Forage Res., **45** (3) : pp. 183-188 (2019) **http://forageresearch.in**

HETEROSIS AND COMBINING ABILITY STUDIES IN A DIALLEL CROSS OF GRASS PEA (*LATHYRUS SATIVUS* L.) GENOTYPES FOR GREEN FORAGE YIELD AND ITS COMPONENT TRAITS

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(Received : 28 October 2019; Accepted : 30 December 2019)

SUMMARY

A field experiment was conducted at the Instructional-cum-Research Farm of Assam Agricultural University, Jorhat (Assam), India during *Rabi* 2017-18 to evaluate genotypes for high forage yield coupled with low ODAP content. Seven diverse parental lines of grass pea were crossed in a 7×7 diallel mating design excluding reciprocals. The twenty one F1 hybrids obtained were evaluated along with their parents in randomized block design with three replications. Analysis of variance revealed significant differences among the parents and the F1's for all the characters studied. The studies on combining ability indicated the predominance of dominance variance for most of the characters studied except for days to 50% flowering and leaves per plant. The parent Prateek was the best general combiner for both green forage yield per plant and for low ODAP content. Based on SCA effect and *per se* performance the cross Nirmal × Prateek was the best specific combiner for green forage yield, while the cross Prateek × JCL-3 was the best specific combiner for low ODAP content**.** Significant heterosis was observed in desirable direction for most of the traits. From the estimation of heterosis over mid parent and better parent, the cross JCL-2 × JCL-3 was the best heterotic cross for green forage yield per plant while the crosses Prateek × JCL-3 was recognized as best heterotic cross for ODAP content.

Key words : Grass pea, heterosis, combining ability

Grass pea (*Lathyrus sativus* L.) is a dual purpose crop. The major use of this crop includes as pasture crop, green fodder, dried stover, seeds as feed and as human food. In South Asia, Ethiopia and China, the crop is of dual purpose and in other regions it is mostly used as fodder and feed (Jackson and Yunus, 1984). In fodder lathyrus, (cut at 50% flowering stage) the crude protein content ranged from 13.97-21.32%, Neutral detergent fibre ranged from 35.72-52.45%, Acid detergent fibre from 27.18-41.45%, hemicullose 6.50-14.43%, cellulose from 20.17-32.45% and lignin 4.70-9.39% (Anonymous, 2012). The consumption of grass pea has been known to cause a motor neuron disease called lathyrism (paralysis of lower limbs). A neurotoxin, ß-N-oxalyl-L-a, ß-diaminopropionoc acid (ODAP also known as BOAA) is the causative principle for lathyrism and is present in all parts of the plant (Campbell *et al.*, 1994). Grass pea is increasingly recognized as an important feed and fodder crop by the resource poor farmers of semi-arid and dry areas. Acceptability of low ODAP varieties by the farmers of non-traditional grass pea growing areas and high nutritional composition makes the grass pea a perfect dual purpose for crop securing food, feed and fodder security in the region. In fodder lathyrus, biomass yield and neurotoxin content are the major traits of importance. Due to the importance of this crop in developing countries, breeding programmes have been established mainly focused on getting a genotype with high biomass yield coupled with low in ODAP toxicity. In India, so far no forage type grass pea variety has been released for cultivation at national level. Very little success has been achieved in the past for developing high forage yielding varieties with low ODAP content. Therefore a selection criterion for developing of high forage yield and low ODAP varieties in grass pea is to be of utmost importance. The study was undertaken to assess the extent of heterosis and to identify the best combiners among the genotypes which will be useful for further breeding programme.

