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Analysis of Gene Effects Controlling Some Traits in Garden Pea (*Pisum Sativum* L.)

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Abstract: A 6x6 half diallel cross was used to study gene action involved in the inheritance of 9 agronomical characters in garden pea (*Pisum Sativum* L.) and estimation of general and specific combining ability effects. The genotypes used in the present study were; Metior, Snow wide, Herawt, Dwarf gray sugar, Early perfection and Alaska. Significant genotypic differences were observed for all studied characters which included plant height, No. of branches and pods per plant, No. of green pods per plant, green pod weight per plant, total soluble solid (TSS), No. of seeds per pod, ten pods weight and green pod width. Both additive and non-additive effects are important in the control of these traits, while additive effects is predominant. Meanwhile, the TSS after two days storage was mainly controlled by dominance effects. The Wr/Vr graphs indicated partial dominance for green pods weight, green pods number, TSS in fresh pods, Ten pods weight and green pod width. complete dominance was inferred for TSS after two days storage and No. of seeds per pod. While, overdominance was found for number of branches and plant height. The cultivar Alaska was the best combiner for No. of branches per plant, pods weight per plant and No. of pods per plant. While, Early perfection was the best combiner for seed number per pod and ten pods weight. Snowwide was the best combiner for pod width. While, Metior was the best combiner for TSS fresh. Favorable additive genes for TSS fresh, seed number per pod and pod width were also found in the parent Herawt. Further dominance effects due to specific combinations and/or epistasis (Sij) were observed for most studied characters. Phenotypic correlation between the tested traits was also studied. The parental genotypes used in the present study possessed favorable genes for most studied traits, which could be utilized in the breeding programs designed to improve garden pea (*Pisum Sativum* L.).

Key words: Pea, Genetic studies, diallel crosses, general and specific combining ability.

INTRODUCTION

Garden peas (*Pisum Sativum* L.) is one of the most popular vegetable crops grown in Egypt. The genetic improvement of such a crop might be approached either through selection or by hybrid development depending upon the magnitude of the additive and non-additive genetic variation of the most important economical traits. The diallel analysis developed by Hayman (1954 & 1960) and Jinks (1954) provide the breeders with detailed information concerning the genetic systems and gene action involved in the expression of the important traits available in the breeding material.

Using diallel cross analysis in garden pea, additive gene action was found to be much more important than non-additive gene action in the inheritance of yield and yield components including plant height, number of branches, pod length, pod width, pods weight/plant, No. of pods/plant, number of seeds/pod and seed weight (Shalaby, 1974; Dhillon and Chahal, 1981; Kumar and Agrawal, 1981; Waly, 1982 and Gupta and Dahiya, 1986). In contrast, non-additive gene effects were predominant in controlling number of seeds per pod (Dhillon and Chahal, 1981) and 100-seed weight (Gupta, 1982). While, Gupta (1982) found that both additive and non-additive effects were equally important for number of seeds per pod. Arndt (1980) studied heterosis in 147 crosses of pea and found weak heterosis in certain hybrids for length of pod, seeds per pod and 1000-seed weight. In a six pea cvs. diallel cross, Pacucci and Troccoli (1985) showed that additive effects generally predominated while, dominance and epistasis effects were of little or no importance.

In addition, an inference could be made from diallel crosses about combining ability of the parents, a general concept considered collectively for classification of an inbred line relative to its crosses performance (Griffing, 1956). Such information is helpful for breeders to identify the best combiners which may be hybridized either to exploit heterosis or to build up favorable fixable genes. Several researchers have been stated the significance of both general and specific combining ability effects (GCA and SCA) for yield and other important traits in pea (Singh *et al*, 1999; Singh and Singh 1990; Zayed *et al*, 1999; Kumar and Jain, 2002; Singh and Mishra, 2003 and Sood and Kalla, 2006). However, non-additive gene action (SCA) was pre-dominant for 8 characters in pea (Singh and sharma, 2001) and pod width (Zayed *et al*, 1999). El-Shabrawy (2006) found that GCA were larger than SCA for all studied traits. He also found that Allepo, Allaska, and early perection were excellent general combiners for seed yield components and the majority of cross combinations showed desirable SCA effects and significant heterosis values for most studied traits. These promising crosses could be used for isolating new high yielding pea cultivars.

