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DETERMINING RELATIONSHIPS AMONG YIELD AND YIELD COMPONENTS USING CORRELATION AND PATH COEFFICIENT ANALYSES IN SUMMER SOWN COMMON VETCH (*VICIA SATIVA* L.) GENOTYPES

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Abstract

Common vetch (*Vicia sativa* L.) is an important leguminous crop. Its breeding program can be improved by understanding the interrelationships among yield and yield components. Using 152 summer-sown genotypes originated from different sources, the present study was conducted in Mediterranean basin of Antalya, Turkey, with the aims to determine relationships among 13 agronomic characters and evaluate estimates of predicted direct and indirect responses to selection for characters using correlation and path coefficient analyses. Results based on the correlation analysis indicated that seed yield was correlated positively with biologic yield (0.810**), spring vigor (0.681**), number of seeds per plant (0.486**), harvest index (0.423**) and number of pods per plant (0.418**). However, when path coefficient analysis split the correlation coefficients into direct and indirect effects, the significant direct effects on the seed yield were biologic yield (0.795), harvest index (0.490) and number of seeds per plant (0.105). Biologic yield was correlated positively with seed yield (0.810**), spring vigor (0.777**), number of seeds per plant (0.462**), number of pods per plant (0.450**) and plant height (0.301**). There was negative direct effect of harvest index on biologic yield (-0.470). Overall results suggested that common vetch breeding studies should focus on biologic yield, harvest index, number of seeds per plant for seed yield, and seed yield, spring vigor and harvest index traits should be taken in account for biologic yield.

Introduction

Common vetch (*Vicia sativa* L.) is one of the most widely distributed annual forage leguminous crop, commonly utilized as fodder, hay production, green manure or seed production. As a legume crop it provides nitrogen to the soil and reduces the incidence of diseases in succeeding non-leguminous crops. Growing concerns about environment and declining soil fertility, increasing nitrogen fertilizer costs have led to renewed interest in legume crops (Cakmakci & Acikgoz, 1994; Ayed *et al.*, 2001; Caballero *et al.*, 2001; Mueller & Thorup-Kristensen, 2001).

Future program for common vetch research will focus on improving the existing varieties and developing new ones to address the future demands. One of the main concerns in common vetch productions as well as in many other agricultural crops production is to harvest increased yield and high quality crops. Since genotypes and environmental factors are the main components determining yield and quality in crops, a primary objective should be the determination of effects of genotypic factors in selection. Correlation coefficient analyses show relationships among independent traits and the degree of linear relation between these traits (Cakmakci, 1992; Berger *et al.*, 2002;

Iannucci *et al.*, 2002). However, determined relationship between two traits is not enough to identify the causal relationship among the characteristics under study. Correlation coefficient analyses have been extensively used in plant breeding studies (Ranalli & Cubero, 1997; Iannuci *et al.*, 2002; Purcell *et al.*, 2002). Although these estimates are very helpful in determining the components of the traits such as yield and yield related components they do not provide an exact picture of the relative importance of the component characters. Path coefficient analysis is a standardized partial regression analysis and this method measures the direct influence of one variable upon another and allows the separation of the correlation coefficient into components of direct and indirect effects (Turgut *et al.*, 1995; Finne *et al.*, 2000; Donaldson *et al.*, 2001; Sinebo, 2002).

Path coefficient analysis will be useful when researchers wish to know the causes. This analysis will inform us by determining the amount of direct and indirect effect of the causal components on the effect component. Although path coefficient analyses have been used intensively in many crops (Boe & Ross, 1983; Donaldson *et al.*, 2001; Sinebo, 2002), and in some leguminous crops (Ranalli & Cubero, 1997; Ball *et al.*, 2001; Iannucci *et al.*, 2002; Purcell *et al.*, 2002), its use is limited in common vetch. Phadnis *et al.*, (1970) determined effective yield components in chickpea (*Cicer arietinum* L.). Guler *et al.*, (2001) determined positive and significant relationships between number of seeds per pod and number of pods per plant, and between seed yield per plant and number of pods per plant in chickpea using correlation and path analyses.

Since path coefficient analysis can split the correlation coefficients into direct and indirect effects, the significant direct and indirect effects of components can be studied. Plant breeders can use path coefficient and correlation coefficient analyses to define well-known varieties or genotypes for common vetch improvement studies. The present study was undertaken to determine the relationships among 13 agronomic characters and evaluate estimates of predicted direct and indirect responses for the selection of characters using path coefficient analyses in 150 common vetch genotypes and two cultivars.

