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Morphological variation among various Double accessions of *Polianthes tuberosa* L.

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Abstract
Tuberose (*Polianthes tuberosa* Linn.) occupies a very special position among various bulbous aromatic ornamental plants. It is highly valued for its loose flowers, cut flowers and its lingering fragrance, which makes it highly valued for use in perfumery industry and in manufacture of aromatic essential oils. Two types of tuberoses i.e. single and double type are reported in India with a number of cultivars. There is a huge confusion in the naming of tuberose, all the double tepalled cultivars of tuberose are normally referred to as double tuberose and all the single tepalled cultivars of tuberose are normally referred to as single tuberose and there is lacking of proper nomenclature of various double and single tuberoses found in different states of India. So, maintaining the purity of these different tuberose cultivars becomes primarily important in such a scenario. Here attempt has been made to mark the variations in these different cultivars of double tuberoses using various morphological markers. Eight double tepalled germplasm accessions were taken for the studies and were evaluated using twenty eight different morphological markers. The morphological characterization of nine cultivars depicted clear differences. The analysis of data indicated that the cultivars did not differ significantly in few traits like leaf waxiness, flower colour, flower type, rows of tepals and anthers while clear differences were recorded in eighteen floral characters and five foliage characters. The present study on these nine double tepalled cultivars successfully demonstrate that these double cultivars of tuberose differ significantly in 23/28 characters, which makes the present tools strong descriptors for characterizing tuberose genotypes and can be of help for future researchers.

Keywords: Tuberose, morphological markers, Morphological Variation, DUS testing. loose flower, cut flower

Introduction
Tuberose (*Polianthes tuberosa* Linn.) occupies a very special position among various bulbous aromatic ornamental plants. It is highly valued for its loose flowers, cut flowers and its lingering fragrance, which makes it highly valued for use in perfumery industry and in manufacture of aromatic essential oils, due to which it is cultivated all over the world, especially in Egypt, China, France and Morocco (Datta, 2017) [5]. In India, 30,000 hectare area is under cultivation of tuberose for commercial purpose and the leading states cultivating tuberose include Andhra Pradesh, Assam, Gujarat, Haryana, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh, Uttarakhand and Orissa (Singh *et al.,* 2010). Owing to long spikes, tuberose is used for garden decoration, striped leaf margins are used for preparing artistic garlands. Cut flowers are also used for making bouquets and loose flowers for making floral ornamental (Khandagale *et al.,* 2014; Navabi *et al.,* 2016) [8, 9]. Tuberose flowers have also been long been used as a source of essential oils, in perfumery industry and for extracting aroma compounds, which are synthesized in various plant parts. (Dudareva and Negre 2005) [6].
There are 2 types of tuberose based on whorls, i.e. single and double with a number of varieties reported in India (Biswas *et al.,* 2002) [2]. There is a huge confusion in the naming of tuberose, all the double tepalled cultivars of tuberose are normally referred to as double tuberose and all the single tepalled cultivars of tuberose are normally referred to as single tuberose and there is lacking of proper nomenclature of various double and single tuberoses found in different states of India. So, maintaining the purity of these different tuberose cultivars becomes primarily important in such a scenario (Bharti *et al.*, 2015) [1]. Proper identification of species, variety or cultivars is the most important step for making a crop improvement programme successful. Two types of tuberoses i.e. single and double type are reported in India with a number of cultivars. Morphological characters are used as a strong tool for studying the genetic diversity among species or varieties (Schut *et al.,* 1997) [11]. Hence, the morphological studies form a strong base for solving taxonomic, classification or even genetic diversity problems (Van Bueningen and Busch, 1997; Cox and Murphy, 1990; Kameshwari *et al.,* 2014) [14, 4, 8].

Various morphological markers were used in the present study to characterize different double tepalled cultivars of tuberose already released over the years, to distinguish between these similar looking double cultivars, so that reliable identification keys can be developed for future use for studying variation among different cultivars and while implementing DUS testing as DUS testing has not been performed on tuberose under Punjab conditions as yet.

Such morphological characters are already known in some crop (Chen *et al.*, 2004; Ranchana *et al.*, 2013; Sirohi *et al.*, 2017) [3, 10, 13] and ornamental plants (Wen and Hsiao, 2004) [15] to assess systematic taxonomic relationship.

