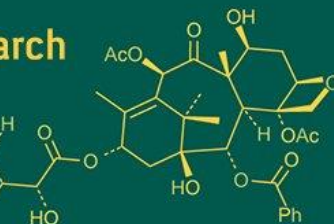
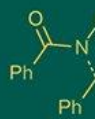


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Combining ability analysis for high yield and low ODAP content in *Lathyrus* (*Lathyrus sativus* L.)

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Abstract

The present investigation entitled “Combining ability analysis for high yield and low ODAP content in *lathyrus* (*Lathyrus sativus*)”. The experimental material consisted of thirteen lines and three testers crossed in a Line × Tester mating design to produce thirty-nine F₁ crosses. The parents and F₁ crosses were evaluated in a Randomized Block Design with three replications during the rabi season 2025-26 at the Research Farm of the Agricultural Botany Section, College of Agriculture, Nagpur. Observations were recorded for days to first flowering, days to 50% flowering, days to maturity, plant height, number of branches plant⁻¹, number of pods plant⁻¹, 100-seed weight, seed yield plant⁻¹ and ODAP content. Analysis of variance revealed highly significant difference among the genotypes for all the characters studied. Analysis of variance of combining ability indicated significant mean squares due to lines for all traits, due to testers for all traits except plant height and due to line × tester interactions for all characters except days to first flowering suggesting the importance of additive gene effects. The predictability ratio ranged from 0.68 for days to 50 % flowering to 0.99 for ODAP content, indicating the predominance of additive genetic effects for most of the characters. Among the lines, NLM-12, NLM-23 and NLK-73 were identified as superior general combiners for seed yield and important yield-contributing traits. Among the testers, Ratan was identified as a desirable general combiner, particularly for yield-associated traits. The crosses NLM-23 × Mahateora, NLM-23 × Prateek, NLM-12 × Mahateora and NLK-73 × Ratan exhibited negative significant specific combining ability effects along with appreciable per se performance for seed yield and associated traits and were identified as promising combinations for advancement in subsequent segregating generations.

Keywords: *Lathyrus*, Line × Tester, GCA, SCA, seed yield, ODAP

Introduction

Lathyrus sativus L., commonly known as grass pea or Kesari dal, is an important pulse crop belonging to the family Fabaceae. It is cultivated mainly for human consumption, livestock feed and fodder, particularly in regions where other crops perform poorly under adverse environmental conditions. The crop is well adapted to marginal and low-rainfall areas and possesses considerable tolerance to drought and other environmental stresses. In India, *Lathyrus* is cultivated mainly in states such as Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh and Maharashtra, and contributes significantly to pulse production. Its ability to grow under rainfed conditions with relatively low cultivation inputs makes it an important crop for subsistence farming and food security.

Grass pea is nutritionally valuable, with seeds containing substantial amounts of protein and carbohydrates, in addition to minerals and vitamins. The crop also contributes to soil fertility through biological nitrogen fixation, leaving a considerable amount of nitrogen for the succeeding crop. In several parts of India, *Lathyrus* is cultivated as a relay or utera crop in standing rice fields during the rabi season. Its adaptability to drought, low soil fertility and variable environmental conditions provides an opportunity for its expansion in marginal agricultural areas.

Despite its agronomic and nutritional importance, the utilization and improvement of *Lathyrus* are constrained by the presence of the neurotoxin β-N-oxalyl-L-α,β-diaminopropionic acid (β-ODAP), which is associated with neurolathyrism when consumed in excessive quantities over prolonged periods.

Therefore, the development of high-yielding and low-ODAP *Lathyrus* varieties is an important objective of grass pea breeding programmes. Exploitation of genetic variability for yield, yield-contributing traits and ODAP content is essential for achieving these objectives.

Combining ability analysis is an important tool in crop improvement for identifying superior parents and promising cross combinations. General combining ability (GCA) provides information on the average performance of parents in hybrid combinations and is mainly associated with additive genetic effects, whereas specific combining ability (SCA) indicates the performance of particular cross combinations and is largely related to non-additive genetic effects. Information on GCA and SCA helps breeders understand the genetic control of quantitative traits and facilitates the selection of suitable parents and cross combinations for developing improved varieties.

The Line $\times$ Tester mating design provides an efficient approach for evaluating a large number of parental lines and their hybrids. It enables the estimation of GCA and SCA effects and assists in understanding the relative contribution of additive and non-additive gene action in the inheritance of economically important traits. Such information is valuable for formulating effective breeding strategies and identifying parents with desirable combining ability and superior cross combinations.

