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Evaluation of Combining Abilities for Traits Improvement in Chrysanthemum

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ABSTRACT

Background: In the case of chrysanthemums, a commercially important ornamental plant, understanding of combining ability can significantly improve breeding efficiency, allowing for the development of new cultivars with desired traits such as better flower quality, longer shelf life, disease resistance and adaptability to different environmental conditions. Combining ability is a powerful tool in chrysanthemum breeding, enabling breeders to make informed decisions about which parent plants to use for creating hybrids with desired traits. By focusing on GCA and SCA, breeders can enhance traits like flower size, color, disease resistance and environmental adaptability, leading to the development of superior chrysanthemum varieties for both ornamental and commercial purposes. An experiment was carried out in the research plot of Department of Floriculture and Landscaping, OUAT, Bhubaneswar Odisha to study the combining ability effects in chrysanthemum.

Methods: Eight varieties of chrysanthemum were crossed using half-diallel mating design (excluding reciprocals). After crossing, 28 number of hybrids were produced which were studied for combining ability.

Result: Shova and SS were reported to be the best general combiners for flower yield attributes, while the hybrids Shova × Arka Kirti, Shova × UHFS-56, SS × A.Kirti , Shova × ACC-1, Shova × SS were found to have significant desirable SCA effects for number of flowers per plant.

Key words: Combining ability, GCA, Half-diallel design, SCA.

INTRODUCTION

Chrysanthemum (*Chrysanthemum morifolium*) is a widely cultivated ornamental plant known for its diverse flower forms, colours and extended blooming duration. The economic importance of Chrysanthemum in the global floriculture industry underscores the need for continuous improvement in its genetic traits. Breeding programs in chrysanthemum often aim to enhance traits such as flower size, number of flowers per plant and plant height.

Combining ability analysis, first proposed by Sprague and Tatum (1942), distinguishes between general combining ability (GCA), which refers to the average performance of a genotype in hybrid combinations, whereas the specific combining ability (SCA), which reflects upon the performance of specific hybrid combinations. The higher side of SCA directs the importance of the magnitude of non-additive gene effects to the total genetic variance (Falconer and Mackay, 1996). Combining ability is an effective tool, which gives useful genetic information for the choice of parents in terms of performance of their hybrids (Chezhian *et al.,* 2000). GCA is associated with additive genetic effects, while SCA is linked to non-additive genetic effects, including dominance and epistasis. GCA facilitates the identification of genotypes that, over several crosses, consistently and favourably contribute to desired attributes including flower size, color favourably contribute to desired attributes, including flower size, colour and yield. It helps choose parents that have better additive genetic effects to employ in a breeding program so that the desired feature can grow steadily and predictably. SCA is useful even in cases where a genotype pair does not have a high GCA since it can find genotype pairs that generate exceptional offspring for specific attributes. It helps create hybrids with better traits by taking advantage of certain parental genotype combinations that have significant SCA impacts.

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By focusing on crosses with high SCA, breeders can achieve significant improvements in traits influenced by non-additive genetic interactions, producing potentially superior hybrids.

Understanding these components in Chrysanthemum breeding can guide the selection of parent lines and optimize hybridisation strategies. The primary objective of this study is to evaluate the GCA and SCA of various Chrysanthemum genotypes for key ornamental traits. Our study aims at identifying the most promising lines and hybrid combinations for developing superior Chrysanthemum cultivars.

MATERIALS AND METHODS

The study was conducted in the research plot of Department of Floriculture and Landscaping, OUAT Bhubaneswar in Rabi season of 2021-22 and October 2022- February 2023 with eight diverse chrysanthemum genotypes selected based on their distinct morphological characteristics and known breeding potential (Table 1). The following parameters were studied *viz*., plant height (cm), number of branches, number of leaves per branch, stalk length (cm), days to flower bud initiation, days to final bloom, number of flower buds per plant, number of flowers per branch, number of flowers per plant.

These genotypes were crossed in half-diallel fashion (excluding reciprocals) and 28 hybrids were produced. The terminal cuttings of 15 cm were raised in sand beds during the rainy season. These cuttings were transferred to polybags post-rooting. The plants were then re-potted in pots. Uniform cultural practices, including fertilization, irrigation and pest control, were applied to all plants to minimize environmental differences and ensure a precise assessment of their genetic potential.

Table 1: Genotypes used for the experiment.

Notation	Genotypes
G1	Shova
G2	ACC-1
G3	SS
G4	Arka kirti
G5	Pusa chitrakshya
G6	BCKV-123(check)
G7	UHFS-68
G8	UHFS-56

Statistical analysis

The data was subjected to analysis of variance (ANOVA) to determine significant differences among the genotypes. GCA and SCA effects were estimated using the method outlined by Griffing 's-II diallel method. GCA effects were calculated for each parent, while SCA effects were calculated for each hybrid combination. The significance of GCA and SCA effects was tested using the appropriate statistical procedures and the ratio of GCA to SCA variance components was used to determine the relative importance of additive and non-additive genetic effects (Table 2). The visualization of graphs and data analysis were carried out using R Studio, PBTools (IRRI, Los Baños, Philippines) and TNAUSTAT, respectively.