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Evidently, such controversial results as to the relative importance of additive and non-additive genetic variation are related to the parents involved in each study as well as environment in which they were grown. The objective of the present study was to gather information about the nature of gene action involved in the inheritance of various agronomic characters in garden pea (*Pisum Sativum* L.) and estimation of general and specific combining ability effects. The information so derived may be effectively exploited to further streamline the pea improvement program.

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, during the seasons of 2010/2011 and 2011/2012. The soil types was clay. Six cultivars of garden pea (*Pisum Sativum* L.), namely Metior (P_1), Snowwide (P_2), Herawt (P_3), Dwarf Gray Sugar (P_4), Early perfection (P_5) and Alaska (P_6) were crossed in a diallel pattern without reciprocals to produce 15 F_1 hybrids in the 2010/2011 season. In season 2011/2012, seeds of the 6 parents and 15 hybrids were planted in the field for evaluation on 1st November using a randomized complete block design with three replicates. Each entry of the diallel cross was represented in each block by a plot of one row of 10 plants spaced 20 cm apart with rows set 60 cm from each other.

At harvest, plant height (cm), number of branches and pods/plant, number of green pods/plant, green pod weight/plant, total soluble solid(TSS) fresh and after two days storage according to A.O.A.C. (1980), number of seed/pod, ten pods weight and green pod width were recorded.

A diallel analysis as developed by Hyman (1954 & 1958), Mother and Jinks (1971) and Griffing (1956) was performed on the collecting data.

RESULTS AND DISCUSSION

The mean values of plant height, No. of branches, in addition to pod characters (No. of pods/plant, green pods/plant and green pod weight/plant), total soluble solids (TSS), No. of seed pods/plant, ten pods weight and green pod width for the 6 pea parents and their 15 F_1 hybrids are found in table (1). The results revealed that pea cultivars genetically varied from each other in one or more character. However, phenotypic expression of any trait is the outcome of the genotype x environment interaction. The analyses of variance revealed highly significant differences between the tested genotypes for all characters under investigation which indicate a wide genetic variability for studied characters and hence, the feasibility for genetic improvements using such genetic pools of pea (Table 2). In a 12 pea cvs diallel cross, Tewatia *et al*. (1988) found that the differences among genotypes were highly significant for pod length and total soluble sugar content.

The diallel analysis (Table 3) reveals that both additive “a” and non-additive “b” genetic variance were highly significant, except TSS after two days storage. However, the additive effects are high in comparison with the non-additive effects. Therefore, it could be concluded that both additive and non-additive effects are important in the control of these traits, while additive effects is predominant. Meanwhile, the TSS after two days storage was mainly controlled by dominance effects as indicated by the significance of (b) and non-significance of (a) items. These results are also substantiated by the significance of GCA and SCA as shown in Table (2). Similar results were also found by Shalaby (1974), Pacucci and Troccoli(1985) and Gupta and Dahiya (1986). Kumar and Agrawal (1981) found that pod length, the number of seeds per pod and 25-seed weight in a 10x10 diallel analysis were predominantly controlled by additive gene action. While, Sood and kalia (2006) and Singh et al. (2010) reported that non-additive gene action was predominant for the inheritance of pod yield.

The overall dominance, b, was partitioned to its components i.e., b_1 , b_2 , and b_3 as shown in Table (3). The b_1 was significant for green pods weight/plant, green pods number/plant, TSS fresh and green ten pods weight confirming the presence of dominance direction for these characters. The b_2 item was significant for all studied traits except green pod width indicating asymmetrical distribution of genes affecting these traits at loci showing dominance. In addition, the b_3 was significant for all studied traits except number of tillers per plant indicating the presence of further dominance effects due to specific combinations and/or epistasis.

Wr/Vr Analysis:

The Wr/Vr graphs (Fig1a-i) revealed that slope of the regression line did not differ from unity but significantly different from zero, indicating an additive/dominance model for the genetic systems controlling all studied characters, except TSS after two days storage and green ten pods weight in which the regression value was not significantly different from zero and unity.

The regression line cuts the Wr axis above the origin point in green pods weight, green pods number, TSS in fresh pods, ten pods weight and green pod width indicating additive gene action with partial dominance. Sood and kalia (2006) observed partial dominance with mainly additive gene action for pod yield in pea. While, the regression line cuts the Wr axis in the origin indicating complete dominance for TSS after two days storage and

No. of seeds per pod. The Wr/Vr graphs indicated overdominance for number of branches and plant height. Due to over dominance, such characters seem difficult to fix and the progress in selection will be inherently slow. Overdominance was also reported by Sood and kalia (2006) while weak heterosis was found in some of the 147 crosses analyzed by Arndt (1980).

