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## Original Research Article

# Combining Ability Analysis in Lentil (*Lens culinaris* Medik. L.)

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**A B S T R A C T**

Using L × T mating design with three lines as females and five testers used as male the general combining ability (GCA) of parents and specific combining ability (SCA) of crosses were carried out for grain yield and its attributes. The SCA variances recorded greater than the GCA variance for grain yield and yield components, suggesting the preponderance of dominance and epistatic gene action in the expression of these traits. Parents RL 7, EC 267554 and JL 3 were found as good general combiners for seed yield and its compounds, whereas, IPL 81 and L 4717 were good for earliness. Similarly, the cross combinations IPL 81×EC 267554, L 4076×EC 267583, JL 3×RL 7, IPL 81×RL 7 and L 4076×L 4717 were found to be desirable with respect to yield and most of its components. IPL 81×EC 267554 having high SCA effects and involved one of the high GCA parent showed high *per se* performance, pods per plant and harvest index. The cross seems to be promising and can be exploited for transgressive segregation in yield improvement programme of lentil.

**Keywords**

GCA, SCA, Lentil and Line × Tester

## Introduction

Lentil is also commonly known as "Poor man's meet", as it is one of affordable protein rich legume. During the past few years, world production of lentil has increased from 2.76 to 3.60 metric tons. In India, lentil was cultivated on 1.47 million hectares in 2014-15 with a production of 1.04 metric ton (Anonymous, 2016). Lentil is recognized as one of the most nutritious pulse crops ranking next to chickpea amongst *Rabi* pulses. Lentils are relatively tolerant to drought, and are grown throughout the world.

The first step in successful yield improvement programme of lentil is to select appropriate parents. The line x tester analysis method is used to breed both self and cross-pollinated plants and to estimates favourable parents and crosses and their general and specific combining abilities (Kempthorne, 1957). Combining ability analysis is an important tool for the selection of desirable parents together with the information regarding nature and magnitude of gene effects controlling quantitative traits (Basbag *et al.*, 2007; Kumar *et al.*, 2015). Combining ability analysis provides to the breeders an insight into the nature and relative magnitude of fixable and non-fixable genetic variance which is helpful in planning of a sound breeding programme. Marilia *et al.*, (2001) stated that specific combining ability (SCA) effects of hybrids alone had limited power for parental selection in breeding programme and must be used in combination with other parameters such as hybrid means and GCA of the respective parents. The hybrid combinations with high mean performance, desirable SCA estimates and involving at least one of the parents with high GCA would likely enhance the concentration of favorable alleles (Thirumeni *et al.,* 2000; Manivannan and Ganesan, 2001; Kenga *et al.,* 2004; Gnanasekaran *et al.,* 2006). Keeping in view the above considerations, the present investigation was undertaken to identify the desirable parents and cross combinations on the basis of combining ability by using line × tester method, for their use in future lentil improvement programme.

## Materials and Methods

The material for the present study combining ability comprised three lines *viz.*, L 4076, JL 3 and IPL 81 and five testers *viz.*, RL 7, EC 267554, LL 4710, L 4717 and EC 267583 through line × testers design during *Rabi* season 2015-16.

The generated 15 crosses along with their parents were grown in randomized complete block design during *Rabi* 2016-17 with three replications at Research and Instructional Farm, IGKV, Raipur. Each genotype was grown in a row of 2 meter length. The row to row distance was 30 cm and 5-7 cm between plants. All the recommended package of practices was followed to facilitate crop growth and development.

Five competitive plants were randomly selected for each genotype in each replication and biometrical observations were recorded. The mean data was analyzed for combining ability following the standard method of Kempthorne (1957).

## Results and Discussion

The results revealed sufficient variability present in the material under study. The comparative estimates of variance due to GCA and SCA revealed the importance of SCA variance, suggesting the significance of dominance and epistatic gene action for controlling the yield components (Table 1).

