***Original Research Article***

**Assessment of combing ability and *per se* performance of CGMS based hybrids in Chilli (*Capsicum annuum L*.) through LT design**

**ABSTRCT**

Exploitation of male sterility in chilli offers an efficient and strategic approach to maximising heterosis for hybrid development. The present research investigates the potential of CGMS lines in chilli for exploiting heterosis. Twenty four F1 hybrids were developed by crossing three diverse CGMS lines with eight testers using Line Tester mating design. The present study was conducted at Department of Vegetable Science, Kerala Agricultural University from May 2022 to November 2024. Combining ability analysis serves as a fundamental and highly effective tool for identifying desirable parents in breeding programs. Variance due to GCA and SCA showed significant and non-significant effects across different traits. The CGMS lines AVPP0517 and AVPP9907 along with tester Ujwala, Anugraha, VI059382 and AVPP9703 showed significant GCA for yield and other component trait.Highest significantly positive SCA recorded in AVPP0516 Anugraha (34.25) for fruits plant.-1 These crosses are also exhibited desirable SCA and the highest *per se* performance for yield plant-1 with a maximum in AVPP0516 Anugraha (176.55) and AVPP0517 VI059382 (172.57). Among the lines, AVPP9907 exhibited positive GCA for plant height, whereas the cross AVPP0517 LC217 recorded the highest SCA for this trait. Three hybrids AVPP0516 Anugraha, AVPP0517 VI059382 and AVPP9907 Ujwala were identified as most promising based on combining ability studies and *per se* performance. The analysis of gene action revealed that non-additive gene action predominantly influenced the expression of most the traits. The inheritance pattern strongly emphasized the importance of a hybrid breeding strategy for enhancing specific traits in chilli.

**Key word-** Combining ability, GCA, SCA, Chilli, CGMS

**1. INTRODUCTION**

Chilli (*Capsicum annuum* L) holds a prestigious status as a valuable industrial spice crop and is often referred to as the wonder spice. Its significance extends beyond culinary applications to medicinal, pharmaceutical, and industrial uses, making it highly sought after world wide. Chilli is a widely cultivated capsicum species grown across tropical and subtropical regions. It is a dual-purpose export commodity, serving as both a spice and a vegetable. Southern Mexico is recognized as the primary centre of origin, while India is considered as the secondary centre of diversity for *Capsicum*. Chilli cultivation has spread throughout India since its introduction by the Portuguese in the 15th century. Currently, the crop covers an area of 423,700 hectares, with a production and productivity of 4,588,700 MT and 10.8 MT/ha, respectively. In India, Andra Pradesh stands first in area, production and productivity. Kerala shares an area of 1.32000 MT/ha with a production of 4.25 MT and productivity of 3.21 MT/ha, respectively (India stat, 2024). Dry chilli is the second largest spice exported from India, after black pepper. It accounted for about 42% of the country's total spice exports in 2022 (FAO, 2022). Heterosis breeding has shown to be increased the yield of chilli by 30-35% (Dhaliwal et al., 2014). In India, the demand for F1 hybrids has been growing steadily due to their genetic uniformity, built in resistance, wider adaptability and higher yield potential (Lata et al., 2023). These hybrids offer farmer’s a promising opportunity with increased productivity, consistent fruit quality, and enhanced export potential, making them highly profitable for commercial cultivation. Any crop improvement commences with identification of parental genotypes from diverse population. Prediction of hybrids based on per se performance of parents may not always be reliable, as the desirable traits are not always reliably inherited by the hybrids (Kadambavanasundaram, 1980). Combining ability is a fundamental tool in crop improvement, enabling the evaluation of parent’s breeding potential or the best combiner that can be hybridised to take advantage of heterosis and fix desirable genes (Chadha *et al*., 2001). Furthermore, it facilitates the evaluation of inbreds based on their genetic value and aids in selecting the most suitable parents for hybridization in chilli. GCA and SCA are the two components in combining ability analysis. GCA determines the average performance of parents in a series of crosses and specific combining ability gives the relative performance of parents involved in crosses. Magnitude of significant GCA and SCA effects show the efficacy of improvement in particular traits through suitable breeding method. Understanding the relative significance of additive and non-additive gene action is crucial for plant breeders in designing an effective hybridization program (Dudley and Moll, 1969). Additionally, selecting parents based on their combining ability is essential to achieving enhanced heterotic effects. LT analysis evaluates both general and specific combining ability variances, along with their effects and genetic variance components, such as dominance (H) and additive (D) components, across a large number of germplasms, while minimizing the number of crosses required. Compared to full and half diallel methods,in this genetic analysis is more efficient in terms of space, resources, and time. The tester should be chosen strategically to provide the most comprehensive insights into the genetic performance of lines upon hybridization, even under varying environmental conditions, thereby ensuring broader adaptability (Manjunath et al.,2025). The hectic emasculation process poses a significant challenge in developing heterotic hybrids in chilli. In order to address this, integration of CGMS system has an immense potential for developing hybrids in Chilli (Prasad et al., 2025). In this context the study aims to analyse combing ability and gene action in chilli by using CGMS lines through LT design (Kempthorne, 1958).

