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COMBINING ABILITIES FOR GRAIN YIELD AND LEAF CHARACTERS IN PEA PARENTS AND CROSSES

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ABSTRACT

The crosses by line x tester (12 cross combination) between Sprinter, Bolero, Manuel and Carina (line) and B_1, B_6 and B_{12} line (tester) were made in 2000 growing season. The F_1 hybrids together with the parents were evaluated during 2003-2004 growing seasons at the Konya ecological conditions. In the research, grain yield, leaf area, leaf length, leaflet area, leaflet length, leaflet width, leaflets per leaf and tendril length were measured, counted, weighted in all parents and F_1 hybrids. The general combining ability (GCA) and specific combining ability (SCA), narrow sense heritability and the correlation of parent and F_1 hybrids were calculated by using the line x tester method. Broad genetic variability was observed among the parents and hybrids. The ratio of GCA and SCA indicated the predominance of non-additive genes in pea. While Sprinter, Manuel and B_6 were best general combiners among the parents, Sprinter x B_{12} and Carina x B_1 were the best crosses for grain yield. An estimate of heritability (narrow sense) was low due to the major role of environmental factors in expression of grain yield and leaf characters in pea. Correlation studies showed that the grain yield was significant positive correlated with leaf area and leaflets per leaf. The highest direct effect was exhibited by leaf area, indirect effects, especially through the leaflets per leaf in pea.

Keywords: *Pea, line x tester, general and specific combining ability, yield, leaf characters, path analysis*

BEZELYE EBEVEYN VE MELEZLERİNDE DANE VERİMİ VE YAPRAK KARAKTERLERİNİN KOMBİNASYON YETENEKLERİ

ÖZET

Sprinter, Bolero, Manuel ve Karina çeşitleri (ana) ile B_1, B_6, B_{12} hattı (baba) arasında 2000 yılında çoklu dizi analiz yöntemine göre melezlemeler (12 melez kombinasyonu) yapılmıştır. F_1 generasyonu ve ebeveynler 2003-2004 yılında Konya Ekolojik şartlarında kışlık olarak yetiştirilmiştir. Araştırmada dane verimi, yaprak alanı, yaprak boyu, yaprakçık alanı, yaprakçık boyu, yaprakçık eni, yaprak da yaprakçık sayısı ve sülük boyu ilişkin ölçüm, sayım, tartımlar yapılmıştır. İncelenen özellikler için ebeveyn ve F_1 generasyonları line x tester analiz yöntemine göre genel kombinasyon yetenekleri (GCA) ve özel kombinasyon yetenekleri (SCA), dar anlamda kalıtım derecesi ve özellikler arası ilişkiler tespit edilmiştir. Genetipler arasında geniş genetik çeşitlilik gözlenmiştir. Bezelyede GCA ve SCA oranları eklemeli olmayan gen etkisinin baskın olduğunu göstermiştir. Dane verimi için en uygun ebeveynler Sprinter, Manuel ve B_6 hatları iken, en uygun melezler ise Sprinter x B_{12} ve Carina x B_1 kombinasyonlarıdır. Bezelyede dane verimi ve yaprak karakterleri üzerine çevre faktörlerinin etkilerinin yüksek olması yüzünden dar anlamda kalıtım derecesi düşük çıkmıştır. Dane verimi ile yaprak alanı ve yaprak da yaprakçık sayısı arasında pozitif önemli korelasyonlar belirlenmiştir. Yapılan path analizinde bezelyede dane verimi üzerine en yüksek doğrudan etkiyi yaprak alanı gösterirken, dolaylı etkiyi ise özellikle yaprakda yaprakçık sayısıgöstermiştir.

Anahtar Kelimeler: *Bezelye, line x tester analizi, kombinasyon yetenekleri, verim, yaprak karakterleri, path analizi*

INTRODUCTION

Pea is important world a grain legume. It occupies significant place in human nutrition and animal feed as source of protein, carbohydrates, vitamins and minerals. In Turkey, pea is mainly used for human consumption (generally through canning) (Akcin 1988). It is grown in many cropping systems all over the world. The total pea sown areas, seed yield and production in Turkey is 130 000 ha, 2.3 ton ha^{-1} and 299 000 tons, respectively (Anonymous 2005).

