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Phenotypic characterization and grouping of gladiolus genotypes using DUS descriptors

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ABSTRACT

Phenotypic characterization of 84 Indian and exotic gladiolus genotypes was carried out at ICAR-Indian Agricultural Research Institute, New Delhi during two consecutive winter seasons of 2017-18 and 2018-19. Twenty one characteristics including vegetative, corm and floral parts were used to distinguish and grouped selected genotypes. Biometric data was recorded at full flowering stage using DUS (Distinctiveness, Uniformity and Stability) guidelines established by the Protection of Plant Varieties and Farmers Rights Authority, New Delhi. Among these DUS characters, seven were assessed as dimorphic and 14 as polymorphic. Characterization information for different traits could be used as reference collection for precise identification and distinction of gladiolus varieties. This information may assist the farmers, nurserymen and breeders to pursue protection for their new varieties under PPV and FRA, New Delhi.

Key words: Distinctiveness, Characterization, Grouping, Protection, Phenotype

Gladiolus (*Gladiolus* × *hybridus* L.) is an important bulbous flower crop of family Iridaceae. Wide diversity of gladiolus species has been reported from South Africa, Europe and Western Asia (Goldblatt and Manning 1998). They have huge demand in market for their attractive florets and long vase life. Cut flowers are used for flower arrangements, bouquet preparation and bedding purpose in the garden. In India, gladiolus is cultivated under open conditions in major states like West Bengal, Maharashtra, Assam, Uttarakhand, Karnataka, Haryana and Himachal Pradesh (Anonymous 2016). *Gladiolus* species and cultivars show high heterozygosity due to cross pollination. It displays a wide range of flower shapes, flower colours and flowering habits in cultivated varieties derived through continuous hybridization and selection over the centuries. Novel varieties with improved flower colour, vase life, resistance to pest and diseases are released annually to meet the consumer needs.

Protection of Plant Varieties and Farmers' Rights Authority (PPV and FRA) of India encourage the research and development in agriculture by giving protection to the varieties of farmers, nurserymen and breeders. Systematic characterization and evaluation of accessions may be practiced by using DUS (Distinctiveness, Uniformity and Stability) descriptors and molecular techniques. Precise identification of varieties and elimination of duplicates in conserved germplasm can be realized through DUS test. Characterization may also help in identifying more reliable traits excluding frequently used traits such as flower colour, spike length, number of florets per spike, flower diameter and vase life for selecting superior genotypes in hybridization. PPV and FRA have developed crop specific DUS guidelines to characterize and evaluate the newly released varieties for many horticulture crops including gladiolus. Therefore, present study was carried out to characterize and grouping of gladiolus genotypes using DUS descriptors.

MATERIALS AND METHODS

The study was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi during two consecutive winter seasons of 2017-18 and 2018-19. The experimental material consisted of 84 diverse Indian bred (Malaviya Shatabdi, Malaviya Kiran, Malaviya Kundan, Kalima, Neelima, Praha, Roshni, Pusa Gunjan, GS-2, Anjali, Dhanvantari, Pusa Shagun, Pusa Shabnam, Pusa Lohit, Pusa Manmohak, Pusa Sindhuri, Pusa Sringarika, Pusa Red Valentine, Neel Rekha, Pusa Suhagin, Pusa Urmi, Pusa Chirag, Pusa Archana, Arka Darshan, Pusa Sarang, Urmil, Delhi Callianthus, Pusa Urvashi, Pusa Chandni, Suchitra, Surya Kiran, Pusa Shweta, Pusa Srijana, Pusa Gulal, Pusa Kiran, Pusa Bindiya, Pusa Mohini, Arka Tilak, Arka Nazrana, Arka Aayush, Arka Sapna, Arka Keshar, Arka Amar, Arka Poonam, Arka Gold, Arka Aarti, Arka Naveen, Punjab Glad 1, Punjab Morning, Punjab Glance, Punjab Glad 2, Punjab Dawn, Punjab Lemon Delight, Punjab Pink Elegance, C. P.G) and exotic bred (Yellow Star, Amethyst, Aldebaran, Tiger Flame, Nova Lux, Euro Vision, Nicole, Fidelio, True

