Genetic analysis for seven pea varieties and their half diallel hybrids for forage and seed yield

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Abstract:

The present experiment was conducted at the experimental farm of Qlyasan research Station- College of Agriculture during two growing seasons from November 2008 to may 2010 in a Randomized Complete Block Design (RCBD) with three replications, to study some genetic parameters in seven pea varieties (Avolla, America, Jeza, Joneor, Pack land, Wild local arvena and Samara) using half diallel crossing system. The highest value for number of root nodules/plant, weight of root nodules/plant produced by the hybrid Joneor× Wild local arvena. The desirable high negative heterosis value for the character number of days to 50% flowering and maturity recorded by the hybrid Jeza× Wild local arvena as the result of reducing the values of these characters in this hybrid comparing to its parental values. Regarding the general combining ability effect, the parents America, Jeza and Pack land were the best general combiner in reducing number of days to flowering and maturity. Parent Joneor was found to be the best general combiner for most studied characters such as plant height, plant dry weight, number of root nodules/plant, weight of root nodules/plant.The hybrids Jeza× Wild local arvena and Avolla× Samara recorded maximum negative value for the characters number of days to 50% flowering and physiological maturity respectively. Maximum positive value of this effect for the characters plant height and weight of root nodules/plant exhibited by the hybrid Avolla× Joneor, while the hybrid Jeza× Wild local arvena showed maximum effect for the characters number of basal branches/plant, root dry weight/plant. The variance components due to sca was larger than that of gca for most studied character except number of days to 50% flowering, recording the ratio of σ^2gca/σ^2sca to be more than one in these characters.The average degree of dominance was more than one in most studied characters, confirming the importance of non additive gene effect in the inheritance of these characters. Heritability in broad sense was found to be high in most studied characters. Heritability in narrow sense was high for the characters number of days to 50% flowering, physiological maturity, while it was moderate for the characters plant height, number of basal branches/plant, plant dry weight, leaf/stem ratio, dry weight root/plant, number of root nodules/plant, weight of root nodules/plant.

Key words: Pea, gca, sca, Heterosis.

I. Introduction:

Pea (*Pisum sativum*, 2n=14) is a grain legume crop plant of world-wide importance. It is also one of the most intensively studied plants in physiological, biochemical, genetic, molecular biological and breeding experiments. Pea has received attention as an experimental plant largely because it has large flowers, a self-pollinating sexual mechanism and a wide array of easily observable seed, seedling and adult plant phenotypes [1]. Pea is one of the world's oldest crops, as it was first cultivated with cereals as barley and wheat, 9000 years ago [2]. Pea also referred as dry pea to distinguish it from the vegetable type, is one of the most important grain legumes occupying an area of more than 7m ha in the world. The significant pea growing nations are china, France, Australia and India [3]. Breeding for superior varieties requires selection of parents capable of transmitting their desirable qualities. A rational approach for breeding is to select parents based on their combining ability rather than on visual observation of their traits. Studies on combining ability provide useful information for the selection of parents to be included in a hybridization programme by defining the parent of gene action in the expression of quantitative traits [4 and 5]. Pea was chosen as the second species for two reasons. First, this crop has been the object of many genetic studies [6 and 7]. Diallel crosses have been used in genetic research to determine the inheritance of important traits among a set of genotypes and to identify superior parents for hybrid of cultivar development. Conventional diallel analysis is limited to partitioning the total variation of the data in to general combining ability (gca) of each genotype and specific combining ability (sca) of each cross [8]. The objective of the present study is to evaluate the performance of seven pea varieties, which were never appeared to be tested before for their breeding potential per se in general combinations (gca) and their overall performance in specific crosses (sca), and also to ascertain the best combination for important trait pertaining to forage yield.

II. Materials and Methods:

The present study was carried out at Qliyasan Agricultural research station, college of agriculture/ University of Sulaimani, 2Km north west of the city of Sulaimani (35◦ 34′ 307″ N latitudes; 45◦ 21′ 992″ E with an altitude 765masl). Seven varieties of field pea were crossed in all possible combinations with out reciprocals namely (Avolla, America, Jeza, Joneor, Pack land, Wild local arvena and Samara).

Evaluated characters:

Data of agronomic traits were recorded from five plants of each genotype from each replication: Number of days to 50% flowering, Number of days to Physiological maturity, Plant height (cm), Number of basal branches per plant, Plant dry weight (g), Leaf: stem ratio, Root dry weight per plant (g), Number of root nodules per plant and Weight of root nodules per plant (g).