Combining ability analysis revealed that the estimates of *sca* variance were greater than the *gca* variance for days to 50% flowering, days to maturity, number of pods per plant, 100-seed weight, number of seeds per plant and seed yield, indicating the predominance of non-additive gene action for these traits and suggesting that selection and inter mating in early segregating generations will be desirable for exploiting non-additive gene effects. Joshi *et al.*, (2005) also reported the important role of non-additive gene action for all these characters in lentil. Non-additive gene effects for days to maturity and grain yield were also reported by Khan *et al.,* (2006) whereas, Kumar and Srivastava (2007) reported that additive gene action was predominant in inheritance of seeds per pod, 100-seed weight and grain yield and non-additive gene action for days to 50% flowering, plant height and branches per plant, pods per plant and harvest index in lentil.

The estimates of *gca* effects showed that parent RL 7 was found as best general combiner for seed yield per plant, earliness, number of seeds per plant, seed boldness and high biomass whereas, parent EC 267554 was found as best general combiner for seed yield per plant, plant height, number of seeds per plant. While, parent JL 3 was found as best general combiner for seed yield per plant, tallness, number of pod clusters per plant, number of seeds per plant and high biomass production.

**Table.1** Analysis of variance for line x tester for yield and its attributes in Lentil

| Source of variation | DF | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branchesplant$^{-1}$ | No. of secondary branches plant$^{-1}$ | No of pods plant$^{-1}$ | No. of pod clusters plant$^{-1}$ | No. of seeds plant$^{-1}$ | Length of first pod bearing node (cm) | 100 seed weight (g) | Protein content (%) | Seed yield plant$^{-1}$ (g) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 2.26 | 0.13 | 0.30 | 0.10 | 21.46 | 1.28 | 23.98 | 27.25 | 0.02 | 0.00 | 0.49 | 0.09 | 10.24 |
| Treatments | 22 | 15.83** | 52.90** | 6.84** | 0.67** | 114.23** | 20720.27** | 5324.36** | 25562.97** | 2.13** | 0.17** | 10.47** | 17.35** | 143.35** |
| Parents | 7 | 10.26** | 8.95** | 2.43** | 0.97** | 27.41* | 5831.09** | 2404.12** | 6863.17** | 3.44** | 0.11** | 6.79* | 2.59** | 292.80** |
| Parents vs hybrids | 1 | 29.95** | 394.79** | 0.83 | 6.56** | 816.80** | 277778.75** | 86569.27** | 352724.60** | 1.28 | 0.71** | 22.16** | 231.30** | 1.77 |
| Hybrids | 14 | 17.61** | 50.45** | 9.47** | 0.10 | 107.46** | 9803.54** | 981.28* | 11544.18** | 1.53* | 0.16** | 11.47* | 9.45** | 78.74** |
| Lines | 2 | 28.07 | 92.36 | 5.26 | 0.10 | 95.76 | 16495.60 | 2296.82 | 17751.22 | 0.31 | 0.15 | 21.23 | 3.75 | 258.45 |
| Testers | 4 | 18.74 | 13.41 | 11.37 | 0.07 | 6.72 | 10597.70 | 804.59 | 8706.96 | 0.80 | 0.25 | 0.34 | 13.24 | 35.38 |
| Lines vs testers | 8 | 14.43** | 58.49** | 9.58** | 0.12 | 160.76** | 7733.44** | 740.74* | 11411.04** | 2.20** | 0.12* | 14.60** | 8.97** | 55.48** |
| Error | 44 | 1.48 | 0.33 | 0.38 | 0.06 | 8.27 | 7.25 | 10.33 | 17.66 | 0.37 | 0.00 | 0.64 | 0.10 | 4.82 |
| Total | 68 | 6.15 | 17.33 | 2.47 | 0.26 | 42.94 | 6708.35 | 1729.98 | 8282.60 | 0.93 | 0.06 | 3.82 | 5.68 | 49.80 |
| $\sigma^2$gca | | 0.75 | -0.47 | -0.11 | -0.01 | -9.13 | 484.44 | 67.50 | 151.51 | -0.14 | 0.01 | -0.32 | -0.04 | 7.61 |
| $\sigma^2$sca | | 4.32 | 19.39 | 3.07 | 0.02 | 50.83 | 2575.40 | 243.48 | 3797.79 | 0.62 | 0.04 | 4.65 | 2.96 | 16.89 |
| $\sigma^2$gca/ $\sigma^2$sca | | 0.18 | -0.02 | -0.04 | -0.50 | -0.17 | 0.19 | 0.28 | 0.04 | -0.23 | 0.25 | -0.07 | -0.02 | 0.46 |

