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Estimates of combining ability effects of parents & crosses for different characters

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Abstract
Pulses in India have long been considered as only source of poor man's protein. India is the largest importer, producer and consumer of pulses (Jitendra *et al*., 2011). India accounts for 33% of the world area and 22% of the world production of pulses (Amarender, 2009). Pulses production in India 18.34 million tonne (ICAR 2013-14). Combining ability analysis is frequently employed to identify the desirable parents for inclusion in hybridization programme. Both additive and non-additive components of gene action contributed significantly for most of the characters except yield plant^{-1} and number of branches plant^{-1}, so for improvement of most of the characters population improvement method may produce desirable results. HUM-12 and PS-16 were found to be best general combiners for a number of traits. Bireswar was found as good combiners for plant height, days to maturity, pod length, number of branches plant^{-1}, 100 seed weight, seed yield plant^{-1} and protein content and PS-16 for days to 50% flowering, days to maturity, pod length and pod width and protein content. Significant positive sca effect for yield plant^{-1} was observed in the cross PS-16 x Bireswar which was also significant and desirable sca effect for 100 seed weight, number of pods plant^{-1} and protein content in seed.

Keywords: Estimates, combining ability, parents, different characters

Introduction
Mung bean (Vigna radiata L. Wilczek) is a pulse species of the pan-tropical region (kumar *et al*., 2004) [8]. But (Tomooka *et al*., 1992) [14, 15], considered it as native to Asia and widely cultivated in Africa, Asia and Latin America. They also examined the variations of seed proteins in mung bean landraces from Asia, and proposed is as diverse region for mung bean. According to their study, the region of protein type diversity is found in West Asia (Afghanistan-Iran-Iraq area) rather than in India. Judging from the geographical distribution of protein types, mung bean might have spread mainly to the east by two routes, one route is from India to Southeast Asia strains consisting of a few protein types with prominent protein type were disseminated by this route and another dissemination pathway may have been the route known as the Silk Road. By this route, protein type 7 and 8 strains spread from West Asia or India to China and Taiwan via the Silk Road, not by the route from Southeast Asia. Sprague and Tatum (1942) [12] defined general combining ability as the average the performance of a particular inbred in a series of hybrid combinations. The term specific combining ability refers to the performance of the two specific inbreds in a particular cross combination. The results confirmed that general combining ability was primarily due to additive effects of genes and specific combining ability was due to dominance effect and epistatic interactions. Several methods have been developed to estimate the combining ability of inbreds in different crops viz., top cross (Jenkins and Branson, 1932) [4], diallel analysis (Griffing, 1956) [3] and Line x tester analysis (Kempthorne, 1957) [6]. Combining ability analysis is frequently employed to identify the desirable parents for inclusion in hybridization programme.

Significant gca and sca effects were noticed by Yohe and Poehlman (1975) [17] in mung bean and only gca effect in a similar study by Swindell and Poehlman (1976) [13]. On the contrary only non-additive genetic variance conditioning this trait was reported by Ayyangouda Patil *et al*., (2003) [2], Shubhra and Roopa (2011) [11], Sathya and Jayamani (2011) [10]. Barad *et al.*, (2008), also reported the preponderance of additive type of gene action for this trait from a study of fifteen genotypes as lines and three varieties as testers of mung bean were studies in line x tester analysis. Similar results was also reported by Sathya and Jayamani (2011) [10] and Shubhra and Roopa (2011) [11]. Yadav and Lavanya (2011) [16], reported both the role of both additive and non-additive gene action for this trait.

Roopa (2011) [11] in a combining ability analysis also revealed predominance of non-additive gene action for these characters. On the contrary, Kumar *et al.,* (2010), reported the importance of only additive gene action for this trait. Similar results was also found by Patil *et al.,* (2011) [9]. Yadav and Lavanya (2011) [16], also revealed that the variances due to GCA and SCA were highly significant, indicating the importance of both additive and non-additive gene action for this trait. Similar result was also reported by Patil *et al.,* (2011) [9].

Materials and Methods

Plant material: For estimation of protein by Lowry's Method, 27 genotypes and 21 genotypes of mung bean from each genotype was pipette in different test tube separately. In this method, the blue colour developed by the reduction of the phosphomolybdic-phosphotungstin components in the Folin-Ciocalteu's reagent by the amino acids tyrosine and tryptophan present in the protein plus the colour developed by the biuret reaction of the protein with alkaline cupric tartrate are measured in the Lowry's Method at 660nm with the help of spectrophotometer.