RESULTS AND DISCUSSION

Estimates of genetic components of variance

The estimate of genetic components of GCA and SCA variances and their ratios for flower yield and its components are given in Table 3. Combining ability has been a crucial genetic parameter in plant breeding, particularly for harnessing heterosis (Kumar *et al.,* 2006). Variations in GCA are primarily attributed to additive genetic variance, while variations in SCA are linked to non-additive genetic variance (Falconer, 1982). In this study, both GCA and SCA components were found to be highly significant with respect to all the growth and flowering traits. Notably, substantial GCA effects were observed for the number of flowers per plant and the duration of flowering (in days), suggesting that additive gene action plays a significant role in these traits. The predominance of additive gene action for the aforementioned was also reported by Gupta *et al.* (2001) in marigold.

Combining ability (GCA, SCA) effects

A wide range of variability was recorded among the parents for the characters studied. Among all the parents none of the parents were found to be good general combiner for all the characters examined. For traits such as plant height, days to flower bud initiation and flowering duration, negative general combining ability (GCA) effects are preferred. SS was found to have highest GCA effect for number of flowers per plant (Table 4). Pusa Chitrakshya reported highest GCA effect for the trait number of flowers per branch (0.25) followed by ACC-1 (0.17). The parent SS (G3) was examined

Table 2: Analysis of variance for combining ability of different parameters of Chrysanthemum in F_1 generation.

Source	Df	Plant height (cm)	Number of branches	Number of leaves per branch	Stalk length (cm)	Days to flower bud initiation	Days to final bloom	Number of flower buds per plant	Number of flowers per branch	Number of flowers per plant
GCA	7	22.5906**	5.6789**	2.5840**	9.9200**	10.0051**	25.6894 **	6.9814**	0.3694**	2.6020**
SCA	28	5.0608**	1.1080**	0.5681**	2.0305**	4.5760**	4.8334**	7.1346**	0.1238**	2.4332**
Error	70	0.3137	0.0115	0.1562	0.4328	1.1485	0.5036	1.0135	0.0351	0.2553

as a good combiner for the traits number of flowers per plant (1.04) and days to final bloom (-1.79). Similarly estimation of GCA effects revealed that among the eight diverse parents expression of plant height (-2.11), days to flower bud initiation (-1.27) were found to be significant in Shova in desirable direction.

These parents can be used in further breeding programmes to enhance the said characters. Kumar *et al.* (2006) reported similar findings in chrysanthemum, suggesting that these traits are predominantly controlled by additive genetic effects. Datta and Gupta (2017) emphasized the role of combining ability in Chrysanthemum breeding, particularly for traits related to ornamental value. They noted that plant height showed higher GCA, inferring that it is controlled by additive gene action.

The SCA effects varied significantly across the hybrid combinations. The study of SCA effects revealed that the crosses Shova × ACC-1, Shova × SS, Shova × Arka Kirti and Shova × UHFS-68 exhibited highest significant SCA effect for flower yield (Table 5). The hybrid Shova × Arka Kirti was reported to demonstrate highest significant SCA effects for the traits number of flowers per plant (2.62) followed by Shova × UHFS-68 (2.37), whereas the trait days to flower bud initiation was found highest negatively significant in the hybrid SS × UHFS-56 (-4.38) followed by ACC-1 × UHFS-56 (-3.75). ACC-1 × UHFS-68 was found to have highest negative sca effects (-3.08) for plant height, these parents can be exploited to create dwarf hybrids. SS × UHFS-56 was reported to have highest negative sca effect (-4.07) for days to final bloom. Good general combining inbred parents may not always show high SCA effects in their cross combinations (Otusanya *et al*., 2022). Thus it may be concluded that the information on GCA effects alone may not be sufficient to predict the extent of hybrid vigour by a particular cross combination (Chakraborty *et al.,* 2010). The crosses Shova × ACC-1, Shova × A. Kirti and ACC-1 × UHFS-68 were found to be the best cross combinations due to their desirable sca effects.

σ^2SCA was found higher for all the traits than σ^2GCA, such results demonstrate that the non-additive quality impacts played more imperative part than added substance quality impacts on the legacy of these characters (Table 3).

Table 3: Estimates of variance components and degree of dominance for different parameters of Chrysanthemum in F_1 generation.