**2. MATERIALS AND METHODS**

The field experiment was conducted at the Department of Vegetable Science, Kerala Agricultural University from May 2022 to November 2024. Parental genotypes were evaluated in previous years and suitable genotypes were selected for crossing programme. The Selected lines in Table (1) include, AVPP0516, AVPP0517 and AVPP9907 as female parent and eight genotypes, AVPP1127, AVPP9703, VI059328, AVPP9905, Chivar-1, EC566920, EC37862, LC 217, Anugraha and Ujwala as male tester for production of hybrids. Selected females were pollinated with different pollen sources and seeds were collected from the female plants. The F1 seeds harvested from corresponding female lines were grown for hybrid evaluation and testing combing ability. Twenty four hybrids along with eleven parent and one commercial hybrid check, Sierra were evaluated for various growth and yield parameters. Crop management was done based on the Adhoc recommendation by Kerala Agricultural University (KAU,2016).Thirty days old seedlings were transplanted in rain shelter with two replications in randomized block design. Observations for various traits were recorded from five randomly selected plants, and the mean values were documented. Computation of combining ability and analysis of variance were carried out using the grapes Agri1 package of R software (Gopinath et al, 2021).

**3. RESULT AND DISCUSSION**

ANOVA for combining ability (Table. 2) demonstrated, significant mean sum squares for parents, crosses, and parents vs. crosses for most traits, indicating a broad range of variability among the parental lines, hybrids, and their interactions. This variability among parents can be effectively utilized through selection by analyzing heterosis, general combining ability, and specific combining ability. *Per se* performance should not be ignored but given equal importance when assessing economic heterosis, with the ultimate goal of identifying superior hybrids. Mean sum of square due to parents vs hybrids showed significant differences except for primary branch plant,-1average fruit weight, and fruit length. Lines and testers were shown variation for all the studied characters.The differences due to linetester interactions were significant for all the traits supported by earlier findings of Meena, 2017; Hemalata, 2022). This indicates the presence of wide genetic variability in the studied material, providing an excellent opportunity to identify superior general combiners and to develop promising hybrids.

*Per se* performance revealed significant differences across various traits among twenty four hybrids (Table 3 and 4). The hybrids AVPP0516Anugraha, AVPP0517VI059328, AVPP9907Ujwala excelled their performance based on superiority of average fruit weight, fruit length, and fruits plant.-1Growth parameters like plant height was found to be maximum in AVPP0516Chivar-1(126.10 cm) followed by the hybrid AVPP9907 EC566920 (123.60 cm) which was on par with AVPP0517 EC566920 (123cm). Multiple researchers have also emphasized the excellence of hybrids for various traits utilizing male sterile lines in chilli (Shankargouda, 2013; Siddappa et al., 2019; Shankarnag,2004). Primary branches plant-1 found highest in AVPP0516LC217. Among the crosses, AVPP9907Ujjwala had the highest number of secondary branches plant-1.Vegetative parameters have a profound impact on overall performance of a plant. Plant spread found maximum in AVPP0517EC566920. The earliest days of first flowering recorded by AVPP0516 Chivar-1(30.70 days). Similar variation for days to first flowering was reported by (Prasath and Ponnuswami,2008; Bhutia *e*t al*.* 2015). The same cross was found to be the earliest in fruiting and reaching maturity for harvesting. AVPP0516AVPP9703 had the maximum average fruit weight (8.67g) and fruit length (12.02 cm). Highest fruits plant-1 exhibited by the cross AVPP0516 Anugraha (179) followed by AVPP9907 Ujjwala (172.60).The same hybrids exhibited the highest yield plant1 attaining 822.12 g and 820.80 g, respectively. Previous studies on male sterile lines reported that, MS-6 Solan Bharpur identified as supreme in terms of number of fruit and yield plant-1 (Shabnam Rana. 2023) while MS-7 UHF-CAP-27 had the maximum plant spread (Rana, 2022).Thirteen CGMS hybrids released by IIHR excelled in yield and yield related traits. Arka Nihira exhibited the highest green fruit yield (1.63 kg plant plant-1 ), followed by Arka Yashasvi, H-25, H-26 and Arka Tanvi (Kapte et al, 2023).