Table 1: Mean performance different studied traits in 6 pea parental genotypes and their F_1 crosses.

Traits / Parents and F1.s	No. of branches	Plant height	Pods weight per plant	Pods number per plant	Tss fresh	Tss after storage two days	Seeds number per pods	Ten pods weight	Pod width
P_1 x P_1	4.3	70.0	216.3	55.57	17.0	16.0	4.750	38.7	1.25
P_2 x P_2	5.7	65.0	54.00	8.500	13.0	15.3	4.670	42.0	1.62
P_3 x P_3	3.9	85	102.7	26.50	14.0	11.3	7.560	42.0	1.32
P_4 x P_4	5.4	125.1	62.30	28.00	9.70	16.3	5.720	27.0	1.04
P_5 x P_5	4.6	90.8	252.3	57.50	12.3	11.7	8.060	58.0	1.33
P_6 x P_6	7.54	103.5	459.3	128.0	16.3	15.0	7.0	37.3	1.18
P_1 x P_2	5.0	68.7	126.7	31.50	16.0	16.0	4.720	40.7	1.44
P_1 x P_3	5.3	106.8	111.0	36.50	15.3	11.3	7.110	35.5	1.29
P_1 x P_4	4.8	113.8	184.7	55.50	10.0	13.6	7.080	39.0	1.21
P_1 x P_5	4.0	77.0	99.00	21.50	10.7	15.3	6.500	45.0	1.37
P_1 x P_6	3.7	68.2	85.00	55.00	14.0	11.7	7.420	39.3	1.18
P_2 x P_3	6.7	120.3	94.00	26.50	14.0	15.7	6.530	47.7	1.42
P_2 x P_4	5.0	100.0	52.70	16.00	11.7	13.7	5.190	35.0	1.33
P_2 x P_5	5.5	68.8	66.30	15.00	14.3	12.7	7.50	50.0	1.38
P_2 x P_6	5.5	81.0	187.0	43.00	12.3	13.3	5.750	38.0	1.39
P_3 x P_4	5.3	105.8	28.30	16.00	11.3	14.3	6.330	20.0	1.23
P_3 x P_5	5.0	132.4	128.7	37.00	12.0	12.7	8.330	39.7	1.31
P_3 x P_6	4.2	110.3	193.7	55.00	13.0	17.0	6.420	43.7	1.25
P_4 x P_5	4.9	120.3	112.0	34.00	9.3	12.3	7.550	34.7	1.15
P_4 x P_6	4.9	69.1	160.0	57.50	12.7	14.3	5.580	29.0	1.13
P_5 x P_6	5.0	105.9	261.0	67.00	12.3	15.3	5.830	37.7	1.26
L.S.D $_{(0.05)}$	2.00	32.13	136.4	4.21	2.20	4.29	2.001	5.993	0.21

Table 2: Mean squares for genotypes and combining abilities for the evaluated traits of pea cultivars and their F_1 hybrids.

Traits		No. of Branches	Plant height	Pods weight per plant	Pods number per plant	Tss fresh	Tss after storage two days	Seeds number per pods	Ten pods weight	Pod width
S. O. V.	d. f.									
Bolck	2	1.96*	87.64	555.86**	119.05**	1.44	2.72	0.34	100.25*	0.049*
Genotypes	20	2.36**	1489.79**	28679.24**	2056.74**	13.83**	22.62**	7.48**	196.55**	0.046**
GCA	5	3.12**	1752.31**	73743.58**	6527.16**	35.24**	7.67	8.72**	523.8**	0.181**
SCA	15	2.12**	1402.28**	13657.8**	566.68**	6.69**	27.6*	2.02**	87.46**	0.0043
Error	40	0.49	132.99	43.55714	6.5	1.77	6.74	0.49	13.18	0.0041

Table 3: The diallel analyses of variance for different studied traits in 6 pea pareparents and F_1 generation.