Therefore, combining ability analysis of *Lathyrus* for yield, yield-contributing characters and ODAP content can provide useful information for the selection of elite parents and promising crosses. The identification of good combiners and superior cross combinations may contribute to the development of high-yielding and comparatively low-ODAP *Lathyrus* varieties, thereby supporting the improvement and wider utilization of this nutritionally important and stress-tolerant pulse crop.

Materials and Methods

The experimental material comprised of thirteen lines viz., NLK-6, NLK-42, NLK-37, NLK-56, NLK-102, NLK-49, NLK-74, NLK-73, NLK-38, EC-207071, NLM-12, NLM-17, NLM-23 and three testers viz., Ratan(check), Prateek(check) and Mahateora(check). During rabi 2024-25 thirteen lines and three testers were crossed following the Line $\times$ Tester mating design to obtain thirty-nine F_1 cross combinations. The resulting crosses, along with their parents and standard check varieties, were evaluated during the rabi season of 2025-26 in RBD design with three replications at the Research Farm of the Agricultural Botany Section, College of Agriculture, Nagpur. Observations were recorded on five randomly selected plants from each cross on days to first flowering, days to 50 % flowering, days to maturity, plant height, number of branches plant⁻¹, number of pods plant⁻¹, 100-seed weight(g), seed yield plant⁻¹(g) and ODAP content (%). The combining ability analysis was carried out as per standard method given by Kempthorne (1957)^[4] and ANOVA as per Panse and Sukhatme(1954)^[7].

Result and Discussion

Analysis of variance for experimental design

The analysis of variance revealed highly significant differences among the genotypes for all the characters studied, indicating the presence of considerable genetic variability in the experimental material as presented in table 1. The variability observed among the parents and crosses

provided sufficient scope for further assessment of combining ability and identification of superior parental lines and cross combinations for seed yield, yield-associated traits and ODAP content. In accordance to this results Lyngdoh *et al.* (2019)^[5], Nawale *et al.* (2024)^[6] and Singh *et al.* (2025)^[9] also observed significant genotypic variation for important agronomic traits in *lathyrus*.

Mean performance of parents and crosses

Most of the crosses exhibited intermediate mean performance of their respective parents for the characters studied, which may be attributed to the quantitative nature of these traits as observed from table 2. Out of the thirty-nine crosses evaluated, seventeen crosses showed significant superiority over the standard check Ratan for days to maturity, sixteen for plant height, four each for number of branches plant⁻¹, number of pods plant⁻¹ and seed yield plant⁻¹ and eleven crosses for ODAP content in the desirable direction. The crosses NLM-23 $\times$ Ratan, NLM-12 $\times$ Ratan, NLM-12 $\times$ Prateek and NLK-73 $\times$ Prateek showed desirable performance for seed yield and important yield-contributing traits along with reduced ODAP content. However, according to Allard (1960)^[11] *per se* performance of crosses gives only some indication of their usefulness in selecting potential crosses but their long term potential was not known, hence combining ability analysis was carried out for further evaluation. Similar to this result Gonmei *et al.* (2018)^[3], Sayyad *et al.* (2017)^[8], Nawale *et al.* (2024)^[6] and Singh *et al.* (2025) also reported that the *per se* performance of the parents and crosses were not sufficient for identification of superior parents and crosses.

Analysis of variance for combining ability

The analysis of variance for combining ability revealed that the mean squares due to lines were highly significant for all the characters studied, indicating substantial differences among the lines in their general combining ability. The mean squares due to testers were significant for all the traits except plant height. The line $\times$ tester interaction was significant for all the characters except days to first flowering, indicating considerable variation among the cross combinations and the importance of specific combining ability as presented in table 3. The magnitude of mean squares due to lines was higher than that of testers for days to 50 per cent flowering, days to maturity, plant height, number of branches plant⁻¹, number of pods plant⁻¹ and seed yield. plant⁻¹, suggesting greater genetic diversity among the lines for these characters. The significant effects of lines, testers and line $\times$ tester interactions indicated the importance of both general and specific combining ability in the inheritance of the characters studied. Similar findings were reported by Sayyad *et al.* (2017)^[8] and Nawale *et al.* (2024)^[6] in *lathyrus*.

