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Combining ability analysis for pod yield and its components in vegetable Indian bean (*Dolichos lablab* L)

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Abstract
General (GCA) and specific (SCA) combining ability for 13 different traits of seven parental genotypes and 21 F1s derived from a 7 x 7 diallel cross without reciprocal was assessed for pod yield and its components in vegetable Indian bean. Combining ability analysis revealed importance of both additive and non-additive genetic components for pod yield and its contributing traits indicating their importance in the expression of various traits. However, relatively high magnitude of SCA variance for all traits indicated preponderance of non-additive gene action in the inheritance of the traits except pods per cluster. The estimates of GCA effects revealed that none of the parent was good general combiner for all the traits. Parent NI-06-68 was found to be good general combiner for branches per plant, pods per plant, pod length, pod yield per plant and protein content; NI-13-465 for days to 50 per cent flowering, pods per cluster, pod length, seeds per pod, pod yield per plant, average pod weight, shelling ratio, protein content and total soluble sugar. Based on estimation of SCA effects, crosses viz., NI-13-465 x NI-08-203, NI-06-68 x NI-05-19, NI-06-68 x NI-13-465, NI-05-19 x NI-08-225 and NI-06-68 x NI-08-225 registered high and significant SCA effects for pod yield per plant and yield contributing components. The per se performance of crosses did not reflects in SCA effects.

Keywords: pod yield, vegetable, *Dolichos lablab* L

Introduction
Indian bean (*Dolichous lablab* L.) is an important pulse crop of Gujarat. It belongs to family *Fabaceae* (Subfamily *Papilionaceae*) with chromosome number of (2n = 22), is also known as lablab bean, labia bean, Egyptian bean, field bean and poor man's bean. *Dolichous* in Greek means long pod and *lablab* is an Arabic Egyptian name indicating the dull rattle of seed inside the dry pod. It considered as a minor pulse crop in India. The green pods are used for vegetable purpose whereas; ripe and dried seeds are consumed as split pulse. It fits well in a variety of cropping systems such as cover crop, mix crop and catch crop. It is a multipurpose crop grown for pulse, vegetable and forage. It is mostly planted in late *kharif.*

There are two cultivated types, Typicus and lignosus. Typicus is a garden type and is cultivated for its soft and edible pods. Lignosus is known as field bean and mainly cultivated for dry seed as pulse and is more popularly recognized as 'Wal', 'Wal–papdi' or 'Valor' in Gujarat state. The fresh/immature pods contain 4.5% proteins and 10% carbohydrates. Very little efforts have been attempted towards the study of Genetics in Indian bean. In any breeding programme the choice of suitable parents should depends not only on their per se performance but also on their combining ability.

The concept of combining ability has a major landmark in understanding genetic architecture of populations and in planning breeding programmes. General combining ability (GCA) measures the average performance of a parent in hybrid combination. Specific combining ability (SCA) refers to those instances in which the performance of a hybrid is relatively better or worse than would be expected on the basis of the average performance of the parents involved. A relatively large GCA/SCA variance ratio suggests the importance of additive gene effects and a low ratio implies presence of dominant and/or epistatic gene effects. A high magnitude of additive gene effect is useful to the Indian bean breeders involved in developing pure line, whereas, information concerning non-additive gene effect (dominance and epistasis) is important for development of Indian bean hybrids (Singh *et al.*, 2015). Therefore the present investigation was undertaken to estimate the extent of combining ability effects and gene action of the seven parents of valor type Indian bean.

Materials and Methods

The experimental material for present investigation comprised of 7 parents and their 21 half-diallel hybrids and check GNIB-21. Seven genetically diverse parents of Indian bean *viz*, NI-06-68, NI-05-19, NI-07-164, NI-08-225, NI-09-253, NI-13-465 and NI-08-203 were selected for this study and crossed in a half-diallel design during late *kharif* 2015-17. The experimental material consisting of 29 treatments were sown at 120 cm x 90 cm spacing in a randomized block design with three replications during 20015-16 at Pulses and Castor Research Station, Navsari Agricultural University, Navsari. Crossing programme was carried out in late *kharif*, 2015-16 and evaluation of the parents along with F_1s is carried out during late *kharif*, 2016-17 for genetic parameters. Observations were recorded for thirteen characters, *viz*. Days to 50 per cent flowering, plant height (cm), branches per plant, pods per cluster, pods per plant, pod length (cm), seeds per pod, pod yield per plant (g), average pod weight (g), shelling ratio, protein content (%), fiber content (%) and total soluble sugar content (%). General and specific combining ability effects were estimated according to method describe by Griffing's (1956) [5].