III. Results and Discussions:

A. *Number of days to %50 flowering:*

Data recorded on number of days to %50 flowering represented in Table I and appendix 3, exhibited highly significant differences between genotypes. The parent number 6 took maximum days to %50 flowering with 142.333 days, while the parent number 2 with 113.000 days had taken the shortest period to %50 flowering. Differences between parents reflected significantly on their progenies in their values. Maximum number of days to %50 flowering recorded by the cross 1×6 which was 139.333 days, but the cross 1×2 and 1×3 showed minimum days to %50 flowering which was 113.000 days. Previously it was observed that the number of days to %50 flowering was varied between genotypes and it was 70-199 days [9], Similar results were ratified by [10 and 11]. Data in the same Table showed significant positive and negative heterosis values, detected as the percentage of F1 deviation from mid parental value. Maximum positive heterosis value was 8.854% exhibited by the cross 1×6, but maximum negative value was -11.197% showed by the cross 3×6. The presence of highly significant differences due to mean squares of genotypes for this character as shown in appendix 3, confirmed the necessity of genetic analysis. The variance component due to gca and sca was highly significant, similar results obtained by [10, 12 and 13].

Table.I: The average Number of days to %50 flowering (diagonal and upper diagonal values) for parents and F1and hybrids % heterosis (sub diagonal values).

Parents	1	2	3	4	5	6	7	$L.S.D_{(0.05)}$
1	113.667	113.000	113.000	118.000	113.667	139.333	120.333	9.346
2	-0.294	113.000	119.333	114.667	120.333	121.667	115.667	
3	-1.881	3.919	116.667	119.333	116.000	115.000	115.667	
4	-0.701	-3.235	-0.831	124.000	116.667	126.000	117.667	
5	-0.438	5.710	0.288	-2.235	114.667	125.000	114.000	
6	8.854	-4.700	-11.197	-5.382	-2.724	142.333	129.667	
7	4.638	0.872	-0.715	-2.080	-1.299	0.258	116.333	
S.E				0.915				

Data in Table II showed the estimation of general and specific combining ability effect and some genetic parameters for number of days to %50 flowering. The parents 1,2,3,5 and 7 showed negative effect values for gca which were -1.217, -2.772, -2.661, -2.291 and -1.106 respectively, confirming the ability of these parents in reducing the number of days to %50 flowering. Concerning the specific combining ability effect as represented in Table II maximum negative $\hat{S}ij$ were -11.293, -7.404 and -5.071 recorded by the crosses 3×6, 1×7 and 1×5 respectively, resulted in reducing the time of flowering. Maximum variance of $\hat{g}ii$ was 89.650 showed by parent number 6, indicating the high contribution of this parent in the inheritance of this character in its crosses. Regarding the variance of $\hat{S}ij$ as shown in Table II, maximum value recorded by the parents 6 and 1 were 860.343 and 640.689 respectively, confirming the ability of these parents in transferring this character to some of their hybrids without others, while parent 4 with 24.631 gave minimum value of $\sigma^2\hat{S}ij$, this explain the contribution of this parent is high in most of its hybrids.

Some genetic parameters represented in the same table, such as σ^2gca/σ^2sca, which were found to be more than one i.e 1.613, and the average degree of dominance was 0.787, this indicated the predominance of additive type of gene action in the inheritance of this character. Similar results were reported by [14,15,16,17 and 18], while other researchers confirmed the importance of non additive gene action in controlling this character, [19], but [20 and 21], indicated the importance of both additive and non additive gene action in controlling the inheritance of flowering.

Heritability values in broad and narrow sense were 0.811 and 0.619 respectively, these results indicated the importance of direct selection to improve this character. Previous results recorded heritability in broad and narrow sense were found to be 0.95 and 0.45 respectively [22], and high heritability value of 0.79 was recorded by [23].

Table.II: Estimation of general and specific combining abilities effect, their variances and genetic parameters for number of days to 50% flowering.

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	-2.442	-2.553	2.447	-5.071	23.410	-7.404	-1.217	0.446	640.689
2		5.336	-2.516	5.965	13.152	0.113	-2.772	6.650	242.987
3			2.040	1.521	-11.293	0.002	-2.661	6.047	162.654
4				-0.997	-3.478	-1.183	0.524	-0.760	24.631
5					-1.663	-2.035	-2.291	4.213	65.182
6						1.818	9.523	89.650	860.343
7							-1.106	0.188	57.340
S.E			1.572				1.645		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
10.865	17.741	10.996	1.613	35.482	0.787	0.811	0.619