Source	Plant height (cm)	Number of branches	Number of leaves per branch	Stalk length (cm)	Days to flower bud initiation	Days to final bloom	Number of flower buds per plant	Number of flowers per branch	Number of flowers per plant
σ^2GCA	1.7540	0.4571	0.2014	0.7890	0.8857	2.5186	0.0100	0.0246	0.1999
σ^2SCA	4.7462	1.0966	0.4122	1.5976	3.4275	4.3298	6.1116	0.0888	1.8304
σ^2GCA/σ^2SCA	0.3696	0.4169	0.4885	0.4939	0.2584	0.5817	0.0016	0.2769	0.1092
σ^2A	3.5080	0.9142	0.4028	1.578	1.711	3.979	0.020	0.0492	0.8252
σ^2D	4.7462	1.0966	0.4122	1.5976	3.4275	4.3298	6.1116	0.0888	1.8304
h^2bs	0.988085	0.998161	0.940190	0.956636	0.926666	0.983215	0.000106	0.928196	0.941727
h^2ns	0.266624	0.293639	0.308570	0.316243	0.215584	0.314768	0.959834	0.201103	0.387874

*Significant at P= 0.05, **Significant at P= 0.0.

Table 4: General combining ability effects of parents for different parameters of Chrysanthemum.

Traits / Genotypes	Plant height (cm)	Number of branches	Number of leaves per branch	Stalk length (cm)	Days to flower bud initiation	Days to final bloom	Number of flower buds per plant	Number of flowers per branch	Number of flowers per plant
G1	-2.11**	-1.42**	0.40**	-1.78**	-1.27**	-1.32**	0.13	0.10	-0.54*
G2	-1.44**	-0.86**	0.61**	-0.16	0.51	-1.72**	-0.03	0.17**	-0.15
G3	1.80**	0.22**	0.23	0.69**	-1.14**	-1.79**	-1.32**	-0.28**	1.04**
G4	-0.26	0.28**	0.56**	1.67**	-0.89**	-0.44*	1.28**	0.12*	0.23
G5	2.22**	0.05	-0.40**	-0.38	0.09	0.26	1.02**	0.25**	0.11
G6	-0.89**	0.34**	-0.66**	-0.37	0.35	0.75**	-0.16	-0.10	-0.54*
G7	0.27	0.78**	-0.24*	-0.09	1.24**	1.87**	-0.52	-0.23**	0.09
G8	0.42*	0.61**	-0.51**	0.43*	1.11**	2.40**	-0.38	-0.03	-0.25
Gi	0.1656	0.0317	0.1169	0.1946	0.3192	0.1927	0.2992	0.0554	0.1473
gi-gj	0.2504	0.0479	0.1767	0.2942	0.4825	0.2913	0.4523	0.0837	0.2227

*Significant at P= 0.05, **Significant at P= 0.01.

G1-Shova; G2- ACC-1; G3-SS; G4- Arka kirti; G5- Pusa chitrakshya; G6- BCKV-123(check); G7- UHFS-68 G8- UHFS- 56 (Table 1).

Table 5: Specific combining ability effects of hybrids for different traits of Chrysanthemum.