MATERIALS AND METHODS

The experiment was carried out at the Instructional cum Research Farm, Assam Agricultural University, Jorhat. The F_1's were developed by crossing seven parents (Nirmal, Madhuri, Prateek, JCL-1, JCL-2, JCL-3 and JCL-4) in half diallel mating fashion. The twenty one crosses along with seven parents were grown in Randomized Block Design in three replications during *rabi* 2017-18. The recommended package and practices were followed to raise a good crop of grass pea (*Lathyrus sativus* L.). Five plants representing one genotype from each replication were randomly sampled and observations were recorded for the characters plant height, days to 50% flowering, primary branches per plant, secondary branches per plant, nodes per plant, leaves per plant, crude protein (%), , chlorophyll content (mg/g) ODAP content (%), dry matter yield (g/plant) and green forage yield (g/plant). Analysis of variance for randomized block design including parents and F_1's was carried out as per the formulae given by Singh and Chaudhary (1977). The magnitude of heterosis was estimated in relation to mid-parent (MP) and better parent (BP) as percentage increase or decrease of F_1 over respective parental values. Average values over replications were used for estimating the heterosis over mid and better parent. Emphasis to say heterotic cross depended upon the trait that may be desired in any one of the two sides higher or lower. General combining ability (GCA) and specific combining ability (SCA) variance and effects for diallel mating design were analyzed by adapting Griffing's (1956) Method -2, Model -1, since the present study includes parents and F_1's without reciprocals.

RESULTS AND DISCUSSION

The analysis of variance of the parents and F_1 progenies for green forage yield and the other characters revealed significant difference among the parents and F_1's for all the characters which indicated the presence of considerable variability among the parents and F_1's (Table 1). The analysis of variance for combining ability for green forage yield and other characters revealed that both general combining ability (GCA) and specific combining ability (SCA) were highly significant for all the characters (Table 2). The relative magnitude of GCA: SCA (Table 2) indicated preponderance of additive gene action for days to 50% flowering (Quader, 1985) and leaves per plant as their values were more than unity. GCA: SCA ratio was close to unity for green forage yield indicating that this character was equally governed by additive and non-additive genetic system. GCA/SCA values were less than unity for plant height, dry matter yield, primary branches per plant, secondary branches per plant, nodes per plant, ODAP content, chlorophyll content and crude protein content indicating the predominance of non- additive gene action in the inheritance of these characters. Similar findings were reported by Kumari and Mehra (1991) and Tripathy *et al*. (2015).

The general combining ability effects of the parents are presented in Table 3. Although none of the parents were found to be good general combiner for all the characters simultaneously, yet the parent Prateek was observed as the best general combiner not only for green forage yield per plant but also for four other yield components *viz*., low ODAP content, dry matter yield per plant, leaves per plant and plant height. This could be a potential parent for hybridization programme for development of grass pea varieties giving good forage yield coupled with low ODAP content. Besides this parent, Nirmal exhibited its potentiality as a good general combiner for green forage yield per plant, low ODAP content, primary branches per plant, secondary branches per plant, plant height, nodes per plant, leaves per plant and crude protein %. The parent JCL-4 could also be important in its inclusion in hybridization programme from its superior general combining ability for late days to 50% flowering which is an important character in case of development of fodder crop.

The specific combining ability effects of the crosses are presented in Table 3. Among the crosses, Nirmal × Prateek and Nirmal × Madhuri were good specific combiners exhibiting high positive sca effects for green forage yield per plant. The cross Nirmal × Madhuri also exhibited high positive sca effects for secondary branches per plant while it exhibited high negative sca effects for days to 50% flowering. The crosses Prateek × JCL-3 and JCL-1 × JCL-2 were good specific combiners exhibiting high negative sca effects for ODAP content. Tripathy (2015) also reported negative and significant sca effect for ODAP content. These crosses were also good specific combiners for primary branches per plant. Such promising crosses could be further improved through conventional breeding methods such as pedigree selection and recurrent selection.

As regards to days to 50% flowering, two

TABLE 1
Analysis of variance of grass pea genotypes (Parents+Progenies) for various characters

Source of variations	Mean sum of squares											
	Degree of freedom	Days to 50% flowering	Plant height (cm)	Primary branches plant	Secondary branches/ plant	Leaves/ plant	Nodes/ plant	Crude protein (%)	Chlorophyll content (%)	ODAP content (%)	Green matter yield (g/plant)	Dry forage yield (g/plant)
Replication	2	0.68	17.29*	0.15*	4.22	1.91	5.40*	0.14	0.004	0.00019	0.46	0.29
Treatments	27	22.46**	317.39**	0.16**	18.52**	421.30**	8.49**	2.73**	0.07**	0.15**	81.04**	3.41**
Parents	6	57.04**	173.56**	0.40**	17.07**	607.41**	5.23**	2.55**	0.18**	0.25**	69.69**	1.18**
Hybrids	20	11.81**	338.96**	0.08*	17.76**	378.26**	8.88**	2.57**	0.03**	0.09**	83.57**	3.56**
Parents vs. Hybrids	1	28.00**	750.89**	0.35**	42.34**	165.47*	20.40**	6.94**	0.08**	0.75**	98.43**	9.76**
Error	54	1.88	4.35	0.03	2.12	26.89	1.09	0.24	0.01	0.0001	0.87	0.10
C. D. (P=0.05)		2.29	3.49	0.33	2.44	8.67	1.75	0.82	0.17	0.02	0.54	1.56
CV (%)		1.5	4.004	6.23	11.45	7.99	6.44	3.06	1.61	1.87	5.24	7.82