Line x tester cross designs are frequently used in plant breeding research to obtain information on genetics effects for a fixed set of parental lines estimates of GCA and SCA variance components and heritability for a population from chosen parental lines (Sing and Chaudhary 1979). The line x tester scheme involves crossing *l* parental lines with each of *t* tester. The crossing yields *lt* progenies, i.e. *lt* full-subfamilies. In the scheme, two different sets of parents (males and females) are used. In addition the line x tester cross system was reported to provide early information on the genetic behavior of these attributes in early generation.

The pea leaf consists of two stipules, several pairs of leaflets and it terminates in branched tendrils (Akcin 1988). The morphological variation in leaf characters is fairly wide. Therefore, in this study, leaf length; leaflet length, leaflet width, number of leaflet per leaf and tendril length have been investigated by quantitative approach. The inheritance of yield and its components in peas has been investigated, while the genetic nature of leaf characteristic in peas has not been much investigated in past. Rosen (1944) studied hybrids between *Pisum sativum* and *Pisum abyssinicum* and discovered that the differences between the traits with one pair and two to three pairs of leaflets are caused by a single gene. The absence of leaflet trait is caused by the action of recessive in pea (Khangildin 1966). Duarte (1966) reported additive gene action for leaf size and complete dominance of genes for high leaf number in common bean.

One of the problems in breeding plant genotypes is knowledge of relationships between grain yield and leaf characters. Correlation coefficients have been used by many researchers (Cousin et all. 1985; Walton, 1990; Sarawat et al., 1994; Ceyhan ve Mülayim, 2003) in determining relationships between grain yield and its components in pea, while Correlation coefficients have been little used by any researchers in determining relationships between grain yield and leaf characters in pea. Both positive and negative significant association between grain yield and leaf area was reported in pea cultivars by Cousin et all. (1985). The path analysis has been used by a few researchers (Ceyhan and Önder, 2001) to determine the direct and indirect effects of pea.

Although numerous studies have examined combining ability for grain yield and its components, little information is available on combining ability for leaf characters, which may provide practical information to breeders during the development of pea breeding programs aimed at improved leaf characters. Therefore, it is important to understand the genetics interrelationships among leaf characters to foresee the effects of selection for each feature. Most pea breeding programs selected high yield, leaf and semi-leaf. Understanding the relationships among leaf characters is important for selection criteria. So this study attempts have been made to determine the relative combining ability of seven pea genotypes considering characters which are directly correlated with grain yield and leaf traits.

MATERIALS AND METHODS

Seven pea genotypes which different agronomic traits were divided into four lines, Sprinter, Manuel, Carina and Bolero, and three testers, B_1, B_6 and B_{12}, selected from the Selcuk University pea-breeding programe in Konya by proceed Dr. Ahmet Tamkoç (genotypes of winter pea line) and were used for line x tester crosses at the experimental site of Faculty of Agriculture, Selcuk University, in Konya. The crosses by line x tester between four pea cultivars (Sprinter, Bolero, Manuel and Carina) and three pea lines (B_1, B_6 and B_{12}) were made in 2000 growing season.

Parents and their F_1 hybrids (line x tester set) were grown at the experimental field of the Faculty of Agriculture, Selcuk University, Konya, Turkey during 2003-2004 growing season. The soil was clay loam, with pH= 8.03 and phosphorous, potassium, iron, zinc, organic matter and $CaCO_3$ contents of 55.9, 17.9 kg ha^{-1}, 14.74, 0.32 ppm and 37.6, 2.25%, respectively. 10 –year annual precipitation is 289.7 mm per year, annual mean temperature is 9.2 ^oC and average relative humidity is 60.4%. Total annual precipitation was 314.9 mm, which was more than 10-year average of (289.7 mm) of the site. During the experimental period, average temperature was 9.8 ^0C and lowest temperature was -16.0 ^0C.

The experiment was a Randomized Complete Block Design with three replications. Sowings were made on 18 October 2003. Each plot consisted of 12 F_1 or parent plants on a single 1.5 m rows which were 50 cm apart. Plant spacing was 10 cm. The experimental materials were bordered by the pea lines B_6 to avoid border effects. Weeds were removed manually, when necessary. In the 2003-2004 growing season, no-irrigation was required due to the rainy season. Plants were grown without fertilization and harvested on 5 July 2004.

Grain data were collected at the maturity on five plants in each plot. Leaf characters data were collected at the green seed stage on five plants in the middle of each plot. Leaf area and leaflet area were measured to square centimeter using a plan meter. Leaf length, leaflet length and tendril length were measured to closest centimeter using a meter scale. Leaflet width was measured from the widest point of the leaflet using a vernier caliper. Number of leaflet was obtained from number leaflet of a leaf.

