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**OK Chaugule**
M. Sc. Student, Department of Agricultural Botany, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**UB Pethe**
Associate Professor (CAS), Department of Agricultural Botany, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**MG Palshetkar**
Assistant Professor, Department of Agricultural Botany, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**SS More**
Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**SN Kale**
Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**SS Misal**
M. Sc. Student, Department of Agricultural Botany, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

**Corresponding Author:**
**OK Chaugule**
M. Sc. Student, Department of Agricultural Botany, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

# Combining ability analysis for yield and quality traits in cowpea (*Vigna unguiculata* (L.) Walp.)

**OK Chaugule, UB Pethe, MG Palshetkar, SS More, SN Kale and SS Misal**

**Abstract**
A study was conducted to determine combining ability analysis among crosses derived from nine selected cowpea genotypes. In a Line x Tester design, eighteen cross combinations were generated by crossing three distinct lines with six testers. The analysis of variance revealed significant variation among the genotypes for all the characters. Based on general combining ability effects, the parents Phule Vithai, PCP-991102, and CP-13 were identified as good general combiners. The most promising specific combiners for yield and yield components were Konkan Sadabahar X CP-08, Phule Vithai X PCP-991102, Konkan Safed X CP-13, and Konkan Sadabahar X CP-15.

**Keywords:** Combining ability, line x tester, cross, variance, yield

## Introduction
Cowpea (*Vigna unguiculata* (L.) Walp.) stands out as a versatile, drought-tolerant, nitrogen-fixing crop and holds a prominent position among grain legumes due to its exceptional value as a low-cost protein source. The cowpea grain is rich in essential nutrients, featuring high-quality protein (23.4%), carbohydrates (60.3%), and a moderate amount of fat (1.8%). Additionally, it provides significant quantities of essential minerals such as calcium (76 mg/100g) and iron (57 mg/100g), along with essential vitamins including thiamine (0.92 mg/100g), riboflavin (0.18 mg/100g), and nicotinic acid (1 mg/100g). (Chatterjee and Bhattacharya, 1986) [2]. Cowpea seeds are distinguished by their rich protein content, particularly abundant in the essential amino acids lysine and tryptophan, surpassing that found in cereal grains. Notably, germinated cowpea seeds emerge as an excellent source of vitamin C. This positions cowpea seeds as an optimal nutritional supplement to cereals. It exhibits maximum genetic diversity in plant type and it offers a unique opportunity for cowpea breeders to develop desirable plant types with high yield.

The primary goal of all crop improvement programs is to develop high-yielding hybrids or varieties. Despite the current utilization of advanced technologies such as genetic engineering and recombinant DNA techniques in these programs, the method of hybridization retains its distinct advantages and is frequently employed in breeding initiatives focused on enhancing yield. Yield, being a complex quantitative trait, is dependent on various components. Therefore, to effectively improve crops, a thorough understanding of the genetics governing both overall yield and its components is essential. The objective of hybridization is to combine desirable genes from two or more different varieties, resulting in the production of pure-breeding progeny that surpass the parental types in various aspects. In self-pollinating crops like cowpea, variability is often introduced through carefully chosen parental combinations in hybridization. The knowledge of combining ability and gene action becomes a prerequisite in any plant breeding program, guiding the selection of superior parents and the creation of improved cross combinations.

In light of this perspective, the present investigation was conducted to estimate the effects of general combining ability and specific combining ability for various traits in cowpea of superior parents and the development of enhanced cross combinations in cowpea breeding programs.

## Materials and Methods

The 18 $F_1$s were obtained by crossing 9 genotypes in line X tester design (3 lines and 6 testers) during *rabi* 2022-23. The experimental materials comprised of 9 genotypes and their 18 $F_1$s were grown in a randomized block design with two replications during the summer 2023 at Experimental Research farm, Department of Agricultural Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (MS). Two rows, each consisting of 40 plants, were planted for each genotype, with a row-to-row spacing of 30 cm and a plant-to-plant distance of 30 cm. Observations were recorded for fourteen characters namely Days to initiation of flowering, Days to 50 percent flowering, Days to maturity, Plant height (cm), Number of clusters per plant, Number of pods per cluster, Number of pods per plant, Pod length (cm), Number of seeds per pod, Test weight (g), Grain yield per plant (g), Harvest index (%), Protein content (%) and Iron content (ppm). The general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of hybrids were worked out as suggested by Kempthorne (1957) [5].

