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Research Paper

Evaluation of Genetic Parameters and Cormlet Yield in Gladiolus Offspring

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Abstract

The research aimed to produce new genotypes by hybridization. It was conducted in the Ornamental Plants Research Center of Mahallat from 2016 to 2018. Four varieties of gladiolus including 'Amsterdam', 'White Prosperity', 'Advance Red' and 'Rose Supreme' were chosen for hybridization. The progenies were evaluated in a randomized complete block design with three replications. The highest heritability in traits was estimated to be 98.46% for cormlet number and diameter and the lowest was 12.90% for crown diameter. These results indicate that most traits have a very low phenotypic and genetic diversity coefficient, indicating that they had lower environmental effects since the progenies were cultivated under similar and controlled conditions. The results of the factor analysis, based on the eight assessed traits, showed that the four factors accounted for 60.90% of the total variance. The first factor captured 22.80% of the variance and among its traits, crown diameter and leaf number had the highest positive coefficients. The progenies OPRC07 and OPRC09 derived from 'Advance Red' × 'White Prosperity' and 'Amsterdam' × 'Advance Red' had a significant difference with others and had the highest cormlet weight compared to the progenies tested. The progeny OPRC09 was superior to other cormlets in leaf length, leaf width, stem diameter, leaf number, days to germination, and cormlet weight and diameter. Also, the progeny OPRC04 was superior in cormlet production by producing 2.49 cormlets per seed.

Keywords: Cormlet, Hybridization, Progenies, Variation.

INTRODUCTION

Gladiolus (*Gladiolus grandiflora* Hort.) belongs to the family Iridaceae, the sub-family Ixioideae, the tribe Ixieae, and the sub-tribe Gladiolines (Ranjan *et al*., 2010) and it is usually called the queen of bulbous flowers (Randhawa and Mukhopadhyay, 2000). Gladiolus is popularly known as sword lily or corn lily and originated from South Africa (Poon *et al*., 2012). There are 260 species of gladiolus in the world, of which 250 are native to sub-Saharan Africa and 10 are native to Eurasia (Manning and Goldblatt, 2008). More than 3000 varieties of gladiolus have, so far, evolved by formal breeding (Singh, 2006) of which about 20 are grown commercially. It is one of the most important bulbous ornamental plants for cut flowers and the fourth leading cut flower in international trade after rose, carnation, and chrysanthemum (Farhat, 2004). The major gladiolus producing countries are the United States, Holland, France, Poland, Italy, Bulgaria, Brazil, Australia, and India. It is the eighth leading flower in the global cut flower trade and the first in the domestic bulbous flower trade (Pragya *et al*., 2010).

Corms and cormlets are the propagating materials for gladiolus. Cormlets grow in between mother and daughter corms (Larson, 1992). The new varieties of gladiolus are evolved through hybridization, which is recognized as the most important source of evolution and crop improvement. A plant breeding program can be divided into three stages, i.e. building up a gene pool of variable germplasm, selecting an individual from the gene pool, and using the selected individual to evolve superior variety (Kempthorne, 1957).

Among the three different methods of pollination of gladiolus cultivars, including natural self-pollination, artificial self-pollination, and open pollination, the artificial self-pollination has generally provided the best results (Dhaduk *et al*., 1987). Reduced natural cross-pollination may have resulted from a lack of pollinating insects (Ohri and Khoshoo, 1981). Moreover, the participation of inhibitory specificities of pollen cholinesterase in the pollen-stigma interaction has failed to get matured seeds from the crosses (Semenova and Roshchina, 1993). The presence of a dry type of gladiolus stigma may be another reason for their incompatibility (Clarke *et al*., 1977). Hossain *et al*. (2012) indicated a wide variability among the genotypes considering crossing parameters and variations for capsule length, capsule breadth, the number of seeds per capsule, and 1000-seed weight. The number of true seeds produced (F1 seed) varies among gladiolus crosses. Therefore, studying the seed setting habit in gladiolus can provide an insight into percent seed setting in different cross combinations, nature, and compatibility of crossing with desired parents. Gladiolus varieties are good general combiners for many traits and additive type of gene action has been noticed for many traits (Kumar *et al*., 2008).