Genotypes \ Traits	Plant height (cm)	Number of branches	Number of Leaves per branch	Stalk length (cm)	Days to flower bud initiation	Days to final bloom	Number of flower buds per plant	Number of flowers per branch	Number of flowers per plant
G1 × G2	-0.18	0.70**	-0.18	-3.15**	-2.15**	-1.60**	-0.32	-0.22**	1.22**
G1 × G3	1.27**	-0.64**	0.65**	-1.01**	0.42	-0.45	3.52**	0.40**	1.72**
G1 × G4	0.49*	-0.12**	0.58**	0.77**	-0.45	0.67*	2.38**	-0.04	2.62**
G1 × G5	1.14**	-0.41**	0.04	-1.18**	-2.06**	1.89**	1.62**	0.15*	1.86**
G1 × G6	0.21	-0.01	-0.34*	0.68*	0.7	1.06**	1.54**	0.27**	-0.14
G1 × G7	-0.29	0.55**	-0.96**	1.64**	-1.29**	-0.45	0.99*	0.25**	2.37**
G1 × G8	3.88**	0.06	-1.39**	0.60*	1.12**	1.29**	-2.45**	-0.07	-0.64*
G2 × G3	1.91**	0.37**	-0.03	0.29	1.50**	0.32	1.05**	0.16*	-0.33
G2 × G4	0.94**	0.29**	0.01	0.00	-0.52	0.06	1.14**	0.13	1.32**
G2 × G5	-0.04	0.55**	-0.54**	1.31**	-0.16	-1.87**	0.92*	0.01	-0.12
G2 × G6	1.05**	-0.26**	-0.02	1.45**	-0.3	0.15	0.42	0.17*	-0.31
G2 × G7	-3.08**	1.87**	-1.07**	1.34**	-0.1	-2.02**	3.05**	0.40**	0.84**
G2 × G8	1.29**	0.96**	0.15	0.24	-3.75**	-3.31**	-0.39	0.16*	0.05
G3 × G4	1.20**	0.15**	0.72**	0.33	0.39	-1.19**	-5.37**	-0.14	1.43**
G3 × G5	2.12**	1.26**	0.33*	1.38**	-1.30**	-0.13	-2.40**	-0.56**	-0.5
G3 × G6	0.70**	2.15**	-0.26	1.60**	-0.21	0.08	1.48**	-0.52**	0.48
G3 × G7	2.13**	-1.19**	-0.50**	-0.49	-1.82**	-1.77**	2.82**	-0.28**	-1.55**
G3 × G8	-1.23**	-0.78**	-1.33**	-0.02	-4.38**	-4.07**	1.84**	-0.19*	-1.31**
G4 × G5	0.19	0.99**	-0.64**	0.82**	-0.34	-0.23	1.66**	-0.27**	-0.52
G4 × G6	-0.18	-1.41**	-0.11	1.43**	-0.56	-1.67**	-0.53	0.38**	0.34
G4 × G7	-0.97**	-0.47**	-0.38*	0.51	-3.08**	-0.39	-3.47**	0.46**	-0.53
G4 × G8	-0.95**	0.32**	-0.42**	-1.80**	-1.28**	-2.30**	-3.91**	0.35**	-0.5
G5 × G6	-0.65**	-0.74**	0.35*	-0.24	-0.31	-0.25	1.54**	0.17*	1.15**
G5 × G7	2.91**	0.36**	0.10	0.32	0.02	-1.30**	-0.41	0.06	-0.17
G5 × G8	1.98**	-0.36**	-0.53**	1.64**	-1.64**	-2.15**	1.77 **	-0.27**	-1.03**
G6 × G7	3.03**	1.59**	1.32**	0.51	1.33**	-0.93**	2.38 **	0.02	0.95**
G6 × G8	2.13**	0.75**	0.98**	0.17	2.28**	3.24**	-1.06 **	-0.47**	1.03**
G7 × G8	-0.65**	-0.07	0.43**	0.43	0.62	1.86**	-0.30	-0.24**	-0.58
Sii	0.4417	0.0844	0.3117	0.5189	0.8511	0.5139	0.7978	0.1477	0.3928
Sij	0.5077	0.0970	0.3538	0.5965	0.9783	0.5907	0.9171	0.1698	0.4515
Sii-Sij	0.6134	0.1172	0.4328	0.7206	1.1819	0.7136	1.1080	0.2051	0.5455
Sij-Sik	0.7512	0.1436	0.5301	0.8826	1.4475	0.8740	1.3570	0.2512	0.6681
Sij-Skl	0.7083	0.1353	0.4998	0.8321	1.3648	0.8240	1.2794	0.2369	0.6299

*Significant at P= 0.05, **Significant at P= 0.01.

G1-Shova; G2- ACC-1; G3- SS; G4- Arka kirti; G5- Pusa chitrakshya; G6- BCKV-123(check); G7- UHFS-68 G8- UHFS-56 (Table -1).

The relative estimates of variance due to specific combining ability (SCA) were higher than general combining ability (GCA) variances for all twelve traits, indicating predominance of non-additive gene action as reported by Patial *et al.* (2022).

Kalloo *et al.* (1974) emphasized the part of non-additive quality activity for locules number, TSS and corrosiveness. Cheema *et al.* (1996) detailed that both added substance and non-additive quality impacts were vital for the legacy of natural product estimate and natural product abdicate. Georgiev (1991) concluded that the added substance quality impacts were included within the legacy of pericarp thickness, whereas Dod *et al.* (1995) detailed the part of non-additive quality activity for pericarp thickness. Dhaliwal *et al.* (2004) found that proportion of σ^2SCA/σ^2GCA was more than solidarity in case of number of locules, pericarp thickness, polar breadth, TSS, natural product weight and add up to surrender, which energized for heterosis breeding for change of over specified characteristics.

CONCLUSION

This study comprehends the utility of combining ability analysis in Chrysanthemum breeding, providing valuable insights into the genetic architecture of crucial ornamental traits. Identifying parent lines with high GCA and specific hybrid combinations with high SCA offers a pathway for developing superior Chrysanthemum cultivars. The findings highlight the importance of both additive and non-additive genetic effects in shaping the expression of traits in

Chrysanthemum, suggesting an optimised breeding approach. The present investigation provides a practical understanding of selection criteria for parent lines and hybrid combinations. Significant GCA effects were observed for traits like plant height and number of flowers per plant, indicating that these traits are primarily controlled by additive genetic factors, making them amenable to selection in breeding programs. This experiment highlights the need to carefully select parental combinations to exploit heterosis and develop hybrids with enhanced ornamental values in future.

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Disclaimers

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Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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