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Combining ability analysis for yield enhancement and its attributes in grass pea (*Lathyrus sativus* L.)

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Abstract
In the present investigation ten F_1 hybrids of grass pea and their 5 parents were evaluated in a randomized complete block design in three replication to estimate combining ability of genotypes by using Half diallel mating design for the yield and yield contributing characters during the *Rabi* December 2017-2018. Combining ability analysis indicated contribution of non-additive gene effect playing an important role for most of the characters and the analysis of variance due to general combining ability (GCA) and specific combining ability (sca) revealed highly significant for most of the characters. The parent, Prateek was recorded as the best general combiner for seed yieldplant^{-1} and seed protein content while, for pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1} and low ODAP in both seed and flour, Siraha Local was observed as the best general combiner. In the crosses, Ratan x RLS 3004 and Prateek x Siraha Local proved to be the best specific combiner for seed yield plant^{-1} and other related traits.

Keywords: Combining ability, general combiner, specific combiner, grass pea

Introduction
Grass pea is the most important, crop of economic significance in various nations including India, Bangladesh, Pakistan, Ethopia, Nepal (Kumar *et al*.). It was also cultivated in china and many countries of Europe, Middle East and Northern Africa. In South African countries, grass pea is commonly grown for both grain and fodder purpose. However, the crop has gained more importance for use as animal feed then human food. The seeds of grass pea contain 28-30% protein, 41% carbohydrate, 17% total dietary fiber (2% soluble and 15% insoluble), 2% fat and 2% ash, on a dry matter basis (Akalu *et al*., 1998). Grass pea has capability to withstand in extreme temperature with outstanding tolerance to drought, excess precipitation and flooding hence, as a highly nutritive food crop with low water demand grass pea can play a key role in alleviating global malnutrition. However, to date, very limited research effort have been made due to presence of a neurotoxin ODAP content in both leaf and seed. Therefore, further addition of knowledge about improvement of *Lathyrus* is needed. This can be done through using various breeding methods among the *Lathyrus* population. Therefore, the aim of present investigation was combing ability analysis is grass pea for yield and its attributing characters.

Materials and Methods
Five diverse genotypes Mahateora, Ratan, Prateek, Siraha Local, RLS 3004 of grass pea with wide variation were crossed in a half diallel fashion to raise a set of 10 F_1 crosses evaluated in a randomized complete block design (RCBD) with three replication, combining ability and Gene for each phenotype was estimated for yield and its attributes following a procedure given by Jinks and Hayman (1954) [3].

The data were analyzed following model suggested by Griffing (1956) [2] as well as Hayman (1954) [4] for combining ability analysis.

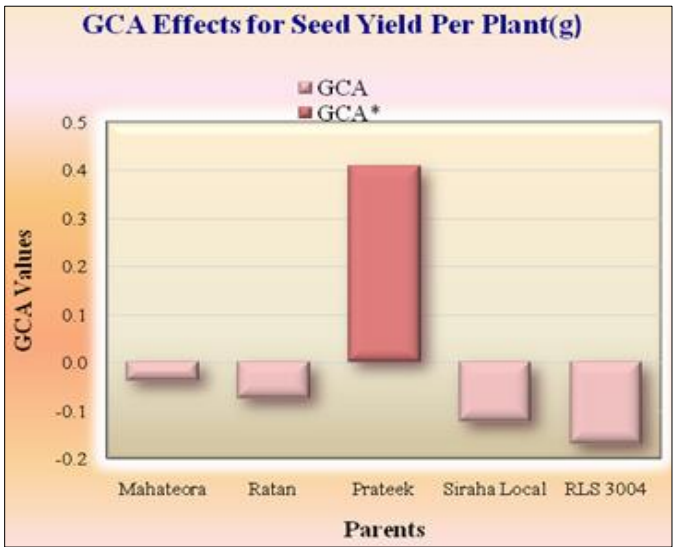
Results and Discussion

The analysis of variance due to general combining ability (GCA) revealed highly significant variances for most of the characters except nodes on main stem, seed yield plant^{-1} and seed protein content. The variance due to specific combining ability (sca) was significant for all the characters.

The comparative variances due to general combining ability and specific combining ability for different characters under study and their ratio presented in the Table 2, revealed that non-additive genetic variances accomplished an important role in the expression of different traits. Similar findings were reported by Kumari and Mehra (1995) [5] and Tikariha (2012) [7] which indicated the predominance of non-additive gene action in the inheritance of above mentioned traits.

