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GENETIC VARIABILITY AND ASSOCIATION STUDIES IN GLADIOLUS

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ABSTRACT

The present study was done at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the year 2022 and 2023. The experiment was laid out in Randomized block design with three replicates and fourteen gladiolus genotypes were studied for sixteen commercially important quantitative characters, including different vegetative, floral and corm yield attributes. Assessment for variability, the transmissibility of characters, trait interrelationships and path coefficient analysis were carried out. Identifying key traits essential for selection during crop improvement governs success of any breeding program. In the present study, traits like corm fresh weight, cormel fresh weight and cormel number per plant depicted significantly high values of GCV and PCV with the highest estimates of heritability and genetic gain. Moreover, traits like the number of days it took for spikes to emerge, the length of cut spikes and rachis, leaves produced per plant, vase life, floret diameter, corm diameter and cormel's fresh weight were proved to positively and directly enhance the florets yield per spike in gladiolus, the most important trait for rendering the cut spikes as marketable. Thus, selection for above traits will prove to be useful in future breeding programmes in gladiolus.

***Keywords*:** Genotypes, variability, heritability, selection, crop improvement.

Introduction

Gladiolus spikes are valued for their exceptional keeping qualities, florets of diverse shapes, sizes and hues ranging from pink to reddish or light purple with white to cream contrasting markings (Dhiman *et al.*, 2021; Bhatt ZA and Sheikh, 2015) and most of all for the sequential opening of florets over a longer duration (Amin and Diab, 2020). All these beautiful characteristics account for it's high demand for bouquets, interior decorations, other exquisite floral arrangements, and for beddings or displays (Gangwar *et al.*, 2023).

Hybridization and polyploidy have had a substantial impact on gladiolus evolution, improving its different qualitative and quantitative features (Ohri and Khoshoo, 1983). The outbreeding tendency of gladiolus allows for different genetic parentages in modern garden cultivars, resulting in cumulative heterozygosity for numerous traits associated with the complicated genetic constitution (Aswath *et al.*, 2021; Cantor and Tolety, 2011). That's why great variation exists in its genotypes and we need to study these continuously arising variations over time as genetic variability is a key element in the planning and execution of a breeding program to generate new kinds (Singh P, 2021, Terfa and Gurmu, 2020; Bhujbal *et al.*, 2013). Estimates for analyzing variance across different growth and floral factors help select for economic traits in genotypes (Sharma *et al.*, 2023). The coefficients of variation at the genotypic and phenotypic levels should be studied to understand the nature of variability in each breeding population (Sharma *et al.*, 2023, Singh, 2021 and Kumari *et al.*, 2017) to make sure that a trait will pass on to the next generation and the magnitude of its transmissibility can be computed through the estimates of heritability (Guddaraddi *et al.*, 2025).

Furthermore, correlation studies provide useful information regarding the interrelationships and associations between multiple traits as well as the influence of each component trait on yield, which aids in selection (Bennurmath *et al*., 2021, Singh, 2021 and Sharma *et al*., 2018) Whether one variable is directly impacting yield traits or indirectly through any other variable, this could be figured out through path coefficient analysis (Saleh *et al*., 2020). The floret number displayed in the spike of gladiolus is a very important polygenic character determining the quality of the cut spikes, so it's important to study how the other variables are impacting this characteristic trait. The study thus assessed gladiolus genotypes to assist breeders in improving this characteristic yield trait and overall cultivar performance in crop improvement programs of gladiolus by selecting for the most important traits.

Materials and Methods

The current study was done in 2022 and 2023 at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan, H.P at the Department of Floriculture and Landscape Architecture's Experimental farm (lying at lat 32°5'10" N, long 77°11'30" E and alt 1276 m asl.). The region has sub-temperate climatic conditions with cool winters and gentle moderate summers.