Gladiolus is largely propagated by corms and cormlets whereas seed propagation is used to evolve new cultivars and to recover and maintain the threatened germplasm. Moreover, seed production is more prevailing than cormlet production in gladiolus (Gonzalez *et al*., 2003). Although, plants grown from seeds require four seasons to come into blooming under ordinary conditions, it can be reduced to two seasons (Bose *et al*., 2003) and the plants produced from seeds can flower in the second year (Cohat, 1993) if the best cultural treatments are provided.

In recent years, a lot of work has been done on investigating seeds to improve the germination rate and uniformity of growth and reduce the emergence time of some field crops (Basra *et al*., 2003) and it is highly desirable in breeding programs with a limited number of genotype seeds obtained from controlled or manual pollination. To enhance seed germination, several treatments are needed to adopt better techniques for postharvest seeds, but before sowing (Taylor *et al*., 1998).

Environmental factors in combination with genetic and physiological factors play an important role in determining plant potential for material propagation. These characters appear to be under strong genetic control (Sukarin *et al*., 1987; Roy *et al*., 2004). The key to the success of a genetic breeding program is the availability of genetic variability for the desired traits (Heller, 1996).

Environmental variance is a source of error in genetic studies and includes all the variations in non-genetic origin. It reduces the efficiency of the selection procedure by the interaction between genotypes and phenotypes (Lynch and Walsh, 1998). To breeders, the genetic variance is more important because it determines the rates at which characters respond to selection. Dudley and Moll (1969) indicated that the total genetic variance (VG) is composed of additive genetic variance (VA), dominance genetic variance (VD), and epistatic genetic variance (VI). The most important component is VA, which is the variance of selection values. Johnson *et al*. (1955) state that heritability, assessed in conjunction with calculating expected genetic gains using h^2n (broad-sense heritability) or h^2b (narrow-sense heritability) estimates, are more effective and reliable in predicting improvement through selection.

Anuradha and Gowda (1994) studied the genetic variability of 25 genotypes of gladiolus for 24 characters and recorded a high degree of variability for all the characters except for the number of side shoots and the number of side spikes. High phenotypic and genotypic coefficients of variation were observed for leaf area, rachis length, the number of capsules, and the number of seeds per capsule, while these were lower for the number of side spikes, floret diameter, floret length, and the number of leaves. Heritability was low for floret length, the longevity of individual floret, days to spike emergence, and spike length whereas genetic advance was high for the number of capsules and the number of seed per capsule. Wide hybridization enables the interspecific gene transfer, which may serve as an additional source of variation for the desirable characters (Anandhi *et al*., 2013). Takatsu *et al*. (2001) made an interspecific hybridization between a modern cultivar of *Gladiolus grandiflora* Hort. (2n=60) and the wild species *G. tristis* L. (2n = 30) to introduce characteristics of the wild species into the cultivated one. They reported the best pollen tube growth, fertility, and fruit set in their cross at lower air temperatures for F1 hybrid plant production (15-20°C) (Takatsu *et al*., 2001). Hossain *et al*. (2012) indicated the existence of wide variability among the gladiolus genotypes considering crossing parameters, and variations were observed in capsule length (cm), capsule breadth, the number of seeds per capsule, and 1000-seed weight (g). The number of seeds per capsule ranged from 15.08 to 38.40. The highest number of seeds per capsule was produced by the cross 'Yellow × Red' (38.40) while the lowest number was produced by the cross 'Violet × Red' (15.08). Grabowska (1983) reported that among 50 inter-varietal hybrids, 'Eurovision' showed better crossing capability than 'Pres. de Gaulle' (46.4 and 28.9%, respectively) when crossed with red cultivars having similar pollen parents. The hybrid seeds of 'Bird of Dawning' gave more seedlings and corms (55.8%) than the seeds of 'West Point' (13%); these figures for hybrid seeds of 'Eurovision' and 'Pres. de Gaulle' were 38.3 and 22.9%, respectively.

The present research aimed to produce new hybrids of gladiolus through hybridization, evaluate genetic variability heritability, and identify important yield-attributing characters to shed light on how to develop high-yielding gladiolus genotypes.