Predictability ratio and nature of gene action

The predictability ratio ranged from 0.68 for days to 50 per cent flowering to 0.99 for ODAP content. The predictability ratio was greater than 0.50 for all the characters, being 0.93 for days to first flowering, 0.68 for days to 50 per cent flowering, 0.69 for days to maturity, 0.69 for plant height, 0.76 for number of branches plant⁻¹, 0.73 for number of pods plant⁻¹, 0.75 for 100-seed weight, 0.69 for seed yield plant⁻¹ and 0.99 for ODAP content. The higher predictability ratios suggested the predominance of additive

gene effects for the inheritance of the characters studied. The similar result was recorded by Sayyad *et al.* (2017) ^[8], Nawale *et al.* (2024) ^[6] and Singh *et al.* (2025). This indicated that the predictability of superior performing crosses/progenies could be effectively done based on general combining ability effects of parents alone. Therefore, selection strategies based on crosses involving parents showing significant gca effects would be useful for the genetic improvement of these characters in *Lathyrus*. In contrary to this finding Sayyad *et al.* (2017) ^[8] and Nawale *et al.* (2024) ^[6] also observed the situation where the performance of the progeny can be judged or predicted on the basis of parents gca effects and sca effect of crosses for different traits.

General combining ability effects

The gca effects of thirteen lines were calculated for all the nine characters and for testers it was estimated for all characters except for plant height as presented in Table 4. When the gca effects were compared for the nine characters, lines NLM-12 and NLM-23 recorded significant positive gca effects for seed yield plant⁻¹, number of pods plant⁻¹, number of branches plant⁻¹ and plant height. Similarly, another line NLK-73 exhibited significant positive gca effects for seed yield plant⁻¹, number of pods plant⁻¹ and number of branches plant⁻¹. Hence, these three lines, NLM-12, NLM-23 and NLK-73, were identified as good general combiners and can be used in the crossing programme. Among the testers, Ratan recorded significant positive gca effects for 100-seed weight and number of branches, non-significant but positive gca effects for seed yield plant⁻¹ and number of pods plant⁻¹. So, Ratan can also be used as a good combiner parent in the crossing programme. These parents may therefore be utilized in future hybridization programmes for simultaneous improvement of seed yield

and ODAP content.

Specific combining ability effects: The sca effects of thirty-nine crosses for all characters except days to first flowering were calculated and presented in Table 5. The crosses with significant sca effect involved high × poor combining parents for seed yield plant⁻¹, number of pods plant⁻¹ and number of branches plant⁻¹ and for ODAP content, low × low and low × high combining parents.

Specific combining ability effects of the crosses and the mean performance of the crosses were found to be in correspondence with one another. The mean performance of the identified crosses was intermediate between the two parents involved and at par with the superior check Ratan. Negative significant effects indicate the involvement of additive gene action for yield and yield components, which is a general situation in self-pollinated crops. Due to the presence of additive gene action in the crosses NLM-23 × Mahateora, NLM-23 × Prateek, NLM-12 × Mahateora and NLK-73 × Ratan, the genotypes of the inherent superiority can be produced from this population by blending and fixing maximum favourable genes. Improvement for seed yield can also be done by simple selection methods or any method which can effectively capitalize on additive gene action. These crosses also involved at least one parent having desirable GCA effects for seed yield and important yield components.

Based on the mean performance of crosses, GCA effects of parents and SCA effects of cross combinations, NLM-23 × Mahateora, NLM-23 × Prateek, NLM-12 × Mahateora and NLK-73 × Ratan were identified as promising cross combinations. These crosses may be advanced to subsequent segregating generations and subjected to simple selection for the development of high-yielding *lathyrus* genotypes with reduced ODAP content.

Table 1: Analysis of variance for different characters in *lathyrus*

Sources of variation	D.F	Mean squares								
		Days to first flowering	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of branches plant ⁻¹	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
Replications	2	2.44	1.17	3.02	24.99	0.05	35.77	0.024	0.9	0.0003
Genotypes	54	3.58**	4.32**	7.44**	70.59**	0.36**	176.92**	0.241**	12.187**	0.0540**
Error	108	1.12	0.55	1.66	28.25	0.03	22.29	0.121	2.05	0.0002

Note *, ** = Significant at 5% and 1% level respectively

Table 2: Mean performance of parents and crosses for various characters in *lathyrus*

Sr. No.	Genotypes	Days to first flowering	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of branches plant ⁻¹
	Lines					
1	NLK-6	51.00	55.67	122.00	68.67	4.13
2	NLK-42	53.67	55.67	124.00	68.00	3.87
3	NLK-37	51.67	57.33	126.33	63.67	3.53
4	NLK-56	53.00	56.67	124.33	63.33	4.07
5	NLK-102	53.67	57.33	122.00	62.00	3.93
6	NLK-49	51.00	55.67	125.00	66.67	3.93
7	NLK-74	53.67	58.33	124.33	63.33	3.67
8	NLK-73	53.33	58.67	127.67	69.00	4.13
9	NLK-38	51.00	55.33	125.33	66.33	3.40
10	EC-207071	53.00	58.33	123.00	69.00	4.27
11	NLM-12	50.33	56.33	123.00	64.00	4.00
12	NLM-17	53.00	58.33	123.67	68.67	4.33
13	NLM-23	51.67	58.00	125.00	67.67	3.60
	Testers					
14	Ratan	51.00	55.67	125.00	72.00	4.53
15	Prateek	55.00	58.33	122.33	64.67	4.33
16	Mahateora	52.00	55.67	125.33	62.67	4.20

