARTC) in Diyarbakır, Turkey (37°56′ N Lat., 40°15′ E Long. and 607 m elevation). The research fields were flat or near flat with very little erosion, and the soil layer had a deep or medium deep profile. According to the soil analysis, the experimental area soils had a clay loam structure, and were red-brown in color. Moreover, the soils were rich in terms of calcium (12.54%) and potassium (480 kg ha^{-1} K_2O) contents, whereas organic matter (1.60%) and phosphorus (28.5 kg ha^{-1} P_2O_5) contents were relatively low. Also, due to the high limestone content, the pH status of the soils was slightly alkaline (pH 7.67). The Southeastern Anatolia region is one of Turkey's seven census-defined geographical regions, and is characterized by a continental climate. In this region, summers are dry and hot, whereas winters are cool and rainy. Rainfall in the region is variable both within and among years. The long-term annual average (1975-2011) total precipitation is 479.8 mm, approximately three-quarters of which (75-80%) falls from November to May. The region's forage and seed yields obtained from annual legume crops depend greatly on the spring rainfall. Monthly average temperature, humidity and total precipitation records during the study years, and the long-term averages, are summarized in Table 1 (Diyarbakır Regional Directorate of Meteorology records, 2011). The experiments were conducted under rainfed conditions, according to a randomized complete block design with three replications. Each plot consisted of six rows, 5 m in length, and 20 cm between rows. Diammonium phosphate fertilizer (DAP 18-46-00) (150 kg da^{-1}) was applied to the experimental plots at planting. Weed control was performed manually. The seeding rate was 200 seeds m^{-2} (Acıkgoz, 2001). The seed was sown in well-annealed soil, using an experimental drill. Sowing dates for three consecutive growing seasons were November 14, 2008, November 20, 2009, and November 11, 2010. At harvest, one-half meter at the beginning and end of each plot was discarded to account for alley effects.

Table 1. Climatic data of the location in 2009, 2010, 2011 and long-term average (1975-2012) at the location, Diyarbakır, Turkey

	S	O	N	D	J	F	M	A	M	J	
Years	Mean air temperature (°C) (Monthly)										Mean
2008-09	24.1	16.8	10.1	2.2	1.4	5.6	7.9	11.8	18.2	25.9	12.4
2009-10	22.9	18.5	9.8	7.1	5.4	6.6	11.1	14.2	20.4	27.2	14.3
2010-11	27.0	18.1	11.1	6.5	3.5	4.7	9.0	13.0	17.7	25.5	13.6
1975-2012	24.7	17.0	8.9	3.8	1.7	3.5	8.2	13.7	19.1	26.3	12.7
	Mean relative humidity (%) (Monthly)										Mean
2008-09	26.3	50.2	50.6	57.3	73.3	82.5	73.8	71.3	51.8	32.2	56.9
2009-10	33.0	42.0	70.6	83.5	80.9	79.9	66.6	60.4	49.3	29.1	59.5
2010-11	27.4	56.0	41.1	68.9	73.4	69.5	56.4	75.7	67.6	38.0	57.4
1975-2012	30.9	48.0	67.1	76.7	77.1	72.8	65.6	63.2	56.3	35.9	59.4
	Total precipitation (mm) (Monthly)										Total
2008-09	68.2	59.2	50.5	52.2	12.4	70.0	63.9	43.7	9.1	25.8	455.0
2009-10	25.2	62.4	55.6	87.2	113.4	40.2	68.7	22.4	31.6	11.2	517.9
2010-11	0.4	63.4	2.0	48.0	40.0	49.9	46.6	209.0	80.1	13.6	553.0
1975-2012	4.7	34.6	53.3	70.7	62.3	72.1	68.2	64.6	40.2	9.1	479.8

All statistical analyses were performed using the TARPOPGEN statistical software (Ozcan and Acikgoz, 1999; Kaya et al., 2009). As suggested previously, path coefficient analysis was employed to determine the nature of the association among common vetch traits (Anlarsal and Gulcan, 1989; Williams et al., 1990; Sabanci, 1996; Rodriguez et al., 2001; Seker and Serin, 200); Yucel, 2004; Ilker, 2011). In path coefficient analysis, SDY was the dependent variable and the other traits were considered independent variables.

This study involved the following common vetch traits: SDY, days to physiological seed maturity (DSM), PNP, SNP, BLY, straw yield (SWY), TSW, and HTI. They were measured in accordance with technical instructions for leguminous forage crops as published by the Seed Registration and Certification Center, Ankara, Turkey (SRCC, 2001).