Results and Discussion

The genetic variances were estimated from the analysis of variance for combining ability for different characters studied in the present investigation and its results are presented in Table 1. The GCA and SCA mean sum of squares were observed significant to highly significant for all the traits except plant height and pods per cluster for GCA mean sum of squares and pods per cluster for SCA mean sum of squares which indicated that both additive and non-additive gene action played important role for the inheritance of these traits. The results are in accordance with Bagade (2001) [1], Kannan *et al.* (2003) [7], Tukadiya *et al.* (2006) [15] and Modha *et al.* (2007) [8] for days to 50 per cent flowering; Kannan *et al.* (2003) [7] for plant height; Valu *et al.* (1999) [16] and Modha *et al.* (2007) [8] for branches per plant; Valu *et al.* (1999) [16], Kannan *et al*. (2003) [7], Modha *et al.* (2007) [8] and Das *et al.* (2014) [3] for pods per plant; Valu *et al.* (1999) [16], Kannan *et al.* (2003) [7], Tukadiya *et al.* (2006) [15], Rahman *et al.* (2009) [10] and Das *et al.* (2014) [3] for pod yield per plant; Valu *et al.* (1999) [16], Tukadiya *et al.* (2006) [15] and Modha *et al.* (2007) [8] for pod length; Valu *et al.* (1999) [16], Bagade (2001) [1], Kannan *et al.* (2003) [7] and Tukadiya *et al.* (2006) [15] for seeds per pod; Modha *et al.* (2007) [8] and Das *et al.*(2014) [3] for average pod weight and Modha *et al.* (2007) [8] for protein content.

The ratio of σ^2GCA / σ^2SCA suggested preponderance of non-additive gene action for all the characters under study except pods per cluster. The results are in harmony with Gawali *et al.* (2011) [4] for days to 50 per cent flowering; with Modha *et al*. (2007) [8] and Gawali *et al*. (2011) [4] for plant height; Bagade *et al.* (2001) [1] and Gawali *et al.* (2011) [4] for branches per plant; Kabir and Sen (1990) [6], Sawant *et al.* (2006 & 2007) [12, 13] and Gawali *et al.* (2011) [4] for pods per plant; Kabir and Sen (1990) [6], Sawant *et al.* (1994) [11] and Bagade *et al.* (2003) [2] for pod yield per plant; Sawant *et al.* (1994) [11], Gawali *et al*. (2011) [4] and Das *et al.* (2014) [3] for pod length; Bagade *et al.* (2001) [1], Gawali *et al.* (2011) [4] and Das *et al.* (2014) [3] for seeds per pod and with Gawali *et al.* (2011) [4] for protein content.

The estimates of general combining ability effects of parental lines (Table 2) revealed that none of the parental line was good general combiner for all the studied traits. Parent NI-06-68 was found to be good general combiner for branches per plant, pods per plant, pod length, pod yield per plant, protein content and fibre content; NI-05-19 for days to 50 per cent flowering, shelling ratio and protein content; NI-07-164 for days to 50 per cent flowering, average pod weight, shelling ratio and fibre content; NI-08-225 for days to 50 per cent flowering, pod length, average pod weight and fibre content; NI-13-465 for days to 50 per cent flowering, pods per cluster, pod length, seeds per pod, pod yield per plant, average pod weight, shelling ratio, protein content and total soluble sugar content; NI-08-203 for total soluble sugar content. Therefore, parent NI-06-68 and NI-13-465 can be utilized for future breeding programme in Indian bean.

The characters wise estimates of specific combining ability (SCA) effects are presented in Table 3. Based on estimation of SCA effects, the crosses *viz*., NI-13-465 x NI-08-203, NI-06-68 x NI-05-19, NI-06-68 x NI-13-465, NI-05-19 x NI-08-225 and NI-06-68 x NI-08-225 registered high and significant SCA effects for pod yield per plant and yield contributing traits. Such combination may be useful for isolating hybrids. They were most promising for pod yield per plant on the basis of per se performance, highest significant standard heterosis for pod yield and also possess high SCA effects.

Comparative study of most promising hybrids having high SCA effects for pod yield per plant along with GCA effects of parents involved in the crosses showed in table 3 revealed that the best performing parents may have atleast one good general combiner. This suggested that while selecting the parents for hybridization programme, *per se* performance of parents should be given due consideration. Such parallel behaviour of *per se* performance and general combining ability was also reported by Patel (1999) [9], Vashi *et al.* (1999) [17] and Bagade *et al*. (2002) in Indian bean.