Sr. No.	Genotypes	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
	Lines				
1	NLK-6	39.00	7.47	15.88	0.565
2	NLK-42	38.80	7.37	16.58	0.621
3	NLK-37	39.47	7.73	17.24	0.572
4	NLK-56	40.00	7.53	16.23	0.491
5	NLK-102	38.87	7.13	16.26	0.576
6	NLK-49	40.07	7.57	15.55	0.486
7	NLK-74	38.73	7.47	15.85	0.490
8	NLK-73	50.33	7.20	18.82	0.247
9	NLK-38	38.67	7.17	13.52	0.522
10	EC-207071	52.13	7.53	17.83	0.524
11	NLM-12	40.87	7.17	17.89	0.256
12	NLM-17	38.53	7.17	18.04	0.178
13	NLM-23	39.13	7.60	13.90	0.170
	Testers				
14	Ratan	56.73	7.83	18.52	0.250
15	Prateek	53.53	7.20	16.57	0.284
16	Mahateora	47.47	7.47	17.23	0.278

Table 2. Continued....

Sr. No.	Genotypes	Days to first flowering	Days to 50 % flowering	Days to maturity	Plant height (cm)
	Crosses				
17	NLK-6 × Ratan	51.33	55.33	123.67	63.33
18	NLK-6 × Prateek	52.33	56.67	124.33	62.67
19	NLK-6 × Mahateora	51.00	55.67	125.00	62.33
20	NLK-42 × Ratan	51.33	56.33	125.33	70.00
21	NLK-42 × Prateek	53.33	58.00	122.00	69.67
22	NLK-42 × Mahateora	52.33	58.33	121.67	64.33
23	NLK-37 × Ratan	51.00	56.33	122.33	57.67
24	NLK-37 × Prateek	53.67	58.00	121.33	56.67
25	NLK-37 × Mahateora	51.00	55.33	123.33	65.33
26	NLK-56 × Ratan	53.00	58.33	125.00	59.67
27	NLK-56 × Prateek	53.67	58.67	121.67	61.67
28	NLK-56 × Mahateora	52.33	57.33	125.00	59.00
29	NLK-102 × Ratan	51.67	56.00	122.67	59.67
30	NLK-102 × Prateek	53.00	57.67	125.33	68.00
31	NLK-102 × Mahateora	52.33	57.33	122.67	64.00
32	NLK-49 × Ratan	50.67	54.67	126.00	66.67
33	NLK-49 × Prateek	51.33	55.67	122.00	63.67
34	NLK-49 × Mahateora	50.33	56.33	125.00	67.33
35	NLK-74 × Ratan	52.00	56.33	124.67	71.00
36	NLK-74 × Prateek	52.33	57.33	121.33	67.67
37	NLK-74 × Mahateora	52.00	57.33	125.00	67.33
38	NLK-73 × Ratan	51.00	55.67	122.33	56.67
39	NLK-73 × Prateek	53.33	58.33	120.67	62.33
40	NLK-73 × Mahateora	51.67	57.33	121.67	66.67
41	NLK-38 × Ratan	51.33	55.67	124.00	64.67
42	NLK-38 × Prateek	53.67	58.33	125.67	55.33
43	NLK-38 × Mahateora	53.33	57.33	124.00	55.33
44	EC207071 × Ratan	50.33	55.33	123.67	58.00
45	EC207071 × Prateek	51.33	55.33	125.33	66.67
46	EC207071 × Mahateora	52.33	56.00	124.00	58.33
47	NLM-12 × Ratan	51.67	58.33	121.33	73.67
48	NLM-12 × Prateek	51.33	54.67	123.33	78.33
49	NLM-12 × Mahateora	51.33	55.67	125.00	60.00
50	NLM-17 × Ratan	51.00	56.33	123.00	64.00
51	NLM-17 × Prateek	52.33	55.67	122.00	62.00
52	NLM-17 × Mahateora	53.00	58.33	122.33	73.00
53	NLM-23 × Ratan	50.67	58.00	124.33	70.67
54	NLM-23 × Prateek	52.33	55.67	122.67	68.33
55	NLM-23 × Mahateora	51.33	56.00	121.33	67.00
	Mean	52.05	56.81	123.67	64.88
	S.E (m)	0.611	0.429	0.745	3.069
	C.D 5%	1.714	1.203	2.089	8.603

Table 2. Continued....