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Love, Vink's Glory, Anglia, Sancerre, Victor, Creamy Green, Friendship, Pink Lady, Plumtart, Lucky Shamrock, Peter Pear's, Vicki Lin, African Star, Apple Blossom, Summer Sunshine, Algarve, Fire Flame, Lady Jane, Yellow Stone, Rose Supreme, Jacksonville Gold) genotypes collected from various institutes (IARI, New Delhi; IIHR, Bengaluru; NBRI, Lucknow; PAU, Ludhiana; BHU, Varanasi) working on crop improvement of gladiolus across India. Uniform corms (4 - 5 cm diameter) of selected genotypes were planted under open field conditions at spacing of 30 cm × 30 cm in a Randomized Block Design (RBD) with three replications in October. Uniform package of practices was followed throughout the season to reduce experimental errors. Twenty one important DUS characteristics including vegetative (plant height, length of the leaf blade, width of the leaf blade, leaf blade colour), corm (corm colour, corm diameter, number of corms per plant, number of cormlets per plant) and floral (arrangement of florets on spike, flower colour (main colour), flower length, flower width, days to flowering, bract length, bract anthocyanin colouration, flower shape, flower attitude, outer whorl shape, outer tepal length, outer tepal width) parts were considered for evaluation of genotypes. The biometrical observations were recorded at full flowering stage under daylight conditions on five random competitive plants per replication as per the criteria described in DUS descriptor of gladiolus released by PPV and FRA, New Delhi (Kalloo *et al*. 2013). Border plants in rows were excluded from taking observations. Flower colour (main colour) and corm colour of outer skin was recorded using Royal Horticultural Society (RHS) colour chart (5th edition, 2015) as per the guidelines recommended by the International Union for the Protection of New Varieties of Plants (UPOV), Geneva, Switzerland (Anonymous 2015). Characteristics suggested by PPV and FRA (plant height, flower colour and corm colour) and UPOV, Geneva (flower width and days to flowering) are used for grouping gladiolus genotypes. Notes (0-9) are used to describe the state of each character for all gladiolus genotypes.

RESULTS AND DISCUSSION

Vegetative characters: Vegetative traits used to characterize the gladiolus genotypes are depicted in Table 1. Characters such as length of the leaf blade (cm), width of the leaf blade (cm) and leaf blade (main colour) distinguished the genotypes into different states. Leaf blade length was dimorphic and remaining characters were polymorphic among the selected genotypes. Length of the leaf blade categorized into two states with most (82) of the genotypes having short (<60 cm) leaf blade length whereas, Praha and Rose Supreme had medium (60 – 80 cm) leaf blade length. Sixty seven genotypes were found to have medium (2.5-4.0 cm) leaf blade width, whereas 14 genotypes had narrow (< 2.5 cm) leaf blade width. Genotypes such as Pusa Red Valentine, Malaviya Shatabdi and Creamy Green were recorded broad (> 4 cm) leaf width. It is assumed that genotypes with broader leaf width have inherent ability of capturing more sunlight to carry out

Table 1 Characterization of gladiolus genotypes based on vegetative, corm and flowering traits

Characteristic	State	Note	No of genotypes
Length of the leaf blade (cm)	Short	3	82
	Medium	5	2
Width of the leaf blade (cm)	Narrow	3	14
	Medium	5	67
	Broad	7	3
Leaf blade (main colour)	Light green	1	22
	Dark green	2	47
	Yellowish-green	3	15
Corm fresh weight (g)	Lighter	3	52
	Medium	5	31
	Heavy	7	1
Corm diameter (cm)	Medium	5	3
	Broad	7	81
Number of corms per plant	One	1	5
	Two	2	33
	More than two	3	46
Number of cormlets per plant	Few	3	52
	Medium	5	27
	More	7	5
Arrangement of florets on spike	One Row	1	2
	Two Rows	2	36
	Zig – Zag	3	46
Flower length (cm)	Short	1	2
	Medium	2	22
	Long	3	60
Bract length (cm)	Medium	2	50
	Long	3	34
Bract anthocyanin coloration	Absent	1	31
	Weak	2	26
	Medium	3	14
	Strong	4	7
	Very Strong	5	6
Flower shape	Triangular	1	55
	Star Shaped	2	23
	Round	3	06
Flower attitude	Upright	1	34
	Semi - Upright	2	50
Outer whorl shape	Ovate	1	35
	Elliptic	2	45
	Obovate	3	4
Tepal length (cm)	Medium	5	81
	Long	7	3
Tepal width (cm)	Narrow	3	18
	Medium	5	65
	Broad	7	1

