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Characters Association and Path Coefficient Analysis among Quantitative Traits of Chrysanthemum (*Dendranthema×Grandiflora Tzvelev*)

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ABSTRACT

The present experiment was carried out under naturally ventilated polyhouse at the experimental farm of Division of Flower and Medicinal Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, India for two years during 2019 (August-November) and 2020 (August-December) The experiment was laid out in completely randomized design (CRD) with three replications under naturally ventilated polyhouse. Analysis of variance showed significant differences among genotypes for all the traits. Results revealed that the days to optimum flowering exhibited positive and significant correlation with plant height (0.599), days to bud initiation (0.628), days to first flower opening (0.985) and flowering duration (0.571), whereas, positive significant correlation with flower diameter (0.324). The results of path coefficient analysis using correlation coefficients revealed that days to first flower opening (1.033) exhibited positive and very high direct effect on days to optimum flowering while, number of leaves plant^{-1} (0.040), days to bud initiation (0.056), flower diameter (0.025) and flower duration (0.022) showed positive and negligible direct effect. Therefore, the selection on the basis of traits viz., plant height, days to bud initiation, days to first flower opening, flower duration and flower diameter will be more effective for improvement of the flowering traits in chrysanthemum breeding.

KEYWORDS: Chrysanthemum, correlation coefficient, path coefficient, optimum flowering character

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

The word chrysanthemum is derived from the Greek words *chrysos*, gold, *anthos* means flower (Anderson, 2007, Gortzing and Gillow, 1964). It is an important floriculture crops grown for cut flower, loose flower and as pot mums (Anderson, 2007, Naz et al., 2015). The chrysanthemum has numerous health-promoting benefits (Lin and Harnly, 2010), including its antioxidant, anti-inflammatory, anticancer, antibacterial, and neuroprotective properties, and listed as one of the top herbal flowers (Lu et al., 2016, Arcega et al., 2022). It is a member of the Asteraceae family and is referred to as the 'Queen of the East' in the United States and '*Guldaudi*' in India (Saha et al., 2013). It is native to Northern Hemisphere, chiefly Europe and Asia (Anderson, 1987). Among the ornamental plants, chrysanthemum is the second largest cut flower after rose (Van Der Ploeg and Heuvelink, 2006, Teixeira da Silva et al., 2013, Mubarok et al., 2020) and for more than 2500 years, it has been grown in gardens. Besides, it is planted in the gardens and landscape beds, and it is known for its beautiful flowers, vibrant color, and diverse floral types and shapes (Mekapogu et al., 2022, Hadizadeh et al., 2022).

Chrysanthemum is a short-day plant, critical photoperiod is ≥13.5 h for vegetative growth and ≤12 h for reproductive development (Cockshull, 1985). Therefore, under traditional culture, depending on the geographical location of the growing area, the blooming period is short which results in the low return unit area^{-1}. For the availability of flowers throughout the year for commercial floricultural industry, programmed blooming is necessary (Yang et al., 2018, Fu et al., 2014) for which photoperiodic manipulation is imperative (Chumber and Jhanji, 2022, Park and Jeong, 2020). Determination of response group of varieties is crucial for deciding artificial lighting and blackout dates (Rose and Kiplinger, 1951). Response group is determined by counting number of weeks from the starting of the short days (black-out) until optimum flowering.