MATERIALS AND METHODS

Plant materials

Four varieties of gladiolus including 'Amsterdam (1), 'White Prosperity (2), 'Advance Red (3) and 'Rose Supreme (4) were used for hybridization in the Ornamental Plants Research Center (OPRC) of Mahallat, Iran in 2016-2018.

Hybridization diagram

After spike emergence of gladiolus varieties, a full diallele crossing was carried out among the four genotypes to study seed setting in cross-combinations and the combining ability of seed characters. According to the formula designed by Griffing (1956) method 1, crosses were made from the four parents (P) [Number of crosses = P (P-1)].

Crosses program

The total entries, therefore, amounted to 16 (parents, crosses, and reciprocals). In the female parent, flowers at the pre-anthesis stage were selected for emasculation, which was carried out in early evenings and bagged with a butter paper cover. Similarly, in the male parents, a few selected flower buds at the pre-anthesis stage were bagged without emasculation to avoid contamination by foreign pollens for the collection of pollen grains. Pollens from the bagged flowers of pollen parents were collected between morning and sundown and dusted on the stigma of the emasculated flowers of the respective female parents. The flowers were bagged with butter paper and then labeled. The covers were removed after ensuring the proper pod setting. The F1 pods were harvested at full physiological maturity when the capsules started to burst. The individual crosses were harvested by hand.

Seedbed preparation and sowing

All seeds of parental crosses (300 seeds from each parental genotype and hybrid) were planted on well prepared and raised seedbeds to produce seedlings. Before sowing in trays, the seeds were rubbed between two layers of cloth to remove the waxy covering and finally they were shaken for 6 hours. It is reported that the waxy covering contains compounds that retard the germination process. Seeds were sown at a depth of 1.5-2 cm in the trays. The seeds were planted in the trays containing 30% perlite and 70% cocopeat in the greenhouse at a temperature of 23 ± 4 °C and humidity of 65 ± 5% in January. The moisture content of the bed was maintained. One-hundred seeds were planted for each replication. The seedlings matured in 110 days in greenhouse conditions and were harvested with cormlets.

Characteristics

Some of the traits including number of days to germination, leaf length (mm), leaf width (mm), crown diameter (mm), the number of leaf, cormlet weight (g), cormlet diameter (mm), and the number of cormlet were measured by using a digital scale, a digital caliper, and rulers.

Statistical analysis

This study was based on a randomized complete block design with three replications. Statistical analysis included descriptive statistics, simple correlation coefficient, analysis of variance, and means comparison with Duncan's multiple range tests. All statistical analysis were performed with SAS 9.1 software.

Estimation of genetic parameters

The broad sense heritability, variances and phenotypic, genetic and environmental variability coefficients were calculated based on the methods of Santos *et al*. (2011):

Mse= Mean square error, Mst= Mean square treatment, R= Replication, δ^2ph= Phenotypic variance, δ^2g= Genotypic variance, δ^2e= Environmental Variance, μ= Grand mean of a character, and h^2_B= Heritability in broad sense.

Genetic Coefficient of Variation (GCV): $(\sqrt{\delta_g} / \mu) \times 100$

Phenotypic Coefficient of Variation (PCV): $(\sqrt{\delta_{ph}} / \mu) \times 100$

Environmental Coefficient Variation (ECV): $(\sqrt{\delta_e} / \mu) \times 100$

Genetic Variance (δ^2_g): $(MS_t - MS_e)/ r$

Phenotypic Variance (δ^2_{ph}): $\delta^2_g + \delta^2_e$

Environmental Variance (δ^2_e): $\delta^2_{ph} - \delta^2_g$

Estimation of heritability: $h^2_B = \delta^2_g / \delta^2_{ph}$

RESULTS AND DISCUSSION

Descriptive statistics, analysis of variance, and comparison of means

Descriptive statistics including mean and standard deviation were calculated for all traits (Table 1). The coefficient of variations (CV) divided characteristics into three groups – the group with low variability ($CV \leq 5$) to which most traits belonged, the group with medium variability ($5 < CV < 10$), and the group with high variability ($CV \geq 10$). The CV variability of the quantitative traits varied from 5.82 to 31.21%. The highest CV was related to crown diameter (31.21%) and lowest to number day to germination (5.82%). The results of variance analysis in progenies (Table 2) showed that all traits were significant ($P<0.01$), implying wide variations in all traits. In an assessment of genetic variations of chrysanthemum cut flowers, the highest diversity was reported in plant height and flower bearing (Langton *et al*., 1999). The results of variance analysis for morphological variations of Iranian native irises (Rahimi *et al*., 2009) showed that the highest coefficient of variations was related to leaf width.