Protein estimation by Lowry method**:** Reagents used in this method are phosphate buffer (pH 8.0) for extraction protein and bovine serum albumin (BSA) for working standard. Preparation of different buffer solutions with their composition are listed below:

Reagent A: 2% sodium carbonate in 0.1(N) sodium hydroxide. 0.4g sodium hydroxide pellet was dissolved in 100ml distilled water to prepare 0.1(N) sodium hydroxide solution. 2g sodium carbonate was added and dissolved in 0.1(N) sodium hydroxide solution. Reagent B: 0.5% copper sulphate (CuSO4 5H20) in 1% potassium sodium tartrate. 0.5% copper sulphate was dissolved in 100ml distilled water. Then 1g potassium sodium tartrate was added and dissolved completely. Reagent C: alkaline copper solution: Mixture of 50ml of reagent A and 1ml of Reagent B Reagent D: Folin and Ciocalteu's Phenol Reagent 1(N).

Result and Discussion

Estimates of general combining ability effects of the parents for different characters

The estimation of gca effects of six parents for eleven characters are presented in (table 2). PS-16 showed significant negative gca effect while all the other showed average gca effect. PS-16 showed the significant negative gca effect and the rest showed average effect while WBM-314 showed positive gca effect. WBM-314 again showed significant negative gca effect while PS-16 showed positive significant effect followed by TM-99-50 while the rest showed average gca effect. The highest significant positive gca effect was found in HUM-12 followed by TM-99-50 and negative significant effect was found in WBM-314 followed by Bireswar and the rest showed average gca effect. Basanti showed a significant negative gca effect for this trait and all the others showed average gca effect with no significance. The highest positive significant gca effect was shown by WBM-314 followed by Basanti and the highest negative significant gca effect was shown by TM-99-50. WBM-314 showed a positive significant gca effect while Basanti showed a negative significant gca effect and all the others showed average effect. WBM-314 showed the highest positive gca effect followed by PS-16 and the significant negative gca effect was shown by TM-99-50 followed by Basanti and all others showed average gca effect. The highest significant positive gca effect was shown by WBM-314 followed by Basanti and the highest significant negative gca effect was shown by HUM-12 followed by TM-99-50 while others showed average effect. Bireswar showed highest positive gca effect followed by WBM-314, while the highest negative gca effect was shown by Basanti followed by PS-16 and by HUM-12. The highest desirable positive significant gca effect was shown by Bireswar followed by WBM-314 whereas PS-16 and TM-99-50 showed negative gca effect while the other two showed average effect with no significance. PS-16 was fond as good general combiner for days to 50 % flowering, HUM-12 was a poor general combiner. Significant negative general combining ability was highlighted by PS-16.. HUM-12 followed by TM-99-50 was found good combiner, for number of branches plant^{-1}. WBM-314 followed by PS-16 showed best general combiner for number of pods plant^{-1}. All the genotypes except Basanti were found to be average general combiners for number of seeds pod^{-1} and Basanti was depicted as poor general combiner. WBM-314 followed by Basanti was found to be good general combiner for pod length. For 100 seed weight, high general combiner was WBM-314 followed by Basanti. Bireswar, WBM-314 was noticed as best general combiner for protein content in seed. WBM-314 was found to be best general combiners for a number of traits like pod length, pod width, number of pods plant^{-1}, (100) seed weight, protein content and seed yield plant^{-1} but was poor combiner for number of primary branches plant^{-1} and days to maturity. On the contrary PS-16 was superior general combiners for plant height and days to 50% flowering, days to maturity, number of pods plant^{-1} but was poor combiner for seed yield plant^{-1}, primary branches plant^{-1} and protein Content. Combination of these two parents may help to develop ideal plant type in mung bean with efficiency to give high yield with high protein content in seed and earliness.