Traits		No. of branches	Plant height	Pods weight per plant	Pods number per plant	Tss fresh	Tss after storage two days	Seeds number per pods	Ten pods weight	Pod width
S. O. V.	d. f.									
Bolck	2	3.16*	1.21	68.7	121.44**	1.44	3	0.32	100.26**	0.06**
a	5	5.45**	1683.79**	58940.13**	6513.98**	35.24**	7.68	6.33**	523.81**	0.22**
b	15	1.75*	1483.32**	11019.28**	569.18**	6.69**	28.65**	5.70**	87.47**	0.01**
b1	1	3.21	55.40	37291.09**	2117.5**	16.19**	5.16	0.19	101.6**	0.01
b2	5	2.81**	1377.33**	7298.06**	606.63**	6.04*	25.75**	3.04**	60.48**	0.01
b3	9	1.00	1700.87**	10167.53**	376.33**	6**	32.87**	7.79**	100.89**	0.02**
Error	40	0.80	181.42	43.557	6.52	1.78	7.02	0.50	13.19	0.0045

General (GCA) and Specific (SCA) Combining Ability:

The combining ability estimates help in the identification of promising parents and desirable combinations for the improvement of plant traits through selection and breeding. In the present study, the comparisons between GCA effects (δ^2gi) associated with each parent (Table 4) revealed that the P_6 possessed the highest significant positive "gi" values for No. of branches/plant, pods weight/plant and No. of pods/plant. It is also good combiner for TSS fresh and after storage in addition to ten pods weight. The parent P_5 was the best combiner for seed number per pod and ten pods weight. It is also good combiner for pods weight/plant and pod width. The parent P_2 was the best combiner for pod width and good combiner for TSS fresh and after storage in addition to ten pods weight. While, the P_1 was the best combiner for TSS fresh and good combiner for pod number/plant. Favorable additive genes for TSS fresh, seed number/pod and pod width were also found in the P_3 parent. These results indicated that the studied parental genotypes possessed favorable genes for most studied traits, which could be utilized in the breeding programs designed to improve pea. Similar results were also obtained by Singh and Mishra (2003) who found that GCA and SCA variances were highly significant for all the characters studied in both generations except for seeds/pod in F_1 and F_2 in general combining ability indicating the role of additive as well as non-additive gene effects for the expression of these characters. El-Shabrawy (2006) found that GCA were larger than SCA for all studied traits. He also found that Allepo, Allaska, and Early perection were excellent general combiners for seed yield components.

Further dominance effects due to specific combinations and/or epistasis (Sij) were observed for most studied characters (Table 5). The best crosses displayed positive and significant Sij effects towards large number of branches per plant were obtained from the crosses (P_1x P_3), (P_2 x P_3), (P_3 x P_4) and (P_3 x P_5). Epistatic effects in pods weight and number per plant were indicated by the significance of positive Sij values of the crosses (P_1x P_2), (P_1xP_4) and (P_2xP_3). In TSS in fresh pods, 4 combinations were positive and significant while, only one cross (P_3xP_6) showed positive significance for TSS after two days storage. However, for seeds number/pod, 7 crosses were positive and significant, while only 3 crosses were positive and significant for green ten pods weight. In pod width, 9 crosses were positive and significant. Meanwhile, no significant positive combinations were found for plant height. El-Shabrawy (2006) found that the majority of cross combinations showed desirable SCA effects and significant heterosis values for most studied traits. These promising crosses could be used for isolating new high yielding pea cultivars. Arndt (1980) studied heterosis in 147 crosses of pea and found weak heterosis in certain hybrids for length of pod, seeds/pod and 1000-seed weight. In a six pea cvs diallel cross, Pacucci and Troccoli (1985) showed that additive effects generally predominated while, dominance and epistasis effects were of little or no importance.

Table 4: Estimates of general combining ability effects (gi) for different studied traits in six pea cultivars.

Traits / Parents and F1,s	No. of Branches	Plant height	Pods weight per plant	Pods number per plant	Tss fresh	Tss after storage two days	Seeds number per pod	Ten pods weight	Pod width
P_1	-0.489**	-8.184	3.333	2.59**	1.19**	0.197	-0.359**	0.07	-0.005**
P_2	0.449**	-9.024	-47.208**	-17.64**	0.49**	0.468**	-0.773**	2.94**	0.146**
P_3	-0.141**	4.817	-31.417**	-8.33**	0.40**	-0.582**	0.580**	-0.18	0.015**
P_4	0.042*	11.692 *	-43.750**	-6.95**	-2.01**	0.314*	-0.252**	-7.51**	-0.112**
P_5	-0.228**	5.665	19.917**	-0.08	-0.89**	-0.824**	0.829**	6.40**	0.013**
P_6	0.368**	-4.967	99.125**	30.40**	0.82**	0.426**	-0.025	1.72**	-0.057**
SD $_{(Gi)}$	0.017	4.61	3.025	0.23	0.06	0.16	0.017	0.46	0.0002

Table 5: Estimates of specific combining ability effects (Sij) for different studied traits in the F_1 crosses of six pea cultivars.