*, ** differed significantly at 5 and 1 per cent, respectively

**Table.2** General combining ability effects of parents for yield and its attributes in Lentil

| Parents | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branches plant$^{-1}$ | No. of secondary branches plant$^{-1}$ | No. of pods plant$^{-1}$ | No. of pod clusters plant$^{-1}$ | No. of seeds plant$^{-1}$ | Length of first pod bearing node | 100 seed weight (g) | Protein content (%) | Seed yield plant$^{-1}$ | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lines | | | | | | | | | | | | | |
| L 4076 | -0.06 | 0.31 | -0.36* | -0.08 | -2.52** | -27.87** | 4.42* | -23.88** | -0.10 | 0.12** | -0.67* | -0.19 | 1.37 |
| JL 3 | 1.40** | 2.31** | 0.68** | 0.08 | 0.04 | 36.68 | 9.55** | 39.43* | -0.06 | -0.04 | 1.37** | 0.57** | 3.29** |
| IPL 81 | -1.33** | -2.62** | -0.32 | -0.01 | 2.52** | -8.80* | -13.97** | -15.56* | 0.16* | -0.07* | -0.70* | -0.38* | -4.66* |
| SE (Lines) | 0.08 | 0.03 | 0.04 | 0.02 | 0.19 | 0.17 | 0.21 | 0.28 | 0.04 | 0.00 | 0.05 | 0.02 | 0.15 |
| Tester | | | | | | | | | | | | | |
| RL 7 | -1.91** | -1.58 | -0.04 | -0.02 | -0.67 | 30.14 | 1.18 | 30.55** | -0.13 | 0.13** | 0.08 | 1.21** | 2.28* |
| EC 267554 | 0.42 | 0.98* | 1.05** | -0.07 | 0.97 | 33.43 | -7.49** | 30.64** | 0.00 | -0.25 | -0.33 | 1.22** | -0.91 |
| LL 4710 | 0.87* | 1.09 | 1.09 | 0.11* | 0.91 | -15.71* | 6.18* | -16.45 | 0.40* | 0.02 | 0.10 | -0.89 | 0.27 |
| EC 267583 | 1.64 | 0.53* | -0.51 | 0.07 | -0.47 | 1.49 | 11.51** | -3.30 | -0.40 | -0.07 | 0.17 | -0.09 | 1.21 |
| L 4717 | -1.02* | -1.02* | -1.58** | -0.09 | -0.74 | -49.35** | -11.38** | -41.43* | 0.13 | 0.17** | -0.03 | -1.45* | -2.85** |
| SE (Tester) | 0.13 | 0.06 | 0.07 | 0.02 | 0.32 | 0.29 | 0.35 | 0.46 | 0.07 | 0.00 | 0.09 | 0.04 | 0.24 |