Healthy, disease-free corms of gladiolus genotypes were planted in the first week of March, during both the years (30 cm x 10 cm distance). The germplasm studied comprised of seven hybrid genotypes of gladiolus bred at Dr YS Parmar UHF, Solan, named UHFS Gla 1-27, UHFS Gla 2-25, UHFS Gla 3-24, UHFS Gla 3-41, UHFS Gla 4-48, UHFS Gla 9-16 and Solan Mangla; varieties released from IARI, New Delhi (Pusa Gulal, Pusa Kiran); IIHR, Bangalore (Arka Amar, Arka Ranjini) and different exotic varieties (American Beauty, Novalux, Thamboliana).

Observations recorded

Data were collected on a range of variables including corm sprouting percentage, days required for corm sprouting, and spike emergence (counted since the date of planting). When spikes reach harvesting stage (lowermost 2-3 florets starts showing color), height of plant (up to the spike's tip), the leaves produced in each plant, the floret number in each spike (including the closed buds), length of the cut spike (cm) (from the point of harvesting, above two pair of leaves up to spike's tip), the length of the rachis (cm) (from the point of attachment of lowermost floret to the last floret's tip in the spike), the floret diameter (cm) (by working out the average of values obtained by holding a vernier caliper from one tepal's extreme to the other tepal's extreme of the second most floret in NS and EW directions), the number of days until the cut spikes were harvested and the vase life of the cut spikes (until the wilting of the third most florets on the spike) were recorded. At the time of corm upliftment, the fresh weight of corms and cormels was measured using a weighing balance and corm diameter was measured in NS and EW direction, followed by the calculation of the average of the two. The number of corms and cormels produced by each plant from the mother corms that were planted depicts the corm and cormels yield per plant.

Statistical analysis

The study was conducted using the Randomized Block Design (RBD) design, and additional analysis was carried out in accordance with the recommendations of Gomez and Gomez (1984). OPSTAT software was used to analyze the data. Variability was measured using the GCV and PCV formulas suggested by Burton and De-Vane (1953). Genetic Advance and Heritability (in a broad sense) were calculated as per formulas given by Allard (1960). Genetic Gain was calculated as per the formula suggested by Johanson *et al.* (1955). The method suggested by Al-Jibouri *et al.* (1958) was used to calculate both genotypic and phenotypic correlations. The Dewey and Lu (1959) equations were used to figure out the direct and indirect effects.

Result and Discussion

Coefficients of variability

Variability present in a population is a prerequisite for crop improvement programs. Interactions between genetic and environmental factors result in variations shown in many phenotypes. It becomes clear from the data in Table 1 that PCV was slightly greater than GCV which can be attributed to the influence of external environmental factors on the expression of the traits studied.

The calculated values of coefficients of variability ranged in magnitude from low to high, according to the trait being analyzed. It indicates that experimental material contained a considerable level of variation. The PCV and GCV respectively were found high for the parameters, fresh weight of corms (38.16%) (37.83%), fresh weight of cormels (42.84%) (42.58%) and number of cormels per plant (44.99%) (44.72%), according to pooled analysis for two consecutive years. This implies that these parameters are more amenable to breeding and that selection for these traits during crop improvement in gladiolus will prove to be fruitful. Prior research on gladiolus by Swetha *et al*., 2020, Kispotta *et al*., 2017, Mishra *et al*., 2014, Choudhary *et al*., 2012 and Kumar *et al*., 2011, revealed that for the majority of the aforementioned features, a higher PCV values than GCV were obtained.

Heritability

Heritability estimates provide estimates of whether characters can be transferred from one generation to the next generation, allowing breeders to isolate elite selections in the crop. Traits Depicting high heritability shows a greater possibility of improvement through direct selection as trait expression is driven by genetic factors and the environment plays the least role in it (Merrick *et al*., 2022, Labroo *et al*., 2021, Schmidt *et al*., 2019, Dhiman *et al*., 2015 a, Dhiman et a, 2015 b and Tester and Langridge, 2010) and traits are highly transmissible to next generations during breeding programmes. In contrast, the traits that showed low heritability shows that the environment has influenced the character expression thus for such parameters direct selection will not be effective (Merrick *et al*., 2022).