It is also evident from Table 4 that best performing hybrids for various characters also had desired SCA effects. Thus, the potentiality of a strain of is used as a parent in hybridization or cross to be used as a commercial hybrid may be judged by comparing *per se* performance of parents and hybrids, colony with combining ability effects of parents and heterotic response of hybrids. The crosses exhibiting higher *per se* performance and significant desirable SCA effects (Table 4) for various traits involved either good x good, good x average, good x poor, average x average, average x good, poor x good and poor x average combining parents. Thus, crosses exhibiting high SCA effects did not always involve parents with high GCA effects. It is suggested that interallelic interactions were also important for these characters.

The best hybrids for number of pod yield per plant NI-13-465 x NI-08-203 (G x P) had high SCA effects, high heterosis as well as high *per se* performance for most of yield contributing characters *viz.*, branches per plant, pods per cluster and shelling ratio. This appeared appropriate as yield being a complex Character Depends On A Number Of Its Component Traits.

Table 1: Mean squares due to general and specific combining ability for different characters in Indian bean

Source of variations	d.f.	Days to 50% flowering	Plant height (cm)	Branches per plant	Pods per cluster	Pods per plant	Pod length (cm)	Seeds per pod	Pod yield per plant (g)	Average pod weight (g)	Shelling ratio (%)	Protein content (%)	Fiber content (%)	TSS (%)
GCA	6	92.019**	9.203	0.565**	0.070	401.940**	3.377**	0.086*	5048.767**	0.301**	108.940**	6.306**	1.169**	0.417**
SCA	21	16.169**	33.149*	0.752**	0.040	405.330**	0.830**	0.072*	5478.731**	0.292**	29.945**	5.590**	0.837**	1.765**
Error	54	1.367	16.406	0.120	0.033	41.357	0.127	0.035	595.099	0.038	0.288	0.141	0.006	0.019
σ^2 GCA		10.073	-0.8	0.05	0.004	40.065	0.361	0.006	494.852	0.029	12.072	0.685	0.129	0.012
σ^2 SCA		14.802	16.743	0.632	0.007	363.973	0.703	0.037	4883.632	0.254	29.657	5.448	0.831	0.677
σ^2 GCA / σ^2 SCA		0.68	-0.048	0.078	0.619	0.11	0.514	0.155	0.101	0.115	0.407	0.126	0.155	0.017

*, ** Significant at 5 % and 1 % level of probability, respectively.

Table 2: Estimation of GCA effect of parents for various characters in Indian bean

Sr. No.	Parents	Days to 50% flowering	Plant height (cm)	Branches per plant	Pods per cluster	Pods per plant	Pod length (cm)	Seeds per pod	Pod yield per plant (g)	Average pod weight (g)	Shelling ratio (%)	Protein content (%)	Fiber content (%)	TSS (%)
1	NI-06-68	1.582 **	0.471	0.372 **	-0.119 *	12.656 **	0.278 *	0.006	28.342 **	-0.313 **	-0.148	1.115 **	0.217 **	-0.154 **
2	NI-05-19	-1.788 **	1.16	-0.239 *	0.03	2.971	-0.807 **	-0.028	4.752	-0.043	5.496 **	0.400 **	-0.301 **	-0.085 *
3	NI-07-164	-0.974 **	1.141	-0.350 **	0.044	-6.974 **	-0.211	-0.179 **	-12.106	0.135 *	2.018 **	-0.795 **	0.490 **	0.195 **
4	NI-08-225	-5.122 **	-0.355	-0.087	-0.044	-7.029 **	0.497 **	0.013	4.952	0.146 *	-3.558 **	-1.139 **	0.244 **	-0.073 **
5	NI-09-253	3.619 **	-1.37	0.102	-0.089	-0.381	-0.325 **	0.043	-36.434 **	-0.147 *	-3.202 **	-0.322 **	-0.094 **	-0.055
6	NI-13-465	-1.085 **	-1.122	0.002	0.133 *	-0.64	0.978 **	0.150 *	27.456 **	0.198 **	2.458 **	0.868 **	0.019	0.101 **
7	NI-08-203	3.767 **	0.075	0.202	0.044	-0.603	-0.411 **	-0.005	-16.961 *	0.024	-3.062**	-0.127	-0.576 **	0.072 **
S.E.$_{(gi)}\pm$		0.361	1.250	0.107	0.056	1.985	0.110	0.058	7.528	0.060	0.166	0.116	0.025	0.024
S.E.$_{(gi - gj)}\pm$		0.551	1.909	0.163	0.086	3.032	0.168	0.089	11.500	0.092	0.253	0.177	0.038	0.037

*, ** Significant at 5 % and 1 % level of probability, respectively.