B. Physiological maturity:

Table (III) shows the average number of days to physiological maturity for parents and their hybrids. Highly significant differences among genotypes were observed (Appendix 3). Maximum days to physiological maturity exhibited by parent number 6 which was 198.000 days, while the parent number 2 showed minimum number of days to maturity which was 167.333 days. The hybrids 1×6, 2×6 and 4×6 showed maximum days to physiological maturity which was 198.000 days, but the shortest period to physiological maturity among the hybrids was 168.000 days exhibited by the hybrid 4×7. previous research confirmed that the days to maturity was varied between genotypes 134 to 260 days [9]. The highly significant differences among parents caused the presence of significant differences among their diallel hybrids. As shown in Table III there were significant positive and negative heterosis in maturity period because of the presence of great differences between parents and their hybrids. Maximum positive heterosis value was 8.394% exhibited by the hybrid 2×6, and followed by 7.027% showed by the hybrid 1×6. Maximum negative heterosis value produced by the hybrids 3×6, 3×4 and 5×6 which were -6.316, -6.227 and -5.946% respectively. The presence of highly significant mean squares for genotypes confirmed the necessity of genetic analysis for this character. Highly significant mean squares due to gca and sca were detected. Highly significant mean squares due to gca and sca was calculated previously by [10, 12 and 13].

Table.III: The Physiological maturity (diagonal and upper diagonal values) for parent and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D$_{(0.05)}$**
1	172.000	171.333	173.333	172.667	173.333	198.000	170.667	6.258
2	0.982	167.333	174.667	176.000	176.000	198.000	178.000	
3	-2.072	0.000	182.000	170.667	172.000	178.000	169.333	
4	-2.448	0.763	-6.227	182.000	172.000	198.000	168.000	
5	0.775	3.733	-2.825	-2.825	172.000	174.000	170.667	
6	7.027	8.394	-6.316	4.211	-5.946	198.000	189.333	
7	-0.775	4.912	-4.331	-5.085	-0.775	2.342	172.000	
S.E	0.935							

Table IV explain the effect of gca and sca and their variances, most parents showed negative general combining ability effect value, such as parent 1,2,3,5 and 7, which were -1.831, -1.238, -1.979, -4.201 and -3.312 respectively, The parents 4 and 6 with 0.169 and 12.390 showed positive value of ĝii. Regarding the specific combining ability effect of the hybrids, maximum negative value was -11.634 produced by the hybrid 5×6, and followed by -9.856 exhibited by the hybrid 3×6. Maximum positive value of Ŝij was 26.587 showed by the hybrid 1×6, and followed by 17.338 for the hybrid 1×7. The variances of ĝii and Ŝij recorded in Table IV, maximum σ^2ĝii was 153.055 showed by the parent 6. Concerning the variance of Ŝij, it was noticed that the parents 1 and 6 produced maximum values which were 1020.892 and 1096.752 respectively. Parents 3 and 4 with 127.774 and 128.573 respectively, showed minimum values for σ^2Ŝij, Some genetic parameters for this characters represented in Table IV. The ratio of σ^2gca/σ^2sca was 0.921, and the average degree of dominance value was more than one (1.042). Previous results indicated the importance of additive gene effect in controlling the inheritance of days to maturity [10 and 24]. Heritability values in broad and narrow sense were 0.952 and 0.617 respectively indicating the importance of direct selection in improving this character.

Table.IV: Estimation of general and specific combining abilities effect, their variances and genetic parameters for physiological maturity.

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	-3.043	-0.302	-0.969	-2.450	26.587	-17.338	-1.831	2.887	1020.892
2		0.439	-0.376	3.994	9.403	5.105	-1.238	1.069	137.184
3			-4.969	0.735	-9.856	-2.821	-1.979	3.451	127.774
4				-1.413	7.996	-6.302	0.169	-0.435	128.573
5					-11.634	0.735	-4.201	17.181	157.548
6						2.810	12.390	153.055	1096.752
7							-3.312	10.504	379.931
S.E	1.911						2.132		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
4.871	31.289	33.973	0.921	62.578	1.042	0.952	0.617

C. Plant height (cm):

Data in Table V and appendix 3 indicated the presence of highly significant differences between genotypes in plant height, Maximum plant height was 78.900 cm produced by parent 4 and followed by parent 1 with 74.067cm. Minimum plant height recorded by parent 3 which was 30.67cm. As shown in the same Table maximum plant height reached to 144.200cm by the cross 1×4, and followed by the cross 4×5 with 127.500cm. Minimum plant height recorded by the cross 2×7 which was 13.833cm. maximum positive heterosis value was 104.929% recorded by the cross 4×5, and followed by 96.146% for the cross 3×4, while maximum negative heterosis recorded by the cross 2×7 which was -69.463% highly significant mean squares due to genotypes was noticed, this confirmed the necessity of splitting this mean square to gca and sca which were found to be highly significant also (Appendix 3). Similar results reported by [10]. but significant differences between genotypes reported by [9 and 25]. As shown in Table VI the parents 2,3,5,7 produced negative values for general combining ability effect which were -15.872, -9.032, -2.184, -14.280 respectively, while the parents 1,4,6 showed positive ĝii values which were 6.878, 28.620 and 5.870 respectively. Regarding the specific combining ability effect of the hybrids it was revealed that most hybrids have positive effects which were restricted between 2.095 and 74.997 for the crosses 2×4 and 1×4 respectively, while the negative Ŝij values were restricted between -45.522 and -0.175 for the crosses 1×5 and 3×5 respectively. Maximum variance for ĝii was 799.422 showed by parent 4. Parent 1 and 4 showed maximum values due to the variance of $\hat{S}ij$ which were 8619.33 and 2682.60 respectively; The lowest variance of $\hat{S}ij$ was 654.601 in parent 3.