Sr. No.	Genotypes	Number of branches plant ⁻¹	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
	Crosses					
17	NLK-6 × Ratan	4.20	50.33	7.93	16.52	0.388
18	NLK-6 × Prateek	4.33	53.07	7.13	17.61	0.508
19	NLK-6 × Mahateora	3.73	44.87	7.53	17.90	0.438
20	NLK-42 × Ratan	4.20	50.60	8.10	17.24	0.413
21	NLK-42 × Prateek	4.13	42.53	7.20	15.67	0.548
22	NLK-42 × Mahateora	3.93	45.20	7.47	15.73	0.473
23	NLK-37 × Ratan	3.93	43.67	7.70	16.24	0.363
24	NLK-37 × Prateek	3.40	38.87	7.90	16.39	0.488
25	NLK-37 × Mahateora	3.93	47.73	7.47	16.72	0.398
26	NLK-56 × Ratan	3.80	42.67	7.70	16.70	0.263
27	NLK-56 × Prateek	3.93	42.93	7.87	16.07	0.413
28	NLK-56 × Mahateora	4.13	44.20	7.17	16.21	0.323
29	NLK-102 × Ratan	4.20	42.40	7.97	17.90	0.393
30	NLK-102 × Prateek	3.73	48.27	7.20	16.24	0.523
31	NLK-102 × Mahateora	3.93	38.73	7.47	15.38	0.443
32	NLK-49 × Ratan	4.07	41.33	7.70	17.26	0.243
33	NLK-49 × Prateek	3.87	40.53	7.53	15.88	0.393
34	NLK-49 × Mahateora	4.13	42.73	7.23	16.57	0.303
35	NLK-74 × Ratan	3.93	48.67	7.77	15.71	0.258
36	NLK-74 × Prateek	3.87	40.53	7.13	16.18	0.408
37	NLK-74 × Mahateora	4.13	42.00	7.87	17.78	0.318
38	NLK-73 × Ratan	3.93	39.87	7.23	16.68	0.148
39	NLK-73 × Prateek	4.87	65.87	7.67	21.91	0.228
40	NLK-73 × Mahateora	4.33	53.47	7.67	18.22	0.213
41	NLK-38 × Ratan	3.93	41.93	7.53	15.73	0.333
42	NLK-38 × Prateek	3.40	39.60	7.20	15.85	0.473
43	NLK-38 × Mahateora	4.20	41.80	7.20	17.58	0.393
44	EC207071 × Ratan	4.07	40.93	7.40	15.22	0.313
45	EC207071 × Prateek	4.07	42.00	7.53	16.24	0.463
46	EC207071 × Mahateora	3.60	37.60	8.03	14.68	0.373
47	NLM-12 × Ratan	4.93	66.73	7.17	23.33	0.177
48	NLM-12 × Prateek	4.87	65.87	7.20	22.24	0.206
49	NLM-12 × Mahateora	4.27	41.07	7.43	16.56	0.183
50	NLM-17 × Ratan	3.93	40.53	8.07	14.87	0.163
51	NLM-17 × Prateek	3.93	51.00	7.27	16.53	0.238
52	NLM-17 × Mahateora	3.80	48.13	7.63	17.28	0.158
53	NLM-23 × Ratan	4.93	68.40	7.87	24.37	0.160
54	NLM-23 × Prateek	4.27	47.67	7.80	16.56	0.223
55	NLM-23 × Mahateora	4.07	43.20	7.30	15.53	0.148
	Mean	4.05	45.45	7.51	16.97	0.353
	S.E (m)	0.102	2.726	0.121	0.828	0.007
	C.D 5%	0.287	7.641	0.388	2.322	0.020

Table 3: Analysis of variance for combining ability in *lathyrus* for different characters

Sources of variation	D.F	Mean squares								
		Days to first flowering	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of branches plant ⁻¹	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
Lines	12	3.42**	5.09**	7.73**	142.11**	0.63**	267.91**	0.14**	19.78**	0.1032**
Testers	2	16.78**	3.41**	7.25*	9.8	0.21**	174.8**	0.77**	8.02*	0.1542**
Lines × Testers	24	1.31	3.88**	6.48**	65.91*	0.26**	159.54**	0.29**	12.28**	0.0009**
Error	76	0.899	0.507	1.699	33.32	0.038	20.69	0.039	2.026	0.0001
GCA vs SCA		0.93	0.68	0.69	0.69	0.76	0.73	0.75	0.69	0.99

Note: *, ** = Significant at 5% and 1% level respectively.