Combining ability of the parents (Table 2) revealed that male sterile line AVPP0516 had a positive significant GCA for secondary branch (0.56), plant spread (9.46), average fruit weight (0.36) and fruit length (0.37). Similarly, AVPP0517 was found to be good combiner for plant spread (9.96), days to maturity (0.15) and fruits plant-1 (3.70). Potential of male sterile line as an excellent general combiner is noteworthy in genetic improvement of chilli. Earlier findings suggested that, male sterile lines CA1450 and DPChMS9-2 proved to be strong general combiners for fruit plant-1 and marketable yield, while Ms-12 also showed robust performance across various growth and yield traits (Nagaraju et al., 2017; Payakkabab et al., 2012; Lata et al., 2023). Negative GCA for fruiting and flowering is a desirable trait for marketable yield. AVPP0516 had negative GCA for these traits. Among the tester, VI059382 and Anugraha (166.90) had negative GCA for days to first flowering, fruiting and maturity. The line AVPP0907 proved to be a good combiner for average fruit weight (0.31), fruit length (0.9) and yield plant-1 (27.11). Considering other traits, potential donors for fruits plant-1 was noticed Ujwala (55.28), while the highest yield plant-1 was recorded by Ujwala (222.10) followed by VI059382 (151.83), Anugraha (145.23), and AVPP9703(60.16) respectively. .

Estimates of SCA for certain crosses (Tables 3 and 4) were used to identify the best combiners based on their positive and significant combining ability. Identifying the best parental combiners in breeding helps in selecting suitable cross combinations. The heterotic performance of hybrids can be assessed by evaluating the most effective parental combiners. The estimation of heterosis is based on the SCA of the hybrids, which determines their overall superiority. Current study identifies various combiners associated with different traits. The SCA effects for fruits plant-1 ranged from -26.79.10 to 34.25, with a maximum in hybrids AVPP0516 Anugraha (34.25), AVPP0517 VI059382 (31.36) and AVPP9907Ujjwala (20.80). These crosses are also exhibited desirable SCA for yield plant-1 with maximum in AVPP0516 Anugraha (76.55), and AVPP0517VI059382 (172.5) respectively. GMS derived chilli hybrids MS 9-2 × HPM-2 was found significantly positive SCA for yield related traits (Lata et al., 2024). Among the hybrids, only AVPP0517LC 217 exhibited a positive significant SCA for plant height. Maximum significantly positive SCA was recorded in AVPP9907 VI05932 for primary branches plant.-1 Highest SCA for plant spread recorded in AVPP9907AVPP9703 (12.94). A notable negative and significant SCA effect for days to first flowering, fruiting, and maturity was observed in the crosses AVPP0516 × AVPP9703, AVPP0516 × Ujwala, and AVPP9907 × EC37862. The highest and significantly positive SCA was observed in AVPP0516AVPP9703 (1.08) for average fruit weight followed by AVPP9907EC566920. Earlier studies on male sterile hybrids identified MS 341PP 402 had high SCA for plant height, SD 463 × PS 403 for plant spread (Singh et al., 2014). Specific combining ability involving male sterile lines were well corroborated by several previous reports.(Shankargouda, et al., 2017; Meena et al., 2020; Rani et al., 2021).

Perusal of nature of gene action (Table 2 ) showed that additive variance (σ² GCA) was lower than dominant variance (σ² SCA), indicating a predominance of non-additive gene action. As a result, the estimated magnitude of gene action was less than unity, suggesting that heterosis breeding would be an effective strategy for improving all the traits studied. Notably the specific crosses such as AVPP0516 Anugraha, AVPP0517 VI059382 and AVPP9907Ujwala demonstrated exceptional *per se* performance, in terms of fruit and yield plant-1 .Hence, these crosses are highly recommended for developing superior heterotic hybrids in chilli. In this study, the *per se* performance of parents emerged as a key criterion for selecting heterotic hybrids, especially for yield and fruit and yield plant.-1 The presence of favourable dominant alleles in hybrids with high SCA is likely responsible for the manifestation of superior heterosis.

**4. CONCLUSION**

The integration of male sterility could significantly reduce the labour intensive emasculation process, thereby reducing hybrid seed production cost. The present study identifies three superior crosses with higher SCA for yield contributing traits, highlighting their potential for maximizing heterotic performance. Furthermore, the study generates different donor parents with strong GCA for specific traits, making them valuable candidates for future chilli breeding. Breeders can utilise male sterile lines as parents by considering combining ability, gene interaction and other various gene linkage studies, that would allow favourable allelic interaction in specific traits which shall pave in the development of heterotic hybrids. **REFERENCES**