photosynthesis. Length and width of the leaf blade may vary due to growing conditions like light intensity, soil moisture content and nutrient availability in soil. Main colour of leaf blade was visually assessed by observing the group of plants. Intensity of leaf blade colour was dark green in 47 genotypes, light green in 22 genotypes while, 15 had yellowish – green leaf blade. Variation in leaf blade colour of different genotypes may be attributed to the concentration of chlorophyll pigments in leaves of particular genotype. Dark green colour of genotypes indicate their ability to grow in low light intensity whereas, light green colour and yellowish – green coloured varieties require high light intensity for their growth.

Corm characters: Corm characters such as corms per plant, cormlets per plant and corm colour were polymorphic except corm diameter which was dimorphic among the genotypes studied (Table 1). Corm fresh weight was found to be lighter (<50 g) in 52 genotypes, while medium weight (50-100 g) in 31 genotypes. Victor was found to possess heavier (>100 g) corms among all the studied genotypes. Photosynthetic capacity of individual genotype might have caused the variation in fresh weight of corms. Out of 84 genotypes, 46 genotypes were found to produce more than two corms per plant at the end of the season and hence proved to be good multipliers, whereas 33 genotypes were recorded to yield two corms per plant while, five genotypes produced only single corm per plant. Eighty one varieties had broad (> 4.0 cm) corms, whereas three varieties such as Malaviya Kiran, Algarve and Yellow Star had medium (2.5-4.0 cm) corm diameter. 52 genotypes were found to produce very few cormlets per plant (< 15), while 27 were recorded medium (15 - 50) number of cormlets per plant. Five varieties such as Arka Keshar, Creamy Green, Punjab Lemon Delight, Punjab Glance and Punjab Glad 1 yielded more cormlets per plant (>50) at the end of season. Swaroop *et al*. (2010) reported significant morphological variation for the above corm characteristics among 28 gladiolus genotypes. Corm characters may be typical to individual genotypes and also influenced by the existing environment during production.

Floral characters: Characters such as bract length, days to flowering, outer tepal length, outer tepal width and flower attitude were observed as dimorphic and remaining parameters were found polymorphic among the gladiolus genotypes (Table 1). Forty six genotypes were visually observed to have zig – zag arrangement of florets on spike whereas, two row arrangement was found in 36 genotypes. Two genotypes, viz. GS -2 and True Love were found to have single row or straight arrangement florets on spike. Arrangement of florets on spike was found to be unique with particular genotype. Sixty genotypes had long (>9.0 cm) florets, 22 genotypes had medium (7.5-9.0 cm) florets while, Short (<7.5 cm) florets were recorded in Pusa Urvashi and Fidelio. Bracts were recorded medium (3.0-5.0 cm) in length for 50 genotypes, whereas long (>5.0cm) bracts were observed in 34 genotypes. Visual observation of anthocyanin colouration intensity in bracts differentiated genotypes into five groups. It was found that no anthocyanin pigmentation recorded in bracts of 41 genotypes while, it was very weak in 26 genotypes. Medium pigmented bracts were observed in 14 genotypes, whereas seven genotypes had strong anthocyanin coloration. Anthocyanin coloration was very strong in six genotypes like Roshni, Arka Nazrana, Pusa Red Valentine, Pusa Suhagin, Arka Aarti and Pusa Srijana. Bract anthocyanin coloration can be used as potential trait to distinguish different gladiolus genotypes. Bract colour was used to characterize bananas as it is associated with composition of anthocyanins and found to be distinctive to species and sub species (Simmonds 1962). Genotypes are divided into three categories based on flower shape, viz triangular, star shaped and round. Fifty five genotypes were found to be triangular, 23 were star shaped and round flowers were noticed in remaining six varieties (Friendship, Pusa Kiran, Pink Lady, Anjali, GS - 2 and Yellow Star). Flower attitude was semi - upright in 50 genotypes while, upright in 34 genotypes. On the basis of outer whorl shape of florets, genotypes were categorized into ovate (35), elliptic (45) and obovate (4) types. Variation in flower shape and attitude is cultivar specific and contributed by genetic constitution of individual genotype. Eighty one varieties recorded medium outer (4.0 - 7.5 cm) tepal length while, it was longer (>7.5 cm) in three varieties such as Summer Sunshine, Algarve and True Love. Width of outer tepal in florets categorized genotypes into 18 narrow (<3.5 cm) and 65 medium (3.5-5.5 cm) types. Variety Summer Sunshine was recorded broader (>5.5 cm) tepal width.