Estimates of specific combining ability effects of the crosses for different characters

The estimation of sca effects of fifteen crosses in 11 characters are given in (table 3). Highest significant negative sca effect was exhibited by WBM-314 X TM-99-50 (-9.454) followed by WBM-314 x Hum-12, Basanti X TM-99-50, Basanti x Bireswar and Basanti X PS-16, while rest of the hybrids were with average sca effect. Only PS-16 in Basanti X PS-16 had high gca effect while all the other crosses showing negative sca effect had parents with average general combining ability. Significant desirable negative sca effect to the highest extent was observed in WBM-314 x TM-99-50 followed by WBM-314 x PS-16 and WBM-314 x Basanti and it was poor with significant positive effect in Basanti x Bireswar and TM-99-50 x Bireswar followed by PS-16 x Bireswar. Average general combiners were responsible to effect desirable sca effect in the character except in WBM-314 x PS-16 where one of the parents had high desirable general combining ability. Highest desirable negative significance sca effect was observed in WBM-314 x PS-16 (-6.77) followed by PS-16 x TM-99-50 and WBM-314 x Basanti showing early maturity while it was significantly poor in WBM-314 x Hum-12 followed by HUM-12 x Basanti. Among the cross showing desirable sca effect WBM-314 x PS-16 had one parent with high general combining ability while average general combiners were responsible to exert significant desirable sca effect towards earliness. The cross WBM-314 x Hum-12 showed the highest positive significant sca effect for this trait (0.22) and the significant negative sca effect was found in WBM-314 x Basanti followed by PS-16 x TM-99-50. PS-16 x Bireswar had parents with average gca effect while high and poor gca effect parents were involved in WBM-314 x Hum-12. Most of the crosses highlighted average sca effect except WBM-314 x Hum-12 which showed significantly negative sca effect and their parents were also found to be average general combiners except, Hum-12 which was expressed as poor general combiner. Highest significant positive sca effect for the character was found in WBM-314 x Basanti followed by Basanti x PS-16, PS-16 x TM-99-50, while it was significantly poorest in WBM-314 x Hum-12. Parents with high gca effect was involved in WBM-314 x Basanti while high and poor and average combiner were associated in Basanti x PS-16, PS-16 x TM-99-50. All the crosses were found to have average sca effect for pod width. Though high general combining parent was involved in the crosses PS-16 x TM-99-50, WBM-314 x Basanti. Parents with high gca effect was involved are WBM-314 x Basanti. The crosses WBM-314 x Bireswar, HUM-12 x Basanti followed by WBM-314 x PS-16, PS-16 x Bireswar and WBM-314 x HUM-12, showed highest significant desirable positive sca effect and the cross Basanti x PS-16, WBM-314 x Basanti, WBM-314 x TM-99-50 and Basanti x TM-99-50 exhibited significantly poor sca effect. Both the parents had high general combining ability in WBM-314 x PS-16 and one of the parents was with high gca effect in crosses Basanti x Highest significant desirable positive sca effect was evident in WBM-314 x Basanti followed by PS-16 x Bireswar, WBM-314 x TM-99-50 and HUM-12 x PS-16. And it was significantly negative in WBM-314 x HUM-12 followed by HUM-12 x TM-99-50. Parents with high gca effect, high and average gca effect, poor gca effect and poor and average gca effect were responsible for high positive sca effect in respective crosses like WBM-314 x Basanti, HUM-12 x TM-99-50. Significantly positive sca effect for protein content in seed was observed in WBM-314 x Bireswar, followed by PS-16 x Bireswar and Basanti x Bireswar. In contrast significant negative sca effect was exhibited by HUM-12 x Basanti followed by HUM-12 x PS-16, HUM-12 x Bireswar and WBM-314 x TM-99-50. Average combining parents showed significant positive sca effect in Hum-12 x TM-99-50 while average and high combiners showed significant positive sea effect in WBM-314 x Bireswar and parents with high and poor general combiners produced such effect in Basanti x Bireswar. Most of the crosses were accompanied by average sca effect except PS-16 x Bireswar and WBM-314 x HUM-12 with significant positive and negative sca effect respectively. WBM-314 x HUM-12 was in combination with average and high gca effect parents and PS-16 x Bireswar with poor and high gca effect parents, Significant positive sca effect for yield plant^{-1} was observed in the crosses PS-16 x Bireswar and this cross is also accompanied by significant desirable sca effect for 100 seed weight, Pods Plant^{-1} and protein content in seed. Similarly WBM-314 x HUM-12 was accompanied by plant height and days to 50% flowering, days to maturity, primary branches, number of pods plant^{-1} but it was poor for seed yield, pod length and number of seeds pods^{-1} (100) seed weight. Both the crosses showed average sca effect for the character like pod dimension, number of seeds pod^{-1}, number of branches plant^{-1} and maturity. Parents with high and average gca effect were most frequent to show significant desirable sca effect in a number of crosses for a number of characters which were followed by parents with high x poor general combining abilities. All sorts of combination from high to poor were found to effect significant sca effect High general combiners could not always effective to produce significant positive sca effect which may be due to internal cancellation of gene effect of the genotype as suggested by Jones (1958) or may be due to presence of poor genetic diversity between the combining parents. Superior sca effect in hybrids from combination of high and poor general combiners may be resulted due to dominant x recessive type of interaction with non-additive and non-fixable components and random mating followed by selection among the segregants can lead to develop transgressive segregants in advanced generations. While poor general combiners or average general combiners exhibiting high sea effect may be due to higher order of interactions or inclusion of highly diverse genotypes and these hybrids may provide desirable transgressive segregants by adopting cyclic selection or by following parental breeding system.