Regarding the statistical analysis, the data recorded on parents and the F_1 hybrids were analyzed together as suggested by Sing and Chaudhary (1979). The combining ability analysis was done following Kempthore (1957). Narrow sense heritabilities were calculated for each character by using the Falconer's (1982) methods. Correlations among these traits were computed with predictions direct and correlated responses to single character selection. Analysis of variance, coefficients of correlation and path coefficient analysis of the results were done using a computerized statistical program called "TARIST" obtained from the Faculty of Agriculture, Ege University, Izmir, Turkey.

RESULTS AND DISCUSSION

Analysis of variance for hybrids, lines and testers along with estimation of variance due to combining ability effects is given in Table 1. Mean sum of squares of parents were highly significant for almost all characters except for grain yield and number of leaflet. Variation due to crosses showed significant differences for all characters. Parent x crosses were significant for all traits excepting leaf length and tendril length. Variation due to lines showed significant difference for leaf area and leaf length while testers no differed for all characters. The interaction between line and tester was significant for grain yield, leaf area, leaflet length and leaflet width.

Table 1 also reveals the fact that the ratio of variance of GCA and SCA was much less than unity for all characters which indicate the predominant role of non-additive gene action in the inheritance of most of the traits in pea. Low heritability (narrow sense) was obtained for all traits (Table 1). Low heritability in case of all traits suggest nonfixable component of variation governing these traits and therefore, F_1 population should be exploited to utilize these components of variation. Thus, these traits can be improved by making selections among the recombinants obtained through segregating populations.

Table1. Analysis of variance for Line x tester in pea.

Source of Variation	Df	Grain Yield	Leaf Area	Leaf Length	Leaflet Area
Replications	**2**	6.970	2.347	0.664	1.435
Treatments	**18**	390.086**	160.972**	9.301**	4.118**
Parents	**6**	23.191	50.595**	12.232**	4.472**
Parents vs crosses	**1**	4460.249**	1290.664**	7.828	12.685**
Crosses	**11**	220.195**	118.479**	7.837**	3.147**
Lines	**3**	470.839	303.299*	23.267**	5.522
Testers	**2**	122.370	62.454	1.387	3.381
Lines x testers	**6**	127.481**	44.744**	2.271	1.881
Error	**36**	26.480	12.089	2.332	0.937
Variance component estimate					
gca		3.999	3.181	0.240	0.055
sca		33.667	10.885	-0.020	0.315
gca/sca		0.119	0.292	------	0.175
h^2		0.11	0.16	0.10	0.02
Source of Variation	**Df**	**Leaflet Length**	**Leaflet Width**	**Leaflets per Leaf**	**Tendril Length**
Replications	**2**	0.111	0.036	0.228	1.583
Treatments	**18**	0.529**	0.835**	1.926**	4.128**
Parents	**6**	0.899**	1.833**	0.333	7.114**
Parents vs crosses	**1**	0.381*	1.261**	14.778**	0.132
Crosses	**11**	0.340**	0.252**	1.626**	2.863*
Lines	**3**	0.411	0.408	2.185	6.752
Testers	**2**	0.342	0.061	2.694	0.994
Lines x testers	**6**	0.304**	0.238**	0.991	1.541
Error	**36**	0.080	0.028	0.543	1.189
Variance component estimate					
gca		0.002	0.001	0.027	0.057
sca		0.075	0.070	0.149	0.117
gca/sca		0.027	0.014	0.181	0.487
h^2		0.03	0.01	0.01	0.01

** : $p < 0.05$, ** : $p < 0.01$*

Lejeune –Heanut et al. (1992) and Sharma et al. (1999) observed nature of dominance and non-additive genes for grain yield. This study confirms nature of dominance and non-additive genes for grain yield. Rosen (1944) studied hybrids between *Pisum sativum* and *Pisum abyssinicum* and discovered that the differences between the traits with one pair and two to three pairs of leaflets are caused by a single gene. The absence of leaflet trait is caused by the action of recessive in pea, which also causes branching and development of tendrils (Khangildin 1966). Duarte (1966) reported additive gene action for leaf size and complete dominance of genes for high leaf number in common bean. This study clearly showed that leaf characters are generally nature of dominance and non-additive genes.