Table.V: The average Plant height (diagonal and upper diagonal values) for parent and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	74.067	58.833	78.133	144.200	61.333	86.967	55.267	40.753
2	1.554	41.800	59.567	86.200	66.500	59.567	13.833	
3	50.064	65.770	30.067	106.867	59.967	83.333	41.667	
4	88.538	42.833	96.146	78.900	127.500	88.600	117.400	
5	2.564	52.290	58.642	104.929	45.533	100.000	44.933	
6	23.474	9.699	72.058	21.620	78.042	66.800	71.733	
7	-10.038	-69.463	5.664	83.868	-4.735	24.106	48.800	
S.E				9.466				

Table VI shows some genetic parameters that explains the type of gene action that controll the inheritance of this character, the ratio of σ^2gca/σ^2sca was 0.767, this made the average degree of dominance to be more than one (1.304) indicating the importance of the role of non additive gene action in the inheritance of this character, while previous results indicated to the presence of both additive and non additive gene action that control the inheritance of plant height [10 and 26]. Heritability in broad and narrow sense value as recorded in the same Table was 0.777 and 0.470 respectively, this made the hybridization method be more suitable to improve this character. High heritability 0.73 was found previously for this character [25] but [22] calculated heritability in broad and narrow sense to be 0.94 and 0.49 respectively.

Table.VI: Estimation of general and specific combining abilities effect, their variances and genetic parameters for plant height.

				$\hat{S}ij$					
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	-3.530	8.930	74.997	-45.522	10.916	-28.839	6.878	27.625	8619.333
2		13.11	2.095	13.199	25.611	-27.373	-15.872	232.243	1647.739
3			15.921	-0.175	15.137	-6.379	-9.032	61.899	654.601
4				29.707	-17.248	31.702	28.620	799.422	7946.947
5					24.957	-9.960	-2.184	-14.904	3730.565
6						8.785	5.870	14.784	1881.255
7							-14.280	184.229	2682.601
S.E				5.589			5.862		
MSe	σ^2GCA	σ^2SCA		σ^2GCA/σ^2SCA	σ^2A		a'	h^2bs	h^2ns
206.596	217.574	288.743		0.767	435.148		1.304	0.777	0.470

D. Number of basal branches/plant

Data recorded on the average number of basal branches / plant represented in Table VII, and Appendix 3, confirming the presence of highly significant differences among genotypes. Similar results exhibited by [25, 27 and 28]. Maximum basal branches number per plant produced by parent 6 was 4.000 branches, while parent 3 with 1.667 exhibited minimum basal branches number per plant. The F1s hybrid values were restricted between 1.000 for both hybrids 2×3 and 2×7 to 5.000 for the hybrid 3×6. Maximum negative heterosis was -53.848% for the hybrid 2×7 followed by -50.000% for the hybrid 2×3, while maximum positive heterosis percentage was 84.615 showed by the hybrid 1×3 and followed by the hybrid 3×6 and 4×5 with 76.471 and 62.500% values respectively. Highly significant mean squares due to genotypes confirmed the necessity of splitting these mean squares to general and specific combining ability. Significant mean square due to gca and sca was previously reported by [9, 25 and 27].

Table.VII: The average Number of basal branches per plant (diagonal and upper diagonal values) for parent and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	2.667	3.000	4.000	2.667	3.667	4.333	3.000	1.879
2	20.000	2.333	1.000	2.667	2.667	1.667	1.000	
3	84.615	-50.000	1.667	3.333	3.000	5.000	2.000	
4	0.000	6.667	53.846	2.667	4.333	2.333	3.000	
5	37.500	6.667	38.462	62.500	2.667	4.000	3.333	
6	30.000	-47.368	76.471	-30.000	20.000	4.000	3.667	
7	28.571	-53.846	9.091	28.571	42.857	22.222	2.000	
S.E				8.445				

From Table VIII it was noticed that maximum negative ĝii value was -0.741 recorded by parent 2, while maximum positive ĝii value was 0.630 showed by parent 6. Regarding the sca effect of the hybrids as represented in the same Table maximum negative effect was -1.249 produced by the hybrid 4×6, while maximum positive effect value of sca was 1.639 for the hybrid 3×6. The variance due to ĝii represented in Table VII confirmed that parent 2 and 6 showed maximum values with 0.507 and 0.355 respectively, while parent 6 with 7.205 showed maximum value of $\sigma^2\hat{S}ij$, however parent 5 produced minimum value of $\sigma^2\hat{S}ij$ which was 1.264. Some genetic parameter, represented in Table VIII confirmed that the variance component due to gca was 0.171 which was less than the variance component due to sca with 0.262, which made the ratio of σ^2gca / σ^2sca to be less than one (0.653).