*Significant at 5 % probability level **Significant at 1 % probability level.

TABLE 2
Analysis of variance for combining ability for different characters in grass pea

Source of variations	Mean sum of squares											
	Degree of freedom	Days to 50% flowering	Plant height (cm)	Primary branches plant	Secondary branches/ plant	Leaves/ plant	Nodes/ plant	Crude protein (%)	Chlorophyll content (%)	ODAP content (%)	Dry matter yield (g/plant)	Green forage yield (g/plant)
GCA	6	18.62**	269.84**	0.06**	6.87**	449.09**	2.57**	0.49**	0.03**	0.08**	2.87**	84.01**
SCA	21	2.82**	58.92**	0.05**	6.17**	52.25**	2.91**	1.02**	0.01**	0.04**	0.65**	10.73**
Error	54	0.88	1.45	0.01	0.70	8.93	0.36	0.08	0.003	0.0001	0.03	0.28
σ^2 gca		1.97	29.82	0.005	0.68	48.90	0.24	0.04	0.003	0.009	0.31	9.30
σ^2 sca		1.94	57.47	0.03	5.46	43.31	2.54	0.94	0.01	0.04	0.62	10.44
GCA : SCA		1.01	0.51	0.15	0.12	1.13	0.09	0.05	0.22	0.23	0.49	0.89

GCA : SCA is a ratio of var(GCA): var(SCA) as per model 1, Method 2 of Griffing.
*Significant at 5 % probability level **Significant at 1 % probability level.

crosses involving parent JCL-4 *viz.*, Nirmal × JCL-4 and JCL-3 × JCL-4; and two crosses involving JCL-3 *viz.*, Nirmal × JCL-3 and Prateek × JCL-3 exhibited highly significant positive sca effects. Thus, these crosses should be exploited to develop late flowering grass pea varieties which give more vegetative growth hence important for forage purpose. In case of plant height, two hybrid combinations, *viz.*, JCL-2 × JCL-3 and Madhuri × Prateek were found to exhibit significant positive sca effects. JCL-2 × JCL-3 was also the best specific combiner for primary branches per plant. The best specific combiners for the other yield attributing characters *viz*., Madhuri × Prateek for dry matter yield; Nirmal × JCL-3 for leaves per plant; Madhuri × JCL-4 for chlorophyll content and crude protein content; JCL-1 × JCL-4 for secondary branches per plant and Prateek × JCL-2 for nodes per plant could be further evaluated for development of forage type grass pea varieties.

The estimates of heterosis over the standard check revealed significant heterosis in desirable direction for green forage yield and quality traits in many cross combinations which are presented in the Table 4. The crosses JCL-2 × JCL-3, Nirmal × Prateek, Madhuri × Prateek, Nirmal × Madhuri , JCL-3 × JCL-4 and Madhuri × JCL-1 exhibited highly significant positive heterosis for green forage yield per plant. The crosses also exhibited highly significant positive sca effects for green forage yield per plant indicating involvement of dominance and non –additive effects which also contributed towards its high heterotic response. Hence these crosses may be further improved for obtaining good green forage yielders. Similar reports indicating significant and positive heterosis was given by Parihar *et al.* (2006) and Nanda *et al.* (2008).

The negative heterosis for seed ODAP content is considered to be an index of low neurotoxin content. The crosses Prateek × JCL-3, JCL-1 × JCL-2 and JCL-

3 × JCL-4 showed highly significant negative heterosis for both BP and MP respectively for ODAP content. The crosses also exhibited highly significant negative sca effects. These crosses are important for further development of low ODAP content varieties. Tiwari and Campbell (1996) reported significant heterosis producing higher seed ODAP than the higher ODAP parent. Nanda *et al.* (2008) also reported significant negative heterosis for ODAP content.