Materials and Methods

This research was conducted in Akdeniz University, Faculty of Agriculture experimental fields during 1999-2000. Seed sowings were carried out during last weeks of March and harvested in July for two experiment years. A summary of the meteorological data on average temperatures, precipitation and relative humidity for the site is given in Table 1.

Table 1. Meteorological data for the 1999-2000 growing seasons (monthly average)*.

	Average temperature (°C)		Rainfall (mm)		Relative humidity (%)	
Months	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
March	12.8	11.4	104.0	65.8	62.6	55.3
April	16.3	16.4	31.1	105.2	69.3	65.9
May	22.3	20.8	0.9	84.1	59.6	57.3
June	26.5	27.7	13.1	0.1	52.9	42.6
July	29.1	29.9	0.7	0.0	56.6	53.3

*: Turkish State Meteorological Service, Antalya Meteorology Station

Plant genotypes used in this study consisted of 150 accessions and two varieties viz., 'Nilufer' and 'Emir' as controls. Accessions were collected from different countries, ICARDA-Syria, USDA-U.S.A, Ministry of Agriculture- England, Hungary, and Turkey. Common vetch accessions along with the two cultivars were seeded at 0.1 kg ha^{-1} in plots with 1 m-long apart in the rows and the distance between rows was 1 m for two years (Acikgoz, 2001). The results were analyzed using the randomized complete block design with 3 replications. During the experiment field preparation for planting, 30 kg ha^{-1} nitrogen in the form of diammonium phosphate (DAP) was used as fertilizer (Cakmakci & Acikgoz, 1994). Soil samples taken from 30 cm below of the field surface composed of clay state with a pH of 8.12, lime 22%, organic matter 2.4%, total nitrogen 0.108%, and available phosphorus 13.14 ppm. Experimental fields received one hoeing during seedling stage and a total of 9 irrigations for each growing season.

Plant height (cm), number of leaflets per leaf, number of pods per node, number of pods per plant, number of seeds per pod, number of podding nodes and number of seeds per plant (numbers) were scored and measured using 5 plants randomly collected from each row. In addition, spring vigor, scored on a 1-10 rating scale: (1=poor, 10=very good), 1000-seed weight (g), number of days to flower (days), biologic yield (g m^{-2}), seed yield (g m^{-2}) and harvest index (%) were also evaluated. Coefficients of correlation analysis and path coefficient analysis were performed using the computerized statistical program MSTAT-C (MSTAT-C, 1990) and TARPOPGEN obtained from the Faculty of Agriculture, Ege University, İzmir, Turkey.

Results

There were significant differences between the two growing seasons. A total of 9 irrigations were performed for each growing season and the amount of watering were adjusted to each experimental year. This was done to reduce the effects of drought stress on plant characters studied. The main aim of the watering and hoeing practices were to reduce water stress which may cause detrimental effects on plant growth and development and in turn possibly reducing the biomass and seed production differences in the two experimental seasons.

Path coefficient analyses between seed yield and other components, and between biologic yield and other yield components were calculated. In the first analysis, the seed yield was considered the dependent variable and other traits were considered independent variables. In the second analysis, biologic yield was used as dependent variable and other yield components were used as independent variables. Correlation coefficients calculated between biologic yield and other variables along with path coefficient analyses revealing direct and indirect effects are given in Table 1 and 2, respectively. High significant year, genotype x year effects were observed in all traits studied with the exception of number of pods per node trait at the 0.01 level. Results also indicated that there were high levels of genotype variations among the genotypes at the 0.01 level. This indicated that accessions were genetically different.

Correlation and path analyses between seed yield and other variables: Simple correlations coefficient calculated between the seed yield and other variables are given in Table 2. Positive and significant relationships (correlations) were found between the seed yield and biologic yield (0.810**), plant height (0.296), spring vigor (0.681**), number

of seeds per plant (0.486**), harvest index (0.423**), and number of pods per plant (0.418**). This indicated that there were significant interrelationships between these yield components and the seed yield. These results were consistent with the findings of some other studies dealt with correlations analyses. Crebert (1934) observed significant interrelations between number of seed per plant and seed yield in common vetch. Cousin *et al.*, (1985) found that harvest index was the most important factor influencing the seed yield in peas. Cakmakci & Acikgoz (1994) stated that spring vigor character positively affected seed yield traits using 178 common vetch strains.