Table.VIII: Estimation of general and specific combining abilities effect, their variances and genetic parameters for number of basal branches per plant .

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	0.528	0.973	-0.361	0.417	0.788	-0.842	0.296	0.046	2.603
2		-0.990	0.454	0.158	1.528	-0.805	-0.741	0.507	4.219
3			0.565	-0.064	1.639	-0.361	-0.185	-0.008	4.813
4				1.047	-1.249	0.417	0.037	-0.040	3.231
5					0.121	0.454	0.333	0.069	1.264
6						0.491	0.630	0.355	7.205
7							-0.370	0.095	1.853
S.E	0.171						0.177		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
0.439	0.171	0.262	0.653	0.342	1.238	0.579	0.328

The average degree of dominance was found to be more than one (1.238) ratifying the importance of non additive gene effect in controlling the inheritance of this character. Heritability values in broad and narrow sense were 0.579 and 0.328 respectively, signifying the importance of hybridization method to improve this character. High heritability 0.84 was found previously for this character [25], while moderate heritability 0.44 was calculated for basal branches/ plant by [23] and [9], they showed high heritability value 0.84 for this character.

E. *Plant dry weight (g):*

Data on the character of average plant dry weight represented in Table IX, and Appendix 3, confirming the presence of highly significant differences between genotypes. The parental values were restricted between 7.697 to 30.763g for the parents 3 and 5 respectively.

Table.IX: The average plant dry weight (diagonal and upper diagonal values) for parent and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	29.35	26.44	29.55	41.333	23.27	31.00	28.32	16.210
2	26.30	12.51	20.86	31.21	30.04	23.34	12.72	
3	59.53	106.5	7.69	37.10	20.51	30.06	22.49	
4	84.64	123.5	221.07	15.41	61.51	26.08	33.93	
5	22.56	38.83	6.65	166.44	30.76	38.17	22.07	
6	43.13	76.33	177.53	77.53	73.10	13.97	10.87	
7	37.97	5.16	132.01	150.34	3.99	15.26	11.69	
S.E	14.732							

Maximum plant dry weight for the hybrids was found to be 61.517g exhibited by the hybrid 4×5 and followed by 41.333g for the hybrid 1×4, while minimum plant dry weight was 10.873g showed by the hybrid 6×7. The positive heterosis values restricted between 3.996% showed by the hybrid 5×7 and 221.073% for the hybrid 3×4. The hybrids 1×5 and 6×7 gave negative heterosis with -22.566 and -15.262% respectively. Highly significant mean squares due to genotypes ratified the necessity of separating this mean square to general and specific combining ability. Data in Table X showed general and specific combining abilities affect values and their variances. Maximum negative $\hat{g}ii$ values were -5.859 for parent 7 followed by parent 2 and 3 with -4.099 and -3.395 respectively. The parent 4 and 5 showed maximum positive values with 6.162 and 5.680 respectively. Concerning the specific combining ability effect maximum negative value was -12.265 for the hybrid 1×5 and followed by -7.588 for the hybrid 3×5, while maximum positive effect value of sca was 23.862 for the hybrid 4×5 and followed by 15.348 showed by the hybrid 1×4. The same Table showed the maximum variance of gca effect was 34.852 for parent 3 and followed by parent 7 with 31.211 and parent 5 with 29.147. The highest value of $\sigma^2\hat{S}ij$ was 945.406 recorded by parent 4 and followed by parent 5 with 864.135. Parent 2 and 7 with 145.461 and 150.000 showed minimum values for $\sigma^2\hat{S}ij$. Some genetic parameters represented in Table (X) showed that the variance component due to sca was larger than the variance component due to gca. This reflected in the value of the ratio of $\sigma^2gca / \sigma^2sca$ which was 0.314, while the average degree of dominance value was more than one (1.785), indicating the importance of non additive gene effect in the inheritance of this character. Heritability values in broad and narrow sense were 0.772 and 0.298 respectively. These results ratified that non additive gene action is important in the inheritance of this character, therefore the hybridization method is more suitable to improve this character.