The mean values of the parents ranged from 23.22 to 30.80 g for grain yield, from 12.07 to 22.77 cm^2 for leaf area, from 9.73 to 17.17 cm for leaf length, from 3.02 to 6.34 cm^2 for leaflet area, from 2.43 to 4.00 cm for leaflet length, from 1.10 to 2.60 cm for leaflet width, from 3.33 to 4.33 number for leaflets per leaf, from 5.20 to 9.83 cm for tendril length among the parents and varied from 30.39 to 57.25 g for grain yield, from 17.67 to 36.93 cm^2 for leaf area, from 12.43 to 16.80 cm for leaf length, from 3.32 to 6.85 cm^2 for leaflet area, from 2.37 to 3.43 cm for leaflet length, from 1.07 to 2.23 cm for leaflet width, from 4.00 to 7.00 number for leaflets per leaf, from 5.60 to 8.80 cm for tendril length among in the F_1 generations. Hybrid performance was generally better than parental performance for all characters except for leaflet width (Table 2). This result was in agreement with Lejeune – Heanut et al. (1992), Sarawat et al. (1994), Amurrio et al. (1996), Kumar et al. (1996), Santalla et al. (2001), Kof et al. (2002), Prajapati and Kumar (2002) and Ceyhan (2003).

The estimated GCA effects of parents (Table 3) revealed considerable differences among the parents. The parents that proved to be good general combiners on the basis of their desirable GCA effects were Bolero for leaf area and leaflet area, Sprinter for leaflet length, Manuel leaflets per leaf. Carina exhibited positively significant GCA effects for leaflet area, leaf length and leaflet width. B_{12} expressed significant GCA in leaf area. B_1 exhibited positively significant

GCA effects for leaflet width and leaflets per leaf. However, among the parents the highest positive effect for grain yield was exhibited by Sprinter, Manuel and B_6 hence they should be considered as the best female and male combiners. In this study, one of the seven lines showed significant, positive GCA effects for at least one of these parameters.

Table 2. Mean grain yield and leaf characters in pea crosses and parents

Lines	Grain Yield (g)	Leaf Area (cm^2)	Leaf Length (cm)	Leaflet Area (cm^2)	Leaflet Length (cm)	Leaflet Width (cm)	Leaflets per Leaf (cm)	Tendril Length (cm)
Sprinter	25.01	12.07	12.08	3.02	2.90	1.47	4.00	6.50
Bolero	23.22	13.20	11.47	3.30	2.83	1.10	4.00	5.97
Manuel	24.38	22.77	17.17	6.34	4.00	2.60	3.33	9.83
Carina	24.49	19.43	15.27	4.86	3.67	2.17	3.67	6.00
Testers								
B_1	28.70	13.73	14.40	3.48	3.57	1.77	4.00	7.47
B_6	30.80	16.83	9.73	4.21	2.43	1.33	3.67	5.20
B_{12}	24.39	12.13	15.07	3.04	3.23	1.23	4.33	7.67
Hybrids								
SprinterxB_1	49.08	18.60	14.83	5.08	3.43	1.07	5.33	7.83
SprinterxB_6	46.96	24.90	16.23	4.09	3.10	1.43	4.67	7.50
SprinterxB_{12}	56.20	27.70	15.57	4.18	3.37	1.50	4.67	6.93
BoleroxB_1	36.00	29.87	12.43	4.69	2.37	2.23	5.33	6.43
BoleroxB_6	46.78	35.63	12.50	5.07	3.13	1.47	4.00	6.83
BoleroxB_{12}	33.37	36.93	13.60	4.09	3.20	1.67	5.33	7.17
ManuelxB_1	49.95	22.90	14.27	6.14	2.40	1.50	7.00	5.67
ManuelxB_6	57.25	18.63	16.07	3.32	3.10	1.63	5.33	6.07
ManuellxB_{12}	43.17	21.97	13.60	4.78	3.10	1.67	5.00	6.17
CarinaxB_1	43.78	26.27	16.80	6.16	3.30	2.00	4.67	8.80
CarinaxB_6	37.45	17.67	16.23	5.50	3.13	1.70	4.67	8.57
CarinaxB_{12}	30.39	26.33	16.70	6.85	3.13	1.63	4.67	5.60

Table 3. General combining ability and specific combining ability related grain yield and leaf characters in pea