## Results and Discussion

The analysis of variance showed significant differences for all the traits studied among the parents which indicated wide genetic variability among parents (Table 1). These results were in accordance with the results obtained by Idahosa and Alika (2013) [4]. Mukati *et al*., (2014) [7], Satish Kumar *et al*., (2017) [11] and Pethe *et al*. (2018) [10].

The results derived from the general combining ability effect (as presented in Table 2) revealed that, among the three tested lines, Konkan Sadabahar emerged as a commendable general combiner for earliness-contributing characters, displaying a desirable significant negative performance for all three earliness-contributing characters i.e., days to initiation of flowering, days to 50% flowering, and days to maturity. Simultaneously, the tester CP-13 was identified as a proficient general combiner for the traits of days to initiation of flowering and days to maturity. Among lines, Phule Vithai demonstrated a desirable significant GCA effect for the traits number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, test weight, grain yield per plant, harvest index, protein content, and iron content showing good general combining ability for improvement in these traits. Among testers, PCP-991102 was determined to be a superior general combiner for the following traits: number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, grain yield per plant, and harvest index. Tester CP-13 was the next good general combiner for the traits as follows number of clusters per plant, number of pods per cluster, number of pods per plant, grain yield per plant, and harvest index. These results are in agreement with Idahosa and Alika (2013) [4], Mukati *et al*., (2014) [7], Satish Kumar *et al*., (2017) [11], Deepa Priya *et al*., (2018) [3], Pethe *et al*., (2018) [10], Owusu *et al*., (2018) [8], and Verma *et al*., (2020) [12].

The results obtained in specific combining ability effect (Table 3) indicated that among 18 $F_1$ cross combinations the highest magnitude of negative SCA effect for days to initiation of flowering was exhibited for cross Konkan Sadabahar X CP-06(-1.750) and for days to 50% flowering was exhibited for cross Konkan Sadabahar X CP-13(-1.556). The negative SCA effect is desirable because early maturity than the parents is advantageous. The assessments of the SCA effect indicated that none of the hybrids consistently demonstrated superiority across all traits.

The cross combinations Konkan Sadabahar X CP-08, Phule Vithai X PCP-991102, Konkan Safed X CP-13, and Konkan Sadabahar X CP-15 were identified as the most promising specific combiners for most of the yield and yield contributing characters. The cross Konkan Sadabahar X CP-08 had been identified as the best specific combiner for the number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, grain yield per plant, harvest index, and iron content. Subsequently, the cross Phule Vithai X PCP-991102 was observed to be a promising specific combiner with respect to traits such as the number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, test weight, grain yield per plant, and harvest index. The cross Konkan Safed X CP-13 was found to be a good specific combiner for the number of pods per plant, pod length, number of seeds per pod, grain yield per plant, harvest index, protein content, and iron content. Meanwhile, the cross Konkan Sadabahar X CP-15 recorded a significant SCA effect for the number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, grain yield per plant, harvest index, and protein content.

For grain yield per plant, seven cross combinations *viz*., Phule Vithai X PCP-991102, Konkan Safed X PCP-171107, Konkan Sadabahar X CP-08, Konkan Sadabahar X CP-15, Konkan Sadabahar X CP-06, Konkan Safed X CP-13, and Konkan Safed X CP-06 were observed as best specific combiners. The crosses that involve parents with high *gca* normally give high *sca* effects (Atanuk Pal and Sabesan, 2009) [1]. Few of the three cross combinations for grain yield per plant were Phule Vithai X PCP-991102 (good x good), Konkan Safed X CP-13 (poor x good) and Konkan Sadabahar X CP-08 (poor x poor) had positive desired SCA effects and significant desired heterotic response over better parents as well as over all the standard checks. The crosses exhibiting high heterosis with desirable SCA effects did not always involve parents with high GCA effects thereby suggesting the importance of interallelic interaction. High-yielding hybrids had high SCA effects, high heterosis as well as high *per se* performance for most of the yield-contributing characters. This appears appropriate as grain yield being a complex character depends on a number of components traits. It is also clear that high degree of non-additive gene action for grain yield and its component traits observed in the present study favours hybrid breeding program these findings are in agreement with the earlier findings Pandey B and Singh, (2010) [9], Meena, *et al*., (2010) [6], Deepa Priya *et al*., (2018) [3], and Pethe *et al*., (2018) [10].