Grouping characters: Based on plant height, 51 gladiolus genotypes are categorized into short (< 60 cm), 27 were medium (60 – 70 cm) and 6 varieties were tall (> 70cm) types (Table 2). Kadam *et al*. (2014) revealed broad variation in plant height (ranged from 63.97cm to 115.87cm) among studied genotypes. Singh *et al*. (2018) mentioned that significant variation in plant height among 50 different cultivars of gladiolus is attributed to prevailing environment during growing period. Genotypes are categorized into different flower colour (main colour) groups such as White (10), Yellowish - Green (1), Yellow (18), Orange (4), Pink (18), Red (16), Purple Red (10) and Violet Blue (7). Victor had distinct Yellowish – Green colour among all the studied genotypes. Flower colour is a qualitative trait assumed to be most reliable trait for identification of genotypes as it is less influenced by environmental factors. Based on flower width, 52 genotypes were small (6.5 - 9.0 cm) and 32 were medium (9.0 - 11.5 cm). Genotypes are classified into Light Yellow (25), Dark Yellow (12), Yellowish - Orange (14), Orange (12), Red (10), Purple (7) and others (4) based on corm colour of outer skin. Varieties belong to other colour group such as Darshan, Arka Poonam, Arka Gold and Algarve had creamy white coloured corms. Corm colour of outer skin in addition to flower colour may help in more accurate documentation of genotypes. Clear understanding of inheritance of corm colour could be helpful to use it as selection criteria in hybridity analysis. Days to flowering recorded medium (60 - 90 days) in 10 genotypes while,