Lines / Tester	Grain Yield	Leaf Area	Leaf Length	Leaflet Area	Leaflet Length	Leaflet Width	Number of Leaflet	Tendril Length
Sprinter	6.55**	-1.88	0.64	-0.54	0.24*	-0.29**	-0.17	0.46
Bolero	-5.48**	8.53**	-2.06**	-0.38	-0.16*	0.16**	-0.17	-0.15
Manuel	5.92**	-4.45**	-0.26	-0.25	-0.207*	-0.03	0.72**	-1.00**
Carina	-6.99**	-2.19*	1.68**	1.17**	0.13	0.15**	-0.39	0.69**
B_1	0.50	-1.21	-0.32	0.52	-0.19*	0.08*	0.53*	0.22
B_6	2.91*	-1.41	0.36	-0.50	0.05	-0.07	-0.39	0.28
B_{12}	-3.42*	2.62*	-0.04	-0.02	0.14	-0.01	-0.14	-0.50*
Hybrids								
SprinterxB_1	-2.17	-3.93	-0.39	0.11	0.32*	-0.34**	-0.08	0.19
SprinterxB_6	-6.70*	2.58	0.33	0.14	-0.25	1.17*	0.17	-0.20
SprinterxB_{12}	8.86**	1.35	0.06	-0.25	-0.07	0.18*	-0.08	0.01
BoleroxB_1	-3.22	-3.07	-0.09	-0.45	-0.34*	0.37**	-0.08	-0.60
BoleroxB_6	5.15	2.90	-0.70	0.96	0.18	-0.26**	-0.50	-0.26
BoleroxB_{12}	-1.93	0.17	0.79	-0.51	0.16	-0.11	0.58	0.85*
ManuelxB_1	-0.68	2.94	-0.06	0.87	-0.28	-0.18*	0.69	-0.52
ManuelxB_6	4.21	-1.13	1.07	-0.93	0.18	0.10	-0.06	-0.18
ManuellxB_{12}	-3.54	-1.82	-1.01	0.06	0.10	0.08	-0.64	0.70
CarinaxB_1	6.07*	4.05	0.54	-0.53	0.30*	0.15	-0.53	0.93*
CarinaxB_6	-2.67	-4.35*	-0.70	-0.17	-0.11	-0.01	0.39	0.63
CarinaxB_{12}	-3.40	0.29	0.16	0.70	-0.19	-0.14	0.14	-1.56**

** : $p < 0.05$, ** : $p < 0.01$*

The SCA effects (Table 3) clearly revealed that it would not be possible to isolate crosses where all traits are in the most desirable combinations. Also, it appeared that desirable SCA effects of the cross combinations were not necessarily depended on the level of GCA effects of parents involved. The SCA estimates for leaf area, leaflet area, leaf length and leaflets per leaf showed no combination in desirable direction. However the SCA estimates of the crosses "Sprinter x B_{12}" and "Carina x B_1" were highly significant for grain yield. Similarly, "Sprinter x B_6", "Sprinter x B_{12}" and "Bolero x B_1" showed significant positive SCA effects for leaflet width, "Sprinter x B_1" and "Carina x B_1" for leaflet length, while "Bolero x B_{12}" and "Carina x B_1" had significant positive SCA effects for tendril length. This suggests that on the basis of general combining ability studies it would be difficult to make definite breeding plans as the high grain yielding combination was obtained from parents which did not show significant GCA effect in desirable direction. However, the high SCA effects of the crosses "Sprinter x B_{12}" and "Carina x B_1" further confirm the predominance of non-additive gene actions in pea. Hence, it is suggested that in pea emphasis should be given to specific crosses followed by selection in progenies rather than pursuing GCA by mass selection. General and specific combining ability has previously been shown in pea to be the major contributing factor for grain yield (Krarup and Davies 1970; Srivastava et al. 1986; Sing and Sing 1987; Sarawat et al., 1994; Sharma et al.1999 and Ceyhan 2003).

Correlation coefficients were determined between grain yield and other variables. The indicate correlations coefficients were calculated for each variable (Table 4). Grain yield was significantly positive correlated with leaf area and leaflets per leaf. The same insignificant positive correlations were found between grain yield and leaf length and leaflet length, tendril length. Relationships between leaflet length and leaflet width and tendril length were significant positively correlated. Leaflet width correlated significant positively with tendril length. Grain yield correlated significant negatively with leaflet width. A negative significant correlation between leaflet length and leaflets per leaf was found. Leaflet area correlated significant negatively with leaflet length and leaflet width. Other variables were unimportant; it could be positively and negatively correlation. Walton (1990) found that reduction in leaf area to produce smaller and more highly branched plants would favour yield, and Cousin et al. (1985) found both a negative and positive correlation between grain yields with leaf area in pea cultivars. Variations amongst the cultivars in grain yield can be attributed to varying genetic constructions as well as environmental factors, similarly to previous report by Ceyhan and Mulayim (2003). These results shown that, for high grain yield, winter pea crosses should be moderately with leaf area and leaflets per leaf. In contrast, leaflet length seems to be important; leaflet length may be short.