Correlation coefficients usually show relationships among independent traits and the degree of linear relation between these characters. Consequently, these interrelationships with regards to sign and magnitude were found to be different when path analyses were performed. The relationships determined by path analysis among the examined characteristics in the research are shown in Table 2. The direct effects of spring vigor and number of pods per plant on the seed yield were found to be non-significant. On the other hand, the direct effects of several characters; in order of magnitude, biologic yield harvest index and number of seeds per plant on the seed yield were 0.795, 0.490, and 0.105, respectively. The direct effect of biologic yield on seed yield had the highest path coefficient value. Analysis results showed that the ratio of direct effect of biologic yield on seed yield was 81.9% and indirect effect of biologic yield on other variables was 18.1%. The ratios of direct effects of harvest index and number of seeds per plant on seed yield were 79% and 17%, respectively.

In common vetch, the use of path analysis is limited whereas much work has been done. However, there are path analysis studies in leguminous crops. Our findings are in agreement with the results of Akdag & Sehirali (1992) who observed that direct effects of number of seeds per plant and biologic yield on seed yield were significant in chickpea (*Cicer arietinum* L). Iannucci & Martiniello (1998) using path coefficient analysis observed that the direct effect of biologic yield on the seed yield was significant in Persian clover (*Trifolium resupinatum* L.).

In the present study, we observed that there were positive indirect effects of plant height, number of pods per node, number of pods per plant, number of seeds per pod, number of seeds per plant and spring vigor traits via biologic yield and 1000-seed weight via harvest index on seed yield. Guler *et al.*, (2001) reported that there were positive and significant relationships between the number of seeds per pod and the number of pods per plant, between the number of seeds per plant and the number of pods per plant. Results in the present study also indicated that the smallest positive path coefficient value was 0.00 that was between seed yield and number of pods per node indicating non significant effect of number of pods per node on the seed yield.

Correlation and path analyses between biologic yield and other variables: Simple coefficient of correlations between biologic yield and other variables are given in Table 3. Positive and significant relationships were found between biologic yield and the seed yield (0.810**), number of seeds per pod (0.215**), number of pods per plant (0.450**), number of seeds per plant (0.462**), number of podding nodes (0.095**) and spring vigor (0.777**). Results indicated that there were negative and significant relationships between biologic yield and harvest index (-0.101**). Path analyses among the examined characteristics in the research are given in Table 3.

Table 2. Correlation and path coefficient analyses between the seed yield and other variables.

Biologic Yield (g m^{-2})				Harvest Index (%)			
	CC[1]	PC[2]	%		CC	PC	%
Direct effect	**0.810****	**0.795**	**81.88**	**Direct effect**	**0.423****	**0.490**	**79.82**
Indirect effects				Indirect effects			
-Harvest Index (%)		-0.049	5.09	-Biologic Yield (g m^{-2})		-0.080	13.03
-Plant Height (cm)		0.005	0.49	-Plant Height (cm)		0.001	0.14
-Pods/Node (no)		0.000	0.00	-Pods/Node (no)		0.000	0.00
-Pods/Plant (no)		-0.022	2.23	-Pods/Plant (no)		-0.002	0.27
-Seeds/Pod (no)		-0.003	0.31	-Seeds/Pod (no)		-0.002	0.30
-Seeds/Plant (no)		0.048	4.98	-Seeds/Plant (no)		0.012	2.00
-Leaflets/Leaf (no)		0.000	0.04	-Leaflets/Leaf (no)		0.001	0.12
-1000-Seeds Weight (g)		0.006	0.57	-1000-Seeds Weight (g)		0.015	2.36
-Spring Vigor (1-10)		0.037	3.78	-Spring Vigor (1-10)		-0.000	0.07
-Days to Flowering (days)		0.000	0.00	-Days to Flowering (days)		-0.000	0.04
-Number of Podding Nodes (no)		-0.006	0.63	-Number of Podding Nodes (no)		-0.011	1.85
Plant Height (cm)				**Pods/Node (no)**			
	CC	PC	%		CC	PC	%
Direct effect	**0.296****	**0.016**	**4.19**	**Direct effect**	**0.255****	**0.000**	**0.10**
Indirect effects				Indirect effects			
-Biologic Yield (g m^{-2})		0.239	63.54	-Biologic Yield (g m^{-2})		0.178	60.88
-Harvest Index (%)		0.026	6.98	-Harvest Index (%)		0.051	17.57
-Pods/Node (no)		0.000	0.01	-Plant Height (cm)		0.003	0.85
-Pods/Plant (no)		-0.014	3.79	-Pods/Plant (no)		-0.013	4.36
-Seeds/Pod (no)		-0.002	0.43	-Seeds/Pod (no)		-0.004	1.18
-Seeds/Plant (no)		0.033	8.66	-Seeds/Plant (no)		0.031	10.66
-Leaflets/Leaf (no)		0.001	0.36	-Leaflets/Leaf (no)		0.001	0.28
-1000-Seeds Weight (g)		0.004	1.16	-1000-Seeds Weight (g)		0.001	0.41
-Spring Vigor (1-10)		0.016	4.34	-Spring Vigor (1-10)		0.008	2.81
-Days to Flowering (days)		0.000	0.06	-Days to Flowering (days)		0.000	0.06
-Number of Podding Nodes (no)		-0.024	6.48	-Number of Podding Nodes (no)		-0.002	0.84

