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Gene Action and Combining Ability Effects on Yield and Yield Contributing Traits in Chilli (*Capsicum annuum* L.) Hybrids

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The analysis of combining ability effects and gene action related to yield and yield-contributing traits in chilli (*Capsicum annuum* L.) is crucial for selecting suitable parents to develop high-yielding chilli hybrids by identifying the key general and specific combiners. The present study was aimed at estimating the combining ability effects in 12 novel chilli hybrids for identification of best general combiners and specific combiners for yield and yield contributing traits. The results from line x tester analysis revealed the presence of considerable genetic variation with respect to yield and yield contributing traits. Analysis of variance for combining ability showed significant differences for plant height, number of fruits per plant and fruit yield per plant and SCA variances were found to be higher than the GCA variance for all the traits except for fruit yield per plant. The ratio of

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σ^2GCA/σ^2SCA was less than one for all the traits except for fruit yield per plant indicating the preponderance of dominant gene action, which plays an important role in the exploitation of heterosis through hybrid breeding. The parents Tejaswini, Ruby, Mohana, VNR-1366 and VNR-305 were found to be good general combiners based on significant GCA effects for yield and yield contributing traits. The SCA effects expressed the combinations *viz.,* Tejaswini x VNR-1366, Tejaswini x VNR-145 and Ruby x VNR-1366 as good specific combiners for number of fruits per plant and fruit yield per plant. The results of the current study would help plan for successful hybrid breeding programme for chilli crop improvement.

Keywords: Capsicum annuum L*.; line x tester analysis; combining ability; gene action; fruit yield.*

1. INTRODUCTION

"Chilli (*Capsicum annuum* L.) is an important commercial and export-oriented crop in India. It is an economic hub cultivation in India as a vegetable for its green fruits and as a spice for its red form. It belongs to the Solanaceae family and has a chromosome number of $2n = 2x = 24$. Chilli is the second most valuable solanaceous vegetable in the world after tomato. Chilli is an indispensable spice essentially used in every Indian kitchen due to its pungency, taste, appealing colour and flavour. Chillies have two important qualities i.e. pungency and attractive red colour which are attributed to capsaicin and capsanthin, respectively. "Pungency of chilli is due to a crystalline acrid volatile alkaloid called capsaicin, present in the placenta of fruit which has diverse prophylactic and therapeutic uses in allopathic and Ayurvedic medicines" (Ghosh *et al*., 2024). Red coloured pigment is used as a natural colour additive in food and drugs. "These pigments are also rich in bioflavonoids which are powerful antioxidants and inhibit the progression of chronic diseases such as muscular degeneration, cardiovascular diseases and cancer" (Bosland and Votava, 2000; Chattopadhyay *et al*., 2011; Farwah *et al*., 2020; Komala *et al*., 2023; Husen *et al*., 2023).

The analysis of combining ability is being used in breeding programmes to evaluate the performance of cross combinations. "It helps in determination of hybrid vigour in a population which can be used to select the parents for generating crosses and segregating populations" (Meredith and Brown,1998). For a successful hybridization programme, parents should be selected not only on the basis of their diversity but also on the basis of their combining ability. Hence, the information on combining ability will help the breeder in developing the future breeding programme to be adopted for exploiting additive and /or non-additive components of gene action present in the material thus it helps in developing high yielding genotypes/varieties. "The knowledge of the relative importance of additive and non-additive gene action is essential to a plant breeder for the development of an efficient hybridization programme" (Dudley and Moll, 1969) and "proper choice of parents based on their combining ability is also prerequisite to gain better heterotic effects. Combining ability refers to the capacity or ability of a genotype to transmit superior performance to its crosses. Selection of parents on the basis of combining ability has been used as an important breeding approach to break the yield plateau. The concept of combining ability was originally developed in maize" by Richey and Meyar (1925). Sprauge and Tatum (1942) have defined the terms 'general combining ability' (GCA) and 'specific combining ability' (SCA) as a measure of gene action while working with maize. Griffing (1956), showed the relationship between GCA and SCA variances. The GCA variance is due to additive whereas SCA variance is due to non-additive gene action. Hence, both act as an important diagnostic tool in selection of suitable parents. "Line x tester (L x T) mating design provides a more precise estimate of GCA, SCA and other parameters" (Kempthorne, 1957). Therefore, the present investigation was carried out using L x T mating design to estimate the combining ability effects for yield and its component characters in chilli.

Keeping in view the importance of combining ability, the present study was conducted to analyse the 12 novel chilli hybrids (generated through line x tester design using 4 lines and 3 testers) for their combining ability effects for important yield and yield contributing traits.