Table 4: GCA effect of parents for different characters in *lathyrus*

Sr. No.	Parents	Days to first flowering	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of branches plant ⁻¹	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
Lines										
1	NLK-6	-0.3761	-0.8034 **	0.9487 *	-1.5470	0.0137	3.0752 *	-0.0111	0.2340	0.1112 **
2	NLK-42	0.4017	0.8632 **	-0.3846	3.6752	0.0137	-0.2359	0.0444	-0.8949	0.1446 **
3	NLK-37	-0.0427	-0.1368	-1.0513 *	-4.4359 *	-0.3197 **	-2.9248	0.1444*	-0.6615	0.0829 **
4	NLK-56	1.0684 **	1.4188 **	0.5043	-4.2137 *	-0.1197	-3.0803 *	0.0333	-0.7838	-0.0004
5	NLK-102	0.4017	0.3077	0.1709	-0.4359	-0.1197	-3.2137 *	0.0001	-0.6026	0.1196 **
6	NLK-49	-1.1538 **	-1.1368 **	0.9487 *	1.5641	-0.0530	-4.8137 **	-0.0556	-0.5404	-0.0204**
7	NLK-74	0.1795	0.3077	0.2821	4.3419 *	-0.0974	-2.6137	0.0444	-0.5538	-0.0054
8	NLK-73	0.0684	0.4188	-1.8291 **	-2.4359	0.3026 **	6.7197 **	-0.0222	1.8285 **	-0.1188 **
9	NLK-38	0.8462 **	0.4188	1.1709 **	-5.8803 **	-0.2308 **	-5.2359 **	-0.233**	-0.7226	0.0662 **
10	EC-207071	-0.5983	-1.1368 **	0.9487 *	-3.3248	-0.1641 *	-6.1692 **	0.1111	-1.7293 **	0.0496 **
11	NLM-12	-0.4872	-0.4701	-0.1624	6.3419 **	0.6137 **	11.541 **	-0.277**	3.5996 **	-0.1257 **
12	NLM-17	0.1795	0.0855	-0.9402 *	2.0085	-0.1863 **	0.2085	0.1111	-0.8826	-0.1469 **
13	NLM-23	-0.4872	-0.1368	-0.6068	4.3419 *	0.3470 **	6.7419 **	0.1111	1.7096 **	-0.1563 **
	S.E (lines)	0.316	0.237	0.434	1.924	0.064	1.516	0.066	0.474	0.003
Testers										
14	Ratan	-0.6239 **	-0.3333 **	0.3333	-	0.0838 **	1.1966	0.1581**	0.4132	-0.0553 **
15	Prateek	0.6838 **	0.2308*	-0.4872 *	-	-0.0239	1.2479	-0.111**	0.0722	0.0684 **
16	Mahateora	-0.0598	0.1026	0.1538	-	-0.0598	-2.4444 **	-0.0470	-0.4855 *	-0.0131 **
	S.E (tester)	0.152	0.114	0.209	-	0.031	0.728	0.032	0.228	0.002

Note: As the mean square due to tester was non-significant gca effect of lines were not estimated for plant height.