Table.X: Estimation of general and specific combining abilities effect, their variances and genetic parameters for plant dry weight .

Parents	$\hat{S}ij$ 2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	1.159	3.572	15.348	-12.265	-4.053	0.996	3.567	9.611	398.458
2		2.544	3.334	2.646	11.349	-3.129	-4.099	13.687	145.461
3			8.520	-7.588	9.705	5.934	-3.395	8.412	259.736
4				23.862	-3.835	7.814	6.162	34.852	945.406
5					9.280	-3.557	5.680	29.147	864.135
6						-7.025	-2.056	1.114	370.520
7							-5.859	31.211	150.000
S.E			1.848				1.889		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
32.687	21.342	67.991	0.314	42.684	1.785	0.772	0.298

F. Leaf: stem ratio:

The estimating of leaf: stem ratio calculated based on dry weight represented in Table XI, indicated the presence of highly significant differences between genotypes. The parental values for this ratio restricted between 2.209 and 7.607 for the parents 6 and 1 respectively. The F1's hybrids, were ranged between 1.919 for the hybrid 6×7 to 22.375 for the hybrid 3×7. The negative heterosis ranged between -56.138 to -3.696% for the hybrids 1×4 and 3×5 respectively, while the positive heterosis values ranged between 2.466 to 397.764% for the hybrids 4×6 and 3×7 respectively. Highly significant mean squares due to genotypes confirmed the necessity of separating this mean squares to general and specific combining ability.

Table.XI: The average Leaf: stem ratio (diagonal and upper diagonal values) for parents and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	7.607	12.552	4.748	2.248	3.692	2.307	4.657	8.597
2	146.772	2.566	10.941	2.132	2.869	6.800	10.472	
3	-27.604	170.982	5.510	2.560	4.434	7.983	22.375	
4	-56.138	-18.129	-37.209	2.643	1.960	2.486	2.606	
5	-34.690	-8.392	-3.696	-38.194	3.698	2.083	4.605	
6	-52.988	184.851	106.841	2.466	-29.474	2.209	1.919	
7	-15.997	246.381	397.764	-14.903	28.306	-32.544	3.481	
S.E	26.271							

Results of Table XII showed that parent 4 showed maximum negative ĝii which was -2.424, while maximum positive ĝii value was 5.047 showed by parent 3. Maximum negative value of Ŝij was -5.911 for the hybrid 1×4 while the maximum positive value of this effect was 13.308 for the hybrid 3×7, and followed by 5.855 for the hybrid 1×2. Regarding the variance of gca effect, parent 3 and 4 showed maximum values 5.584 and 5.047 respectively. Parent 3 with 201.289 showed maximum σ^2Ŝij value and followed by parent 7 with 192.412.

Table.XII: Estimation of general and specific combining abilities effect, their variances and genetic parameters for leaf: stem ratio.

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	5.855	-3.411	-5.911	0.508	-1.739	0.505	0.470	-0.654	79.032
2		2.173	-1.660	-1.786	-2.454	2.866	1.079	0.289	53.828
3			-2.695	-1.683	1.759	13.308	2.542	5.584	201.289
4				0.818	1.238	-1.487	-2.434	5.047	44.013
5					-0.027	-0.349	-1.572	1.594	1.713
6						-3.142	-1.465	1.271	18.183
7							1.379	1.026	192.412
S.E	0.864						0.695		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
9.193	2.360	7.885	0.299	4.72	1.828	0.578	0.217

Parent 5 showed minimum value for this variance which was 1.713. The variance component due to sca was much larger than the variance components due to gca, this made the ratio of σ²gca/ σ²sca to be less than one (0.299), while the average degree of dominance value was more than one (1.828), this confirmed the importance of non additive gene effect in controlling this character. Heritability values in broad and narrow sense were 0.578 and 0.217 respectively, these results ratified the importance of hybridization method to be improved in this character.

G. Root dry weight/plant (g):

Data on root dry weight/plant recorded in Table XIII, and the analysis of variance represented in Appendix 3, indicated highly significant differences

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were present among genotypes. Maximum root dry weight reached 0.947g in parent 1, and followed by parent 5 with 0.890g, while parent 7 with 0.427g gave minimum root dry weight. The same Table that F1s hybrids were highly significantly affected by their parental values. Maximum value reached 1.213g exhibited by the cross 3×6 and followed by 1.130 and 1.100g for the hybrids 4×5 and 2×5 respectively, but the hybrid 5×7 with 0.467g showed minimum root dry weight/plant. The negative heterosis ranged between -29.114% to -2.949% for the hybrids 5×7 and 4×7 respectively, but the positive heterosis restricted between 3.271 to 81.546% for the hybrids 3×4 and 3×6 respectively