Results and Discussion

Simple correlation coefficients between seed yield (SDY) and its affecting components in common vetch genotypes are presented in Table 2 and Figure 1. Except for PNP trait, correlated with SDY at significant 0.05 level and positively, all of the examined traits correlated with seed yield highly significantly ($P < 0.01$) and positively. Among the traits the strongest correlated ones with SDY were respectively BLY (r = 0.774) and SWY (r = 0.625) traits (Table 2). Similarly, many researches reported that correlation between seed yield and BLY was stronger than that of the other seed yield components in various annual legume forage species (Cakmakcı et al. 2003, Albayrak et al. 2005; Albayrak and Tongel 2006; Sayar and Anlarsal, 2008, Sayar et al. 2011).

Path coefficient analysis can be used to understand the direct and indirect effects of various traits on yield and on other important traits

(Dewey and Lu, 1959; Bath, 1973, Anlarsal and Gulcan, 1989; Sabanci, 1996; Carpici and Celik, 2010). The results of path analysis in this study are presented in Table 3 and Figure 1. When Table 3 and Figure 1 examined, it could be seen that while BLY (3.7455 and 55.76%) trait had a positive and strong direct effects on SDY, the direct effect of SWY (-3.0385 and 45.34%) was found strong but negative on the seed yield. Likewise; many researchers reported that the direct effect of biological yield on seed yield were greater than other yield components (Cakmakcı et al., 2003; Yucel 2004; Turk et al., 2008). However; the other five traits, DSM, PNP, SNP, TSW, HTI, didn't have any direct effect on the seed yield. The five traits had effects on seed yield indirectly. It was found to be remarkable point that the five traits, despite their high significant correlations with seed yield, they had no direct effects on the seed yield (Table 2,3 and Figure 1).

Table 2. Simple correlation coefficients of seed yield components in common vetch genotypes over three consecutive growing seasons.

	SDY	DSM	PNP	SNP	BLY	SWY	TSW	HTI
SDY	1.000	0.212**	0.155*	0.430**	0.774**	0.625**	0.404**	0.263**
DSM			-0.199**	0.267**	0.544**	0.601**	0.301**	-0.511**
PNP			1.000	0.111^{ns}	0.105^{ns}	0.078^{ns}	-0.430**	0.064^{ns}
SNP				1.000	0.380**	0.327**	0.219**	0.059n^{ns}
BLY					1.000	0.978**	0.312**	-0.383**
SWY						1.000	0.251**	-0.559**
TSW							1.000	0.062^{ns}
HTI								1.000

ns: not significant; * significant at P < 0.05; ** significant at P < 0.01.

SDY, seed yield; DSM, days to physiological seed maturity; PNP, pod numbers per plant; SNP, seed numbers per plant; BLY, biological yield; SWY, straw yield; TSW, thousand seed weight; and HTI, harvest index.

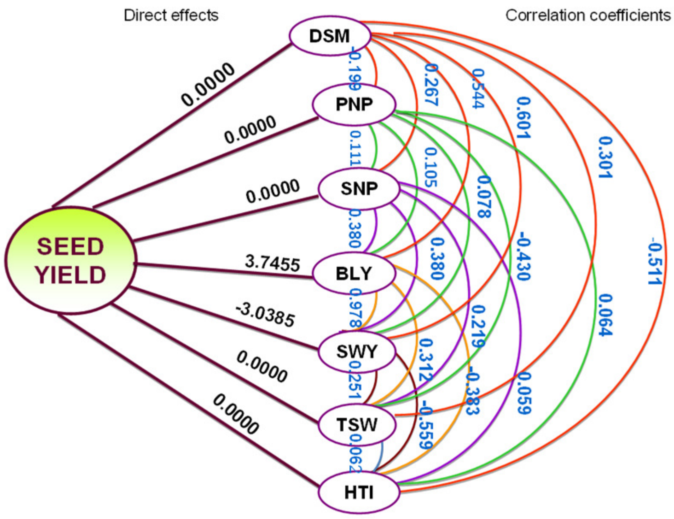

Figure 1. Schematic representation of the direct effects of the yield components on the seed yield and correlation coefficients among the examined traits in this study.

DSM, days to physiological seed maturity; PNP, pod numbers per plant; SNP, seed numbers per plant; BLY, biological yield; SWY, straw yield; TSW, thousand seed weight; and HTI, harvest index.