2. MATERIALS AND METHODS

The field experiments were conducted to evaluate the combining ability effects and gene action for yield and yield contributing traits in chilli. The chilli hybrids were evaluated in a randomized block design (RBD) with two replications at the College of Horticulture, Chinalataripi, Dr. YSRHU, Andhra Pradesh (tropical region), India. The 12 hybrids (crosses) were grown with a spacing of 60 x 50 cm. Data were recorded on five randomly selected plants per replication for all the characters *viz.,* plant height (cm), number of fruits per plant, fruit length (cm), fruit width (cm) and fruit weight per plant (g). "The means for all the observed parameters were worked out further subjected to Analysis of variance and combining ability effects from the replicated data worked out using the AGRISTAT software" (Manivannan, 2014; Nadarajan and Manivannan, 2024). "Adopted the statistical methodology for L x T analysis" (Kempthorne, 1957).

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance for Combining Ability

Analysis of variance for randomized block design was carried out to test the significant differences among the genotypes (Table 1). It suggested the presence of considerable genetic variation with respect to various traits in yield contributing traits and significant differences for plant height, number of fruits per plant and fruit yield per plant. This indicates the existence of wide variability in the material studied and there is an excellent scope to identify good general combiners and to develop promising hybrids and selection is possible to identify the most desirable transgressive segregants. Similar results were reported by Payakhapaab *et al*., (2012), Shilpa *et al*., (2016), Janaki *et al.,* (2017) and Pathare *et al.,* (2023).

The results from line x tester analysis indicated the SCA variance were higher than the GCA variance for all the studied traits except for fruit yield per plant (Table 1). The ratio of σ^2GCA/ σ^2SCA was less than one for all the traits except for fruit yield per plant indicating the preponderance of dominant gene action which plays an important role in the exploitation of heterosis through hybrid breeding. The presence of dominance gene action in the characters indicated the postponement of selection to later generations after effective crosses. Heterosis breeding procedures are effective in harnessing dominance gene action to the full extent. These results are in accordance with Hasanuzzaman *et al*., (2012), Suryakumari *et al*., (2014). Fruit yield per plant was showed predominance of additive gene action in governing these traits due to higher magnitude of GCA variance than SCA variances and high GCA:SCA ratio (>1) suggesting that these traits can be improved through simple selection procedure in segregating generations. The results of this kind of gene action are in conformity with earlier findings of Khalil and Hatem (2014) and Janaki *et al.,* (2017).

3.2 General Combining Ability (GCA) Effects for Yield and Yield Contributing Traits

"Combining ability of parents gives useful information on the choice of parents in terms of expressed performance of their hybrids and progeny" (Dhillon,1975). Simmonds, (1979) reported GCA effect is controlled by additive gene effects which are fixable. Singh and Singh and Singh (1985) suggested that parents with high GCA would produce transgressive segregates in F_2 (or) later generations. Therefore, the selection of parents based on favourable GCA would have an impact on the breeding programme. The general combining ability (GCA) effects of parents for all studied traits were presented in Table 2. In the present study, the line Tejaswini was expressed positively significant for all the traits except for plant height, Ruby negatively significant for number of fruits per plant and Mohana showed negatively significant for fruit yield per plant. These results are supported by the earlier findings of Kamble *et al*., (2009), Hasanuzzaman *et al*., (2012), Janaki *et al*., (2017) and Pathare *et al*., (2023). Among the testers, the tester VNR-1366 was revealed positively significant for plant height and VNR-305 showed negatively significant for plant height. From the above discussions, it was inferred that none of the parents was found to be a good general combiner for all the traits. These results are in accordance with earlier reported by Suryakumari *et al*., (2014), Kranthi Rekha *et al*., (2016) and Janaki *et al*., (2017). This indicated that, these parents are potential parents and can be further utilized in chilli hybrid development programme for exploitation of their good GCA ability.