Table.XIII: The average root dry weight/plant (g) (diagonal and upper diagonal values) for parents and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	0.947	1.033	0.937	0.947	0.713	1.087	0.850	0.364
2	26.789	0.683	0.593	0.760	1.100	0.850	0.537	
3	20.343	-8.247	0.610	0.737	0.557	1.213	0.723	
4	7.372	1.333	3.271	0.817	1.130	0.897	0.603	
5	-22.323	39.831	-25.778	32.422	0.890	1.047	0.467	
6	29.880	20.567	81.546	16.199	29.485	0.727	0.653	
7	23.786	-3.303	39.550	-2.949	-29.114	13.295	0.427	
S.E	5.611							

Table XIV represented the estimation of general and specific combining abilities, their variances and some genetic parameters. It was observed that the parents 2,3 and 7 showed negative values for ĝii which was -0.022, -0.051 and -0.195 respectively, while positive effect of gca were recorded for the parents 1,4,5 and 6 with 0.114, 0.030, 0.039 and 0.085 respectively. Regarding the specific combining ability effect for the hybrids, the negative effect values restricted between -0.235 for the hybrid 1×5 and -0.022 for the hybrid 4×6. The positive Ŝij values that ranged between 0.069 to 0.375 for the hybrids 1×3 and 3×6 respectively. The maximum value of σ^2gca reached to 0.036 in parent 7, indicating that the contribution of this parent is high in transferring this character to its hybrids. Parent 5 showed maximum value of $\sigma^2\hat{S}ij$ reached to 0.292 and followed by parent 3 with 0.240. Some genetic parameters represented in Table XIV, which showed that the variance component due to sca was more than the variance component due to gca, which made the ratio of σ^2gca/ σ^2sca to be less than one (0.643) and the average degree of dominance was more than one (1.247). The value of heritability was 0.653 and 0.367 for broad and narrow sense respectively. These results made hybridization method more suitable to improve the character of root dry weight / plant.

Table.XIV: Estimation of general and specific combining abilities effect, their variances and genetic parameters for the average root dry weight/plant.

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	0.137	0.069	0.079	-0.235	0.129	-0.153	0.114	0.011	0.115
2		-0.138	-0.052	0.278	0.219	-0.051	-0.022	-0.001	0.159
3			-0.047	-0.237	0.375	0.164	-0.051	0.001	0.240
4				0.256	-0.022	-0.037	0.030	-0.001	0.069
5					0.118	-0.183	0.039	0.000	0.292
6						-0.041	0.085	0.006	0.212
7							-0.195	0.036	0.080
S.E	0.038						0.039		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
0.017	0.009	0.014	0.643	0.018	1.247	0.653	0.367

H. Number of root nodules/plant:

Data in Table XV and Appendix 3 confirmed the presence of highly significant differences among genotypes, parent number 4 with 54.667 exhibited highest number of root nodules/plant, where as the lowest number of root nodules/plant showed by parent 6 which was 20.333. Maximum value for this character due to hybrids exhibit by the hybrid 4×6 which was 77.333 nodules and followed by the cross 4×5 with 43.667 nodules, while minimum number was 23.333 nodules produced by the hybrid 1×5. The negative heterosis restricted between -45.594% for the hybrid 3×4 and -9.343% produced by the hybrid 4×5, while the positive heterosis values ranged between 0.826% exhibited by the hybrid 4×7 and 206.475% showed by the hybrid 6×7.

Table.XV: The average Number of root nodles/plant (diagonal and upper diagonal values) for parents and F1 hybrids and heterosis% (sub diagonal values).

Parents	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	32.667	25.667	34.333	59	23.333	51	35	6.727
2	-14.917	27.667	31.667	34.333	23.667	29	30.667	
3	5.641	5.556	32.333	23.667	27	40.333	26	
4	35.115	-16.599	-45.594	54.667	43.667	77.333	40.667	
5	-37.220	-31.731	-27.027	-9.343	41.667	36.333	37.667	
6	92.453	20.833	53.165	106.222	17.204	20.333	71	
7	19.318	14.286	-10.857	0.826	11.330	206.475	26	
S.E	12.582							

Parent 2 with -7.317 produced maximum negative values for ĝii, followed by parent 3 with -5.391. The parents 4 and 6 exhibited positive values for ĝii which were 10.200 and 5.497 respectively. Maximum negative effect value of Ŝij was -23.604 showed by the hybrid 1×5 followed by -18.106 for the hybrid 3×4, maximum positive effect value for specific combining ability was 28.840 for the hybrid 6×7. Maximum variance for ĝii was 103.505 recorded by parent number 4, while parent number 6 with 1985.409 recorded maximum value for the variance of Ŝij due to this character. Some genetic parameters were represented in Table XVI. The ratio of σ^2gca/ σ^2sca was 0.231 and average degree of dominance was found to be more than one (2.079). Heritability values in broad sense was 0.976 while it was 0.309 in narrow sense, this ratified the importance of hybridization method to improve this character.