Table 2 (Cont'd.)

Pods/Plant (no)				Seeds/Pod (no)			
	CC	PC[2]	%		CC	PC	%
Direct effect	**0.418****	**-0.048**	**8.67**	**Direct effect**	**0.270****	**-0.014**	**4.08**
Indirect effects				Indirect effects			
-Biologic Yield (g m^{-2})		0.358	64.56	-Biologic Yield (g m^{-2})		0.171	50.00
-Harvest Index (%)		0.017	3.04	-Harvest Index (%)		0.066	19.25
-Plant Height (cm)		0.005	0.85	-Plant Height (cm)		0.002	0.53
-Pods/Node (no)		0.000	0.01	-Pods/Node (no)		0.000	0.02
-Seeds/Pod (no)		-0.004	0.76	-Pods/Plant (no)		-0.015	4.27
-Seeds/Plant (no)		0.092	16.51	-Seeds/Plant (no)		0.054	15.94
-Leaflets/Leaf (no)		0.000	0.06	-Leaflets/Leaf (no)		-0.000	0.06
-1000-Seeds Weight (g)		-0.003	0.52	-1000-Seeds Weight (g)		-0.007	1.99
-Spring Vigor (1-10)		0.015	2.71	-Spring Vigor (1-10)		0.007	1.91
-Days to Flowering (days)		0.000	0.00	-Days to Flowering (days)		0.000	0.02
-Number of Podding Nodes (no)		-0.013	2.31	-Number of Podding Nodes (no)		0.007	1.93
Seeds/Plant (no)				**Leaflets/Leaf (no)**			
	CC	PC	%		CC	PC	%
Direct effect	**0.486****	**0.105**	**17.02**	**Direct effect**	**0.087****	**0.010**	**8.28**
Indirect effects				Indirect effects			
-Biologic Yield (g m^{-2})		0.367	59.64	-Biologic Yield (g m^{-2})		0.030	25.85
-Harvest Index (%)		0.057	9.34	-Harvest Index (%)		0.037	31.77
-Plant Height (cm)		0.005	0.80	-Plant Height (cm)		0.002	1.94
-Pods/Node (no)		0.000	0.01	-Pods/Node (no)		0.000	0.02
-Pods/Plant (no)		-0.042	6.82	-Pods/Plant (no)		-0.002	1.49
-Seeds/Pod (no)		-0.007	1.18	-Seeds/Pod (no)		0.000	0.27
-Leaflets/Leaf (no)		0.001	0.11	-Seeds/Plant (no)		0.007	6.18
-1000-Seeds Weight (g)		-0.004	0.63	-1000-Seeds Weight (g)		0.010	8.27
-Spring Vigor (1-10)		0.016	2.64	-Spring Vigor (1-10)		0.006	5.13
-Days to Flowering (days)		-0.000	0.01	-Days to Flowering (days)		0.000	0.22
-Number of Podding Nodes (no)		-0.011	1.80	-Number of Podding Nodes (no)		-0.012	10.58

Table 2 (Cont'd.)