1. Bhutia, N.D., T. Seth, V.D., Shende, S. Dutta, and Chattopadhyay,A. (2015). Estimation of heterosis, dominance effect and genetic control of fresh fruit yield, quality and leaf curl disease severity traits of chili pepper (*capsicum annuum. L.) Scientia Horticulturae*,182,47–55.
2. Chadha S, Kumar, J Vidyasagar. Combining ability over environments in tomato(2001). Indian Journal of Agriculture Research, 5 (3),171-175.
3. Dudley, J.W. and Moll, R.H. (1969). Interpretation and use of estimates of heritability and genetic variances in plant breeding. Crop Science, 9, 257-263
4. Dhaliwal, M. S. and Jindal, S. K. (2014). Induction and exploitation of nuclear and cytoplasmic male sterility in pepper (Capsicum spp.): a review. *Journal of Science and Biotechnology.* 89,471- 4 79.
5. Gopinath, P. P.,Parsad, R., Joseph, B., Adarsh, V. S. (2021). grapes Agri1: Collection of shiny apps for data analysis in agriculture. J Open Source Softw. :6(63): 3437. Available:https://doi.org/10.21105/joss.034 37
6. Hemalata(2022).Heterosis and combining ability studies in male sterility based F1 hybrids of chilli (Capsicum annuum L.)Ph. D thesis, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur,(272p)
7. Indiastat. Area, production and productivity of chilli in India. Accessed November 2024. Available:https://www.indiastat.com/table/agriculture/area-production-productivity cocoa-india-1983-1984/371492.
8. Kadambavanasundaram M, 1980. Heterotic system in cultivated species of Gossypium. An appraisal (Abst). Genetic and crop improvement of heterotic systems. Precongress scientific meeting of XV International Congress of Genetics, TNAU, Coimbatore, pp. 20.
9. KAU (Kerala Agricultural University) 2016. Package of Practices Recommendations: Crops (15 th Ed.). Kerala Agricultural University, Thrissur, 393p.
10. Khapte, P.S., Ponnam, N., Boraiah, K.M., Wakchaure, G.C. and Gurumurthy, S.( 2023). Genetic variations and character association among CGMS based chilli F1 hybrids for morphometric, fruit quality, and yield traits in shallow basaltic soils of India.*Indian Journal of Horticulture* . 80(4)353-359
11. Lata, H. and Sharma, A.(2024). Exploitation of heterosis in chilli using genetic male sterile lines for red fruit yield with special reference to high rainfall conditions. *Scientific Reports*, *14*(1), p.23061.
12. Lata, H., Sharma, A., Thakur, H., Thakur, A., Rana, R.S. and Kaur, M.(2023). Heterosis and combining ability vis‐à‐vis association for green fruit yield and component traits involving male sterile lines in chilli (Capsicum annuum) under wet temperate zone of North Western Himalayas. *Plant Breeding*, *142*(4), pp.547-562.
13. Manjunath, K.V., Das, S., Mallick, R.G., Hazra, P., Chattopadhyay, A. and Maji, A., (2025). Combining ability and gene action for fruit yield components, quality, shelf life and reaction to tomato leaf curl virus disease. *Heliyon*.
14. Meena, O. P.; Dhaliwal, M. S. and Jindal, S. K. (2020a). Heterosis breeding in chilli pepper by using cytoplasmic male sterile lines for high-yield production with special reference to seed and bioactive compound content under temperature stress regimes. Scientia Horticulturae, 262:109036.
15. Meena, O. P.; Dhaliwal, M. S.; Jindal, S. K. and Rani, M. (2020b). Cytoplasmic male sterile lines with desirable combining ability enhance the concentration of biochemical attributes and total yield in Capsicum annuum under temperature stress conditions. Industrial Crops & Products, 145: 1-17
16. Meena, O. P.; Dhaliwal, M. S.and Jindal, S. K. (2018). Development of cytoplasmic male sterile lines in chilli (Capsicum annuum L.) and their evaluation across multiple environments. Breeding Science, 68, 404-412.
17. Payakhapaab, S., Boonyakiat, D., and Nikompun, M. 2012. Evaluation of combining ability of yield components in Chillies. Indian Journal of Horticulture, 4 (11),154-161.
18. Prasad, I., Kumar, R., Tiwari, I., Tiwari, C.P., Chaturvedi, V.D. and Singh, P., 2025. Hybrid Seed Production of Chilli (Capsicum annuum L.) for Sustaining Yield and Profitability. In *Hybrid Seed Production for Boosting Crop Yields: Applications, Challenges and Opportunities* (pp. 409-429). Singapore: Springer Nature Singapore.
19. Prasath, D. and Ponnuswami, V. (2008). Heterosis and combining ability for morphological, yield and quality characters in paprika type chilli hybrids.Indian Journal of Horticulture, 65(4), 441-445
20. Rani, M., Jindal, S.K. and Meena, O.P.(2022). Exploitation of heterosis among phenotypically diverse capsicum parents for important fruit traits. *Brazilian Archives of Biology and Technology*, *64*, p.e21200597.
21. Rana, s. (2022). Linex tester analysis in bell pepper (capsicum annuum l.) using male sterile lines.Ph. D thesisDr. Yashwant Singh Parmar University of horticulture and forestry).(120p)
22. Shakarnag, B. (2004). Studies on development of chilli (Capsicum annum L.) F1hybrids using male sterile lines for yield and quality. M. Sc. (Hort.) Thesis, Uniersity of Agricultural Science., Dharwad (India)
23. Shankargouda, (2013).Exploitation of male sterility in development of f1 hybrids in chilli,M. Sc. (Hort.) Thesis, Uniersity of Agricultural Science., Dharwad (India)
24. Shankargouda, S., Ravindra, M. & Evoor, S(2017).Heterosis for growth, earliness and yield in CGMS based hybrids chilli (Capsicum annum L.). Bull. Environ. Pharmacol. Life Science.6, 34–38
25. Siddappa, S., Ravindra, M. and Shashikanth, E. (2019). Combining ability analysis in Chilli (Capsicum Annum L.). *Agricultural Science Digest-A Research Journal*, *39*(3), 220-223.
26. Singh, P., Cheema, D. S., Dhaliwal, M. S., and Garg, N. (2014). Heterosis and combining ability for earliness, plant growth, yield and fruit attributes in hot pepper {Capsicum annuum L.) involving geneticand cytoplasmic-genetic malQ sterile lines. *Scientia Horticulturae*, *168*, 175-188.