Table.XVI: Estimation of general and specific combining abilities effect, their variances and genetic parameters for number of root nodules per plant .

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	-3.753	2.987	27.654	-23.604	16.617	-7.234	-0.280	-0.457	1670.076
2		7.357	-5.567	-3.680	15.803	1.321	-7.317	52.998	360.937
3			-18.160	-2.272	3.210	-5.272	-5.391	28.527	432.802
4				-1.196	24.619	-6.196	10.200	103.505	1768.167
5					-3.826	3.358	-2.354	5.006	599.897
6						28.840	5.497	29.679	1985.409
7							-0.354	-0.410	960.019
S.E			2.999				2.302		

MSe'	σ^2GCA	$\sigma^2SCA=\sigma^2D$	σ^2GCA/σ^2SCA	σ^2A	a'	h^2bs	h^2ns
5.629	36.478	157.797	0.231	72.956	2.079	0.976	0.309

I. Weight of root nodules / plant:

Data on weight of root nodules recorded in Table XVII and Appendix 3, showed highly significant differences among genotypes. Parent 4 gave maximum dry weight of root nodules which was 0.18333g and followed by parent 5 with 0.15333g. The hybrid 4×6 showed maximum value for this character which was 0.26667g, and followed by the hybrid 6×7 with 0.206667g. The negative heterosis ranged between -58.536% to -2.9702% for the hybrids 2×5 and 4×5 respectively, while the positive heterosis ranged between 11.4285% to 313.333% for the hybrids 4×7 and 6×7 respectively.

Table.XVII: The average weight of root nodules/plant (diagonal and upper diagonal values) for parents and F1 hybrids and heterosis% (sub diagonal values).

Parent	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**L.S.D(0.05)**
1	0.120	0.07	0.12	0.18	0.05	0.16	0.13	0.0357
2	-30.00	0.08	0.10	0.11	0.05	0.10	0.10	
3	24.13	34.78	0.07	0.06	0.08	0.16	0.08	
4	18.68	-13.92	-50.64	0.18	0.16	0.26	0.13	
5	-58.53	-54.28	-29.41	-2.97	0.15	0.13	0.13	
6	96.07	58.97	159.45	128.57	27.86	0.05	0.20	
7	56.86	58.97	40.54	11.42	34.42	313.33	0.05	
S.E	18.51							

The estimation of general and specific combining ability effects, their variances and some genetic parameters represented in Table XVIII. Parent 2 gave maximum negative effect of gca which was -0.0274 and followed by parent 3 with -0.214. Maximum positive ĝii which was 0.0367 recorded by parent 4. Regarding the sca effect the hybrid 1×5 showed maximum negative value which was -0.1006, while maximum positive Ŝij value 0.0808 exhibited by the hybrid 1×4. Parent 4 showed maximum value for the variance of ĝii which was 0.001329. Parent 4 and 6 showed maximum variances for Ŝij which were 0.020458 and 0.020861 respectively, The variance components due to sca was much larger than gca, this resulted in decreasing the ratio of gca/sca which was 0.226.the average degree of dominance value was 2.101 indicating the submission of this character under over dominance gene action and a high tendency of non additive gene effect in the inheritance of this character. Heritability values estimated in broad and narrow sense were 0.939 and 0.294 respectively. These results indicated the ability of improving this character by hybridization method.

Table.XVIII: Estimation of general and specific combining abilities effect, their variances and genetic parameters for weight of root nodules per plant.

	$\hat{S}ij$								
Parents	2	3	4	5	6	7	$\hat{g}ii$	$\sigma^2\hat{g}ii$	$\sigma^2\hat{S}ij$
1	-0.023	0.020	0.080	-0.100	0.049	-0.007	0.001	-0.00001	0.0199
2		0.033	-0.015	-0.035	0.054	0.017	-0.027	0.00073	0.0063
3			-0.070	-0.014	0.042	-0.004	-0.021	0.00044	0.0085
4				0.010	0.090	-0.019	0.036	0.00132	0.0204
5					-0.006	0.026	-0.002	-0.000006	0.0123
6						0.073	0.019	0.00038	0.0208
7							-0.006	0.000025	0.0068
S.E				0.010472			0.008462		

MSe'	$\sigma^2 GCA$	$\sigma^2 SCA = \sigma^2 D$	$\sigma^2 GCA / \sigma^2 SCA$	$\sigma^2 A$	a'	$h^2 bs$	$h^2 ns$
0.00016	0.000484	0.002141	0.226	0.00097	2.101	0.939	0.294

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