**Table 1:** Analysis of variance for combining ability for different characters in Line X Tester analysis of Cowpea genotypes.

| Sr. No. | Characters | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | Lines (2) | Testers (5) | L vs. T (10) | Error (26) |
| 1. | Days to initiation of flowering | 10.500 ** | 3.683 * | 84.028 ** | 1.205 |
| 2. | Days to 50% flowering | 21.500 ** | 10.400 ** | 121.000 ** | 1.051 |
| 3. | Days to maturity | 50.000 ** | 22.400 ** | 81.000 ** | 1.574 |
| 4. | Plant height (cm) | 22.320 ** | 21.845 ** | 314.471 ** | 0.554 |
| 5. | Number of clusters per plant | 8.407 ** | 4.715 ** | 0.49 | 0.337 |
| 6. | Number of pods per cluster | 0.035 ** | 0.024 ** | 0.001 | 0.003 |
| 7. | Number of pods per plant | 5.247 * | 48.955 ** | 52.321 ** | 0.981 |
| 8. | Pod length (cm) | 6.153 ** | 2.677 ** | 6.267 ** | 0.015 |
| 9. | Number of seeds per pod | 5.006 ** | 0.806 ** | 25.783 ** | 0.011 |
| 10. | Test weight (g) | 14.328 ** | 5.807 ** | 0.019 ** | 0.002 |
| 11. | Grain yield per plant (g) | 62.382 ** | 27.693 ** | 292.980 ** | 1.221 |
| 12. | Harvest index (%) | 157.882 ** | 33.879 ** | 22.324 ** | 0.391 |
| 13 | Protein content (%) | 4.253 ** | 8.584 ** | 37.638 ** | 0.155 |
| 14 | Iron content (ppm) | 17.971 ** | 853.387 ** | 3113.082 ** | 0.46 |

* Significant at 5% LS and ** Significant at 1% LS

**Table 2:** Estimates of general combining ability of nine cowpea (lines and testers) genotypes

| Sr. No. | Lines/ Testers | Days to initiation of flowering | Days to 50% flowering | Days to maturity | Plant Height (cm) | Number of clusters per plant | Number of pods per cluster | Number of pods per plant |
|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | |
| 1 | Konkan Safed | -0.25 | -0.028 | 1.000 * | 2.172 ** | 0.750 ** | -0.063 ** | 0.444 |
| 2 | Konkan Sadabahar | -0.750 * | -0.444 | -1.250 ** | -3.294 ** | -1.417 ** | 0.062 ** | -2.006 ** |
| 3 | Phule Vithai | 1.000 ** | 0.472 | 0.25 | 1.122 ** | 0.667 ** | 0.001 | 1.561 ** |
| | SE± | 0.669 | 0.624 | 0.764 | 0.453 | 0.354 | 0.031 | 0.603 |
| **Testers** | | | | | | | | |
| 1 | CP-15 | 1.250 * | 1.306 ** | 2.583 ** | -5.961 ** | -1.767 ** | -0.126 ** | -4.722 ** |
| 2 | CP-08 | 1.083 * | 1.806 ** | 2.083 ** | 0.706 * | -0.3 | -0.033 | -1.656 ** |
| 3 | CP-06 | -0.75 | -0.861 | -0.75 | -1.661 ** | -0.900 ** | 0.004 | -1.822 ** |
| 4 | CP-13 | -2.417 ** | -3.194 ** | -3.917 ** | 2.172 ** | 1.700 ** | 0.197 ** | 5.811 ** |
| 5 | PCP-991102 | 0.417 | 0.472 | -0.75 | 2.539 ** | 1.633 ** | -0.006 | 3.811 ** |
| 6 | PCP-171107 | 0.417 | 0.472 | 0.75 | 2.206 ** | -0.367 | -0.036 | -1.422 ** |
| | SE± | 0.946 | 0.883 | 1.081 | 0.641 | 0.5 | 0.044 | 0.853 |