Table 5: SCA effect of crosses for different characters in *lathyrus*

Sr. No.	Crosses	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of branches plant ⁻¹
1	NLK-6 × Ratan	-0.2222	-1.0000	0.5983	0.0274
2	NLK-6 × Prateek	0.5470	0.4872	-0.6325	0.2684 *
3	NLK-6 × Mahateora	-0.3248	0.5128	0.0342	-0.2957 *
4	NLK-42 × Ratan	-0.8889 *	2.0000 **	2.0427	0.0274
5	NLK-42 × Prateek	0.2137	-0.5128	1.1453	0.0684
6	NLK-42 × Mahateora	0.6752	-1.4872	-3.1880	-0.0957
7	NLK-37 × Ratan	0.1111	-0.3333	-2.1795	0.0940
8	NLK-37 × Prateek	1.2137 **	-0.5128	-3.7436	-0.3316 **
9	NLK-37 × Mahateora	-1.3248 **	0.8462	5.9231	0.2376 *
10	NLK-56 × Ratan	0.5556	0.7778	-0.4017	-0.2393 *
11	NLK-56 × Prateek	0.3248	-1.7350 *	1.0342	0.0017
12	NLK-56 × Mahateora	-0.8803 *	0.9573	-0.6325	0.2376 *
13	NLK-102 × Ratan	-0.6667	-1.2222	-4.1795	0.1607
14	NLK-102 × Prateek	0.4359	2.2650 **	3.5897	-0.1983
15	NLK-102 × Mahateora	0.2308	-1.0427	0.5897	0.0376
16	NLK-49 × Ratan	-0.5556	1.3333	0.8205	-0.0393
17	NLK-49 × Prateek	-0.1197	-1.8462 *	-2.7436	-0.1316
18	NLK-49 × Mahateora	0.6752	0.5128	1.9231	0.1709
19	NLK-74 × Ratan	-0.3333	0.6667	2.3761	-0.1282
20	NLK-74 × Prateek	0.1026	-1.8462 *	-1.5214	-0.0872
21	NLK-74 × Mahateora	0.2308	1.1795	-0.8547	0.2154
22	NLK-73 × Ratan	-1.1111 **	0.4444	-5.1795	-0.5282 **
23	NLK-73 × Prateek	0.9915 *	-0.4017	-0.0769	0.5128 **
24	NLK-73 × Mahateora	0.1197	-0.0427	5.2564	0.0154
25	NLK-38 × Ratan	-1.1111 **	-0.8889	6.2650	0.0051
26	NLK-38 × Prateek	0.9915 *	1.5983 *	-3.6325	-0.4205 **
27	NLK-38 × Mahateora	0.1197	-0.7094	-2.6325	0.4154 **
28	EC207071 × Ratan	0.1111	-1.0000	-2.9573	0.0718
29	EC207071 × Prateek	-0.4530	1.4872	5.1453	0.1795
30	EC207071 × Mahateora	0.3419	-0.4872	-2.1880	-0.2513 *
31	NLM-12 × Ratan	2.4444 **	-2.2222 **	3.0427	0.1607
32	NLM-12 × Prateek	-1.7863 **	0.5983	7.1453 *	0.2017
33	NLM-12 × Mahateora	-0.6581	1.6239 *	-10.1880 **	-0.3624 **
34	NLM-17 × Ratan	-0.1111	0.2222	-2.2906	-0.0393
35	NLM-17 × Prateek	-1.3419 **	0.0427	-4.8547	0.0684
36	NLM-17 × Mahateora	1.4530 **	-0.2650	7.1453 *	-0.0291
37	NLM-23 × Ratan	1.7778 **	1.2222	2.0427	0.4274 **
38	NLM-23 × Prateek	-1.1197 **	0.3761	-0.8547	-0.1316
39	NLM-23 × Mahateora	-0.6581	-1.5983 *	-1.1880	-0.2957 *
	S.E (crosses)	0.411	0.753	3.333	0.112

Note: As the mean square due to line × tester was non-significant sca effect of crosses were not estimated for days to first flowering

Sr. No.	Crosses	Number of pods plant ⁻¹	100 seed weight (g)	Seed yield plant ⁻¹ (g)	ODAP content (%)
1	NLK-6 × Ratan	-0.2855	0.2419 *	-1.2332	-0.0014
2	NLK-6 × Prateek	2.3966	-0.2889 *	0.1944	-0.0051
3	NLK-6 × Mahateora	-2.1111	0.0470	1.0388	0.0065
4	NLK-42 × Ratan	3.2923	0.3530 **	0.6156	-0.0097
5	NLK-42 × Prateek	-4.8256	-0.2778 *	-0.6133	0.0016
6	NLK-42 × Mahateora	1.5333	-0.0752	-0.0023	0.0081
7	NLK-37 × Ratan	-0.9521	-0.1470	-0.6210	0.0019
8	NLK-37 × Prateek	-5.8034 *	0.3222 **	-0.1333	0.0033
9	NLK-37 × Mahateora	6.7556 *	-0.1752	0.7544	-0.0052
10	NLK-56 × Ratan	-1.7966	-0.0359	-0.0355	-0.0147 *
11	NLK-56 × Prateek	-1.5812	0.4000 **	-0.3311	0.0116
12	NLK-56 × Mahateora	3.3778	-0.3641 **	0.3666	0.0031
13	NLK-102 × Ratan	-1.9299	0.2641 *	0.9834	-0.0047
14	NLK-102 × Prateek	3.8855	-0.2333 *	-0.3422	0.0016
15	NLK-102 × Mahateora	-1.9556	-0.0308	-0.6412	0.0031
16	NLK-49 × Ratan	-1.3966	0.0530	0.2745	-0.0147 *
17	NLK-49 × Prateek	-2.2479	0.1556	-0.7611	0.0116
18	NLK-49 × Mahateora	3.6444	-0.2085	0.4866	0.0031
19	NLK-74 × Ratan	3.7368	0.0197	-1.2555	-0.0147 *
20	NLK-74 × Prateek	-4.4479	-0.3444 **	-0.4511	0.0116
21	NLK-74 × Mahateora	0.7111	0.3248 **	1.7066 *	0.0031
22	NLK-73 × Ratan	-14.3966 **	-0.4470 **	-2.6677 **	-0.0114
23	NLK-73 × Prateek	11.5521 **	0.2556 *	2.8967 **	-6.84e-05
24	NLK-73 × Mahateora	2.8444	0.1915	-0.2290	0.0115
25	NLK-38 × Ratan	-0.3744	0.0641	-1.0699	-0.0114
26	NLK-38 × Prateek	-2.7590	0.0001	-0.6056	0.0049
27	NLK-38 × Mahateora	3.1333	-0.0641	1.6755 *	0.0065
28	EC207071 × Ratan	2.3966	-0.4137 **	-0.5732	-0.0147 *
29	EC207071 × Prateek	0.5744	-0.0111	0.7911	0.0116
30	EC207071 × Mahateora	-0.1333	0.4248 **	-0.2179	0.0031
31	NLM-12 × Ratan	7.6479 **	-0.2581 *	2.2112 **	0.0248 **
32	NLM-12 × Prateek	6.7299 *	0.0444	1.4556	-0.0132
33	NLM-12 × Mahateora	-14.377 **	0.2137	-3.6668 **	-0.0116
34	NLM-17 × Ratan	-7.2188 **	0.2530 *	-1.7666 *	0.0324 **
35	NLM-17 × Prateek	3.1966	-0.2778 *	0.2311	-0.0170 **
36	NLM-17 × Mahateora	4.0222	0.0248	1.5355	-0.0154 *
37	NLM-23 × Ratan	14.1145 **	0.0530	5.1379 **	0.0385 **
38	NLM-23 × Prateek	-6.6701 *	0.2556 *	-2.3311 **	-0.0225 **
39	NLM-23 × Mahateora	-7.4444 **	-0.3085 **	-2.8068 **	-0.0160 **
	S.E (crosses)	2.626	0.114	0.822	0.006