The knowledge of the presence and extent of genetic variability in a gene pool is a prerequisite for any hybridization programme to be successful (Panwar et al., 2013). For the improvement of economically important traits, indirect selection can be done utilizing the knowledge of association among the traits (Henny et al., 2021). Studies of the correlation coefficient aid in determining the relationship between a plant characters and its nature (Kumari et al., 2017, Dey et al., 2021), assisting in the selection of desirable characteristics for a breeding programme (Rai et al. 2017). Thus, measurements of correlation coefficient between characters are crucial for selection indices which also enable the prediction of correlated response (Lerner, 1958). High positive correlation between the traits indicates that when one character is chosen to be improved, the other character is simultaneously improved (Khangjarakpam et al., 2015). As a result, it is of greater significance and could be effectively utilized in formulating effective selection strategy. The relative importance of the direct and indirect effects of each of the component traits on trait of interest cannot be accurately determined by a correlation study alone. In such case, correlation coefficient can be effectively partitioned into direct and indirect effect of independent variables on dependent variable by path coefficient analysis (Lal et al., 2014). Path coefficient analysis helps distinguish between correlations that are realistic (genetic effects) and inflated (environmental effects) (Khangjarakpam et al., 2015). Keeping in view the above facts, correlation and path analysis studies were undertaken to analyze and identify traits that are having greater interrelationship with days to optimum flowering in order to assist breeders in improvement of chrysanthemum breeding.

2. MATERIALS AND METHODS

The present experiment was carried out under naturally ventilated polyhouse at the experimental farm of Division of Flower and Medicinal Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, India for two years during 2019 (August-November) and 2020 (August-December). The experimental site was located at 13°58' N Latitude, 78°E longitude and at an elevation of 890 m above mean sea level. A total of 31 genotypes were evaluated for vegetative growth and flowering traits in completely randomized design with three replications. The 31 genotypes used as experimental material were A1 Collection, Appu, Arka Chandrakant, Arka Chankdrika, Arka Kirti, Arka Pink Star, Arka Usha Kiran, Arka Yellow Gold, Autumn Joy, Coffee, Fitonia, Flirt, Garden Beauty, Gulmohar, Heritage, Jublee, Marigold, Mayur, NBRI Little Kusum, Pachai Local, Pink Cloud, Ratlam Selection, Rekha, Shukla, Statesman, Sunil, Vasanthika, White Dolley, White Local, White Prolific and Winter Queen. The genotypes were provided with photoperiod of 15/9 h for 30 days after transplanting and black in (dark conditions) until flower bud initiation. Three randomly selected plants from each genotypes and replication were tagged for recording the observations viz., plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1}, days to bud initiation, days to first flower opening, days to optimum flowering, flower diameter (cm), number of flowersplant^{-1} and flower duration (days). The observed data were subjected to statistical analysis.

The estimates of correlation coefficient were calculated by the approach recommended by Al-Jibouri et al. (1958). Days to optimum flowering were used as the resultant variable and its component as causal variables in the path coefficient analysis, which was done using the method described by Dewey and Lu (1959).

3. RESULTS AND DISCUSSION

3.1. Phenotypic and genotypic correlation coefficient for various traits

The correlation coefficients between optimum flowering and other variables along with the interrelationships between the traits have been worked out and are presented in Table 1.

It was observed that the genotypic correlation coefficient in the majority of the characters was higher in magnitude than the phenotypic correlation coefficient, which may be the result of the interaction between genetics and environment. A plant breeder benefits from a positive correlation between two desirable characters since it helps with the simultaneous development of both traits. The results of the positive correlation coefficients indicate significant correlation between the morphological traits of chrysanthemum plants and their capacity for optimal flowering.

It is clear from the data presented in Table 1 that days to optimum flowering exhibited genotypic positive and highly significant correlation with plant height (0.599), days to bud initiation (0.628), days to first flower opening (0.985) and flower duration (0.571), whereas, it showed positive significant correlation with flower diameter (0.324). The associations of these characters with optimum flowering in chrysanthemum are in desirable direction and use of these traits may ultimately help in selection of genotypes required for flowering at a particular time. Khangjarakpam et al. (2015) reported highly significant and positively correlation of days to 50% flowering with plant height, days to first flower opening and flower diameter in China aster. Similarly, Bennurmath et al. (2022) observed positive and highly significant correlation of days to optimum flowering with flower duration in chrysanthemum.

Plant height showed positive and highly significant association with days to bud initiation (0.580), days to first flower opening (0.674), flower diameter (0.510), flowering duration (0.521) and days to optimum flowering (0.599). These results are in accordance with the findings of Bennurmath et al. (2022) in chrysanthemum. These outcomes are consistent with those of Tirakannanavar et al. (2015) and Rai et al. (2017) in China aster.