1000-Weeds Weight (g)	CC	PC	%
Direct effect	**0.292****	**0.046**	**13.16**
Indirect effects			
- Biologic Yield (g m^{-2})		0.097	28.06
-Harvest Index (%)		0.156	44.85
-Plant Height (cm)		0.002	0.43
-Pods/Node (no)		0.000	0.00
-Pods/Plant (no)		0.003	0.88
-Seeds/Pod (no)		0.002	0.59
-Seeds/Plant (no)		-0.009	2.56
-Leaflets/Leaf (no)		0.002	0.58
-Spring Vigor (1-10)		0.012	3.56
-Days to Flowering (days)		-0.000	0.13
-Number of Podding Nodes (no)		-0.018	5.20

Spring Vigor (1-10)	CC	PC	%
Direct effect	**0.681****	**0.047**	**6.22**
Indirect effects			
-Biologic Yield (g m^{-2})		0.618	81.50
-Harvest Index (%)		-0.004	0.57
-Plant Height (cm)		0.006	0.72
-Pods/Node (no)		0.000	0.01
-Pods/Plant (no)		-0.015	2.02
-Seeds/Pod (no)		-0.002	0.25
-Seeds/Plant (no)		0.036	4.75
-Leaflets/Leaf (no)		0.001	0.16
-1000-Seeds Weight (g)		0.012	1.58
-Days to Flowering (days)		0.000	0.01
-Number of Podding Nodes (no)		-0.017	2.21

Days to Flowering (days)	CC	PC	%
Direct effect	**0.292****	**0.046**	**13.16**
Indirect effects			
-Biologic Yield (g m^{-2})		0.003	6.25
-Harvest Index (%)		-0.029	55.98
-Plant Height (cm)		0.001	1.50
-Pods/Node (no)		0.000	0.02
-Pods/Plant (no)		-0.000	0.51
-Seeds/Pod (no)		-0.000	0.42
-Seeds/Plant (no)		-0.002	2.80
-Leaflets/Leaf (no)		0.001	1.13
-1000-Seeds Weight (g)		-0.005	9.47
-Spring Vigor (1-10)		0.001	2.31
-Number of Podding Nodes (no)		-0.006	11.75

Number of Podding Nodes (no)	CC	PC	%
Direct effect	**0.681****	**0.047**	**6.22**
Indirect effects			
-Biologic Yield (g m^{-2})		0.075	26.12
-Harvest Index (%)		0.087	30.00
-Plant Height (cm)		0.006	2.07
-Pods/Node (no)		0.000	0.00
-Pods/Plant (no)		-0.010	3.31
-Seeds/Pod (no)		0.001	0.49
-Seeds/Plant (no)		0.018	6.25
-Leaflets/Leaf (no)		0.002	0.63
-1000-Seeds Weight (g)		0.013	4.44
-Spring Vigor (1-10)		0.012	4.25
-Days to Flowering (days)		0.000	0.14

[1] Simple Correlation Coefficients, [2] Path Coefficients, **: Significant at P< 0.01

Table 3. Correlation and path coefficient analyses between biologic yield and other variables.