*, ** differed significantly at 5 and 1 per cent, respectively

**Table.3** Specific combining ability effects of hybrids for yield and its attributes in Lentil

| Hybrids | Days to 50% flowering | Days to maturity | Plant height (cm) | No. of primary branches plant$^{-1}$ | No. of secondary branches plant$^{-1}$ | No. of pods plant$^{-1}$ | No. of pod clusters plant$^{-1}$ | No. of seeds plant$^{-1}$ | Length of first pod bearing node | 100 seed weight (g) | Protein content (%) | Seed yield plant$^{-1}$ | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L 4076 × RL 7 | -0.82 | -1.76* | -1.18* | 0.08 | -8.72** | -26.68* | 12.69** | -40.15** | -0.52 | 0.06 | -1.93** | -2.30** | -1.83 |
| L 4076 × EC 267554 | -1.82* | -3.98** | 0.53 | 0.12 | -2.09 | -38.71** | 6.36* | -41.24** | 0.95* | -0.12* | 0.23 | -0.37 | -2.64* |
| L 4076 × LL 4710 | -1.26 | -0.42 | 0.10 | -0.12 | 0.97 | -21.97* | -17.31** | -26.15* | -0.85* | 0.04 | -0.23 | -0.74 | -0.24 |
| L 4076 × EC 267583 | 1.95** | 3.47* | -1.41** | -0.01 | 12.75** | 20.96** | -5.31 | 24.76 | 0.15 | -0.06 | 2.60** | 1.74** | -0.54 |
| L 4076 × L 4717 | 1.95** | 2.69 | 1.96 | -0.06 | -2.92 | 66.40** | 3.58 | 82.76** | 0.28 | 0.08* | -0.69 | 1.67** | 5.26** |
| JL 3 × RL 7 | 1.71* | 4.91* | 1.80 | 0.25 | 5.15** | 44.30** | -18.78** | 61.61** | -0.43 | -0.26* | -1.00* | 1.58** | 1.83 |
| JL 3 × EC 267554 | 0.04 | 1.02 | -0.82* | -0.17 | -2.36 | -28.19* | -10.78* | -38.54** | 0.17 | 0.03 | -1.25 | -1.40* | -3.50* |
| JL 3 × LL 4710 | 0.26 | -3.09* | -1.15** | 0.12 | 0.11 | 25.68** | 24.89** | 24.41 | 1.04* | -0.09 | 0.95 | 0.63* | -0.84 |
| JL 3 × EC 267583 | -2.84** | -4.87 | 2.35** | -0.04 | -7.65** | 15.15* | 11.56** | 15.72 | -0.29 | 0.08 | -1.35 | -0.47 | 4.75** |
| JL 3 × L 4717 | 0.82 | 2.02 | -2.18 | -0.15 | 4.75* | -56.94** | -6.89 | -63.21** | -0.49 | 0.24** | 2.65** | -0.34 | -2.25 |
| IPL 81 × RL 7 | -0.88 | -3.16 | -0.62 | -0.32* | 3.56* | -17.62 | 6.09 | -21.47* | 0.95* | 0.20* | 2.93** | 0.72* | 0.00 |
| IPL 81 × EC 267554 | 1.77* | 2.96 | 0.29 | 0.05 | 4.45* | 66.89** | 4.42 | 79.78** | -1.12* | 0.09 | 1.01 | 1.76** | 6.14** |
| IPL 81 × LL 4710 | 1.00 | 3.51** | 1.05* | 0.01 | -1.08 | -3.71 | -7.58 | 1.73 | -0.19 | 0.05 | -0.72 | 0.11 | 1.08 |
| IPL 81 × EC 267583 | 0.88 | 1.40 | -0.94 | 0.05 | -5.10* | -36.11** | -6.24 | -40.49** | 0.15 | -0.02 | -1.26* | -1.26* | - 4.21* |
| IPL 81 × L 4717 | -2.77** | -4.71 | 0.22 | 0.21 | -1.84 | -9.46 | 3.31 | -19.56* | 0.21 | -0.32** | -1.96** | -1.33* | - 3.01* |
| SE (Hybrids) | 4.04 | 0.19 | 0.20 | 0.08 | 0.95 | 0.89 | 1.07 | 1.40 | 0.20 | 0.00 | 0.27 | 0.10 | 0.73 |