Summar and Conclusion

HUM-12 and PS-16 were found to be best general combiners for a number of traits. Bireswar was found as good combiners for plant height, days to maturity, pod length, number of branches plant^{-1}, 100 seed weight, seed yield plant^{-1} and protein content and PS-16 for days to 50% flowering, days to maturity, pod length and pod width and protein content. Significant positive sca effect for yield plant^{-1} was observed in the cross PS-16 x Bireswar which was also significant and desirable sca effect for 100 seed weight, number of pods plant^{-1} and protein content in seed. Parents with high and average gca effect were found to be most frequent showing significant desirable sca effect in a number of crosses for a number of characters and these crosses were of combination of parents with of high and poor gca effect. Both additive and non-additive components of gene action contributed significantly for most of the characters except yield plant^{-1} and number of branches plant^{-1}, so for improvement of most of the characters population improvement method may produce desirable results.

Table 1: Analysis of variance for combining ability and estimates for genetic components for different characters

	d.f	Mean sum of squares										
		Plant Height (cm)	Days to 50% Flowering	Days to Maturity	Primary Branches Plant^{-1}	No. of Seeds	Pod Length cm	Pod width cm	Pods Plant^{-1}	100 Seed Weight	Protein Content	Seed Yield per Plant
GCA	5.00	9.12	14.42***	15.48***	1.12***	0.97*	0.79*	0.005*	4.21**	0.935***	4.96***	6.18***
SCA	15.00	25.84**	6.13***	11.77***	0.03**	0.76*	0.26**	0.002	6.39**	0.321***	1.16***	0.74*
Error	20.00	2.145	0.76	0.78	5.83	0.92	0.34	0.07	0.008	0.002	0.05	0.05
$\sigma^2 g$		0.42	0.28	1.65	0.14	0.08	0.09	-0.0004	0.42	0.13	0.48	0.76
$\sigma^2 s = \sigma^2 D$		20.03	5.07	8.2	0.02	0.42	0.42	0.003	5.62	0.25	1.15	0.38
$\sigma^2 A$		0.83	3.46	3.31	0.28	0.16	0.18	0.008	0.83	0.23	0.93	1.48
h^2 Narrow Sense		0.82	0.94	0.85	0.99	0.64	0.86	0.41	0.89	0.95	0.98	0.92
h^2 Broad Sense		0.10	0.37	0.25	0.92	0.18	0.42	0.57	0.08	0.44	0.45	0.73
Predictability Ratio		0.04	0.42	0.04	0.94	0.28	0.51	1.43	0.13	0.48	0.46	0.83

*** Significant at 0.001 %, ** significant at 1 %, *significant at 5 %

Table 2: Estimates of general combining ability effects of the parents for different characters