Material and Methods

Germplasm, in the form of various cultivated accessions was procured from various sources like Horticultural Research Institutes and Universities of Punjab, Uttrakhand, Himachal Pradesh, Delhi and Rajasthan. The germplasm for present studies included nine double tepalled tuberose genotypes i.e. Suvasini, Pearl, Hyderabad Double, Calcutta Double, Vaibhav, Double Flowering Form, Double, Swarna Rekha, Mexican white double.

The collected germplasm was cultivated in the Plant Conservatory, Punjabi University, Patiala as per the guidelines of Protection of Plant Varieties and Farmers' Rights Authority, India. All accessions were evaluated for morphological parameters related to vegetative and floral characters.

Results and Discussion

The morphological characters of nine germplasm accessions have been observed to be clearly different. Differences were seen in various characters, such as **l**eaf colour is found to be light green in Suvasini, Pearl, Vaibhav, Hydrabad Double, Mexican White Double while dark green in Calcutta Double, Double Flowering form, Double and Swaran Rekha. Similarly leaf variegation is present only in Swarna Rekha and Mexican White Double, while absent in rest of the accessions i.e. Suvasini, Pearl, Vaibhav, Calcutta Double, Double, Double Flowering Form and Hyderabad Double. Leaf Waxiness is present in all accessions. So, no variation was seen in this character. Long Leaf length is found in Suvasini, Pearl, Hyderabad Double while medium leaf length is present in Calcutta Double, Double Flowering Form, Double, Vaibhav, Swarna Rekha, Mexican white double.

In the same way leaf breath is found to be medium in Pearl, Hyderabad Double, Swarna Rekha, Narrow leaf breadth is seen in Calcutta Double, Double Flowering Form, Vaibhav, Double, Mexican White Double and Broad leaf breadth seen in Suvasini.

Pigmentation at leaf base on abaxial side is found Strong in Suvasini and Mexican white double, Medium in Pearl, Hyderabad Double, Double Flowering Form, Double, while weak is present in Calcutta Double, Vaibhav and Swarna Rekha.

Long Bud length is present in Suvasini, Medium bud length is present in Double while the short bud length is found in Pearl, Hyderabad Double, Calcutta Double, Double Flowering Form, Swarna Rekha, Mexican White Double and Vaibhav.

Bud colour was found to be Pink in case of Suvasini, Pearl, Calcutta Double, Double Flowering Form, Double, Mexican White Double while it is green in Hyderabad Double, Swarna Rekha and Vaibhav. There is no variation in flower type as it is double in all the cultivars.

Long Flower length is present in Suvasini, Medium flower length is present in Double, Vaibhav while short flower length is found in Pearl, Hyderabad Double, Calcutta Double, Double Flowering Form, Swarna Rekha, Mexican White Double.

Larger flower diameter found in Suvasini, Calcutta Double, Double, Vaibhav and small flower diameter found in Pearl, Swarna Rekha, Mexican White Double and medium flower diameter present in Hyderabad Double, Double Flowering Form.

Tepal tip is acute in case of Suvasini, Pearl, Swarna Rekha, Vaibhav, Mexican white double, obtuse in case of Calcutta Double, apiculate in case of Hyderabad Double, Double Flowering Form, Double.

Straight inflorescence found in case of Suvasini, Pearl, Swarna Rekha, Vaibhav Slightly bent inflorescence found in case of Hyderabad Double, Calcutta Double and Crooked inflorescence found in case of Double Flowering Form, Double, Mexican white double.

Short inflorescence axis is present in Calcutta Double, Swarna Rekha, Mexican white double, while medium inflorescence axis is present in Pearl, Double Flowering Form, Double, while long inflorescence axis is present in rest of all i.e Suvasini, Hyderabad Double and Vaibhav.

Tubular flower shape is present as in Calcutta Double, Mexican white double, Flower shape is broad funnel in Suvasini, Pearl, Double Flowering Form, Double, and is narrow funnel in Hyderabad Double, Swarna Rekha and Vaibhav.

Flower tube shape is straight in case of Suvasini, Pearl, Hyderabad Double, Calcutta Double, Double, Swarna Rekha, Vaibhav and Bent shaped flower tube is found in Double Flowering Form and Flower tube shape is tubular in case of Mexican white double.