3.3 Specific Combining Ability (SCA) effects for Yield and Yield Contributing Traits

"The specific combining ability is the deviation from the performance predicted on the basis of general combining ability" (Allard, 1960). According to Sprague and Tatum, (1942) the specific combining ability is controlled by Non-Additive gene action. The SCA effect is an important criterion for the evaluation of hybrids

Table 1. Analysis of variance for combining ability of yield and yield contributing traits in chilli

Source of variation	Mean squares					
	d.f.	PH	NFP	FL	FW	FYP
Replication	1	2.72	0.0	0.18	0.01	683.41
Crosses	11	18.16**	2.94*	1.43	0.18	943.16**
Lines (L)	3	4.87	4.08	2.34	0.34	2249.65*
Testers (T)	2	48.32*	1.18	0.58	0.18	274.97**
L x T	6	10.12**	2.40	0.89	0.07	418.67**
Error	11	4.72	0.55	0.63	0.06	387.48
σ^2 GCA		0.33	0.01	0.02	0.003	30.70
σ^2 SCA		2.73	0.93	0.13	0.02	10.60
σ^2 GCA/ σ^2 SCA		0.12	0.01	0.15	0.15	2.90

** and **Significant at P≤0.05 and P≤0.01, respectively. d. f.: Degrees of freedom, PH: Plant height (cm), NFP: Number of fruits per plant, FL: Fruit length (cm), FW: Fruit width (cm), FYP: Fruit yield per plant (g), L x T: Lines x Testers, σ^2 GCA: General combining ability variance, σ^2 SCA: Specific combining ability variance*

Table 2. General combining ability effects for yield and yield contributing traits in chilli

Parents	PH	NFP	FL	FW	FYP
Lines					
Tejaswini	-0.34	1.13**	0.68*	0.30**	21.39*
Ruby	-0.65	-0.77*	-0.58	-0.04	-3.80
Mohana	-0.34	0.06	-0.45	-0.14	-24.54*
Armour	1.33	-0.41	0.35	-0.12	6.95
SE	1.25	0.43	0.42	0.09	11.36
Testers					
VNR-1366	2.71**	-0.20	-0.11	0.11	6.50
VNR-145	-0.81	0.44	-0.17	-0.11	-4.43
VNR-305	-1.89*	-0.24	0.28	0.00	-2.07
SE	1.08	0.37	0.36	0.08	9.84

** and **Significant at P≤0.05 and P≤0.01, respectively. PH: Plant height, NFP: Number of fruits per plant, FL: Fruit length, FW: Fruit width, FYP: Fruit yield per plant, SE: Standard error*

Table 3. Specific combining ability effects for yield and yield contributing traits in chilli

Chilli Hybrids	PH	NFP	FL	FW	FYP
Tejaswini x VNR-1366	2.65	-1.18*	0.21	0.05	-16.64
Tejaswini x VNR-145	-0.98	1.80**	0.25	-0.22	39.27*
Tejaswini x VNR-305	-1.67	-0.62	-0.47	0.17	7.37
Ruby x VNR-1366	1.21	0.46	0.01	0.19	-13.37*
Ruby x VNR-145	0.24	-0.87	0.27	0.01	-2.65
Ruby x VNR-305	-1.45	0.41	-0.28	-0.20	-10.72
Mohana x VNR-1366	-1.82	0.67	-0.55	-0.11	12.61
Mohana x VNR-145	1.25	-0.73	-0.51	0.11	-14.14
Mohana x VNR-305	0.57	0.06	1.06	0.00	1.53
Armour x VNR-1366	-2.04	0.05	0.33	-0.13	-9.34
Armour x VNR-145	-0.51	-0.20	-0.01	0.10	7.52
Armour x VNR-305	2.55	0.15	-0.31	0.03	1.82
SE	2.17	0.74	0.73	0.16	19.68

** and **Significant at P≤0.05 and P≤0.01, respectively. PH: Plant height, NFP: Number of fruits per plant, FL: Fruit length, FW: Fruit width, FYP: Fruit yield per plant, SE: Standard error*

next to mean performance. The SCA, not only involves dominance and epistasis but also a considerable amount of genotype and environment (G x E) interaction. The SCA effects of hybrids for all the traits presented in Table 3. In the present investigation, the hybrid Tejaswini x VNR-1366 was showed negatively significant for number of fruits per plant, Tejaswini x VNR-145 was expressed positively significant for number of fruits per plant and fruit yield per plant and ruby x VNR-1366 was exhibited negatively significant for fruit yield per plant. The results are supported by suryakumari *et al.,* (2014), janaki *et al.,* (2017) and pathare *et al.* (2023).

4. CONCLUSION

The present study revealed that the parents Tejaswini, Ruby, Mohana, VNR-1366 and VNR-305 were found to be good general combiners based on significant GCA effects for yield and yield contributing traits. The SCA effects revealed the combinations *viz.,* Tejaswini x VNR-1366, Tejaswini x VNR-145 and Ruby x VNR-1366 as good specific combiners for number of fruits per plant and fruit yield per plant. The good general and specific combiners identified in this study could be utilized in future chilli hybrid development for improved yield and trait stability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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