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# DUS characterization of pumpkin (*Cucurbita moschata*) genotypes

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ABSTRACT

A total of 76 pumpkin (*Cucurbita moschata* Duchesne ex Poir.) genotypes, purified and maintained as inbreds at Division of Vegetable Science, IARI were morphologically characterized for 21 different traits over two consecutive seasons (spring-summer 2013, 2014) as per DUS guidelines of PPV and FRA. Out of 21 morphological characters under study 14 were assessed visually and seven were measured. All genotypes were grouped into different categories on the basis of these morphological descriptors. With respect to fruit shape at physiological maturity all studied genotypes were observed to have either spherical (CM-350, Punjab Samrat and 25 genotypes) round flat (11 genotypes), oval/ oblong oval (Pusa Vishwas and 12 genotypes), oval spherical (DPU-52, DPU-57, and DPU-75 genotypes), oblong cylindrical (DPU-26), flattish round (Kashi Harit and 14 genotypes), flattish (DPU-22, DPU-27, DPU-76), club (DPU- 35), cylindrical (DPU-58) or heart shape (DPU- 80) fruits. Most of the genotypes under study were grouped into medium category on the basis of their fruit length, fruit thickness, fruit diameter, seed length and seed width. On the basis of fruit skin colour at immature stage, genotypes were grouped into four groups i.e. dark green, medium green, light green and cream coloured with 15, 38, 21 and two genotypes in each group, respectively. With respect to fruit skin colour pattern genotypes were grouped into uniform, striped and mottled categories. Fruit flesh colour was observed either as orange, light orange, yellowish orange, cream white, dark orange, orange yellow, yellow orange with green overcast, light orange with green overcast, dark orange yellow, and dark yellow orange with greenish overcast. All studied characters can be used as grouping traits. The expression of studied characters remained consistent over two consecutive seasons indicating their uniformity. These studied genotypes can be successfully utilized as reference material for protection of other varieties under PPV and FR Act.

**Key words**: Characterization, *Cucurbita moschata*, DUS testing, Pumpkin, PPV and FRA

Pumpkin (*Cucurbita moschata* Duchesne ex Poir.; 2n=2x=40) a native of Northern and Southern America is one of the important cucurbitaceous vegetable crops, grown worldwide under wide range of agro-climatic conditions. There are 27 species under the genus *Cucurbita*, five of which are in cultivation and *C. moschata* is probably the most widely grown species. Pumpkin is relatively high in energy and carbohydrates and a good source of vitamins, especially high in carotenoid pigments and minerals. Numerous studies have implicated that carotenoids possess protective function against several cancers, cardiovascular diseases, cataract, and also enhance immune responses. However, in India, the flowers, leaves, and vine tips of *Cucurbita* are also consumed. Moreover, its seed is an excellent source of proteins and also have pharmacological properties such as antidiabetic (Li *et al*. 2003), antifungal (Wang and Ng 2003), antibacterial, anti-inflammatory (Fu *et al*. 2006) and antioxidant effects (Nkosi *et al*. 2006). Despite its health and dietary benefits, production of pumpkin in India is limited to an area of 47 000 ha with a production of 1031 thousand tonnes (Anonymous 2016).

Every crop improvement programme aims at development of widely adapted high yielding, disease free cultivars. Morphological characterization is the first step in description and classification of the cultivars. It is a clear fact that morphological data cannot be relied upon because of environmental interaction and largely unknown or complex mechanisms of genetic control of such traits (Camussi *et al*. 1983). India became a signatory to the TRIPS agreement in 1994 which need WTO member nations to formulate and enforce an effective system to protect plant genetic resources; a *sui generis* system was adopted. PPV and FR Act was formulated by Government of India in 2001 which provide protection to breeders as well as farmers rights (PPV and FR Act 2001). Varietal testing for distinctness, uniformity and stability (DUS) is the basis for grant of protection under this act and hence it is desirable to characterize the germplasm according to DUS test guidelines for pumpkin prescribed by PPV and FR Authority. Characterization of genotypes is useful to identify and avoid duplication. Therefore, the

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present study was planned to characterize the available pumpkin genotypes for qualitative and quantitative traits as per DUS test guidelines of PPV and FRA, New Delhi.