Based on the results of means comparison for offspring (Table 2), the highest and the lowest leaf length were observed in the offspring of OPRC09 (20.99 mm) and OPRC03 (12.33 mm), respectively. OPRC09 offspring derived from parent's interbreeding of 3×1 showed significant differences with others and had the highest leaf length relative to the tested progenies. Increasing leaf area enhances photosynthesis rate and causes more carbohydrate accumulation, which increases the shelf life of flowers and makes it possible to export flowers to more distant areas (Jozghasemi *et al*., 2015). On the other hand, increase in leaf surface area may cause increase in evaporation of flowers during postharvest life and reduce the flower longevity. Cultivars that have higher leaf area show better quantitative and qualitative traits (Azimi and Banijamali, 2019).

The highest leaf width belonged to the progeny of OPRC09 (4.78 mm) and the lowest to the OPRC06 (2.31 mm). The progenies of OPRC04, OPRC06, and OPRC09 derived from 2×3, 3×1, and 1×3, respectively, showed considerable differences with others and had the highest leaf width in the examined. The progenies of OPRC09 (1.64 mm) and OPRC02 (0.78 mm) showed the highest and the lowest crown diameter, respectively. The progenies of OPRC08, OPRC04, and OPRC09 derived from 2×3, 1×2, and 1×3 crosses, respectively, exhibited significant differences with others and had the highest crown diameter compared to the examined progenies. Azimi *et al*. (2012) stated that the crown diameter had a high correlation with leaf width. Crown diameter and leaf width are very important characteristics according to the vegetative structure of iris because leaf width and length increase with the growth of crown diameter and affect the physiological characteristics and the function of flower and rhizome. This is true for gladiolus, too. The highest and lowest leaf number was observed in the progenies of OPRC04 and OPRC09 (22.11) and OPRC07 (1.44), respectively. The progenies of OPRC04 and OPRC09 derived from 2×3 and 1×3 whose paternal parent was 'Advance Red' had a significant difference with others and had the highest leaf number among the progenies tested. The results of means comparison for progenies (Table 2) showed that the seeds of OPRC04 and OPRC09 germinated after 15.10 and 15.22 days, respectively. Seed germination of the progeny of OPRC01 and self-pollination of 'Amsterdam' occurred after 17.88 and 17.50 days, respectively. The highest cormlet weight was observed in the progenies of OPRC07 and OPRC09 (0.23 g) and the lowest in the progeny of OPRC03 (0.13 g). The progenies of OPRC07 and OPRC09 derived from 3×2 and 1×3 had a significant difference with others and had the highest weight of cormlet among the tested progenies. The maximum cormlet diameter (8.66 mm) and the minimum one (4.84 mm) belonged to OPRC09 and OPRC02, respectively. As well, the highest number of cormlets was obtained from OPRC04 (2.49) and the lowest from OPRC03 and OPRC09 (1.08).

Table 1. Analysis of variance for the assessed progenies.

S.o.V	df	MS							
		Leaf length	Leaf width	Crown diameter	Leaf number	Days to germination	Cormlet weight	Cormlet diameter	Cormlet number
Block	2	1.47^{ns}	0.58^{**}	0.17^{ns}	0.19^{**}	2.65^{**}	0.001^{ns}	0.80^{**}	0.02^{ns}
Treat	8	19.08^{**}	1.87^{**}	0.27^{ns}	0.20^{**}	3.32^{**}	0.003^{*}	3.97^{**}	0.65^{**}
Error	16	2.52	0.33	0.13	0.08	0.9	0.001	0.27	0.01
CV (%)	-	10.44	16.73	31.21	16.30	5.82	16.29	7.72	8.03

*, ** and ^{ns}: Significant at $P < 0.05$, $P < 0.01$ and insignificant, respectively.