Seed Yield (g m^{-2})				Harvest Index (%)			
	CC[1]	PC[2]	%		CC	PC	%
Direct effect	**0.810****	**0.899**	**69.50**	**Direct effect**	**-0.101****	**-0.470**	**53.37**
Indirect effects				Indirect effects			
-Harvest Index (%)		-0.199	15.38	-Seed Yield (g m^{-2})		0.380	43.16
-Plant Height (cm)		-0.002	0.12	-Plant Height (cm)		-0.003	0.03
-Pods/Node (no)		0.003	0.24	-Pods/Node (no)		0.003	0.15
-Pods/Plant (no)		0.034	2.65	-Pods/Plant (no)		0.003	0.32
-Seeds/Pod (no)		0.004	0.30	-Seeds/Pod (no)		0.002	0.22
-Seeds/Plant (no)		-0.030	2.31	-Seeds/Plant (no)		-0.007	0.82
-Leaflets/Leaf (no)		-0.002	0.15	-Leaflets/Leaf (no)		-0.002	0.18
-1000-Seeds Weight (g)		-0.009	0.72	-1000-Seeds Weight (g)		-0.010	1.15
-Spring Vigor (1-10)		0.109	8.39	-Spring Vigor (1-10)		-0.001	0.16
-Days to Flowering (days)		0.000	0.01	-Days to Flowering (days)		0.000	0.03
-Number of Podding Nodes (no)		0.003	0.23	-Number of Podding Nodes (no)		0.004	0.41
Plant Height (cm)				**Pods/Node (no)**			
	CC	PC	%		CC	PC	%
Direct effect	**0.301****	**-0.005**	**1.24**	**Direct effect**	**0.224****	**0.012**	**3.32**
Indirect effects				Indirect effects			
-Seed Yield (g m^{-2})		0.266	64.44	-Seed Yield (g m^{-2})		0.230	62.54
-Harvest Index (%)		-0.025	6.11	-Harvest Index (%)		-0.049	13.44
-Pods/Node (no)		0.002	0.47	-Plant Height (cm)		-0.001	0.22
-Pods/Plant (no)		0.024	5.90	-Pods/Plant (no)		0.022	5.93
-Seeds/Pod (no)		0.002	0.40	-Seeds/Pod (no)		0.004	0.97
-Seeds/Plant (no)		-0.019	4.65	-Seeds/Plant (no)		-0.018	5.00
-Leaflets/Leaf (no)		-0.003	0.74	-Leaflets/Leaf (no)		-0.002	0.52
-1000-Seeds Weight (g)		-0.003	0.74	-1000-Seeds Weight (g)		-0.001	0.23
-Spring Vigor (1-10)		0.055	13.35	-Spring Vigor (1-10)		0.028	7.54
-Days to Flowering (days)		-0.000	0.06	-Days to Flowering (days)		-0.000	0.05
-Number of Podding Nodes (no)		0.008	1.90	-Number of Podding Nodes (no)		0.001	0.22

Table 3 (Cont'd.)

Pods/Plant (no)				**Seeds/Pod (no)**			
	CC	**PC**	**%**		**CC**	**PC**	**%**
Direct effect	**0.450****	**0.082**	**13.79**	**Direct effect**	**0.215****	**0.014**	**3.50**
Indirect effects				Indirect effects			
-Seed Yield (g m^{-2})		0.376	63.23	-Seed Yield (g m^{-2})		0.243	59.23
-Harvest Index (%)		-0.016	2.72	-Harvest Index (%)		-0.063	15.36
-Plant Height (cm)		-0.002	0.26	-Plant Height (cm)		-0.001	0.14
-Pods/Node (no)		0.003	0.54	-Pods/Node (no)		0.003	0.74
-Seeds/ Pod (no)		0.004	0.73	-Pods/Plant (no)		0.025	6.06
-Seed /Plant (no)		-0.054	9.04	-Seed /Plant (no)		-0.032	7.79
-Leaflets/Leaf (no)		-0.001	0.13	-Leaflets/Leaf (no)		0.001	0.12
-1000-Seeds Weight (g)		0.002	0.34	-1000-Seeds Weight (g)		0.005	1.16
-Spring Vigor (1-10)		0.051	8.53	-Spring Vigor (1-10)		0.022	5.37
-Days to Flowering (days)		0.000	0.00	-Days to Flowering (days)		-0.000	0.02
-Number of Podding Nodes (no)		0.004	0.69	-Number of Podding Nodes (no)		-0.002	0.51
Seeds/Plant (no)				**Leaflets/Leaf (no)**			
	CC	**PC**	**%**		**CC**	**PC**	**%**
Direct effect	**0.462****	**-0.062**	**8.78**	**Direct effect**	**0.038**	**-0.022**	**12.32**
Indirect effects				Indirect effects			
-Seed Yield (g m^{-2})		0.437	62.40	-Seed Yield (g m^{-2})		0.079	44.81
-Harvest Index (%)		-0.055	7.86	-Harvest Index (%)		-0.035	20.02
-Plant Height (cm)		-0.002	0.23	-Plant Height (cm)		-0.001	0.41
-Pods/Node (no)		0.004	0.52	-Pods/Node (no)		0.001	0.61
-Pods/Plant (no)		0.072	10.22	-Pods/Plant (no)		0.003	1.67
-Seeds/ Pod (no)		0.007	1.06	-Seeds/ Pod (no)		-0.000	0.18
-Leaflets/Leaf (no)		-0.002	0.21	-Seeds/Plant (no)		-0.004	2.39
-1000-Seeds Weight (g)		0.003	0.39	-1000-Seeds Weight (g)		-0.007	3.82
-Spring Vigor (1-10)		0.055	7.81	-Spring Vigor (1-10)		0.020	11.37
-Days to Flowering (days)		0.000	0.01	-Days to Flowering (days)		-0.000	0.17
Number of Podding Nodes (no)		0.004	0.51	-Number of Podding Nodes (no)		0.004	2.23

Table 3 (Cont'd.)