Table 3: Estimation of SCA effects of hybrids for various characters in Indian bean

Sr. No.	Crosses	Days to 50% flowering	Plant height (cm)	Branches per plant	Pods per cluster	Pods per plant	Pod length (cm)	Seeds per pod	Pod yield per plant (g)	Average pod weight (g)	Shelling ratio (%)	Protein content (%)	Fiber content (%)	TSS (%)
1	NI-06-68 x NI-05-19	-0.806	-5.818	0.431	-0.136	17.778**	0.617	-0.026	78.637**	0.179	2.011**	0.137	-0.180*	0.683**
2	NI-06-68 x NI-07-164	-0.954	-10.332**	0.109	0.049	-10.611	1.254**	0.059	-26.065	0.034	1.526**	2.075**	0.839**	-0.645**
3	NI-06-68 x NI-08-225	2.861**	-6.069	0.446	0.038	5.444	-0.154	-0.500**	53.271*	-0.410*	1.558**	0.596	-0.005	-0.051
4	NI-06-68 x NI-09-253	-5.213**	8.512*	0.424	0.082	-21.537**	0.502	0.304	-32.677	0.482**	1.426**	-0.894**	-0.537**	-0.301**
5	NI-06-68 x NI-13-465	-1.176	2.997	0.357	0.127	-15.611**	1.165**	0.196	67.200**	0.705**	-0.521	1.663**	0.320**	0.568**
6	NI-06-68 x NI-08-203	0.972	1.434	-1.276**	0.216	8.352	-0.846**	-0.181	30.807	-0.088	-3.148**	-2.342**	1.672**	0.734**
7	NI-05-19 x NI-07-164	-0.917	-2.555	-0.513	-0.199	6.074	0.639*	-0.041	19.878	-0.203	1.685**	1.590**	-0.757**	-0.394**
8	NI-05-19 x NI-08-225	1.898	1.075	0.691*	0.256	-16.704**	-0.269	0.033	66.000**	0.253	6.261**	-3.739	-0.284**	-0.593**
9	NI-05-19 x NI-09-253	-2.843**	-7.110	-0.831**	0.001	-1.185	-0.446	0.204	24.015	0.312	4.682**	1.721**	0.514**	0.649**
10	NI-05-19 x NI-13-465	-0.139	4.175	-0.731*	-0.021	11.741*	0.050	0.163	-2.987	0.201	-6.841**	0.441	-1.255**	0.428**
11	NI-05-19 x NI-08-203	-0.324	7.645*	-0.865**	0.068	-5.963	0.672*	0.052	-107.394**	-0.692**	6.555**	0.406	0.300**	-0.259**
12	NI-07-164 x NI-08-225	5.083**	-1.306	0.402	0.142	-26.259**	-0.798*	-0.348*	-91.082**	0.142	5.759**	-3.268**	-1.232**	-0.961**
13	NI-07-164 x NI-09-253	-4.657**	7.508*	-1.854**	-0.081	16.759**	-0.343	-0.278	-58.529**	-0.966**	5.313**	-2.757**	1.123**	1.637**
14	NI-07-164 x NI-13-465	1.713	1.760	0.880**	0.031	-21.315**	-1.046**	0.248	-17.886	0.323	-0.590	-0.801*	0.244**	0.733**
15	NI-07-164 x NI-08-203	-3.472**	2.664	-0.220	-0.047	-32.019**	-0.257	0.404*	-28.935	1.231**	0.166	2.690**	-0.861**	0.114
16	NI-08-225 x NI-09-253	-2.176*	-2.262	-0.917**	-0.392*	-34.519**	1.283**	0.363*	-108.087**	0.690**	2.956**	-1.767**	-1.274**	0.720**
17	NI-08-225 x NI-13-465	-9.139**	3.990	-0.317	0.153	-2.259	0.946**	0.256	-54.377*	-0.288	2.443**	-0.457	1.296**	-0.425**
18	NI-08-225 x NI-08-203	-0.324	6.527	0.350	-0.125	7.704	-0.598	0.078	-13.626	0.019	1.112*	-3.212**	-0.482**	1.310**
19	NI-09-253 x NI-13-465	8.787**	-1.429	1.028**	-0.369*	18.093**	-2.098**	-0.507**	10.475	-0.529**	-0.643	0.600	-0.345**	-0.720**
20	NI-09-253 x NI-08-203	2.602*	-5.992	0.561	-0.081	11.389*	0.491	-0.085	-25.141	-0.621**	-5.394**	-0.905**	0.597**	-0.727**
21	NI-13-465 x NI-08-203	-5.028**	-10.206**	0.861**	0.197	15.315**	0.520	0.074	125.403**	0.334	10.066**	0.465	-0.690**	0.368**
	Sij	1.049	3.635	0.310	0.164	5.772	0.320	0.169	21.895	0.175	0.482	0.337	0.072	0.071
	Sij--Sik	1.559	5.401	0.461	0.244	8.575	0.476	0.251	32.526	0.259	0.716	0.501	0.107	0.000
	Sij--Skl	1.458	5.052	0.431	0.228	8.021	0.445	0.234	30.425	0.243	0.670	0.469	0.100	0.099