Number of branches plant^{-1} showed positive and highly significant correlation with number of flowers plant^{-1} (0.415), however, it exhibited positive significant correlation with number of leaves plant^{-1} (0.255), whereas, negative significant correlation with days to flower initiation (-0.224). This indicated that selection of plants with more number of branches plant^{-1} does not necessarily produce early flowering. Bennurmath et al. (2022) observed that

Table 1: Phenotypic (P) and genotypic (G) correlation coefficient for 9 quantitative traits in chrysanthemum

Trait		Plant height (cm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Days to bud initiation	Days to first flower opening	No. of flowers plant^{-1}	Flower diameter (cm)	Flowering duration (days)	Days to optimum flowering
Plant height (cm)	G	1.000	-0.045	-0.118	0.580**	0.674**	-0.008	0.510**	0.521**	0.599**
	P	1.000	-0.021	-0.117	0.580**	0.663**	-0.008	0.492**	0.501**	0.588**
No. of branches plant^{-1}	G		1.000	0.255*	-0.224*	0.104	0.415**	-0.083	0.075	0.085
	P		1.000	0.094	-0.106	0.072	0.190	-0.026	0.038	0.056
No. of leaves plant^{-1}	G			1.000	-0.274*	0.026	0.392**	-0.249*	-0.063	0.044
	P			1.000	-0.271*	0.022	0.387**	-0.242*	-0.061	0.039
Days to bud initiation	G				1.000	0.621**	-0.209*	0.419**	0.324*	0.628**
	P				1.000	0.612**	-0.208*	0.404**	0.311*	0.617**
Days to first flower opening	G					1.000	0.087	0.346**	0.584**	0.985**
	P					1.000	0.086	0.332*	0.558**	0.969**
No. of flowers plant^{-1}	G						1.000	0.112	-0.010	0.057
	P						1.000	0.110	-0.009	0.056
Flower diameter (cm)	G							1.000	0.361**	0.324*
	P							1.000	0.338**	0.301*
Flower duration (days)	G								1.000	0.571**
	P								1.000	0.542**

Correlation r value at; 5% = 0.2038; 1%=0.3357; *: Significant a p=0.05; **: Significant at p=0.01

the number of branches plant^{-1} showed positive and highly significant association with number of leaves plant^{-1} in chrysanthemum, however, positive association with the number of flowers plant^{-1} was observed in China aster (Rai et al., 2017).

Number of leaves plant^{-1} exhibited positive and highly significant association with number of flowers plant^{-1} (0.392), whereas, negative significant correlation with days to bud initiation (-0.274) and flower diameter (-0.249). Similarly, Sahu et al. (2018) recorded highly significant and positive correlation between number of leaves plant^{-1} and flower yield ha^{-1} at genotypic and phenotypic levels.

Days to bud initiation showed positive and highly significant correlation with days to first flower opening (0.621), flower diameter (0.419) and days to optimum flowering (0.628), whereas, it showed positive significant correlation with flower duration (0.324). Similar results have been reported by Bennurmath et al. (2022) in chrysanthemum. However, days to bud initiation exhibited negative correlation with number of flowers plant^{-1} (-0.209).

Days to first flower opening exhibited positive and highly significant association with flower duration (0.584) and days to optimum flowering (0.985). However, it showed positive and highly significant correlation with flower diameter (0.346). Similarly, Gantait et al. (2016) observed positive and significant correlation for days to spikes initiation with days taken for flowering in gladiolus.

Flower diameter showed positive and highly significant association with flower duration (0.361) and days to optimum flowering (0.324). Flowering duration exhibited positive and highly significant correlation with days to optimum flowering (0.324). These results are in confirmation with the findings of Bennurmath et al. (2022) in chrysanthemum and Poornima et al. (2007) in China aster. Similarly, Gandhi and Bharathi (2020) observed positive correlation between diameter of the floret and duration of flowering in gladiolus.