## MATERIALS AND METHODS

The experimental material for the present study consisted of 76 promising and diverse genotypes of pumpkin including four check varieties collected from different parts of the country. These were further purified and maintained as inbreds at Division of Vegetable Science, IARI, New Delhi and evaluated morphologically for 21 DUS characters [Plant : length of main vine, leaf blade: margin, leaf blade: intensity of green colour, leaf blade: silver patches, peduncle: length, fruit: main colour of skin (at immature fruit stags), fruit: skin colour pattern, fruit: shape at peduncle end, fruit: shape at blossom end, fruit: surface grooves, fruit : marbling (immature stage), fruit: length (mature stage), fruit diameter (mature stage), fruit Shape, fruit main colour of skin (mature stage), fruit: waxiness of skin (at mature fruit stage), fruit: main colour of flesh, fruit: thickness of flesh, seed: length, seed: width, seed: colour of coat] at specified stage of crop growth period over two consecutive seasons (spring-summer 2013, 2014). Out of 21 morphological characteristics 14 were visually assessed and 7 were measured. All recommended package of practices were followed to raise healthy crop for DUS characterization. The list of 76 genotypes used in the present study has been given in the Table 1. The seeds of 76 pumpkin genotypes were sown in plug-trays and seedlings were transplanted in the main field with five rows of 6.4m length and a spacing of 4.5m and 0.8m was maintained between rows and plants, respectively, in Randomized Block Design with three replications. For recording observations 10 plants were randomly selected from each replication. All observations on leaf were recorded on one leaf above the first fruit set nodes. All observations on the leaf blade were recorded on a fully developed leaf blade, from the 15$^{th}$ node upwards to 20$^{th}$ node. Observations on the flowers were recorded on flowers between 10$^{th}$ to 20$^{th}$ nodes. Observations on the immature fruit were recorded 8-14 days after anthesis on fruits borne between 10th and 20th node. Main vine length was recorded at mature fruit stage. All width parameters were measured at the broadest point of the concerned part whereas seed parameters were recorded at fully developed stage in washed and dried seeds; seed colour characteristics were assessed by using Royal Horticultural Society (RHS) colour chart.

## RESULTS AND DISCUSSION

Morphological characterization is the first step in the description and classification of genetic resources. According to Simmonds (1962) greater the variability in available germplasm, better would be the chances of selecting superior genotypes. The present investigation revealed considerable variation among all 76 genotypes. On the basis of 21 morphological traits, 76 genotypes were identified in different category such as viz. plant (length of main vine), leaf (leaf blade margin, intensity of green colour, silver patches), fruit (main colour of skin i.e. at immature fruit stags, skin colour pattern, shape at peduncle end, shape at blossom end, peduncle length, surface grooves, marbling i.e. immature stage, length, diameter, shape, main colour of skin, thickness of flesh, waxiness of skin, main colour of flesh, and seed characters (length, width and colour of seed coat) (Table 1, 2, 3).

*Plant and leaf characters*

Vine length is considered as an important yield contributing trait, because it leads to more number of branches, flowers and fruits, which ultimately result in increased productivity. Longest vine length was observed in DPU-56 and DPU-61 while another 50 genotypes have long vine length (>4.5m) whereas 23 genotypes falls under medium (3.0-4.5m) and DPU-17 under short (< 3m) vine group.

The study revealed that leaf blade margin was weakly incised in 53 genotypes including two check cultivars, viz. Pusa Vishwas and Kashi Harit and very weakly incised in 22 genotypes including check cultivar Punjab Samrat. The check cultivar Kashi Harit along with other 21 genotypes had dark leaf blade, while 12 other genotypes including check cultivar Pusa Vishwas and 42 genotypes including check cultivar Punjab Samrat were observed to have light and medium intensity of green colour on upper side of leaf, respectively. All studied genotypes had silver patches on the leaf blade except DPU-45.