The estimates of combining ability effects for all parents and crosses for half diallel for nineteen characters with their corresponding error are presented in Table-3 and 4 respectively, showed that the parent Mahateora is being the best general combiner for days to 50% flowering, days to maturity, plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1} and low seed ODAP content while, Ratan was found as the best general combiner for plant height, seed density and low ODAP content in both seed and flour. The parent, Prateek was recorded as the best general combiner for seed yieldplant^{-1} and seed protein content. While, Siraha Local was investigated as the best general combiner for pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1} and low ODAP in both seed and flour. Hence it is suggested that these parents can be used in hybridization programme for developing high yielding verities in grass pea.

In all crosses the cross, Ratan x RLS 3004 proved to be the best specific combiner for seeds plant$^{-1,}$ pods plant^{-1}, seed yield plant^{-1} days to 50% flowering and low ODAP content in both in flour and seed. Hence, this cross can be utilized for isolating high yielding varieties with low ODAP content. Prateek x Siraha Local was



*significant

Graph 1: showing that the parent prateek was found as the best general combiner for seed yield plant^{-1}

appeared as the best specific combiner for protein content, plant biomass, seed yield plant^{-1}, pods plant^{-1}, seeds pod^{-1} and seeds plant^{-1}, similarly Mahateora x Ratan was appeared as the best specific combiner for plant height, secondary branches plant^{-1}, pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1} and cross Mahateora x RLS 3004 was observed as the best specific combiner for low ODAP content in seed. Hence preponderance of non-additive gene effects for yield and contributing characters offeres a good scope for exploitation of hybrid vigour and therefore, heterosis breeding may be rewarding for improving grass pea.

Table 1: ANOVA for combining ability analysis for seed yield, its components and Neurotoxin (ODAP) content in grasspea.

Characters/MSS	DF	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
GCA	4	8.21**	7.32**	37.01**	0.35*	0.72*	0.84	0.15**	107.51**	0.09**	0.53**	262.25**	17.38**	0.38	0.15**	11.85**	18.49**	1.13	0.72**	10.35**
SCA	10	9.65**	14.25**	22.46	0.41**	0.94**	1.09**	0.07*	138.05**	0.07**	0.23**	490.2**	8.36**	3.29**	0.13**	21.7**	12.56**	3.5**	0.52**	8.83**
Error	28	0.66	0.61	2.57	0.1	0.19	0.31	0.02	4.28	0.01	0.01	19.4	1.22	0.24	0.02	3.22	1.38	0.48	0.06	0.82

**Significant @1% *Significant@ 5%

Table 2: Components of GCA, SCA and predictability ratio for different characters in grass pea

Type of gene action	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
σ^2 g	1.08	0.96	4.92	0.04	0.07	0.07	0.02	14.75	0.01	0.07	34.69	2.31	0.02	0.02	2.18	1.50	0.09	0.09	1.36
σ^2 s	8.99	13.64	19.89	0.32	0.75	0.78	0.04	133.78	0.07	0.22	1389.80	7.15	3.05	0.11	18.48	11.18	3.01	0.46	8.01
Predictability ratio$2\sigma_2 g/(2\sigma_2 g + \sigma 2 s)$	0.19	0.12	0.33	0.18	0.17	0.16	0.45	0.18	0.27	0.40	0.05	0.39	0.01	0.24	0.19	0.21	0.06	0.29	0.25

**Significant @ 1% *Significant @ 5%

Characters

1. Days to 50% Flowering 2. Days to maturity 3. Plant Height cm) 4. Number of primary Branches Plant-1 5. Number of secondary Branches Plant-1 6. Nodes on Main Stem 7. Internodal Length (cm) 8. Pods Plant-1 9. Pod Length (cm) 10. Seeds Pod-1 (gm) 11. Seeds Plant-1 12. Plant Biomass Plant-1 13. Seed Yield Plant-1 (g) 14. Seed Index (gm) 15. Harvest Index (%) 16. Seed Density (gm) 17. Protein Content (%) 18. ODAP Content in Seed (%) 19. Flour ODAP Content (%)

Table 3: Estimates of General combining ability effects (GCA) for seed yield, its components and ODAP content in grass pea

Parents	Characters																		
	11	22	33	44	55	66	77	88	99	110	111	112	113	114	115	116	117	118	119
11	-1.68**	-1.67**	3.99**	0.29*	0.46**	-0.53**	0.01	0.01	-0.02	-0.14**	-3.98*	0.02	-0.04	-0.08	-0.78	-1.66**	-0.45	-0.21*	0.05
22	0.07	-0.23	-1.89**	-0.32**	-0.07	0.05	-0.11	-6.76**	-0.14**	-0.26**	-8.71**	-0.11	-0.08	-0.12*	-1.58*	1.15**	0.17	-0.35**	-1.24**
33	-0.14	0.93**	-0.82	-0.07	-0.28	-0.13	-0.06	2.38**	-0.01	0.01	2.53	2.20**	0.41*	0.08	-0.85	0.44	0.54*	-0.11	-0.57
44	1.28**	0.52	-0.94	0.10	-0.30	0.25	-0.09	1.68*	-0.01	0.46**	5.41**	0.15	-0.12	-0.10	0.71	-1.09*	0.08	0.31**	2.00**
.5	0.46	0.45	-0.33	-0.01	0.18	0.35	0.25**	2.68**	0.19**	-0.07	4.75**	-.25**	-0.17	0.22**	2.50**	1.15**	-0.34	0.36**	-0.24