1000-Seeds Weight (g)	CC	PC	%
Direct effect	**0.123****	**-0.032**	**6.29**
Indirect effects			
-Seed Yield (g m^{-2})		0.263	51.52
-Harvest Index (%)		-0.149	29.27
-Plant Height (cm)		-0.001	0.09
-Pods/Node (no)		0.000	0.06
-Pods/Plant (no)		-0.005	1.02
-Seeds/Pod (no)		-0.002	0.42
-Seeds/Plant (no)		0.005	1.03
-Leaflets/Leaf (no)		-0.005	0.89
-Spring Vigor (1-10)		0.042	8.17
-Days to Flowering (days)		0.001	0.10
-Number of Podding Nodes (no)		0.006	1.14

Spring Vigor (1-10)	CC	PC	%
Direct effect	**0.777****	**0.159**	**18.83**
Indirect effects			
-Seed Yield (g m^{-2})		0.613	72.43
-Harvest Index (%)		0.004	0.49
-Plant Height (cm)		-0.002	0.21
-Pods/Node (no)		0.002	0.25
-Pods/Plant (no)		0.026	3.09
-Seeds/Pod (no)		0.002	0.24
-Seeds/Plant (no)		-0.021	2.50
-Leaflets/Leaf (no)		-0.003	0.32
-1000-Seeds Weight (g)		-0.008	0.99
-Days to Flowering (days)		-0.000	0.02
-Number of Podding Nodes (no)		0.005	0.64

Days to Flowering (day)	CC	PC	%
Direct effect	**0.004**	**-0.005**	**6.44**
Indirect effects			
-Seed Yield (g m^{-2})		-0.029	38.70
-Harvest Index (%)		0.028	37.37
-Plant Height (cm)		-0.000	0.34
-Pods/Node (no)		0.001	0.64
-Pods/Plant (no)		0.001	0.60
-Seeds/ Pod (no)		0.000	0.30
-Seed /Plant (no)		0.001	1.15
-Leaflets/Leaf (no)		-0.001	1.78
-1000-Seeds Weight (g)		0.004	4.63
-Spring Vigor (1-10)		0.004	5.42
-Number of Podding Nodes (no)		0.002	2.63

Number of Podding Nodes (no)	CC	PC	%
Direct effect	**0.095****	**0.021**	**6.53**
Indirect effects			
-Seed Yield (g m^{-2})		0.127	40.04
-Harvest Index (%)		-0.083	26.27
-Plant Height (cm)		-0.002	0.62
-Pods/Node (no)		0.001	0.15
-Pods/Plant (no)		0.016	5.17
-Seeds/ Pod (no)		-0.002	0.46
-Seed /Plant (no)		-0.011	3.35
-Leaflets/Leaf (no)		-0.004	1.30
-1000-Seeds Weight (g)		-0.009	2.85
-Spring Vigor (1-10)		0.041	13.11
- Days to Flowering (days)		-0.001	0.15

[1] Simple Correlation Coefficients, [2] Path Coefficients, **: Significant at P< 0.01

The direct effects of seed yield and spring vigor on biologic yield were 0.899 and 0.159, respectively. The ratio of direct effect of the seed yield and spring vigor on biologic yield were 69.5% and 18.8%, respectively. We observed that there were positive indirect effects of seed yield via several other components such as plant height (0.266) and number of pods per plant (0.376) on biologic yield. There were also negative indirect effects of harvest index via 1000-seed weight (-0.149) and seed yield (-0.199) on biologic yield.

Discussion

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. In the present study, out of a total of 13 characters a positive and significant correlations among the examined traits was found. However, the direct effects of number of days to flower and number of leaflets per leaf traits on biologic yield, and number of days to flower and number of pods per node on the seed yield were found to be non-significant indicating that these traits should not be considered as the choice of selection characters for seed yield improvement studies. Çakmakci & Acikgoz (1994) and Berger *et al.*, (2002) observed that number of days to flower trait correlated negatively with seed yield in common vetch.