Table 3. Path coefficients for seed yield components of common vetch genotypes over three consecutive growing seasons

DSM vs Seed yield	*r* = 0.212		SWY vs Seed yield	*r* = 0.625	
Direct effect	0.0000	0.00%	Direct effect	-3.0385	45.34%
Indirect effect via PNP	0.0000	0.00%	Indirect effect via DSM	0.0000	0.00%
Indirect effect via SNP	0.0000	0.00%	Indirect effect via PNP	0.0000	0.00%
Indirect effect via BLY	2.0378	52.75%	Indirect effect via SNP	0.0000	0.00%
Indirect effect via SWY	-1.8254	47.25%	Indirect effect via BLY	3.6632	54.66%
Indirect effect via TSW	0.0000	0.00%	Indirect effect via TSW	0.0000	0.00%
Indirect effect via HTI	0.0000	0.00%	Indirect effect via HTI	0.0000	0.00%
PNP vs Seed yield	*r* = 0.155		TSW vs Seed yield	*r* = 0.404	
Direct effect	0.0000	0.00%	Direct effect	0.0000	0.00%
Indirect effect via DSM	0.0000	0.00%	Indirect effect via DSM	0.0000	0.00%
Indirect effect via SNP	0.0000	0.00%	Indirect effect via PNP	0.0000	0.00%
Indirect effect via BLY	0.3933	62.27%	Indirect effect via SNP	0.0000	0.00%
Indirect effect via SWY	-0.2383	37.73%	Indirect effect via BLY	1.1675	60.47%
Indirect effect via TSW	0.0000	0.00%	Indirect effect via SWY	-0.7632	39.53%
Indirect effect via HTI	0.0000	0.00%	Indirect effect via HTI	0.0000	0.00%
SNP vs Seed yield	*r* = 0.430		HTI vs Seed yield	*r* = 0.263	
Direct effect	0.0000	0.00%	Direct effect	0.0000	0.00%
Indirect effect via DSM	0.0000	0.00%	Indirect effect via DSM	0.0000	0.00%
Indirect effect via PNP	0.0000	0.00%	Indirect effect via PNP	0.0000	0.00%
Indirect effect via BLY	1.4247	58.88%	Indirect effect via SNP	0.0000	0.00%
Indirect effect via SWY	-0.9949	41.12%	Indirect effect via BLY	-1.4342	45.80%
Indirect effect via TSW	0.0000	0.00%	Indirect effect via SWY	1.6971	54.20%
Indirect effect via HTI	0.0000	0.00%	Indirect effect via TSW	0.0000	0.00%
BLY vs Seed yield	*r* = 0.774				
Direct effect	3.7455	55.76%			
Indirect effect via DSM	0.0000	0.00%			
Indirect effect via PNP	0.0000	0.00%			
Indirect effect via SNP	0.0000	0.00%			
Indirect effect via SWY	-2.9718	44.24%			
Indirect effect via TSW	0.0000	0.00%			
Indirect effect via HTI	0.0000	0.00%			

DSM, days to physiological seed maturity; PNP, pod numbers per plant; SNP, seed numbers per plant; BLY, biological yield; SWY, straw yield; TSW, thousand seed weight; and HTI, harvest index.

A number of researchers reported that despite a strong correlation between a trait and yield, if the trait had negative or non-significant direct effect on the yield, this would be stemmed from indirect effects of the trait via other traits on the yield. Also, they point out that in case of these situations, the indirect effects gain importance; and the indirect effects should be taken into consideration (Sabancı 1996; Albayrak 2004; Kara and Akman 2007; Turk et al 2008). Accordingly, in the study, in spite of their high correlation coefficient, due to their strong negative indirect effects via SWY on seed yield, DSM (-1.8254 and 47.25%), PNP (-0.2383 and 37.73%), SNP (-0.9949 and 41.12%) and TSW (-0.7632 and 39.53%) traits had no direct effect on the seed yield. On the other hand, despite its high positive correlation with seed yield, SWY (-3.0385 and 45.34%) had high negative direct effect on seed yield. This situation and without direct effectiveness of HTI on SDY probably stemmed from the strong negative indirect effects of the traits via BLY on seed yield (Table 3).

When indirect effects of the investigated traits on SDY examined in Table 3, DSM, PNP, SNP and TSW traits affected SDY only via BLY and SWY traits. While indirect effect of DSM (2.0378 and 52.75%), PNP (0.3933 and 62.27%), SNP (1.4247 and 58.88%) and TSW (1.1675 and 60.47%) traits via BLY were found strongly and positively, the indirect effects of the DSM (-1.8254 47.25%), PNP (-0.2383 and 37.73%), SNP (-0.9949 and 41.12%) and TSW (-0.7632 and 39.53%) traits on SDY were found negative and lower than that of the BLY. On the other hand, even though BLY trait had strong and negative indirect effect on SDY only via SWY (-2.9718 and 44.24%), SWY trait was effective indirectly on SDY only via BLY (3.6632 and 54.66%) strongly and positively. Finally, HTI was found effective on SDY only via BLY and SWY. In contrast to the other traits, indirect effect of HTI on SDY via BLY (-1.4342 and 45.80%) was found negative and strong, via SWY (1.6971 and 54.20%) was strong and positive.

Conclusion

The data obtained from the study as results of the made correlation and path analyses showed that biological yield trait can be accepted as reliable selection criterion in common vetch for breeders and seed producers in order to increase seed yield.

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