3.2. Path coefficient analysis for various traits

Path coefficient analysis divides the association between two traits into direct and indirect effects. Considering days to optimum flowering to be a dependent trait, phenotypic and genotypic coefficients of correlation between days to optimum flowering and all other characters were further partitioned into direct and indirect effects. Path coefficient analysis, as described by Dewey and Lu (1959), is a useful method for determining the direct and indirect cases of association between traits and relative importance of each factor involved in flowering is depicted. By using path analysis, the simple correlation coefficient of the chrysanthemum was divided into direct impacts and indirect effects and the results are presented in Table 2.

Table 2: Path coefficient analysis for 9 quantitative traits in chrysanthemum

Trait		Plant height (cm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Days to bud initiation	Days to first flower opening	No. of flowers plant^{-1}	Flower diameter (cm)	Flowering duration (days)	Days to optimum flowering
Plant height (cm)	P	-0.126	0.003	0.015	-0.073	-0.084	0.001	-0.062	-0.063	0.588
	G	-0.150	0.007	0.018	-0.087	-0.101	0.001	-0.076	-0.078	0.599
No. of branches plant^{-1}	P	0.000	-0.010	-0.001	0.001	-0.001	-0.002	0.000	0.000	0.056
	G	0.001	-0.011	-0.003	0.003	-0.001	-0.005	0.001	-0.001	0.085
No. of leaves plant^{-1}	P	-0.004	0.004	0.038	-0.010	0.001	0.015	-0.009	-0.002	0.039
	G	-0.005	0.010	0.040	-0.011	0.001	0.016	-0.010	-0.003	0.044
Days to bud initiation	P	0.044	-0.008	-0.021	0.076	0.047	-0.016	0.031	0.024	0.617
	G	0.033	-0.013	-0.015	0.056	0.035	-0.012	0.024	0.018	0.628
Days to first flower opening	P	0.656	0.072	0.022	0.605	0.989	0.085	0.328	0.552	0.969
	G	0.696	0.107	0.027	0.642	1.033	0.090	0.358	0.603	0.985
No. of flowers plant^{-1}	P	0.000	-0.005	-0.010	0.006	-0.002	-0.027	-0.003	0.000	0.056
	G	0.000	-0.015	-0.015	0.008	-0.003	-0.037	-0.004	0.000	0.057
Flower diameter (cm)	P	0.003	0.000	-0.001	0.002	0.002	0.001	0.006	0.002	0.301
	G	0.013	-0.002	-0.006	0.011	0.009	0.003	0.025	0.009	0.324
Flower duration (days)	P	0.015	0.001	-0.002	0.009	0.017	0.000	0.010	0.030	0.542
	G	0.011	0.002	-0.001	0.007	0.013	0.000	0.008	0.022	0.571

Diagonal indicates direct effects; Residual effect=0.131; *: Significant a *p*=0.05; **: Significant at *p*=0.01

The residual impact (0.131) showed that the majority of the factors influencing flowering are taken into account in the study. The analysis of path coefficient revealed that the days to first flower opening (1.033) exhibited positive and very high direct effect on days to optimum flowering, while, plant height had negative and low indirect effect on days to optimum flowering through number days to first flower opening (-0.101). Similarly, Gantait et al. (2016) observed negative indirect effect for plant height with days taken for spike initiation and days taken for flowering in gladiolus. The number of leaves plant^{-1} (0.040), days to bud initiation (0.056), flower diameter (0.025) and flower duration (0.022) showed positive and negligible direct effect. However, number of branches plant^{-1} (-0.011) and number of flowers plant^{-1} (-0.037) exhibited negative and negligible direct effect at genotypic level.

3. CONCLUSION

The optimum flowering exhibited genotypic positive and highly significant correlation with plant height, days to bud initiation, days to first flower opening and flower duration, whereas, it showed positive significant correlation with flower diameter. The path coefficient analysis indicated that the traits viz., days to first flower opening, number of leaves plant^{-1}, days to bud initiation, flower diameter and flower duration were dependable indices for the selection of genotypes.

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