Late maturing genotypes with high *per se* performance for lateness is important for breeding fodder crops as it gives more vegetative growth. However in the present study none of the crosses exhibited significant positive heterosis over BP. Five crosses *viz*., Nirmal × JCL-2, Prateek × JCL-2, Madhuri × JCL-1, Nirmal × JCL-3 and Madhuri × JCL-2 exhibited significant positive heterosis over MP. The crosses, however, involve parents having poor gca effects. Thus the heterosis for lateness may be due to additive x additive type of interaction which is fixable.

Taller plant is considered to be desirable because it leads to more number of branches and ultimately result in increased forage productivity. The cross JCL-2 × JCL 3 was the most heterotic for plant height showing highly significant positive heterosis over BP. The cross also exhibited highly significant positive sca effects indicating involvement of dominance and non –additive effects which also contributed towards its high heterotic response.

Besides days to 50% flowering and plant height, the crosses exhibiting high heterosis for yield components could also be useful. The crosses JCL-2

TABLE 3

General combining ability effects of the parents and specific combining ability effects of the crosses for different characters

Source of variations	Mean sum of squares										
	Days to 50% flowering	Plant height (cm)	Primary branches plant	Secondary branches/ plant	Leaves/ plant	Nodes/ plant	Crude protein (%)	Chlorophyll content (%)	ODAP content (%)	Dry matter yield (g/plant)	Green forage yield (g/plant)
The gca effects of the parents											
Nirmal	-1.77**	5.25**	0.09*	1.23**	7.58**	0.68**	0.42**	0.03	-0.09**	0.37**	2.80**
Madhuri	-1.06**	1.94**	0.06	-0.39	4.54**	0.33	-0.19*	-0.11**	-0.01**	0.59**	2.39**
Prateek	-1.47**	8.30**	0.04	0.88**	9.64**	0.35	-0.06	-0.05*	-0.16**	0.66**	3.93**
JCL-1	0.16	-0.41	0.08*	0.24	-5.33**	0.15	0.06	0.05*	0.05**	0.06	-0.21
JCL-2	0.97**	-4.99**	-0.07	0.07	-2.80**	-0.61**	0.08	0	0.12**	-0.60**	-2.68**
JCL-3	1.53**	-3.74**	-0.12**	-0.97**	-6.03**	-0.11	-0.32**	0.06**	-0.01	-0.47**	-2.67**
JCL-4	1.64**	-6.37**	-0.08*	-1.07**	-7.61**	-0.79**	0.01	0.02**	0.09**	-0.61**	-3.57**