Significant variations for vine and peduncle length in pumpkin has been observed by Balkaya *et al.* (2010), Selvi *et al.* (2012), Cyril *et al.* (2014) and Muralidhara *et al.* (2014) whereas Lebeda *et al.* (2007) had observed significant variation for intensity of leaf color of upper side of leaf blade and mottling on leaf lamina, respectively.

*Fruit characteristics*

On the basis of fruit skin colour at immature stage, pumpkin genotypes were grouped into four groups, i.e. dark green, medium green, light green and cream coloured with 15, 38, 21 and 2 genotypes in each group, respectively. Uniform, striped and mottled fruit skin colour pattern was observed in 15, 1 (Pusa Vishwas) and 60 genotypes including check cultivars Kashi Harit and Punjab Samrat, respectively. Pusa Vishwas and 53 other genotypes had weak marbling at immature fruit stage while it was found to be medium in Kashi Harit, Punjab Samrat, DPU-35, DPU-45, DPU-53 and DPU-65 whereas marbling was absent in CM-350 along with 15 other genotypes.

Shape at peduncle end was recorded to be raised, flat, slightly depressed, moderately depressed and strongly depressed in seven genotypes including Pusa Vishwas, 17, 21 and 30 including check Kashi Harit, respectively. With respect to shape at blossom end 3, 26, 35 and 11 genotypes were observed to be raised, flat, slightly and moderately depressed, respectively while genotype DPU-44 was observed to be strongly depressed at blossom end. Fruits surface grooves or ribs were present in all the genotypes except Punjab Samrat

Table 1 Characterization of pumpkin genotypes based on plant and leaf characters

| Characteristics | State of expression | Example genotypes |
|---|---|---|
| Plant : Length of main vine | Short (<3 m) | DPU-17 |
| | Medium (3-4.5m) | DPU-1, DPU-2, DPU-3, DPU-5, DPU-5-2, DPU-10, DPU-16, DPU-19, DPU-21-3, DPU-29, DPU-30, DPU-32, DPU-33, DPU-41, DPU-46, DPU-54, DPU-65, DPU-66, DPU-67, DPU-70, DPU-75, Kashi Harit and Pusa Vishwas |
| | Long (>4.5 m) | DPU-4, DPU-4-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-15, DPU-18, DPU-20-2, DPU-21, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-31, DPU-35, DPU-36, DPU-42, DPU-43, DPU-44, DPU-45, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-56, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-68, DPU-69, DPU-71, DPU-72, DPU-73, DPU-74, DPU-76, DPU-77, DPU-79, DPU-80, CM-350 and Punjab Samrat |
| Leaf blade: Margin | Entire or very weakly incised | DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-15, DPU-16, DPU-19, DPU-20-2, DPU-21-3, DPU23-, DPU-26, DPU-27, DPU-29, DPU-30, DPU-32, DPU-35, DPU-43, DPU-45, DPU-57, DPU-60, DPU64-2 and Punjab Samrat |
| | Weakly incised | DPU-1, DPU-2, DPU-3, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-17, DPU-18, DPU-21, DPU-22, DPU-22-3, DPU-24, DPU-25, DPU-28, DPU-31, DPU-33, DPU-36, DPU-414, DPU-42, DPU-44, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-56, DPU-58, DPU-59, DPU-61, DPU-62, DPU-63, DPU-64, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-72, DPU-73, DPU-74, DPU-75, DPU-76, DPU-77, DPU-79, DPU-80, Kashi harit and Pusa Vishwas |
| | Moderately incised | CM-350 |
| Leaf blade: Intensity of green colour | Light | DPU-5-3, DPU-15, DPU-25, DPU-26, DPU-57, DPU-59, DPU-60, DPU-62, DPU-65, DPU-73, DPU-74 and Pusa Vishwas |
| | Medium | DPU-1, DPU-2, DPU-4-2, DPU-5-2, DPU-6, DPU-8-2, DPU-9, DPU-10, DPU-16, DPU-17, DPU-19, DPU-21, DPU-21-3, DPU-22, DPU-23, DPU-24, DPU-27, DPU-28, DPU-30, DPU-35, DPU-42, DPU-44, DPU-45, DPU-46, DPU-51, DPU-51-3, DPU-54, DPU-56, DPU-58, DPU-61, DPU-64, DPU-64-2, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-72, DPU-75, DPU-77, CM-350 and Punjab Samrat |
| | Dark | DPU-3, DPU-4, DPU-5, DPU-8, DPU-18, DPU-20-2, DPU-22-3, DPU-29, DPU-31, DPU-32, DPU-33, DPU-36, DPU-41, DPU-43, DPU-52, DPU-53, DPU-63, DPU-71, DPU-76, DPU-79, DPU-80 and Kashi Harit |
| Leaf blade: Silver patches | Present | DPU-1, DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-35, DPU-36, DPU-41, DPU-42, DPU-43, DPU-44, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-56, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-72, DPU-73, DPU-74, DPU-75, DPU-76, DPU-77, DPU-79, DPU-80, CM-350, Kashi Harit, Pusa Vishwas and Punjab Samrat |
| | Absent | DPU-45 |