*, ** Significant at 5 % and 1 levels, respectively.

Table 4: A summary table showing the best *per se* performance along with specific combining ability and general combining ability effects of the parents involved in the combination for different characters in Indian bean

Characters	Best specific combination	*Per se* performance	SCA	GCA effects of the parents involved
Days to flowering	NI-08-225 x NI-13-465	62.67	-9.139**	G x G
	NI-05-19 x NI-08-225	73.00	1.898	G x G
	NI-05-19 x NI-07-164	74.33	-0.917	G x G
Plant height (cm)	NI-13-465 x NI-08-203	80.63	-10.206**	A x A
	NI-06-68 x NI-07-164	83.17	-10.332**	A x A
	NI-05-19 x NI-09-253	84.57	-7.110	A x A
Branches per plant	NI-09-253 x NI-13-465	7.93	1.028**	A x A
	NI-13-465 x NI-08-203	7.87	0.861**	A x A
	NI-06-68 x NI-09-253	7.70	0.424	G x A
Pods per cluster	NI-13-465 x NI-08-203	2.80	0.197	G x A
	NI-08-225 x NI-13-465	2.67	0.153	A x G
	NI-05-19 X NI-08-225	2.67	0.256	A x A
Pods per plant	NI-06-68 X NI-05-19	152.00	17.778**	G x A
	NI-06-68 x NI-08-203	139.00	8.352	G x A
	NI-09-253 x NI-13-465	135.67	18.093**	P x A
Pod length (cm)	NI-06-68 x NI-13-465	9.03	1.165**	G x G
	NI-08-225 x NI-13-465	9.03	0.946**	G x G
	NI-08-225 x NI-09-253	8.07	1.283**	G x P
Seeds per pod	NI-08-225 x NI-09-253	4.20	0.363*	A x A
	NI-08-225 x NI-13-465	4.20	0.256	A x G
	NI-06-68 X NI-13-465	4.13	0.196	A x G
Pod yield per plant (g)	NI-13-465 X NI-08-203	596.47	125.403**	G x P
	NI-06-68 x NI-13-465	583.57	67.200**	G x G
	NI-06-68 x NI-05-19	572.30	78.637**	G x A
Average pod weight (g)	NI-07-164 X NI-08-203	5.70	1.231**	G x A
	NI-08-225 x NI-13-465	5.00	-0.288	G x G
	NI-06-68 x NI-13-465	4.90	0.705**	P x G
Shelling ratio (%)	NI-13-465 x NI-08-203	52.69	10.066**	G x P
	NI-05-19 X NI-07-164	52.42	1.685**	G x G
	NI-05-19 X NI-08-203	52.21	6.555**	G x P
Protein content (%)	NI-06-68 x NI-13-465	23.13	1.663**	G x G
	NI-06-68 x NI-07-164	21.88	2.075**	G x P
	NI-05-19 x NI-09-253	21.28	1.721**	G x P
Fiber content (%)	NI-05-19 x NI-13-465	13.49	-1.255**	G x A
	NI-06-68 X NI-07-164	13.48	0.839**	P x P
	NI-07-164 x NI-09-253	13.45	1.123**	P x G
TSS content (%)	NI-07-164 x NI-09-253	4.75	1.637**	A x A
	NI-08-225 x NI-08-203	4.29	1.310**	P x G
	NI-07-164 x NI-13-465	4.01	0.733**	A x G

Conclusion

Therefore, the present investigation revealed that none of the parent was good general combiner for all the traits. Parents NI-06-68 and NI-13-465 were good general combiners for pod yield per plant and yield contributing components. Among specific combinations NI-13-465 x NI-08-203 followed by NI-06-68 x NI-05-19, NI-06-68 x NI-13-465, NI-05-19 x NI-08-225 and NI-06-68 x NI-08-225 were identified as most promising hybrids for pod yield per plant and its component traits. So they can be use for future breeding programme for vegetable purpose.

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