SE (gi)	0.28	0.37	0.26	0.25	0.93	0.18	0.09	0.019	0.002	0.05	0.16
SE (gi-gj)	0.37	0.56	0.40	0.39	1.42	0.28	0.019	0.029	0.004	0.08	0.25
The sca effects of the crosses											
Nirmal × Madhuri	-1.24 **	2.29**	0.08	2.45**	0.23	1.54	1.18**	0.05*	0.37**	0.57**	5.61**
Nirmal × Prateek	-0.17	6.99**	-0.16**	0.06*	-0.75**	2.54*	-0.97**	-0.01	0.16**	0.90**	6.17**
Nirmal × JCL-1	-0.13	4.87**	0.06	1.29**	0.44	0.39	1.09**	-0.14**	0.07**	0.27**	-1.69**
Nirmal × JCL-2	2.06 **	-14.2**	-0.29**	-0.32	-0.73**	-6.97**	0.14	0.00**	-0.12**	-0.59**	-5.75**
Nirmal × JCL-3	2.17 **	6.16**	-0.04	-5.30**	2.86**	6.02**	-0.49**	0.11**	-0.10**	-0.52**	0.79**
Nirmal × JCL-4	1.72 **	0.39	-0.04	0.60	-1.28**	-10.8**	-0.99**	-0.02**	0.24**	-0.29**	-2.33**
Madhuri × Prateek	-0.54	12.10**	-0.17**	1.53**	1.02**	7.7**	0.76**	-0.06*	0.18**	1.45**	3.88**
Madhuri × JCL-1	-0.17	4.89**	0.19**	0.00	-3.60**	1.23	-1.27**	0.11**	0.10**	1.02**	2.22**
Madhuri × JCL-2	1.69 **	5.00**	-0.16**	0.1	-0.95**	-3.3*	1.78**	0.15**	0.24**	-0.11	0.08
Madhuri × JCL-3	0.80 *	-3.28**	-0.20**	3.45**	-0.35	-3.87**	-0.68**	0.09**	-0.06**	0.98**	-0.25
Madhuri × JCL-4	-0.24	-1.62**	-0.05	1.68**	-0.56*	-4.66**	1.99**	0.20**	-0.07**	-0.91**	-3.25**
Prateek × JCL-1	1.57 **	0.89	0.05	1.90**	0.114	-4.1**	0.77**	0.14**	-0.02**	0.34**	0.71**
Prateek × JCL-2	1.76 **	8.33**	0.06	-1.10**	2.53**	20.5**	0.52**	0.05*	0.18**	0.61**	1.61**
Prateek × JCL-3	1.54 **	-0.41	0.31**	1.97**	-1.53**	-5.08**	-0.11	0.13**	-0.21**	-0.21**	-1.22**
Prateek × JCL-4	-0.57	-0.41	0.02	-0.05	-0.28	-2.09	-0.39**	0.07**	0.13**	-0.58**	-2.12**
JCL-1 × JCL-2	0.46	-0.24	0.19**	1.23**	-0.76**	-1.24	-0.71**	-0.01	-0.20**	0.11	1.55**
JCL-1 × JCL-3	-3.09 **	-6.49**	0.17**	-2.92**	-0.66**	1.17	0.83**	-0.13**	0.20**	-0.34**	-1.56**
JCL-1 × JCL-4	0.13	5.66**	0.00	2.88**	0.18	4.95**	-0.17	0.19**	-0.01	-0.04	0.64**
JCL-2 × JCL-3	-2.91 **	12.53**	0.38**	2.74**	0.28	5.64**	-0.28*	0.04	0.11**	0.04	2.94**
JCL-2 × JCL-4	-1.69 **	-7.92**	0.15**	-2.25**	-2.86	5.02**	-0.15	0.02	0.03**	0.64**	2.04**
JCL-3 × JCL-4	1.35 **	0.79	0.26**	-1.66**	0.70	1.24	0.62**	-0.21**	-0.07**	0.88**	3.03**
SE(ij)	0.84	1.08	0.10	0.75	0.54	2.70	0.11	0.05	0.007	0.16	0.48