Table 1-List of genotypes used for evaluation

|  |  |
| --- | --- |
| Line | Sources |
| AVPP0310 | World vegetable centre |
| AVPP0516 | World vegetable centre |
| AVPP0516 | World vegetable centre |
| Tester |  |
| AVPP9907 | World vegetable centre |
| AVPP9703 | World vegetable centre |
| Chivar-1 | IIVR Varanasi |
| EC37862 | NBPGR, |
| LC 217 | Local collection, Vellanikkara |
| Anugraha | KAU, Vellanikkara |
| Ujwala | KAU, Vellanikkara |

Table 2.Analysis of variance for combing ability

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source of variation** | **PH** | **PB** | **SB** | **PS** | **DFF** | **DFR** | **DM** | **AFW** | **FL** | **FPP** | **YPP** |
| σ² GCA | 5.53 | 0.003 | 0.37 | 23.09 | 0.46 | 0.40 | 0.57 | 0.18 | 0.33 | 153.20 | 3030.232 |
| σ² SCA | 36.38 | 0.56 | 2.1 | 77.23 | 3.85 | 2.84 | 3.48 | 0.34 | 0.80 | 376.28 | 8723.126 |
| Additive variance/dominance variance | 0.15 | 0.00 | 0.17 | 0.29 | 0.11 | 0.14 | 0.16 | 0.52 | 0.41 | 0.40 | 0.34 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sources** | **df** | **Plant height** | **PB** | **SB** | **PS** | **DFF** | **DFR** | **DM** | **AFW** | **FL** | **FPP** | **YPP** |
| Replication | 1 | 21.065 | **0.12** | 6.62 | 14.99 | 13.27 | 18.70 | 14.90 | 0.009 | 0.10 | 5.00 | 883.4535 |
| Genotypes | 34 | 215.59\*\* | 1.53\*\* | 22.76\* | 522.59\*\* | 22.93\*\* | 20.88\* | 24.42\*\* | 5.92\*\* | 6.69\*\* | 2319.981\*\* | 53909.57\*\* |
| Parents | 10 | 265.77\*\* | 1.75\*\* | 23.48 \*\* | 531.84\*\* | 36.78\*\* | 36.95\*\* | 37.40\*\* | 12.29\*\* | 7.51\*\* | 539.27\*\* | 219968.70\*\* |
| Parent Vs hybrids | 1 | 565.180\*\* | 0.78 | 234.88 \*\* | 222.20\* | 55.76\*\* | 50.37\*\* | 78.11\*\* | 0.07 | 2.08 | 4062.72\*\* | 183030.33\*\* |
| hybrids | 23 | 178.58\*\* | 1.46\* | 10.64 \*\* | 531.63\*\* | 15.48\*\* | 12.61\*\* | 16.44\*\* | 3.41\*\* | 6.54\*\* | 3018.43\*\* | 62170.71\*\* |
| Lines (female) | 2 | 237.41 | 0.19 | 12.75 | 4529.96\*\* | 28.00 | 20.14 | 19.76 | 5.49\*\* | 21.27 | 437.95 | 19950.1781 |
| Tester(males) | 7 | 322.123\*\* | 1.88 | 20.99\*\* | 57.94 | 25.30 | 22.08 | 32.08 | 8.19\*\* | 11.92 | 8192.02\* | 161978.71\*\* |
| Lines tester | 14 | 98.41\*\* | 1.43\*\* | 5.16\*\* | 197.28\*\* | 8.79\*\* | 6.79\*\* | 8.14\*\* | 0.74\*\* | 1.74\*\* | 800.27\*\* | 18298.221\*\* |
| Error | 34 | 25.63 | 0.36 | 0.92 | 42.80 | 1.09 | 1.10 | 1.16 | 0.06 | 0.14 | 47.710 | 851.96 |