Most of the parameters in the current study had high heritability values. Data in Table 1 showed high heritability for the following parameters: fresh weight of corms (98.31%), fresh weight of cormels (98.77%), the diameter of corms (99.12%), cormels number per plant (98.80%), leaves number per plant (89.70%), number of days it took for spikes to emerge (99.72%), plant height (98.85%), length of cut spikes (97.09%), rachis length (98.39%), floret diameter (99.22%), days to reach harvesting stage (99.57%), vase life (96.00%), fresh weight of corms (98.31%), fresh weight of cormels (98.77%), diameter of corms (99.12%), number of cormels present in each plant (98.80%), floret count per spike (99.25%), plant height (98.85%). There is a lot of scope for development by focusing on these features. Similar heritability trends were observed by earlier studies conducted by Gantait *et al.* (2016), Thakur *et al.* (2015), Mishra *et al.* (2014), Choudhary *et al.* (2012), Kumar *et al.* (2011) and Kumar *et al.* (2010) in gladiolus.

Genetic advance and genetic gain

Higher heritability values combined with high values of genetic gain are much more useful than only heritability estimates alone when evaluating the overall impact of selection. The parameters like fresh weight of corms (77.28%), fresh weight of cormels (87.17%) and number of cormels per plant (91.57%) showed the greatest genetic gain along with the high heritability estimates. This demonstrates unequivocally that cumulative gene action controls the above trait's expression, meaning selection for them will contribute to crop improvement. The results are supported by earlier outcomes of studies conducted by previous researchers such as Ishwarraddy *et al.* (2018), Kaushik *et al.* (2018), Pattanaik *et al.* (2015), Momin *et al.* (2017), Mishra *et al.* (2014), and Choudhary *et al.* (2012) for different characteristic traits of gladiolus genotypes.

Data in Table 1 demonstrates values of high heritability along with a greater value of GA for fresh weight of corms (41.77%). This illustrates that additive gene action plays a role here and this trait expresses the potential of improvement through hybridization, and selection for this trait will undoubtedly be effective as demonstrated by Dhiman *et al.* (2015a), Dhiman *et al.* (2015b), and Bijma (2014).

Correlation studies

Computing correlation is a useful tool for determining the manner in which characters link with one another, indicating both the strength and direction of the association (Schober *et al*., 2018). Correlations when found positive show that variables are showing changes in the same manner, i.e., they are increasing or decreasing simultaneously, whereas correlations, if negative, show that there is an inverse relationship between the variables for example, a rise in one variable will result in a reduction in another (Sauro and Lewis, 2016; Kumar *et al*., 2012). Therefore, this study looked at correlation coefficients both at genotypic and phenotypic levels for a multiple number of variables.

The florets displayed per spike in gladiolus is a complex, polygenic characteristic controlled by numerous genes and other variables, thus a thorough grasp of the relationships and connections between component qualities and how they affect this yield attribute is necessary for efficient crop improvement in gladiolus. From data in table 2 it is clear that the percentage of corms that sprouted ($r_p = 0.64$, $r_g = 0.96$), the number of leaves present in each plant ($r_p =0.49$, $r_g = 0.54$), the number of days it took for the spikes to emerge ($r_p = 0.37$, $r_g = 0.38$), the plant height ($r_p = 0.77$, $r_g = 0.77$), the cut spike length ($r_p = 0.76$, $r_g = 0.77$), the rachis length ($r_p = 0.76$, $r_g = 0.76$), the diameter of the floret ($r_p = 0.44$, $r_g =0.44$), the vase life ($r_p = 0.87$, $r_g = 0.89$), the fresh weight of the cormels ($r_p = 0.69$, $r_g = 0.70$), diameter of corms ($r_p = 0.75$, $r_g = 0.75$) and cormels produced per plant ($r_p = 0.69$, $r_g = 0.70$) were all positively associated with the floret number displayed in each spike. In earlier studies also a quantity of florets produced in a spike was found to be positively correlated with spike length and rachis length (Patra and Mohanty, 2019 and Nazir *et al*., 2023), with weight of corm for each plant, cormels yielded per plant and corm diameter (Nazir *et al.*, 2023). Ramzan *et al.* (2016) discovered it's significant positive correlation with spike length and leaf count. Furthermore, Rashmi *et al.* (2016) recognised spike length and the number of florets per spike as critical characteristics affecting yield and quality.