Table 2 Categorization of gladiolus genotypes based on grouping traits

Characteristic	State	Note	No of genotypes	Varieties
Plant height (cm)	Short (<60 cm)	3	51	All varieties except those in medium category
	Medium (60-70 cm)	5	27	Pusa Gunjan, Aldebaran, Fire Flame, Tiger Flame, Roshni, Yellow Stone, Sancerre, Pusa Shabnam, Nova Lux, Euro Vision, Jacksonville Gold, Pusa Sringarika, Neel Rekha, Friendship, Arka Keshar, Pusa Archana, Pusa Sarang, Lucky Shamrock, Pusa Chandni, Peter Pear's, Vicki Lin, Pusa Kiran, Apple Blossom, Pusa Bindiya, Mohini, Summer Sunshine, Algarve
	Tall (>70 cm)	7	6	Praha, Dhanvantari, Rose Supreme, Pusa Shagun, Victor, Plumtart
Flower colour (main colour)	White	0	10	Anjali, Sancerre, Malaviya Kiran, Malaviya Shatabdi, Creamy Green, Friendship, Arka Sapna, Pusa Shweta, Arka Poonam, Apple Blossom
	Yellowish-green	1	1	Victor
	Yellow	2	18	Anglia, Aldebaran, GS-2, Yellow Stone, Dhanvantari, Punjab Glad 2, Pusa Shabnam, Nova Lux, Jacksonville Gold, Punjab Lemon Delight, Yellow Star, Pusa Chandni, Arka Gold, Pusa Kiran, Vink's Glory, Summer Sunshine, Algarve, Malaviya Kundan
	Orange	3	4	Punjab Glad 1, Arka Keshar, Lucky Shamrock, Vicki Lin
	Pink	4	18	Pusa Gunjan, Tiger Flame, Punjab Morning, Rose Supreme, Punjab Glance, Punjab Dawn, Pusa Sindhuri, Pink Lady, Pusa Archana, Darshan, Delhi Callianthus, Suchitra, Surya Kiran, True Love, Peter Pear's, African Star, Punjab Pink Elegance, Pusa Bindiya
	Red	5	16	Fire Flame, Praha, Roshni, Pusa Shagun, Arka Tilak, Pusa Lohit, Pusa Manmohak, Euro Vision, Lady Jane, Arka Aayush, Pusa Red Valentine, Pusa Suhagin, Pusa Chirag, Nicole, Arka Amar, Arka Aarti
	Purple red	6	10	Kalima, Arka Nazrana, Pusa Sringarika, Pusa Urvashi, Pusa Srijana, Neel Rekha, Plumtart, Pusa Gulal, Pusa Mohini, C.P.G
	Violet blue	7	7	Amethyst, Neelima, Pusa Urmi, Pusa Sarang, Fidelio, Urmil, Arka Naveen
Flower width (cm)	Small (6.5 – 9.0 cm)	2	52	All varieties except those in medium category
	Medium (9.0–11.5 cm)	3	32	Pusa Gunjan, Kalima, Neelima, GS-2, Praha, Anjali, Roshni, Rose Supreme, Sancerre, Pusa Shagun, Pusa Shabnam, Arka Tilak, Victor, Pusa Manmohak, Pusa Sindhuri, Pusa Sringarika, Yellow Star, Friendship, Arka Keshar, Pusa Suhagin, Nicole, Pusa Sarang, Urmil, Arka Amar, True Love, Peter Pear's, Pusa Shweta, Vicki Lin, African Star, Arka Aarti, Summer Sunshine, Algarve
Corm colour of the outer skin	Light yellow	1	25	Amethyst, Neelima, GS-2, Rose Supreme, Punjab Glance, Sancerre, Punjab Glad 2, Pusa Sindhuri, Nova Lux, Jacksonville Gold, Punjab Lemon Delight, Pusa Sringarika, Yellow Star, Creamy Green, Arka Keshar, Pusa Chirag, Suchitra, African Star, Arka Naveen, Apple Blossom, Punjab Pink Elegance, Vink's Glory, Pusa Bindiya, Mohini, Malaviya Kundan
	Dark yellow	2	12	Pusa Gunjan, Punjab Glad 1, Aldebaran, Tiger Flame, Anjali, Arka Aayush, Friendship, Pink Lady, Arka Sapna, Delhi Callianthus, Pusa Shweta, Summer Sunshine
	Yellowish - orange	3	14	Anglia, Fire Flame, Malaviya Shatabdi, Dhanvantari, Punjab Morning, Pusa Shabnam, Victor, Malaviya Kiran, Pusa Urvashi, Pusa Chandni, Surya Kiran, Pusa Srijana, Pusa Kiran, Arka Aarti
	Orange	4	12	Roshni, Yellow Stone, Punjab Dawn, Lady Jane, Neel Rekha, Pusa Urmi, Fidelio, Urmil, Lucky Shamrock, True Love, Peter Pear's, Vicki Lin
	Red	5	10	Arka Tilak, Pusa Lohit, Pusa Manmohak, Pusa Red Valentine, Pusa Suhagin, Plumtart, Arka Amar, Pusa Gulal, C.P.G, Pusa Sarang
	Purple	7	7	Kalima, Praha, Pusa Shagun, Arka Nazrana, Euro Vision, Nicole, Pusa Archana
	Others	8	4	Darshan, Arka Poonam, Arka Gold, Algarve
Days to flowering (days)	Medium (60-90)	5	10	Fire Flame, Malaviya Shatabdi, Roshni, Yellow Stone, Punjab Glad 2, Pusa Shabnam, Neel Rekha, Arka Sapna, Arka Keshar, Apple Blossom
	Late (>90)	7	74	All other varieties except those in medium category

late (> 90 days) in remaining 74 genotypes. Taloh (2014) reported that the most contributing trait towards genetic divergence among 50 selected gladiolus genotypes was days to flowering. Clear distinction of gladiolus genotypes into medium and late types may indicate that expression of days to flowering is genetically determined. Days to spike initiation and days to first floret opening were seemed to be heritable (Ranjan *et al*. 2010).

Present study suggests that existence of wide variability for vegetative, corm and floral traits in 84 Indian and exotic gladiolus genotypes would be helpful in selecting desirable parents for hybridization. It will help the breeders in understanding varietal performance and selection of reliable traits to develop superior genotypes. Characterization data of different traits could be used as reference collection for identification of gladiolus varieties. This information may assist the breeders to seek protection of their new varieties under PPV and FRA, New Delhi.

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