Table 3 .Mean Genetic components of variances

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parents** | **PH** | **PB** | **SB** | **PS** | **DM** | **DFF** | **DFR** | **AFW** | **FL** | **FPP** | **YPP** |
| **Line** |  |  |  |  |  |  |  |  |  |  |  |
| AVPP0516 | -0.77 | 0.12 | 0.56\* | 9.46\*\* | -1.81\*\* | -1.27\*\* | -1.12\*\* | 0.36\*\* | 0.37\*\* | **2.28** | 12.813 |
| AVPP0517 | -3.40\*\* | -0.09 | -1.02\*\* | 9.96\*\* | 0.15\* | -0.192 | -0.01 | -0.67\*\* | -1.29\*\* | **3.70\*** | -39.929\*\* |
| AVPP09907 | 4.17\*\* | -0.02 | 0.46 | -19.42\*\* | 1.02\*\* | 1.40\*\* | 1.13\*\* | 0.31\*\* | 0.9\*\* | **-5.98\*\*** | 27.116\*\* |
| **Tester** |  |  |  |  |  |  |  |  |  |  |  |
| AVPP9703 | -4.12 | 0.13 | -2.77\*\* | 4.65 | 1.74\*\* | 1.59\*\* | 1.46\*\* | 2.65\*\* | 2.45\*\* | **-22.93\*\*** | 60.16\*\* |
| VI059328 | -10.17\*\* | -0.36 | -1.46\*\* | -3.36 | -4.20\*\* | -3.59\*\* | -3.51\*\* | -0.9\*\* | -1.72\*\* | **33.58\*\*** | 151.83\*\* |
| Chivar-1 | 6.29\*\* | 0.86\*\* | -0.21 | -1.31 | -0.72\* | 0.22 | 0.100 | -0.83\*\* | -1.31\*\* | **-37.53\*\*** | -202.12\*\* |
| EC566920 | 9.67\*\* | -0.76\*\* | -0.14 | 1.86 | 3.07\*\* | 2.69\*\* | 2.46\*\* | -0.05 | -0.85 | **-34.48\*\*** | -174.64\*\* |
| EC37862 | 7.39\*\* | -0.23 | -1.04 | 2.15 | 0.31 | 0.45 | 0.16 | 0.16 | -0.33\* | **-18.48\*\*** | -100.68\*\* |
| LC 217 | 0.47 | -0.33 | 0.88 | -3.51 | -0.02 | -0.44 | -0.30 | 0.20\* | 1.51\*\* | **-16.06\*\*** | -101.88\*\* |
| Anugraha | -8.05\*\* | -0.06 | 1.55\*\* | 2.25 | -1.90\*\* | -2.19\*\* | -1.76\*\* | -0.40\*\* | 0.003 | **40.61\*\*** | 145.23\*\* |
| Ujwala | -1.50 | 0.72\*\* | 3.24\*\* | -2.17 | 1.72\*\* | 1.25\*\* | 1.38\*\* | -0.83\*\* | 0.26 | **55.28\*\*** | 222.10\*\* |

Table 4. Estimates of GCA effects of parents for various characters in c35

Table 5.Estimates of SCA effects and per se performance of hybrids for various s characters in chilli