Path coefficient analysis

A valuable tool in finding out whether a variable has a direct or indirect effect on the other is path coefficient analysis, as demonstrated by Wright (1934), Kumar *et al.* (2012) and Saleh *et al.* (2020). It may be possible to increase yield by concentrating on particular characteristics that have a positive direct influence on yield traits, as suggested by Sinha *et al.* (2023).

Important characteristics of the florets displayed per spike are demonstrated by the path coefficient analysis results, which are displayed in Table 3. The greatest positive direct effect on the floret number in each spike was shown by fresh weight of cormels yielded per plant (1.803), then by rachis length (0.562), floret diameter (0.471), leaves per plant (0.363), days to corm sprouting (0.290) and spike emergence (0.247), cut spike length (0.253), their vase life (0.207) and corm diameter (0.087). Earlier studies by Ramzan *et al.* (2016) also found the cut spike length to have direct effect on the number of florets displayed per spike. Similar studies regarding path coefficient analysis were conducted in gladiolus earlier by researchers such as Gantait *et al.* (2016), Kumar *et al.* (2015) and Rashmi and Kumar (2014).

It is clear in the present study that the traits like corm fresh weight, cormel's fresh weight, and cormel number per plant are of utmost importance in selection during crop improvement programs in gladiolus as they expressed high values of GCV and PCV with the highest estimates of heritability and genetic gain. Direct selection for the traits like the number of days it took for spikes to emerge, the length of cut spikes and rachis, leaves produced per plant, vase life, floret diameter, corm diameter, and cormel's fresh weight would lead to an increase in florets yield per spike.

Table 1 : Values of measures of genetic variability for traits under consideration in the study

S.No.	Characters	Mean	Range	Variability coefficients (%)		h^2	GA (%)	GG (%)
				PCV	GCV			
1.	Days taken to sprouting of corms	18.49	11.97-28.20	20.76	20.69	99.32	7.85	42.48
2.	Percentage of corms Sprouted	94.55	83.33-100.00	6.28	4.20	44.64	5.46	5.78
3.	leaves produced per plant	11.36	8.00-14.53	20.09	19.03	89.70	4.22	37.12
4.	Days required for emergence of spike	77.49	65.17-89.60	9.57	9.55	99.72	15.23	19.65
5.	Height of the plant	117.43	100.40-139.65	8.82	8.77	98.85	21.10	17.97
6.	Length of cut spike	87.97	71.78-99.48	6.84	6.74	97.09	12.03	13.68
7.	Length of rachis	49.35	39.84 - 59.39	12.47	12.37	98.39	12.48	25.28
8.	Diameter of floret	10.06	8.58-10.96	7.20	7.17	99.22	1.48	14.72
9.	Days taken to reach harvesting stage	83.63	73.00-110.17	8.31	8.29	99.57	14.25	17.04
10.	Vase life of cut spikes	8.65	7.00-9.83	9.86	9.66	96.00	1.69	19.50
11.	Fresh weight of corms	54.05	31.32-103.76	38.16	37.83	98.31	41.77	77.28
12.	Fresh weight of cormels	15.35	3.81-24.34	42.84	42.58	98.77	13.38	87.17
13.	Diameter of corms	5.51	4.38-6.83	12.33	12.28	99.12	1.39	25.18
14.	Corm yield per plant	1.52	1.23-1.80	14.71	12.71	74.62	0.34	22.62
15.	Cormels produced per plant	17.09	4.83-27.10	44.99	44.72	98.80	15.65	91.57
16.	Florets produced per spike	15.70	11.33-19.33	13.11	13.06	99.25	4.21	26.79