Traits / Parents and F1,s	No. of branches	Plant height	Pods weight per plant	Pods number per plant	Tss fresh	Tss after storage two days	Seeds number per pod	Ten pods weight	Pod width
P_1 x P_2	-0.02	-5.55	25.923*	5.03**	1.40**	1.30	-0.61**	-1.17	0.0070**
P_1 x P_3	0.91**	8.78	-5.536	0.72	0.82**	-2.32*	0.43**	-3.38	-0.0050**
P_1 x P_4	0.17	18.90	80.464**	18.35**	-2.10**	-1.05	1.24**	7.62**	0.0360**
P_1 x P_5	-0.34**	-11.91	-68.869**	-22.53**	-2.56**	1.92	-0.43**	-0.30	0.0710**
P_1 x P_6	-1.22**	-10.11	-162.077**	-19.18**	-0.94**	-2.99*	1.34**	-2.17	-0.0460**
P_2 x P_3	1.30**	33.12	28.006*	10.95**	0.19	1.74	0.26*	6.08**	-0.0300**
P_2 x P_4	-0.55**	5.91	-0.994	-0.93	0.27	-1.15	-0.25*	0.74	0.0080**
P_2 x P_5	0.22	-20.29	-50.994**	-8.30**	1.82**	-1.01	0.99**	1.83	-0.0710**
P_2 x P_6	-0.38**	3.57	-9.536	-11.28**	-1.89**	-1.60	0.09	-2.05	0.0090**
P_3 x P_4	0.37**	-28.17	-41.119**	-10.24**	0.02	0.50	-0.45**	-11.13**	0.0390**
P_3 x P_5	0.31**	30.48	-4.452	3.89**	-0.44	0.04	0.47**	-5.38*	-0.0100**
P_3 x P_6	-1.12**	-22.09	-18.661	-8.59**	-1.14**	3.12**	-0.60**	6.74**	0.0060**
P_4 x P_5	0.02	11.79	-8.786	-0.49	-0.69**	-1.19	0.51**	-3.05	-0.0420**
P_4 x P_6	-0.61**	-29.09	-39.994**	-7.47**	0.94**	-0.44	-0.60**	-0.59	0.0070**
P_5 x P_6	-0.17	13.77	-2.661	-4.84**	-0.52	1.69	-1.43**	-5.84*	0.0100**
SD $_{(Sij)}$	0.13	34.83	13.309	1.16	0.32	1.19	0.13	2.35	0.0014

Phenotypic Correlation Between the Studied Traits:

Phenotypic correlation coefficients for all comparisons among the studied traits are presented in Table (6). Significant positive correlation ($P<0.01$) was only detected between Pods weight/plant and Pods number/plant. Meanwhile, the other positive correlations were not significant.

Negative and significant correlations ($P<0.05$) were observed between plant height and each of TSS fresh and pod width pod width. Significant negative correlation ($P<0.05$) were also found between Pods number/plant and Pod width Pod width. Negative correlation was also significant (P<0.01) between TSS after storage two days and seeds number/pods.