*, ** differed significantly at 5 and 1 per cent, respectively

**Table.4** Performance of best cross combinations of lentil for seed yield and other traits

| S. No. | Crosses | *Per se* performance | SCA effects | GCA effects $P_1$ | GCA effects $P_2$ | Other traits showing desirable SCA effects |
|---|---|---|---|---|---|---|
| 1. | IPL 81 × EC 267554 | 9.15 | 1.76** | -0.38* | 1.22** | No. of primary branches per plant, No. of secondary branches per plant, No. of pods per plant, No. of pod clusters per plant, No. of seeds per plant |
| 2. | JL 3 × RL 7 | 9.89 | 1.58** | 0.57** | 1.21** | Harvest index, No. of pods per plant, Plant height, No. of primary branches per plant, No. of secondary branches per plant, No. of pod clusters per plant, No. of seeds per plant |
| 3. | IPL 81 × RL 7 | 8.09 | 0.72* | -0.38* | 1.21** | Days to 50% flowering, 100-seed weight, No. of seeds per plant, No. of primary branches per plant, No. of secondary branches per plant, No. of pods per plant, No. of pod clusters per plant |
| 4. | L 4076 × L 4717 | 6.57 | 1.67** | -0.19 | -1.45* | 100-seed weight, Days to maturity, No. of pod clusters per plant, No. of pods per plant, No. of seeds per plant |
| 5. | L 4076 × EC 267583 | 8.00 | 1.74** | -0.19 | -0.09 | Days to 50% flowering, Days to maturity, No. of secondary branches per plant |

*, ** Significant at 5 and 1 per cent levels, respectively

The high *gca* effects are generally ascribed to additive gene effects or additive × additive interaction effects (Griffing 1956) hence, the good general combiners can be used in breeding of lentils (Table 2).

The *sca* effect is an important criterion for the evaluation of hybrids. Among the various gene interactions contributing towards *sca*, the additive × additive type of gene interaction is fixable in later generations in self-pollinated crops like lentil. Thus, the ultimate aim of a breeder is to generate desirable transgressive segregants to develop potential homozygous lines through hybridization. The cross-combinations with significant *sca* effects for various traits listed in Table 3. Cross IPL 81×EC 267554 was recorded as desirable specific combiner for seed yield per plant, number of secondary branches per plant, number of pods per plant, number of seeds per plant and harvest index. Cross L 4076×EC 267583 was recorded as specific combiner for seed yield per plant, number of secondary branches per plant, number of pods per plant and protein content. Cross L 4076×L 4717 was recorded as best specific combiner for seed yield per plant, number of pods per plant, number of seeds per plant, 100-seed weight and harvest index. Cross JL 3×RL 7 was recorded as best specific combiner for seed yield per plant, number of secondary branches per plant, number of pods per plant and number of seeds per plant. Cross IPL 81×RL 7 was recorded as best specific combiner for seed yield per plant, number of secondary branches per plant, length of first pod bearing node, 100-seed weight, protein content and number of pods per plant.

The crosses with significant *sca* effects for different yield components along with mean performance and *gca* effects of the parents are described in Table 4. Three cross combination out of top five having high mean performance and desirable SCA estimates involved at least one of the parents with high GCA *viz.*, IPL 81×EC 267554, JL 3×RL 7 and IPL 81×RL 7. Utilization these type of crosses in lentil improvement programme would likely enhance the concentration of favorable alleles (Thirumeni *et al.,* 2000; Manivannan and Ganesan, 2001; Kenga *et al.,* 2004; Gnanasekaran *et al.,* 2006; Kumar *et al.,* 2015). These cross combinations can profitably be exploited for isolating transgressive segregates for respective traits. It was observed that the desirable cross combinations included high × high, high × low and low × low type of general combiners. The high × high combination could be due to additive and additive × additive type of gene action which is fixable in nature. The desirable performance of cross combinations like low × low general combiners may be ascribed to complimentary gene effects.

IPL 81×EC 267554 having high SCA effects and involved one of the high GCA parent showed high *per se* performance, pods per plant and harvest index. The cross seems to be promising and can be exploited for obtaining transgressive segregants in yield improvement programme of lentil.

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