Correlation coefficients calculated between seed yield and the leaf characters and path coefficient analysis revealing direct and indirect effects of variables on seed yield, are given in Table 5. The highest direct positive effects on grain yield were exhibited by leaf area. Relation between grain yield and leaf area was positive and significant, with a direct effect of 76.53 % and indirect effects of 13.25 %, especially through the leaflets per leaf. The direct effects of leaflets per leaf on grain yield were also positive and significant. These relations for hybrids were further studied using breeding programs. Selection in a breeding program based leaflets per leaf was 64.59 % as effective as selection for grain yield directly. When selection for grain yield was based alone on leaflets per leaf, genetic advance was 64.59 %.

Table 4. Correlations coefficients among grain yield and its components pea crosses

Variable	**Grain Yield**	**Leaf Area**	**Leaf Length**	**Leaflet Area**	**Leaflet Length**	**Leaflet Width**	**Leaflets per Leaf**	**Tendril Length**
Grain Yield	--------							
Leaf Area	0.378**	--------						
Leaf Length	0.219	0.061	--------					
Leaflet Area	0.132	0.125	-0.006	--------				
Leaflet Length	-0.150	0.013	0.358**	-0.324*	--------			
Leaflet Width	-0.357**	-0.027	0.214	-0.346**	0.335**	--------		
Leaflets per Leaf	0.449**	0.171	0.129	0.194	-0.377**	-0.147	--------	
Tendril Length	-0.033	0.046	0.482**	-0.161	0.522**	0.328**	-0.074	--------

**: $p < 0.05$, **: $p < 0.01$*

Table 5. Path coefficient analysis between grain yield and other variables examined among pea genotypes

Variable	Coefficient of correlation	Direct effects		Indirect effects													
				Leaf Area		Leaf Length		Leaflet Area		Leaflet Length		Leaflet Width		Leaflets per Leaf		Tendril Length	
		p	%	*p*	%	*p*	%	*p*	%	*p*	%	*p*	%	*p*	%	*p*	%
Leaf Area	0.378**	0.314	76.53	-----	-----	0.016	3.91	-0.014	3.37	-0.00	0.06	0.010	2.52	0.054	13.25	-0.002	0.37
Leaf Length	0.219	0.262	61.37	0.019	4.50	-----	-----	0.001	0.16	-0.007	1.65	-0.081	18.99	0.041	9.61	-0.016	3.74
Leaflet Area	0.132	-0.110	30.97	0.039	11.07	-0.002	0.44	-----	-----	0.006	1.80	0.130	36.92	0.061	17.31	0.005	1.50
Leaflet Length	-0.150	-0.020	4.71	0.004	0.98	0.094	22.48	0.036	8.56	-----	-----	-0.127	30.42	-0.120	28.71	-0.017	4.14
Leaflet Width	-0.357**	-0.378	69.40	-0.009	1.57	0.056	10.28	0.038	6.99	-0.007	1.21	-----	-----	-0.047	8.57	-0.011	1.99
Leaflets per Leaf	0.449**	0.318	64.59	0.054	10.90	0.034	6.87	-0.021	4.33	0.007	1.51	0.056	11.32	-----	-----	0.002	9.47
Tendril Length	-0.033	-0.033	12.00	0.014	4.10	0.126	36.16	0.018	5.07	-0.010	2.94	-0.124	35.52	-0.024	6.73	-----	-----

* : $p < 0.05$, ** : $p < 0.01$

The negative direct effect of leaflet length was compensated by the positively indirect effects of leaf length. Leaflet length had lowest direct effect on grain yield. The negative direct effect on grain yield was compensated by the positively indirect effects of leaf length, leaflet width and leaflets per leaf.

In conclusion, this study demonstrates that increases in grain yield as a result of favorable weather and genotype increased leaf area, leaflet area and number of leaflet per leaf in the pea hybrids studied. Further a breeding program to improve grain yield should focus on increasing both leaf area, number of leaflet per leaf and leaflet area. In pea, path analysis of yield components revealed that the components showing the highest correlations with yield also had the largest direct effect on yield.

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