Table 2. Means of squares of traits in progenies or hybrids (1 to 9) and parent of gladiolus: Amsterdam (1), White Prosperity (2), Red Advance (3) and Rose Supreme (4), and Amsterdam self-pollination±.

♀×♂	Progeny (Hybrid)	Leaf length (mm)	Leaf width (mm)	Crown diameter (mm)	Leaf number	Days to germination (day)	Cormlet weight (gr)	Cormlet diameter (mm)	Cormlet number
1*4	OPRC01	16.71b	2.99cd	0.99ab	1.55abc	17.88a	0.17bcd	6.53c	1.66cd
3*2	OPRC02	14.08bcd	2.71cd	0.78b	1.50bc	17.16ab	0.15cd	4.84d	1.34c
2*1	OPRC03	12.33d	2.94cd	1.17ab	1.77abc	16.22abc	0.13d	6.51c	1.08d
2*3	OPRC04	14.05bcd	4.17ab	1.49ab	2.11a	15.22c	0.21ab	7.83ab	2.49a
1±	OPRC05	14.76bcd	3.47bc	0.92b	1.66abc	17.50ab	0.21ab	7.15bc	1.86b
3*1	OPRC06	14.98bcd	4.11ab	1.06ab	1.66abc	16.93abc	0.20abc	5.42d	1.16cd
3*2	OPRC07	13.27cd	2.31d	0.89b	1.44c	15.79bc	0.23a	6.78c	1.26cd
1*2	OPRC08	15.73bc	3.47bc	1.46ab	2.00ab	15.33c	0.22ab	7.08bc	1.34c
1*3	OPRC09	20.99a	4.78a	1.64a	2.11a	15.10c	0.23a	8.66a	1.08d

In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Variance component estimation, diversity coefficient, and inheritance

The results of estimating variance component, diversity coefficient, and the inheritance of the assessed traits (Table 3) showed that the highest genetic diversity belonged to Crown diameter, and days to germination had the lowest genetic variation while the highest phenotypic coefficient diversity was obtained for cormlet number (57.17%) and the lowest for days to cormlet germination (11.15%) (Table 3). These results indicated that genetic factors were more influential on cormlet number than environmental factors, so the selection for this trait can be effective. The highest general inheritability was related to the diameter and number of cormlets (95.46% and 98.46%), respectively, and the lowest to crown diameter (12.90%) (Table 3). In a similar study, Moradi (2009) reported that the highest phenotypic and genetic variations in gladiolus were related to cormlet and stem diameter. Also, the researchers stated that the general heritability for the corm weight of gladiolus was 98% (Sarangi *et al*., 1994). Patra and Mohanty (2014) reported that the highest gladiolus diversity coefficient was related to corm weight and the lowest to days to floret opening. They also showed that the maximum percentage of genetic inheritance was in the mean percentage of floret number per spike. In general, the phenotypic diversity coefficient is higher than the genetic diversity coefficient, which is related to environmental conditions. In this study, the difference between the phenotypic diversity coefficient and genetic diversity coefficient of most traits was very low, indicating the fact that the environmental factors have been less effective because the progenies were cultivated in controlled greenhouse conditions. Most quantitative traits are largely influenced by environmental factors, so it is beneficial to estimate heritability. It is important for breeding programs to study the correlation between cormlet function and other economic traits. The preceding studies have stated that corm weight, leaf width and length, plant height, and leaf number of gladiolus had a higher phenotypic and genetic diversity coefficient than the other assessed traits (Patra and Mohanty, 2014). This finding is similar to the results of Balaram and Janakiram (2009) and Kumari *et al*. (2011) who reported that the highest phenotypic and genetic diversity coefficient was related to the corm diameter of gladiolus. The characteristics that are not affected by environmental factors show higher heritability (Poehlman and Borthakur, 1968; 1977). As a result, it will represent a better achievement to select for genetically favorable progenies (Rardhawa *et al*., 1975).