* Significant at 5% LS and ** Significant at 1% LS

**Table 2:** Continued….

| Sr. No. | Lines/Testers | Pod Length (cm) | Number of seeds per pod | Test weight (g) | Grain yield per plant (g) | Harvest index (%) | Protein content (%) | Iron Content (ppm) |
|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | |
| 1 | Konkan Safed | -0.516 ** | -1.016 ** | 0.880 ** | -0.353 | 0.053 | 1.127 ** | -5.845 ** |
| 2 | Konkan Sadabahar | -0.938 ** | 0.138 ** | -0.951 ** | -4.261 ** | -2.327 ** | -1.729 ** | -6.541 ** |
| 3 | Phule Vithai | 1.454 ** | 0.878 ** | 0.071 ** | 4.614 ** | 2.274 ** | 0.602 ** | 12.386 ** |
| | SE± | 0.074 | 0.065 | 0.029 | 0.673 | 0.381 | 0.24 | 0.413 |
| **Testers** | | | | | | | | |
| 1 | CP-15 | 0.657 ** | -0.166 ** | 0.962 ** | -4.103 ** | -2.321 ** | 2.801 ** | 7.635 ** |
| 2 | CP-08 | -0.051 | 0.294 ** | 0.241 ** | -0.369 | 0.269 | 2.153 ** | 13.270 ** |
| 3 | CP-06 | -0.390 ** | -0.026 | 1.529 ** | -0.969 * | -0.103 | 1.991 ** | 3.618 ** |
| 4 | CP-13 | -1.218 ** | -0.912 ** | -1.646 ** | 2.697 ** | 2.374 ** | -2.544 ** | -7.259 ** |
| 5 | PCP-991102 | 0.772 ** | 0.288 ** | -1.230 ** | 3.331 ** | 0.873 ** | -4.326 ** | -3.307 ** |
| 6 | PCP-171107 | 0.229 ** | 0.521 ** | 0.143 ** | -0.586 | -1.091 ** | -0.076 | -13.957 ** |
| | SE± | 0.104 | 0.092 | 0.04 | 0.952 | 0.539 | 0.339 | 0.584 |

* Significant at 5% LS and ** Significant at 1% LS

**Table 3:** Estimates of Specific combining ability effects for different characters in Eighteen hybrids

| Sr. No. | Hybrids | Days to initiation of flowering | Days to 50% flowering | Days to maturity | Plant Height (cm) | Number of clusters per plant | Number of pods per cluster | Number of pods per plant |
|---|---|---|---|---|---|---|---|---|
| 1 | Konkan Safed X CP-15 | -0.25 | 0.528 | -0.167 | -5.539 ** | -3.350 ** | -0.051 | -6.644 ** |
| 2 | Konkan Safed X CP-08 | -0.083 | 0.028 | 0.333 | -3.306 ** | -1.917 ** | -0.014 | -4.511 ** |
| 3 | Konkan Safed X CP-06 | 0.75 | -0.806 | -0.333 | -1.239 * | 0.083 | -0.011 | -0.644 |
| 4 | Konkan Safed X CP-13 | 0.417 | 0.528 | 0.833 | 1.428 * | -0.117 | 0.046 | 2.522 ** |
| 5 | Konkan Safed X PCP-991102 | -0.417 | -0.639 | -0.333 | 2.961 ** | 0.55 | 0.049 | 1.522 * |
| 6 | Konkan Safed X PCP-171107 | -0.417 | 0.361 | -0.333 | 5.694 ** | 4.750 ** | -0.021 | 7.756 ** |
| 7 | Konkan Sadabahar X CP-15 | 0.75 | 0.444 | 0.583 | 0.828 | 1.817 ** | 0.004 | 4.106 ** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | Konkan Sadabahar X CP-08 | 0.417 | 0.444 | -0.417 | 6.261 ** | 1.750 ** | 0.081 * | 5.939 ** |
| 9 | Konkan Sadabahar X CP-06 | -1.750 * | -1.389 | -0.083 | 1.528 ** | 2.850 ** | 0.024 | 7.206 ** |
| 10 | Konkan Sadabahar X CP-13 | -1.083 | -1.556 * | -0.417 | -1.206 * | -0.950 * | 0.001 | -5.028 ** |
| 11 | Konkan Sadabahar X PCP-991102 | 1.083 | 1.778 * | 0.417 | -3.272 ** | -1.783 ** | -0.156 ** | -5.828 ** |
| 12 | Konkan Sadabahar X PCP-171107 | 0.583 | 0.278 | -0.083 | -4.139 ** | -3.683 ** | 0.044 | -6.394 ** |
| 13 | Phule Vithai X CP-15 | -0.5 | -0.972 | -0.417 | 4.711 ** | 1.533 ** | 0.046 | 2.539 ** |
| 14 | Phule Vithai X CP-08 | -0.333 | -0.472 | 0.083 | -2.956 ** | 0.167 | -0.067 | -1.428 |
| 15 | Phule Vithai X CP-06 | 1 | 2.194 ** | 0.417 | -0.289 | -2.933 ** | -0.014 | -6.561 ** |
| 16 | Phule Vithai X CP-13 | 0.667 | 1.028 | -0.417 | -0.222 | 1.067 * | -0.047 | 2.506 ** |
| 17 | Phule Vithai X PCP-991102 | -0.667 | -1.139 | -0.083 | 0.311 | 1.233 ** | 0.106 ** | 4.306 ** |
| 18 | Phule Vithai X PCP-171107 | -0.167 | -0.639 | 0.417 | -1.556 ** | -1.067 * | -0.024 | -1.361 |
| | SE± | 1.638 | 1.53 | 1.872 | 1.111 | 0.866 | 0.075 | 1.478 |