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hybrids** | **MEAN** | **PH** | **MEAN** | **PS** | **MEAN** | **PB** | **MEAN** | **SB** | **MEAN** | **DFF** | **MEAN** | **DFR** |
| AVPP0516AVPP9703 | 99.25 | -7.77\* | 81.80 | 1.40 | 4.3 | -0.42 | 11.95 | -1.11 | 32.05 | -2.86\*\* | 36.00 | -2.25\*\* |
| AVPP0516 VI059328 | 105.40 | 4.42 | 74.55 | 2.17 | 3.10 | -1.12\*\* | 13.38 | -0.58 | **30.70** | 0.96 | **33.60** | 0.32 |
| AVPP0516Chivar-1 | 126.10 | 8.65\* | 83.20 | -8.37 | 6.00 | 0.54 | 16.15 | 0.51 | 34.30 | 0.75 | 37.65 | 0.76 |
| AVPP0516EC566920 | 108.20 | -2.62 | 79.20 | 5.59 | 3.40 | -0.42 | 17.00 | 1.30 | **35.40** | -0.61 | **38.55** | -0.70 |
| AVPP0516 EC37862 | 119.50 | 4.54 | **68.00** | 1.30 | 4.70 | 0.34 | 17.60 | 2.80\*\* | 36.50 | 2.71\*\* | 39.40 | 2.44\*\* |
| AVPP0516LC 217 | 99.15 | -12.47\*\* | 77.05 | -4.22 | **5.80** | 1.54\*\* | 14.65 | -2.08\*\* | 33.40 | 0.51 | 36.55 | 0.06 |
| AVPP0516Anugraha | 105.80 | 2.70 | 76.10 | -0.94 | 4.90 | 0.07 | 16.60 | -0.79 | 32.65 | 1.51\* | 36.45 | 1.42 |
| AVPP0516Ujjwala | 112.30 | 2.65 | 66.55 | 3.07 | 4.80 | -0.54 | **19.00** | -0.04 | 31.60 | -2.98\*\* | 36.10 | -2.07\*\* |
| AVPP0517AVPP9703 | 108.00 | 3.60 | 59.65 | -14.35\*\* | 5.60 | 1.09\*\* | 12.40 | 0.92 | 35.05 | -0.89 | 38.00 | -1.34 |
| AVPP0517 VI059328 | 92.55 | -5.79 | 76.85 | -13.23\*\* | 4.00 | -0.00 | 12.05 | -0.73 | **31.05** | 0.29 | **34.95** | 0.58 |
| AVPP0517Chivar-1 | 109.20 | -5.60 | 84.10 | 1.91 | 5.00 | -0.23 | 14.05 | 0.01 | 34.60 | 0.02 | 37.95 | -0.03 |
| AVPP0517EC566920 | 123.00 | 4.80 | 89.10 | 5.98\* | 3.80 | 0.19 | 15.20 | 1.09 | 37.90 | 0.85 | 41.30 | 0.95 |
| AVPP0517EC37862 | 115.30 | -0.60 | 74.10 | 10.70\* | 3.70 | -0.73 | 12.00 | -1.20 | 34.30 | -0.50 | 37.80 | -0.24 |
| AVPP0517LC 217 | 121.000 | 12.00\*\* | 84.10 | 1.36 | 3.55 | -0.73 | 15.85 | 0.71 | 32.80 | -1.10 | 36.85 | -0.73 |
| AVPP0517Anugraha | 97.10 | -3.35 | 74.95 | 6.20 | 3.90 | -0.40 | 15.05 | -0.75 | **32.40** | 0.24 | **36.40** | 0.28 |
| AVPP0517Ujjwala | 101.95 | -5.05 | 64.45 | 1.41 | 5.95 | 0.82\* | 17.40 | -0.05 | **36.70** | 1.09 | **39.80** | 0.53 |
| AVPP9907AVPP9703 | 116.15 | 4.17 | 54.55 | 12.94\*\* | 4.10 | -0.67 | 13.15 | 0.18 | **41.30** | 3.75\*\* | **44.10** | 3.60\*\* |
| AVPP9907VI059328 | 107.30 | 1.37 | 52.00 | 11.06\* | 5.20 | 1.12\*\* | 15.60 | 1.31 | **31.10** | -1.25 | **34.60** | -0.91 |
| AVPP9907Chivar-1 | 119.35 | -3.04 | 37.17 | 6.46 | 5.00 | -0.30 | 15.00 | -0.53 | **35.40** | -0.77 | 38.40 | -0.73 |
| AVPP9907EC566920 | 123.60 | -2.17 | 37.00 | -11.57\* | 3.90 | 0.22 | 13.20 | -2.39\*\* | 38.40 | -0.24 | 41.25 | -0.24 |
| AVPP9907EC37862 | 119.65 | -3.84 | 46.20 | -12.00\* | 4.60 | 0.39 | 13.10 | -1.59\* | 34.20 | -2.20\*\* | 37.00 | -2.19\*\* |
| AVPP9907LC 217 | 117.05 | 0.47 | 43.85 | 2.86 | 3.30 | -0.80\* | 18.00 | 1.36\* | 36.10 | 0.59 | **39.40** | 0.66 |
| AVPP9907Anugraha | 108.70 | 0.65 | 39.65 | -5.25 | 4.70 | 0.32 | 18.85 | 1.55\* | 32.00 | -1.75\* | **35.55** | -1.71\* |
| AVPP9907 Ujjwala | 117.00 | 2.40 | 10.45 | -4.49 | 4.90 | -0.29 | **19.05** | 0.10 | 39.10 | 1.89\* | **41.95** | 1.53\* |
|  | **11.65** |  | **6.92** |  | **1.02** |  | **1.82** |  | **2.05** |  | **2.07** |  |
|  | **3.98** |  | **4.898** |  | **0.35** |  | **0.62** |  | **0.70** |  | **0.71** |  |
|  | **5.63** |  | **6.927** |  | **0.49** |  | **0.88** |  | **0.99** |  | **1.00** |  |
|  | **5.04** |  | **10.45** |  | **11.01** |  | **5.79** |  | **2.87** |  | **2.64** |  |

Contd .Table 5 Estimates of SCA effects and *per se* performance of hybrids for various s characters in chlli