Plant height trait, although, showed significant correlation with the seed yield and biologic yield, its path coefficient values were smaller in magnitude and sign. Path analyses indicated that there were positive indirect effects of plant height via biologic yield, and 1000-seed weight via harvest index on seed yield. Shrivastava *et al.*, (2001) observed that number of days to flower and some other traits directly affected the seed yield in soybean. Finne *et al.*, (2000) observed a small positive correlation between seed yield and plant height in white clover (*Trifolium repens* L). This indicates that several traits such as plant height are species specific and cannot be considered as universally acceptable selection criteria for the seed yield improvement programs (Iannucci & Martiniello, 1998).

Several traits also affected the seed yield directly or indirectly. Data from path analysis showed that the direct effects of biologic yield, harvest index, number of seeds per plant and spring vigor on seed yield were positive and of greater magnitude than direct effects for the other traits. Results indicated that seed yield and spring vigor traits showed positive direct effects on biologic yield whereas there was negative direct effects of harvest index on biologic yield. Thus, an increase in biologic yield and/or spring vigor is thought to have a positive direct effect on seed yield. However, negative correlation and path coefficients between biologic yield and harvest index indicated that there was an inverse relationship between the two traits. Several previous studies reported that biologic yield and number of seeds per plant in chickpea (Akdag & Sehirali, 1992; Guler *et al.*, 2001), persian clover (Iannucci & Martiniello, 1998) were two main important traits affecting the seed yield. Shrivastava *et al.*, (2001) found that biologic yield, harvest index, plant height and 100-seed weight were also important traits affecting the seed yield. Results of the present study are in general agreement with the results of several previous studies (Akdag & Sehirali, 1992; Iannucci & Martiniello, 1998; Guler *et al.*, 2001; Shrivastava *et al.*, 2001).

Results also indicated that there was negative indirect effects of seed yield via harvest index on biologic yield (-0.199) whereas there were positive and significant correlations between seed yield and biologic yield (0.810**). This meant that correlation between seed yield and biologic yield would have been high had it not been for the large negative indirect effect of harvest index via seed yield on biologic yield. Conversely, the correlation between seed yield and biologic yield was reduced by negative indirect effect of harvest index.

Our findings indicated that the components showing the highest correlations with yield also had the largest direct effect on yield. For instance, correlation coefficient between seed yield and biologic yield was 0.810 and path coefficient value was 0.795. In wheat and chickpea similar observations have been reported (Akanda & Mundt, 1996; Guler *et al.*, 2001). However, our results also indicated that correlation coefficient analysis and path analysis were not always in agreement in sign and magnitude within components studied when the magnitude of the correlation coefficients were low (Guler *et al.*, 2001). For example, correlation coefficient between seed yield and number of pods per plant was 0.418 whereas path coefficient of the relation was –0.048. These results indicated that correlation coefficient analyses should not be considered only the method of choice to determine the real relationship between traits in plant breeding studies, instead correlation and path coefficients analyses should be used together.

The usefulness of path coefficient analysis can be exemplified by a particular relationship. Correlations between the seed yield and biologic yield, (0.810**), harvest index (0.423**), number of seeds per plant (0.486**), were positive and highly significant ($P<0.01$). The path coefficient values between the seed yield and biologic yield, (0.810**), harvest index and number of seeds per plant, were 0.759, 0.490, and 0.105, respectively. On the other hand, path coefficient values between seed yield and plant height (-0.005), number of pods per node (0.012), number of seeds per pod (0.014), number of pods per plant (0.082) and some other variables were low. This suggested that increasing in either biologic yield, harvest index or spring vigor would have a positive effect on the seed yield while increase in either plant height, number of pods per node, number of seeds per pod, number of pods per plant or some other variables with low path coefficients would not directly effect the seed yield.

As a result determining correlation coefficients among components affecting seed yield in common vetch was insufficient to determine selection criteria for the seed yield improvement studies. Although, the path coefficient analysis of variables showed that there were direct and indirect effects of some other traits on the seed yield, our overall results suggested that common vetch breeding studies should focus on biologic yield, harvest index, number of seeds per plant for improvement studies of high seed yielding varieties, and seed yield, spring vigor and harvest index traits should be taken into account for biologic yield selection studies.

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