Table 3. Genotypic variances, phenotypic traits, and heritability.

S.o.V		Leaf length	Leaf width	Crown diameter	Leaf number	Days to germination	Cormlet weight	Cormlet diameter	Cormlet number
Variance	Genotype	5.52	1.76	0.04	0.17	3.02	0.002	3.88	0.64
	Environmental	14.4	0.22	0.27	0.05	0.60	0.001	0.18	0.01
	Phenotypic	19.92	1.98	0.31	0.22	3.62	0.003	4.06	0.65
CV(%)	Phenotypic	28.71	39.86	45.18	25.55	11.15	28.82	29.51	57.17
	Genotypic	21.95	20.79	40.86	24.00	10.95	28.42	29.03	32.62
	Broad sense heritability (%)	27.71	88.88	12.90	77.27	83.42	66.66	95.56	98.46

Correlation quantitative traits

The correlation coefficients of traits between the progenies (Table 4) showed that the highest positive and significant correlation was related to leaf number with crown diameter (r= +0.93), leaf number with leaf width (r= +0.79), crown diameter with leaf width (r= + 0.76) and cormlet diameter with leaf number (r= +0.73). This implies that as leaf number and leaf width increase, corm yield is increased, which is an important factor of gladiolus. The results of this study are consistent with the findings of Moradi (2009) regarding the positive and significant correlation of leaf width with leaf length, stem diameter with leaf number, and leaf width with a dry weight of gladiolus flowers. Azimi *et al*. (2012) reported that crown diameter had a strong correlation with leaf width. Based on the vegetative structure of iris, crown diameter and leaf width are important characteristics. The lowest negative and non-significant correlation was found between the number of days to germination and leaf number (r= -0.79) (Table 4).

Table 4. Correlation of quantitative traits between the genotypes.

Traits	1	2	3	4	5	6	7	8
1. Leaf length	1							
2. Leaf width	0.65**	1						
3. Crown diameter	0.54**	0.76**	1					
4. Leaf number	0.45**	0.79**	0.96**	1				
5. Days to germination	-0.20	-0.40**	-0.79**	-0.73**	1			
6. Cormlet weight	0.44**	0.43**	0.41**	0.35*	-0.49**	1		
7. Cormlet diameter	0.54**	0.55**	0.77**	0.73**	-0.63**	0.59**	1	
8. Cormlet number	-0.25	0.23	0.17	0.35*	-0.17	0.25	0.29*	1

* and **: Significant at $P < 0.05$ and $P < 0.01$, respectively.

Grouping based on quantitative traits

To group the traits (Fig. 1), the Ward method divided the progenies into three main groups. The first group included OPRC01, OPRC02, OPRC03, OPRC05, and OPRC07. The second included OPRCO4 and OPRC06 whose parent was 'Advance Red'. The results of the quantitative traits grouping showed that the populations of the OPRC09 genotype derived from 'Amsterdam' × 'Advance Red' were superior to other genotypes in most traits. The highest genetic proximity was between OPRC01 and OPRC02 derived from 'Amsterdam' × 'Rose Supreme' and 'Advance Red' × 'White Prosperity', respectively.