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hybrids** | **MEAN** | **DM** | **MEAN** | **AFW** | **MEAN** | **FL** | **MEAN** | **MEAN** | **FPP** | **MEAN** | **YPP** |
| AVPP0516AVPP9703 | 54.55 | -2.31\*\* | **8.67** | 1.08\*\* | **12.020** | 0.91\*\* | -21.440 | 75.20 | -6.65 | 539.050 | -21.440 |
| AVPP0516 VI059328 | **51.02** | 0.53 | 3.72 | -0.30 | 5.610 | -1.32\*\* | -79.581\*\* | 133.80 | -4.56 | 572.58 | -79.581\*\* |
| AVPP0516Chivar-1 | 54.25 | 0.24 | 3.55 | -0.55\*\* | 8.280 | 0.94\*\* | -77.371\*\* | 68.10 | 0.85 | 220.82 | -77.371\*\* |
| AVPP0516EC566920 | 57.00 | -0.80 | 4.05 | -0.83\*\* | 8.390 | 0.58\* | -22.360 | 83.55 | 13.25\*\* | 303.31 | -22.360 |
| AVPP0516 EC37862 | 57.15 | 2.11\*\* | 5.46 | 0.36\* | 7.650 | -0.67\* | 33.037 | 88.30 | 2.00 | 432.67 | 33.037 |
| AVPP0516LC 217 | 54.50 | -0.20 | 5.42 | 0.28 | 9.200 | -0.96\*\* | 8.595 | 68.60 | -20.11\*\* | 407.03 | 8.595 |
| AVPP0516Anugraha | 54.55 | 1.73\* | 4.69 | 0.16 | 8.990 | 0.33 | **176.55**\*\* | **179.65** | **34.25\*\*** | **822.120** | **176.55**\*\* |
| AVPP0516Ujjwala | 55.15 | -1.30 | 3.90 | -0.19 | 9.100 | 0.18 | 17.44 | 141.05 | -19.01\*\* | **704.985** | 17.44 |
| AVPP0517AVPP9703 | 56.75 | -1.05 | 6.09 | -0.46\* | 8.590 | -0.84\*\* | 59.78\*\* | 93.40 | 10.13\* | 567.53 | 59.78\*\* |
| AVPP0517 VI059328 | 50.90 | -0.95 | 3.52 | 0.52\*\* | 6.740 | 1.47\*\* | **172.57**\*\* | **171.15** | **31.36\*\*** | 771.99 | **172.57**\*\* |
| AVPP0517Chivar-1 | 55.15 | -0.19 | 3.47 | 0.40\* | 5.680 | 0.01 | -2.429 | 66.40 | -2.26 | 244.525 | -2.429 |
| AVPP0517EC566920 | 59.45 | 0.31 | 3.76 | -0.08 | 5.390 | -0.74\* | 0.102 | 61.60 | -10.11\* | 273.03 | 0.102 |
| AVPP0517EC37862 | 57.00 | 0.62 | 4.10 | 0.03 | 7.560 | 0.90\*\* | -9.751 | 81.85 | -5.86 | 337.140 | -9.751 |
| AVPP0517LC 217 | 55.55 | -0.49 | 4.17 | 0.07 | 8.980 | 0.48 | -43.87\*\* | 93.00 | 2.86 | 301.820 | -43.87\*\* |
| AVPP0517Anugraha | 56.05 | 1.89\* | 2.95 | -0.53\*\* | 6.370 | -0.61\* | -109.76\*\* | 122.50 | -24.31\*\* | 483.050 | -109.76\*\* |
| AVPP0517Ujjwala | 57.65 | -0.14 | 3.10 | 0.04 | 6.580 | -0.66\* | -66.63\*\* | 159.70 | -1.78 | 603.050 | -66.63\*\* |
| AVPP9907AVPP9703 | 62.05 | 3.37\*\* | 6.93 | -0.61\*\* | 11.590 | -0.06 | -38.343\*\* | 70.10 | -3.48 | 536.450 | -38.343\*\* |
| AVPP9907VI059328 | 53.15 | 0.42 | 3.76 | -0.21 | 7.320 | -0.15 | -92.98\*\* | 103.30 | -26.79\*\* | 573.475 | -92.98\*\* |
| AVPP9907Chivar-1 | 56.15 | -0.05 | 4.20 | 0.15 | 6.930 | -0.95\*\* | **79.80** \*\* | 60.40 | **1.41** | 392.300 | **79.80** \*\* |
| AVPP9907EC566920 | 60.50 | 0.49 | 5.75 | 0.91\*\* | 8.500 | 0.15 | 22.25 | 58.90 | -3.13 | 362.235 | 22.25 |
| AVPP9907EC37862 | 54.50 | -2.74\*\* | 4.65 | -0.40\* | 8.630 | -0.23 | -23.28 | 81.90 | 3.86 | 390.650 | -23.28 |
| AVPP9907LC 217 | 57.60 | 0.69 | 4.73 | -0.35\* | **11.195** | 0.48 | **35.27** | 97.70 | **17.25\*\*** | 448.015 | **35.27** |
| AVPP9907Anugraha | 51.40 | -3.62\*\* | 4.85 | 0.37\* | 9.490 | 0.28 | -66.78 \*\* | 127.20 | -9.93\* | 593.075 | -66.78 \*\* |
| AVPP9907 Ujjwala | 60.10 | 1.44 | 4.20 | 0.15 | 9.940 | 0.48 | 84.07\*\* | **172.60** |  | **820.80** | 84.07\*\* |
|  | **4.25** |  | **0.55** |  | **0.831** |  |  | **15.57** |  | **100.11** | **15.57** |
|  | **1.45** |  | **0.18** |  | **0.284** |  |  | **5.32** |  | **34.22** | **34.22** |
|  | **2.06** |  | **0.26** |  | **0.402** |  |  | **7.52** |  | **48.39** | **48.39** |
|  | **3.67** |  | **5.86** |  | **4.85** |  |  | **7.34** |  | **9.92** | **9.92** |