* Significant at 5% LS and ** Significant at 1% LS

**Table 3:** Continued….

| Sr. No. | Hybrids | Pod Length (cm) | Number of seeds per pod | Test weight (g) | Grain yield per plant (g) | Harvest index (%) | Protein content (%) | Iron Content (ppm) |
|---|---|---|---|---|---|---|---|---|
| 1 | Konkan Safed X CP-15 | -0.763 ** | -0.971 ** | 1.661 ** | -6.247 ** | -4.119 ** | -0.017 | -6.736 ** |
| 2 | Konkan Safed X CP-08 | 0.077 | -0.571 ** | 1.591 ** | -4.781 ** | -4.740 ** | -0.214 | -17.261 ** |
| 3 | Konkan Safed X CP-06 | 0.133 | -0.151 | 0.489 ** | 2.469 ** | 1.352 ** | -1.627 ** | 2.600 ** |
| 4 | Konkan Safed X CP-13 | 0.721 ** | 1.516 ** | -0.630 ** | 2.803 ** | 2.669 ** | 0.888 ** | 18.672 ** |
| 5 | Konkan Safed X PCP-991102 | -0.083 | -0.064 | -2.493 ** | -0.731 | 0.991 * | -0.880 ** | 5.660 ** |
| 6 | Konkan Safed X PCP-171107 | -0.085 | 0.242 ** | -0.617 ** | 6.486 ** | 3.848 ** | 1.850 ** | -2.935 ** |
| 7 | Konkan Sadabahar X CP-15 | 0.780 ** | 0.776 ** | 0.038 | 5.111 ** | 3.294 ** | 1.189 ** | -4.841 ** |
| 8 | Konkan Sadabahar X CP-08 | 0.337 ** | 0.196 * | -0.387 ** | 6.428 ** | 4.899 ** | -1.223 ** | 1.314 * |
| 9 | Konkan Sadabahar X CP-06 | -0.264 ** | 0.116 | -0.815 ** | 5.028 ** | 3.728 ** | -0.391 | -13.619 ** |
| 10 | Konkan Sadabahar X CP-13 | -0.371 ** | -0.458 ** | -0.043 | -2.789 ** | -2.815 ** | 0.389 | 8.058 ** |
| 11 | Konkan Sadabahar X PCP-991102 | -0.116 | -0.358 ** | 1.654 ** | -6.872 ** | -3.817 ** | 4.656 ** | 14.071 ** |
| 12 | Konkan Sadabahar X PCP-171107 | -0.365 ** | -0.271 ** | -0.447 ** | -6.906 ** | -5.290 ** | -4.619 ** | -4.984 ** |
| 13 | Phule Vithai X CP-15 | -0.017 | 0.196 * | -1.698 ** | 1.136 | 0.825 | -1.172 ** | 11.577 ** |
| 14 | Phule Vithai X CP-08 | -0.414 ** | 0.376 ** | -1.203 ** | -1.647 | -0.159 | 1.436 ** | 15.947 ** |
| 15 | Phule Vithai X CP-06 | 0.131 | 0.036 | 0.326 ** | -7.497 ** | -5.080 ** | 2.018 ** | 11.019 ** |
| 16 | Phule Vithai X CP-13 | -0.350 ** | -1.058 ** | 0.674 ** | -0.014 | 0.146 | -1.277 ** | -26.730 ** |
| 17 | Phule Vithai X PCP-991102 | 0.200 * | 0.422 ** | 0.839 ** | 7.603 ** | 2.826 ** | -3.775 ** | -19.731 ** |
| 18 | Phule Vithai X PCP-171107 | 0.449 ** | 0.029 | 1.064 ** | 0.419 | 1.442 ** | 2.770 ** | 7.919 ** |
| | SE± | 0.181 | 0.159 | 0.07 | 1.648 | 0.933 | 0.587 | 1.011 |

## Conclusion

The present investigation showed that there was significant variation among all genotypes studied. Line Konkan Sadabahar and tester CP-13 are good general combiners for earliness. For trait protein content, two lines, Konkan Safed and Phule Vithai, and testers CP-15, CP-08, and CP-06 have been shown to be good general combiners, whereas line Phule Vithai and testers CP-15, CP-08, and CP-06 are good general combiners for iron content. Considering the improvement in yield and yield contributing characters, tester PCP-991102, and line Phule Vithai was determined to be a good general combiner.

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