Table 6: Potential crosses identified

Sr. No.	Crosses	Characters	Mean	sca effects	GCA effects	
					P1	P2
1	NLM-23 × Mahateora	Yield	15.53	-2.8068**	1.7096**	-0.4855**
		NOP	43.20	-7.4444**	6.7419**	-2.4444**
		NOB	4.07	-0.2957**	0.3470**	-0.0598**
		ODAP	0.148	-0.0160**	-0.1563**	-0.0131**
2	NLM-23 × Prateek	Yield	16.56	-2.3311**	1.7096**	0.0722
		NOP	47.67	-6.6701**	6.7419**	1.247
		NOB	4.27	-0.1316	0.3470**	-0.0239
		ODAP	0.223	-0.0225**	-0.1563**	0.0684**
3	NLM-12 × Mahateora	Yield	16.56	-3.6668**	3.5996**	-0.4855**
		NOP	41.07	-14.3778**	11.541**	-2.4444**
		NOB	4.27	-0.3624**	0.6137**	-0.0598**
		ODAP	0.183	-0.0116	-0.1257**	-0.0131**
4	NLK-73 × Ratan	Yield	16.68	-2.6677**	1.8285**	0.4132
		NOP	39.87	-14.3966**	6.7197**	1.1966
		NOB	3.93	-0.5282**	0.3026**	0.0838**
		ODAP	0.148	-0.0114	-0.1188**	-0.0555**

Note: Yield = Yield plant⁻¹ (g), NOB = Number of branches plant⁻¹,
 NOP = Number of pods plant⁻¹,
 ODAP (%) = β-N-oxalyl-L-α, β-diaminopropionic acid.

Conclusion

The present investigation demonstrated substantial genetic variability among the evaluated *Lathyrus sativus* genotypes, providing adequate scope for effective selection and genetic improvement. Combining ability analysis revealed significant contributions of lines, testers and line $\times$ tester interactions for most of the studied traits, indicating the involvement of both additive and non-additive genetic effects. The relatively high predictability ratios suggested a predominance of additive gene action, particularly for seed yield, yield-contributing traits and ODAP content, indicating the effectiveness of selection based on superior general combiners. NLM-12, NLM-23 and NLK-73 were identified as promising general combiners, while Ratan was a desirable tester for yield-associated traits. The crosses NLM-23 $\times$ Mahateora, NLM-23 $\times$ Prateek, NLM-12 $\times$ Mahateora and NLK-73 $\times$ Ratan showed desirable specific combining ability and promising performance. These parents and crosses can therefore be effectively utilized in future breeding programmes for developing high-yielding, agronomically superior and comparatively low-ODAP *Lathyrus* varieties.

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