Here, h^2 stands for Heritability(%), GA for Genetic Advance and GG for Genetic gain

Table 2 : Estimates of correlation at Phenotypic (P) and genotypic (G) level among different parameters in gladiolus genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	P	-0.27	-0.28	0.40*	-0.56**	-0.48**	-0.56**	-0.26	0.46**	-0.20	-0.50**	-0.09	-0.47**	-0.36*	-0.11	-0.14
	G	-0.41*	-0.31	0.40*	-0.56**	-0.49**	-0.57**	-0.26	0.46**	-0.21	-0.50**	-0.09	-0.47**	-0.44**	-0.12	-0.14
2	P		0.51**	0.24	0.50**	0.47**	0.55**	0.40*	0.12	0.70**	0.44*	0.48**	0.55**	0.39*	0.50**	0.64**
	G		0.69**	0.35*	0.75**	0.71**	0.78**	0.59**	0.18	0.97**	0.66**	0.68**	0.81**	0.48**	0.72**	0.96**
3	P			0.37*	0.38*	0.36*	0.35*	0.29	0.31	0.51**	0.56**	0.26	0.59**	0.88**	0.25	0.49**
	G			0.38*	0.40*	0.41*	0.38*	0.32	0.32	0.55**	0.61**	0.26	0.63**	0.89**	0.25	0.54**
4	P				0.13	0.11	-0.06	0.34	0.98**	0.32	0.29	0.20	0.26	0.03	0.20	0.37*
	G				0.13	0.11	-0.06	0.34	0.98**	0.33	0.30	0.20	0.27	0.01	0.20	0.38*

5	P					0.96**	0.69**	0.62**	-0.03	0.75**	0.81**	0.57**	0.83**	0.12	0.62**	0.77**
	G					0.98**	0.70**	0.63**	-0.03	0.78**	0.82**	0.58**	0.84**	0.14	0.63**	0.77**
6	P						0.61**	0.51**	-0.05	0.76**	0.73**	0.68**	0.76**	0.09	0.73**	0.76**
	G						0.62**	0.52**	-0.05	0.79**	0.74**	0.69**	0.77**	0.14	0.74**	0.77**
7	P							0.24	-0.22	0.61**	0.65**	0.38*	0.68**	0.27	0.36*	0.76**
	G							0.24	-0.22	0.62**	0.66**	0.39*	0.69**	0.32	0.37*	0.76**
8	P								0.27	0.43*	0.47**	0.03	0.53**	0.06	0.14	0.44**
	G								0.27	0.44*	0.47**	0.04	0.53**	0.09	0.15	0.44**
9	P									0.14	0.16	0.07	0.12	0.01	0.06	0.19
	G									0.14	0.17	0.07	0.12	0.01	0.06	0.20
10	P										0.72**	0.71**	0.79**	0.21	0.75**	0.87**
	G										0.73**	0.73**	0.81**	0.24	0.77**	0.89**
11	P											0.41*	0.96**	0.32	0.42*	0.69**
	G											0.42*	0.96**	0.38*	0.42*	0.69**
12	P												0.42*	0.09	0.99**	0.69**
	G												0.43*	0.08	0.99**	0.70**
13	P													0.33	0.45**	0.75**
	G													0.40*	0.45**	0.75**
14	P														0.05	0.21
	G														0.03	0.27
15	P															0.69**
	G															0.70**

1. Days taken to sprouting of corms, 2. Percentage of corms Sprouted 3. leaves produced per plant 4. Days required for emergence of spike5. Height of the plant 6. Length of cut spike, 7. Length of rachis 8. Diameter of floret, 9. Days taken to reach harvesting stage 10. Vase life of cut spikes, 11. Fresh weight of corms, 12. Fresh weight of cormels, 13. Diameter of corms, 14. Corm yield per plant 15. Cormels produced per plant16. Florets produced per spike