*Significant at 5 % probability level **Significant at 1 % probability level.

TABLE 4

The range of mid parent and better parent heterosis showing significant heterosis for green forage yield and other related traits

Characters	Days to 50% Flowering		Plant Height (cm)		Primary branches/ plant		Secondary Branches/ plant		Leaves/plant		Nodes/ plant	
Crosses	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Nirmal × Madhuri	0.63	-1.84	20.22**	4.41	-3.41	-4.71	50.74**	4.06	0.05	-7.12	-4.18	-9.54
Nirmal × Prateek	3.51	2.53	32.52**	26.62**	-8.44	-13.68*	15.5	0.25	8.40	1.40	-2.05	-4.91
Nirmal × JCL-1	1.21	-4.57*	20.48**	4.88	4.44	-5.04	20.49*	0.00	-1.42	-22.51**	-8.45	-7.42
Nirmal × JCL-2	6.34**	0.00	-29.29**	-42.74**	-11.50*	-21.52**	-3.13	-13.45	-6.97	-29.21**	-2.89	-11.45
Nirmal × JCL-3	5.01*	-3.26	25.17**	0.80	3.26	-14.80**	52.45**	-59.39**	10.04	-15.63**	25.34**	17.29**
Nirmal × JCL-4	-0.82	-2.21	3.04	16.05**	-2.04	-13.68*	7.22	-15.23	-25.13**	-41.26**	-15.10**	-16.59**
Madhuri × Prateek	1.56	0.00	58.04**	42.95**	-8.32	-12.44*	69.09**	28.28*	20.84**	19.87**	1.69	-6.64
Madhuri × JCL-1	5.36*	-3.43	32.94**	32.58**	10.14	1.38	49.76**	18.08	4.17	-13.14	-36.06**	-36.72**
Madhuri × JCL-2	4.42*	0.57	31.66**	21.14**	-6.29	-15.90**	32.61*	-1.61	3.91	-16.40*	-17.91**	-24.90**
Madhuri × JCL-3	1.44	-4.35*	11.56**	2.00	-2.62	-18.78**	74.36**	34.05**	-4.58	-22.58**	-17.77**	-18.05**
Madhuri × JCL-4	3.49	-1.66	7.20	-0.64	-1.81	-12.44*	67.81**	38.86*	-11.61	9.59	7.60	-23.65**
Prateek × JCL-1	3.90	-1.14	24.70**	13.07**	9.21	5.06	46.18**	38.62**	2.71	-14.90*	-4.69	-11.65*
Prateek × JCL-2	5.39*	0.00	42.13**	19.38**	6.76	0.00	2.33	-0.97	60.86**	28.63**	16.31**	15.88*
Prateek × JCL-3	3.51	-3.80	23.16**	2.86	24.53**	7.97	29.35**	26.9	2.29	-17.52*	-7.22	-10.67
Prateek × JCL-4	0.88	-5.52*	14.81**	-2.94	5.31	-2.03	17.15	4.83	2.39	-15.33*	-7.60	-8.72
JCL-1 × JCL-2	0.85	0.57	8.85*	-0.09	18.59**	15.34*	25.61*	15.48	10.97	6.10	-16.97**	-23.31**
JCL-1 × JCL-3	-6.41**	-8.70**	-5.29	-13.63**	25.19**	12.33	-25.05*	-27.60*	7.78	4.15	-10.06	-19.49**
JCL-1 × JCL-4	0.00	-1.66	21.33**	12.18**	10.64	6.85	52.56**	43.46**	9.86	30.08**	-12.99*	-18.43**
JCL-2 × JCL-3	-5.00	-7.07**	51.17**	50.11**	32.28**	21.74**	24.62*	18.39	31.51**	16.42	-0.13	-3.50
JCL-2 × JCL-4	-1.96	-3.31	-25.23**	-25.82**	13.87*	13.04	-20.59	-30.97**	21.48*	-0.74	-33.33**	-34.38**
JCL-3 × JCL-4	0.00	-1.63	7.55	5.95	26.98**	17.65*	-21.26	-28.32*	2.49	-26.44**	0.00	-4.84
S.E.d	1.14	1.32	1.47	1.70	0.14	0.16	1.02	1.18	3.65	4.22	0.74	0.85

*Significant at 5% probability level **Significant at 10% probability level.

TABLE 5

The range of mid parent and better parent heterosis showing significant heterosis for green forage yield and other related traits (contd)