	Plant Height (cm)	Days to 50% Flowering	Days to Maturity	Primary Branches Plant $^{-1}$	No. of Seeds	Pod Length cm	Pod width cm	Pods Plant^{-1}	100 Seed Weight	Protein Content	Seed Yield Plant^{-1}
Basanti	-0.21	-0.41	-0.81	-0.18***	-0.65***	0.52**	-0.037**	-0.76*	0.19*	-0.65***	0.46
Bireswar	0.81	0.58	0.41	-0.24***	0.32	-0.15	0.02	-0.21	0.09	1.35***	1.25***
HUM-12	0.85	0.34	0.26	0.76***	0.24	0.20*	-0.02	-0.16	-0.46***	-0.36***	-0.05
PS-16	-1.46***	-1.47***	2.20***	-0.16**	-0.22	-0.18*	-0.24	0.66*	-0.11	-0.64***	-1.28***
TM-99-50	0.068	-0.50	1.72*	0.15**	0.47	-0.22*	0.005	-0.82*	-0.24***	-0.14	-0.66***
WBM-314	-0.02	2.72***	-1.07***	-0.34***	0.36	0.56***-	0.038**	0.87**	0.53***	0.195***	0.38*
SE(gi)	0.783	0.281	0.481	0.036	0.194	0.091	0.008	0.326	0.076	0.084	0.152
SE(gi-gj)	1.214	0.436	0.746	0.050	0.283	0.146	0.026	0.463	0.108	0.145	0.234
CD at 5 %	1.132	0.723	1.229	0.082	0.491	0.232	0.025	0.764	0.186	0.195	0.376

***Significant at 0.001 %, ** significant at 1 %, *significant at 5 %

Table 3: Estimates of specific combining ability effects of the crosses for different characters

F_2 plants	Plant Height cm	Days to 50% Flowering	Days to Maturity	Primary Branches Plant^{-1}	No. of Seeds	Pod Length cm	Pod width cm	Pods Plant^{-1}	100 Seed Weight	Protein Content	Seed Yield Plant^{-1}
Basanti X Bireswar	-5.26*	4.32***	2.49	0.14	-0.51	0.08	-0.002	-0.92	-0.17	0.85***	-0.16
Basanti X Ps-16	-2.67	-0.28	-0.39	-0.17	1.06	0.59*	0.019	-3.25**	0.19	0.34	0.32
Basanti X Tm-99-50	-6.58**	-0.78	0.86	0.13	-0.36	-0.36	-0.01	-1.85*	0.21	-0.59*	0.39
Hum-12 X Basanti	2.06	0.09	5.24**	0.12	-0.34	0.05	-0.04	2.45**	-0.13	-2.21***	-0.53
Hum-12 X Bireswar	-0.94	-0.34	-0.71	-0.06	0.27	-0.13	0.007	-1.78*	-0.03	-0.79**	0.75
Hum-12 X Ps-16	-1.87	-0.66	-0.59	-0.02	-0.05	-0.19	-0.48	1.68	0.43*	-1.12***	-0.16
Hum-12 X Tm-99-50	2.18	0.35	-0.77	0.01	0.95	-0.51	-0.007	0.162	-0.988***	0.382	0.09
S-16x Bireswar	4.09	2.61**	2.0.5	0.08	-0.85	0.07	0.01	2.29*	0.59**	1.31***	1.78***
Ps-16 X Tm-99-50	4.06	1.29	-3.34*	-0.18*	0.65	0.54*	0.02	-0.01	-0.21	-0.31	-0.24
Tm-99-50 X Bireswar	0.918	2.98**	2.05	0.13	-0.36	-0.036	-0.02	-1.85*	0.21	-0.59	0.39
Wbm-314x Basanti	2.55	-2.21**	-3.10*	-0.19*	0.65	0.98*	0.02	-2.72**	0.72**	-0.12	0.31
Wbm-314 X Bireswar	2.67	-0.08	-0.87	0.16	0.38	-0.07	-0.008	3.89**	-0.17	1.54***	-0.26
Wbm-314 X Hum-12	-7.01**	4.31***	5.39***	0.22*	-1.32*	-0.92*	-0.039	2.18*	-1.12*	-0.003	-1.00*
Wbm-314x Ps-16	1.86	-2.28**	-6.77**	0.07	0.81	0.12	-0.001	2.44**	0.07	-0.013	0.09
Wbm-314 Xtm-99-50	-9.54***	-3.03**	-0.09	-0.09	-0.03	0.32	0.008	-2.614**	0.45*	-0.79**	0.53
SE (Sij)	2.145	0.756	1.207	0.078	0.613	0.242	0.026	0.817	0.192	0.213	0.412
SE(Sij- Sik)	3.192	1.213	1.962	0.122	0.786	0.356	0.038	1.242	0.294	0.313	0.624
SE (Sij- Skl)	2.950	1.036	1.821	0.119	0.719	0.323	0.035	1.113	0.262	0.284	0.587

*** Significant at 0.001 %, ** significant at 1 %, *significant at 5

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