Characters
1. Days to 50% flowering 2. Days to maturity 3. Plant height (cm) 4. Number of primary branches plant-1 5. Number of secondary branches plant-1 6. Nodes on main stem 7. Internodal length (cm) 8. Pods plant-1 9. Pod length (cm) 10. Seeds pod-1 (gm) 11. Seeds plant-1 12.Plant biomass plant-1 13. Seed yield plant-1 (g) 14. Seed index (gm) 15. Harvest index (%) 16. Seed density (gm) 17. Protein content (%) 18 Seed ODAP content (%) 19. Flour ODAP content (%)
Parents 1. Mahateora 2. Ratan 3. Prateek 4. Siraha local 5. RLS 3004

Table 4: Estimates of specific combining effects for seed yield, its components and ODAP content in grass pea

Crosses	Characters																		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
1	1.31	1.00	-0.55	-0.87*	1.02*	0.82	-0.01	6.26**	0.22	0.44**	9.15*	1.89	-0.01	0.11	-4.19*	-0.87	-1.34	0.54*	2.19*
2	3.19**	5.51**	-8.16**	-0.58	-0.17	-1.19*	-0.16	-3.01	0.22*	-0.17	-4.41	-1.46	-0.99*	-0.02	1.61	-0.49	-0.32	0.30	0.52
3	-1.90*	1.84*	6.70**	-0.15	1.25**	1.29*	-0.21	4.15*	-0.05	-0.48**	-6.96	0.63	0.03	0.49**	-4.49*	-0.97	1.08	0.20	-2.05*
4	-1.00	1.05	1.49	-0.78*	-0.83	-0.53	0.07	-1.18	-0.41**	0.12	-6.64	2.79*	0.68	-0.30	-2.67	2.46*	0.70	-1.18**	-1.81*
5	1.57	-6.67**	6.85**	0.50	0.95*	-0.11	0.19	8.02**	0.08	0.09	2.31	-2.16*	-0.24	-0.14	1.48	-1.63	-0.87	0.11	1.81*
6	-2.32**	-0.26	-3.76*	0.46	0.04	-0.02	0.41*	2.65	0.21	-0.89**	-1.90	-0.20	0.28	0.50**	-1.21	-2.11	0.19	-0.32	0.90
7	-3.95**	-1.06	2.10	-0.10	0.89*	0.15	-0.15	21.12**	-0.14	0.04	76.89**	1.95	1.00*	-0.11	1.74	-4.02**	1.68*	-1.03**	-4.52**
8	-1.44	2.98**	2.30	0.01	0.32	2.03**	-0.06	14.85**	0.16	0.74**	65.26**	4.81**	4.40**	0.23	-4.75*	-4.40**	3.91**	-0.22	-0.76
9	-1.41	2.71**	2.23	0.18	-0.90*	-0.07	0.44**	-6.55**	-0.38**	-0.17	-16.48**	0.57	-0.10	0.28	-4.13*	5.70**	-0.62	-0.61*	-1.19
10	6.90**	-0.54	1.50	0.59	-0.46	-0.34	0.05	-7.80**	0.00	-0.36*	-18.36**	2.20*	0.55	0.21	-4.07*	2.56*	-3.07**	0.30	6.57**

*Significant at 5% * **significant at 1%

Characters
1. Days to 50% Flowering 2. Days to maturity 3. Plant Heightcm) 4. Number of Primary Branches Plant-1 5. Number of Secondary Branches Plant-1 6. Nodes On Main Stem 7. Internodal Length (cm) 8. Pods Plant-1 9. Pod Length (cm) 10. Seeds Pod-1 (gm) 11. Seeds Plant-1 12. Plant Biomass Plant-1 13. Seed Yield Plant-1 (g) 14. Seed Index (gm) 15. Harvest Index (%) 16. Seed Density (gm) 17. Protein Content (%) 18. ODAP Content in Seed (%) 19. Flour ODAP Content (%)
Crosses
1. Mahateora x. Ratan 2.Mahateora x Prateek 3. Mahateora x Siraha local 4. Mahateora x RLS 3004 5. Ratan x Prateek 6. Ratan x Siraha local 7. Ratan x RLS 3004 8. Prateek x Siraha local 9. Prateek x RLS 3004 10. Siraha local x RLS 3004

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