*Significantat5%significance level **Significantat1%significance level

Table 3 : Values of various feature's direct and indirect effects on number of florets produced per spike

*C (characters)	Days taken to sprouting of corms	Percentage of corms Sprouted	leaves produced per plant	Days required for emergence of spike	Height of the plant	Length of cut spike	Length of rachis	Diameter of floret	Days taken to reach harvesting stage	Vase life of cut spikes	Fresh weight of corms	Fresh weight of cormels	Diameter of corms	Corm yield per plant	Cormels produced per plant
Days taken to sprouting of corms	**0.290**	0.022	-0.113	0.099	0.169	-0.123	-0.318	-0.123	-0.155	-0.043	0.077	-0.157	-0.041	0.101	0.176
Percentage of corms Sprouted	-0.118	**-0.054**	0.250	0.087	-0.223	0.180	0.438	0.280	-0.062	0.200	-0.103	1.229	0.070	-0.110	-1.101
leaves produced per plant	-0.091	-0.037	**0.363**	0.095	-0.121	0.102	0.211	0.151	-0.108	0.113	-0.095	0.476	0.055	-0.201	-0.377
Days required for emergence of spike	0.117	-0.019	0.139	**0.247**	-0.040	0.028	-0.035	0.160	-0.328	0.069	-0.047	0.362	0.023	-0.003	-0.299
Height of the plant	-0.164	-0.040	0.146	0.033	**-0.299**	0.247	0.392	0.297	0.010	0.161	-0.127	1.038	0.072	-0.032	-0.959
Length of cut spike	-0.141	-0.038	0.147	0.028	-0.292	**0.253**	0.346	0.247	0.017	0.164	-0.114	1.237	0.066	-0.031	-1.120
Length of rachis	-0.164	-0.042	0.136	-0.015	-0.208	0.156	**0.562**	0.114	0.075	0.128	-0.102	0.694	0.059	-0.073	-0.556
Diameter of floret	-0.076	-0.032	0.117	0.084	-0.188	0.133	0.136	**0.471**	-0.091	0.091	-0.073	0.068	0.045	-0.021	-0.222
Days taken to reach harvesting stage	0.134	-0.010	0.117	0.242	0.009	-0.012	-0.126	0.128	**-0.335**	0.029	-0.026	0.125	0.011	-0.001	-0.087
Vase life of cut spikes	-0.060	-0.052	0.198	0.082	-0.232	0.200	0.348	0.208	-0.047	**0.207**	-0.114	1.313	0.070	-0.055	-1.174
Fresh weight of corms	-0.144	-0.035	0.221	0.074	-0.245	0.186	0.370	0.222	-0.055	0.151	**-0.156**	0.749	0.083	-0.086	-0.643
Fresh weight of cormels	-0.025	-0.037	0.096	0.050	-0.172	0.174	0.216	0.018	-0.023	0.151	-0.065	**1.803**	0.037	-0.018	-1.504
Diameter of corms	-0.137	-0.044	0.230	0.066	-0.250	0.194	0.386	0.248	-0.041	0.169	-0.149	0.770	**0.087**	-0.091	-0.686
Corm yield per plant	-0.129	-0.026	0.322	0.003	-0.043	0.035	0.181	0.043	-0.002	0.050	-0.059	0.141	0.035	**-0.227**	-0.052
Cormels produced per plant	-0.033	-0.039	0.090	0.048	-0.188	0.186	0.205	0.069	-0.019	0.160	-0.066	1.781	0.039	-0.008	**-1.523**

Residual effects are -0.003

Future Scope of The Study: The study will surely be helpful in planning future breeding programmes in gladiolus regarding improvement of yield traits and several other traits as it clearly dissipates the interrelationships between traits, heritability trends and there contribution towards variation in the germplasm.

Conflict of Interest: Authors have no Conflict of interest

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