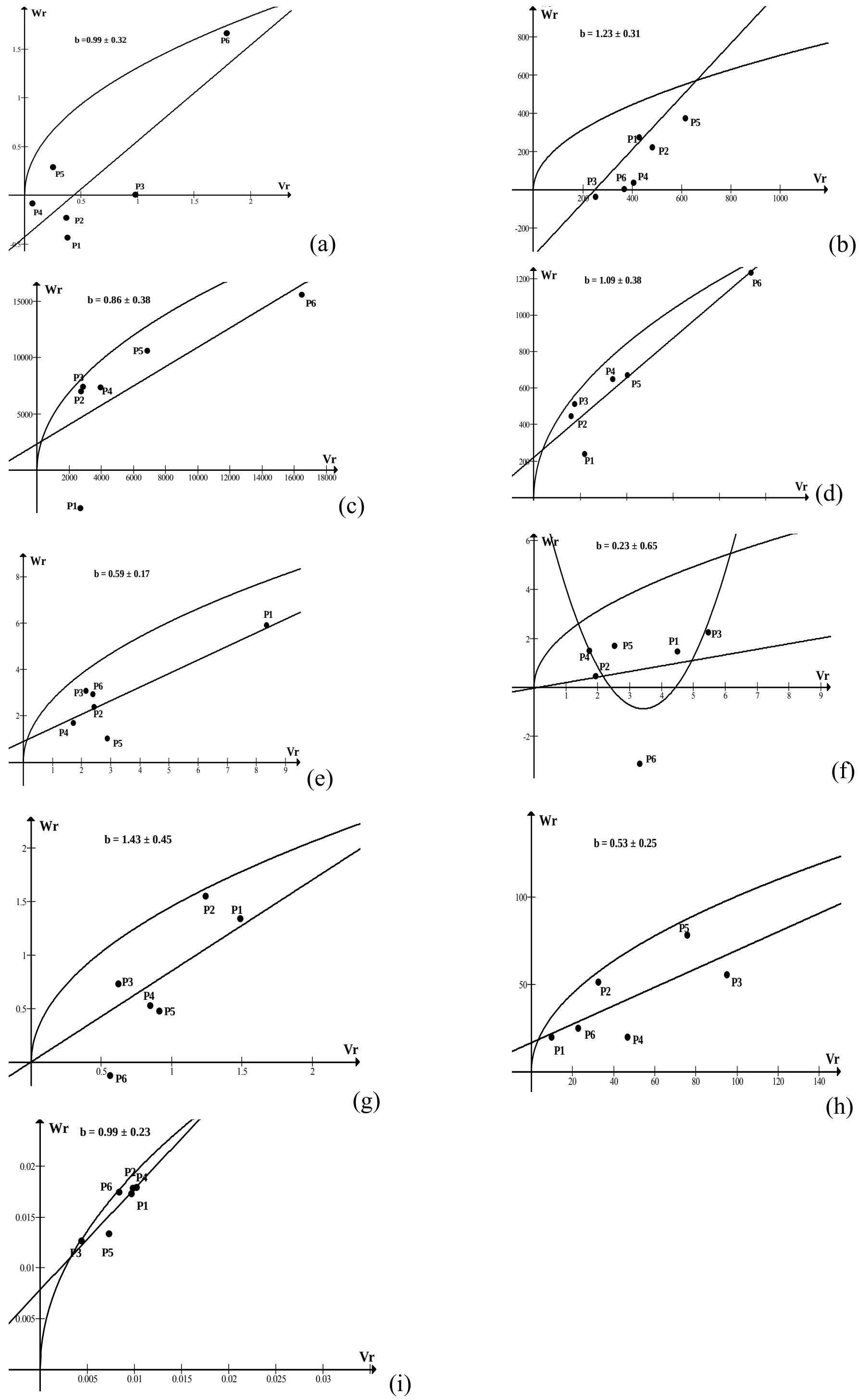

Fig. 1: The Wr/Vr graph of No. of branches/plant (a), plant height (b), pods weight/plant (c), Pods number/plant (d), TSS fresh (e), TSS after two days storage (f), seeds number/pod (g), Ten pods weight (h) and Pod width (i).

Table 6: Correlation coefficients among nine traits studied on six pea cultivars and their 15 F_1 hybrids.

Traits	2	3	4	5	6	7	8	9
1- No. fo branches	0.2820	0.3357	0.2837	0.2027	0.2361	-0.0906	-0.0939	0.1194
2- Plant height	--	0.0701	0.0975	-0.4559*	0.0272	0.3901*	-0.2315	-0.4005*
3- Pods weight/plant		--	0.9388**	0.3485	0.1409	0.1081	0.2011	-0.2273
4- Pods number per plant			--	0.3312	0.0858	0.1628	0.0279	-0.4456*
5- Tss fresh				--	0.0702	-0.1846	0.2509	0.2742
6- Tss after storage two days					--	-0.6851**	-0.1582	0.0418
7- Seeds number per pods						--	0.3278	-0.2405
8- Ten pods weight							--	0.5284*
9- Pod width Pod width								--

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