Flower opening is wide in case of Suvasini, Double Flowering Form, Double, while shy flower opening is present in Pearl, Hyderabad Double, Calcutta Double, Swarna Rekha, Mexican White Double and Vaibhav.

Inflorescence length is long in Suvasini, and short in Calcutta Double, Double Flowering Form, Mexican white double, while medium Inflorescence length is found in rest of all accessions i.e. Pearl, Hyderabad Double, Double, Swarna Rekha and Vaibhav.

Similarly Peduncle thickness is thin in most of accessions i.e. Hyderabad Double, Calcutta Double, Swarna Rekha, Mexican white double, and medium in Double Flowering Form, while thick peduncle is found in Suvasini, Pearl, Double and Vaibhav.

Many flowers are present in Suvasini, Medium flowers are present in Pearl, Hyderabad Double, Vaibhav and few in most of accessions as in Calcutta Double, Double Flowering Form, Double, Swarna Rekha, Mexican white double

Perianth tube length is medium in Suvasini, Pearl, Hyderabad Double, Swarna Rekha and Long in case of Calcutta Double, Double Flowering Form, Double and Vaibhav.

Perianth tube diameter is Medium in Suvasini, while thin in case of Pearl, Hyderabad Double, Calcutta Double, Double Flowering Form, Double, Swarna Rekha, Mexican White Double Perianth lobe is thick in accessions i.e. Suvasini, Hyderabad Double, Calcutta Double, Double Flowering Form, Double, Swarna Rekha, Mexican white double, Vaibhav while Perianth lobe thickness is medium is Pearl.

Pinkish tinge is present in tepal color on abaxial surface in Suvasini, Pearl, Calcutta Double, Double while greenish tinge

is found in rest of all accessions i.e. Double Flowering Form, Swarna Rekha, Mexican White Double and Vaibhav.
Malformed anthers are present in all the accessions. Thrum shaped stigma type is present in almost all accessions i.e Suvasini, Pearl, Hyderabad Double, Calcutta Double, Double, Swarna Rekha, Mexican White Double and Vaibhav while pin shaped stigma type is also found in Double Flowering Form.

Table 1: Morphological markers based on DUS guidelines

Cultivars	Leaf colour	Leaf variegation	Leaf Waxiness	Leaf length	Leaf breadth	Pigmentation at leaf base on Abaxial side	Bud length
Suvasini	Light Green	Absent	Present	Long	Broad	Strong	Long
Pearl	Light Green	Absent	Present	Long	Medium	Medium	Short
Hyderabad Double	Light Green	Absent	Present	Long	Medium	Medium	Short
Calcutta Double	Dark Green	Absent	Present	Medium	Narrow	Weak	Short
Double Flowering Form	Dark Green	Absent	Present	Medium	Narrow	Medium	Short
Double	Dark Green	Absent	Present	Medium	Narrow	Medium	Medium
Swarna Rekha	Dark Green	Present	Present	Medium	Medium	Weak	Short
Mexican white double	Light Green	Present	Present	Medium	Narrow	Strong	Short
Vaibhav	Dark Green	Absent	Present	Medium	Narrow	Weak	Short

Cultivars	Bud colour	Flower colour	Flower type	Flower length	Flower diameter	Tepal tip	Rows of tepal
Suvasini	Pink	White	Double	Long	Large	Acute	>3
Pearl	Pink	White	Double	Short	Small	Acute	>3
Hyderabad Double	Green	White	Double	Short	Medium	Apiculate	>3
Calcutta Double	Pink	White	Single	Short	Large	Obtuse	>3
Double Flowering Form	Pink	White	Double	Short	Medium	Apiculate	>3
Double	Pink	White	Double	Medium	Large	Apiculate	>3
Swarna Rekha	Green	White	Double	Short	Small	Acute	>3
Mexican white double	Pink	White	Double	Short	Small	Acute	>3
Vaibhav	Green	White	Semi Double	Medium	Large	Acute	>3