Characters	Crude protein (%)		Chlorophyll content (mg/g)		Crude protein (%)		Chlorophyll content (mg/g)		Green forage yield (g/plant)	
Crosses	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Nirmal X Madhuri	17.09 **	3.99	17.09 **	3.99	428.00 **	312.50 **	38.12 **	23.20 **	49.65 **	35.36 **
Nirmal X Prateek	-6.22 *	-10.45 **	-6.22 *	-10.45 **	444.83 **	338.89 **	41.28 **	32.80 **	50.09 **	46.61 **
Nirmal X JCL-1	9.09 **	5.19	9.09 **	5.19	68.28 **	0.00	19.44 **	-33.60 **	-3.25	-17.68 **
Nirmal X JCL-2	3.45	-1.51	3.45	-1.51	23.92 **	-27.85 **	-10.75	3.20	-33.42 **	-52.68 **
Nirmal X JCL-3	-3.95	-8.92 **	-3.95	-8.92 **	8.94	-35.68 **	-7.29	-28.80 **	18.77 **	-17.50 **
Nirmal X JCL-4	-5.78 *	-10.11 **	-5.78 *	-10.11 **	119.74 **	29.95 **	-8.46	-26.40 **	-15.80 **	-39.11 **
Madhuri X Prateek	15.70 **	7.20 *	15.70 **	7.20 *	334.88 **	192.19 **	81.73 **	71.82 **	49.95 **	38.58 **
Madhuri X JCL-1	-1.56	-9.63 **	-1.56	-9.63 **	74.90 **	16.75 **	67.20 **	61.22 **	33.81 **	24.94 **
Madhuri X JCL-2	26.05 **	17.13 **	26.05 **	17.13 **	103.53 **	31.51 **	30.82 **	6.12	24.24 **	-5.52
Madhuri X JCL-3	2.04	-4.8	2.04	-4.8	21.67 **	-19.60 **	70.91 **	43.88 **	24.59 **	-7.73
Madhuri X JCL-4	26.90 **	17.69 **	26.90 **	17.69 **	41.76 **	-6.09 **	-8.05	-18.37 *	-14.37 *	-33.55 **
Prateek X JCL-1	8.19 **	7.11 *	8.19 **	7.11 *	35.21 **	-24.61 **	39.30 **	27.27 **	22.33 **	6.18
Prateek X JCL-2	7.80 **	7.46 *	7.80 **	7.46 *	85.89 **	2.28	49.71 **	16.36 *	35.06 **	-2.62
Prateek X JCL-3	0.05	-0.68	0.05	-0.68	-35.75 **	-64.32 **	20.90 **	-2.73	15.69 **	-18.54 **
Prateek X JCL-4	-0.11	-0.21	-0.11	-0.21	82.65 **	1.52	-1.08	-16.36 *	-2.81	-28.65 **
JCL-1 X JCL-2	-1.90	-3.19	-1.90	-3.19	-16.59 **	-21.92 **	25.00 **	4.40	25.28 **	0.25
JCL-1 X JCL-3	7.41 **	5.56	7.41 **	5.56	31.28 **	28.64 **	7.59	-6.59	-1.47	-23.41 **
JCL-1 X JCL-4	1.54	0.41	1.54	0.41	14.43 **	12.69 **	7.78	-1.10	5.75	-13.49 *
JCL-2 X JCL-3	0.11	-0.32	0.11	-0.32	19.14 **	13.70 **	20.31	14.93	59.47 **	53.39 **
JCL-2 X JCL-4	3.17	2.95	3.17	2.95	22.60 **	16.44 **	32.85 **	19.74	26.75 **	23.20 *
JCL-3 X JCL-4	6.52	5.85	6.52	5.85	-5.56 **	-6.03 **	42.66 **	34.21 **	44.44 **	35.20 **
S.E.d	0.34	0.40	0.34	0.40	0.009	0.01	0.22	0.26	0.65	0.75

*Significant at 5 % probability level **Significant at 1 % probability levels.

× JCL-3 for primary branches per plant; JCL-1 × JCL-4 for secondary branches per plant; Prateek × JCL-2 and Madhuri × Prateek for leaves per plant; Nirmal × JCL-3, Prateek × JCL-2 for nodes per plant; Madhuri × JCL-4 and Madhuri × JCL-2 for crude protein content; Madhuri × Prateek for dry matter yield, exhibited high heterosis for their respective component characters. Positive heterosis for primary and secondary branches per plant was also reported by Nanda *et al.* (2008). Similar findings for positive heterosis in protein content were reported by Parihar *et al.,* (2006) and Urga *et al.* (2005). Parihar *et al.* (2006) and Nanda *et al.* (2008) reported similar significant positive heterosis for dry matter yield. Michaelson-Yeates *et al.* (1997) also reported positive heterosis for dry matter production in white clover.

As the main objective of the study is for developing of high forage yield and low ODAP varieties in grass pea, the following points are to be kept in mind during further crop improvement. Prateek showed high combining ability for green forage yield and low for ODAP content. Thus, Prateek can be utilized as the best general combiner in future hybridization programme in grass pea for development of better performing forage grass pea genotypes with low ODAP content. The best specific combiners for green forage yield per plant were Nirmal × Prateek and Nirmal × Madhuri. For ODAP content, the best specific combiners were Prateek × JCL-3 and JCL-1 × JCL-2. Such promising crosses may be improved further through conventional breeding methods. The cross Nirmal × Prateek and JCL-2 × JCL-3 showed high positive heterosis for green forage yield per plant and the crosses Prateek × JCL-3, JCL-1 × JCL-2 and JCL-3 × JCL-4 were recognized as best heterotic crosses for low ODAP content. Hence, these crosses could be further evaluated to obtain superior segregants.

ACKNOWLEDGEMENT

The author is thankful to the Assam Agricultural University for providing the necessary facilities for completion of the research experiment.

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