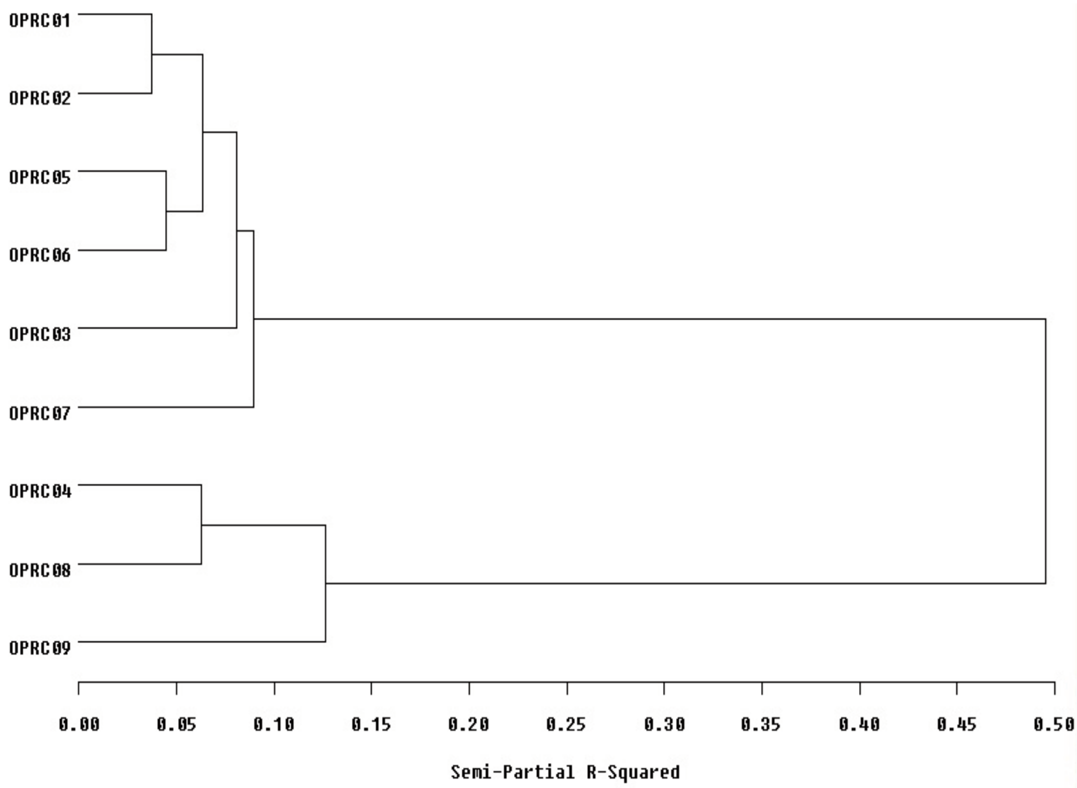

Fig. 1. Cluster analysis of nine hybrids of gladiolus using quantitative traits based on the Ward method.

Table 5. Results of factor analysis for the traits of gladiolus genotypes.

Traits	Factor 1	Factor 2	Factor 3	Factor 4
Leaf length	0.10	0.39	0.24	-0.24
Leaf width	0.27	<u>0.88</u>	0.18	0.12
Crown diameter	<u>0.75</u>	0.49	0.09	0.05
Leaf number	<u>0.70</u>	<u>0.54</u>	0.02	0.23
Days to germination	-0.93	-0.09	-0.28	-0.03
Cormlet weight	0.21	0.13	<u>0.92</u>	0.12
Cormlet diameter	0.45	0.21	0.30	0.17
Cormlet number	0.08	0.10	0.11	<u>0.97</u>
Variance percentage	2.28	1.55	1.14	1.12
Cumulative variation	22.80	38.30	49.70	60.90

Factors analysis

In order to group the traits, a principal component analysis was performed to determine the importance of each of them versus the changes in the total data and to determine the importance of the variables that play a role in the groups (Table 5). The results of the factor analysis, based on the eight assessed traits, showed that the four factors accounted for 60.90% of the total variance. The first factor captured 22.80% of the variance and among its traits, crown diameter and leaf number had the highest positive coefficients. The second factor accounted for 15.50% of the variance in which leaf width and leaf number had the highest positive coefficients. The third factor captured 11.40% of the variance in which cormlet weight had the highest positive coefficient. The fourth factor captured 11.20% of the variance and among its traits, cormlet number had the highest positive coefficients.

CONCLUSION

The results showed that leaf number, leaf width, and crown diameter were more important to distinguishing the progenies because the increase in leaf length and width results in an increase in crown diameter, and this can affect the growth and development and reserves of the underground parts of the plants, which is correct for gladiolus progenies. The populations of the genotype OPRC09 derived from ‘Amsterdam’ × ‘Advanced Red’ were superior in leaf length, leaf width, crown diameter, leaf number, and days to germination, cormlet weight, and cormlet diameter. As well, the populations of the genotype OPRC04 derived from ‘White ‘Prosperity’ × ‘Advance Red’ were superior in cormlet yield. Therefore, the populations of these hybrids can be a candidate for the next step of the selection.

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