Cultivars	Inflorescence	Inflorescence axis	Flower shape	Flower tube shape	Flower opening	Inflorescence length	Peduncle thickness
Suvasini	Straight	Long	Broad funnel	Straight	Wide open	Long	Thick
Pearl	Straight	Medium	Broad funnel	Straight	shy	Medium	Thick
Hyderabad Double	Slightly bent	Long	Narrow funnel	Straight	shy	Medium	Thin
Calcutta Double	Slightly bent	Short	Tubular	Straight	shy	Short	Thin
Double Flowering Form	Crooked	Medium	Broad funnel	Bent	Wide open	Short	Medium
Double	Crooked	Medium	Broad funnel	Straight	Wide open	Medium	Thick
Swarna Rekha	Straight	Short	Narrow funnel	Straight	shy	Medium	Thin
Mexican white double	Crooked	Short	Tubular	Tubular	shy	Short	Thin
Vaibhav	Straight	Long	Narrow funnel	Straight	shy	Medium	Thick

Ultivars	No. of flowers/ inflorescence	Perianth tube length excluding tepals	Perianth tube diameter	Perianth lobe thickness	Tepal colour on abaxial side	Anthers	Stigma type
Suvasini	Many	Medium	Medium	Thick	Pinkish tinge	Malformed	Thrum
Pearl	Medium	Medium	Thin	Medium	Pinkish tinge	Malformed	Thrum
Hyderabad Double	Medium	Medium	Thin	Thick	Greenish tinge	Malformed	Thrum
Calcutta Double	Few	Long	Thin	Thick	Pinkish tinge	Malformed	Thrum
Double Flowering Form	Few	Long	Thin	Thick	Greenish tinge	Malformed	Pin
Double	Few	Long	Thin	Thick	Pinkish tinge	Malformed	Thrum
Swarna Rekha	Few	Medium	Thin	Thick	Greenish tinge	Malformed	Thrum
Mexican white double	Few	Medium	Thin	Thick	Greenish tinge	Malformed	Thrum
Vaibhav	Medium	Long	Thin	Thick	Greenish tinge	Malformed	Thrum

Fig 1: Variation in leaf colour

Fig 2: Variation in bud colour

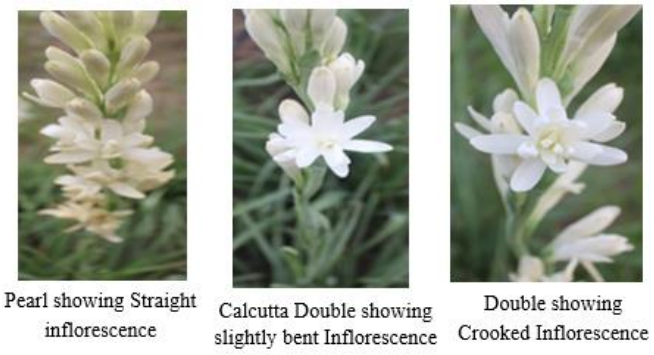

Fig 3: Variation in Inflorescence

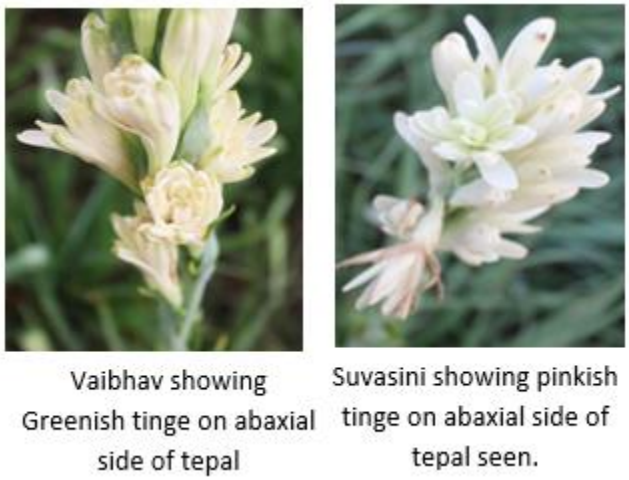

Fig 4: Tepal colour on abaxial side

Fig 5: Anthers

Conclusion

The morphological characterization of nine cultivars depicted clear differences. The analysis of data indicated that the cultivars did not differ significantly in few traits like leaf waxiness, flower colour, flower type, rows of tepal and anthers while clear differences were recorded eighteen floral characters and five foliage characters. Bharti *et al.,* (2015) [1] also got similar results and noticed distinct differences in floral and vegetative characters in tuberose. So, the studies successfully reveal that the present morphological markers can be used to study variations among various cultivars of tuberoses efficiently, and hence can be of great help for the future researchers for studying variation as well as for performing DUS characterization of tuberose.

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