whereas, fruit shape at physiological maturity in all studied genotypes were observed spherical (CM-350, Punjab Samrat and 25 genotypes), round flat (11 genotypes), oval/ oblong (Pusa Vishwas and 12 genotypes), oval spherical (DPU-52, DPU-57, and DPU-75 genotypes), oblong cylindrical (DPU-26), flattish round (Kashi Harit and 14 genotypes), flattish (DPU-22, DPU-27, DPU-76), club (DPU 35), cylindrical (DPU 58) and heart shape (DPU 80) fruits.

Main colour of fruit skin at physiological maturity was observed as brown (44 genotypes); yellow brown (DPU-44 and CM-350); cream brown (DPU-32); dark brown (DPU-51); orange (25 genotypes), dark orange (DPU-75 and DPU-79) and light yellow in DPU-19. Very high, high, medium and light level of waxiness on fruit skin was recorded in DPU-79, 25 genotypes, 27 genotypes including check cultivar Punjab Samrat and 20 genotypes, respectively while 3 genotypes including check cultivar CM-350 completely lack it.

Fruit flesh colour was observed as orange in 17 genotypes including Pusa Vishwas; light orange in 31 genotypes; yellowish orange in 10 genotypes including two check cultivars Kashi Harit and CM-350; creamy white in three genotypes, viz. DPU-3, DPU-19, PDU-44; dark orange in three genotypes DPU-51, DPU-61, DPU-62; orange

Table 2 Characterization of pumpkin genotypes based on fruit characters

| Characteristics | State of expression | Example genotypes | Type of assessment* |
|---|---|---|---|
| Peduncle: Length | Short (<5 cm) | Punjab Samrat | MS |
| | Medium (5-10 cm) | DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-5-3, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-35, DPU-41, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-72, DPU-73, DPU-74, DPU-76, DPU-77, DPU-79, DPU-80, CM-350, Kashi Harit and Pusa Vishwas | |
| | Long (>10 cm) | DPU-1, DPU-6, DPU-36, DPU-51, DPU-56, DPU-57, DPU-71 and DPU-75 | |
| Fruit: Main colour of skin (at immature fruit stags ) | Cream | DPU-32 and CM-350 | VG |
| | Light green | DPU-2, DPU-3, DPU-5, DPU-8, DPU-10, DPU-19, DPU-21-3, DPU-22, DPU-23, DPU-27, DPU-29, DPU-35, DPU-52, DPU-63, DPU-64, DPU-65, DPU-67, DPU-74, DPU-77, Pusa Vishwas and Punjab Samrat | |
| | Medium green | DPU-4, DPU-5-2, DPU-5-3, DPU-8-2, DPU-9, DPU-15, DPU-16, DPU-17, DPU-18, DPU-20-2, DPU-24, DPU-25, DPU-26, DPU-28, DPU-30, DPU-31, DPU-33, DPU-41, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-53, DPU-54, DPU-56, DPU-58, DPU-60, DPU-61, DPU-62, DPU-64-2, DPU-66, DPU-68, DPU-69, DPU-70, DPU-71, DPU-73 and Kashi Harit | |
| | Dark green | DPU-1, DPU-4-2, DPU-6, DPU-21, DPU-22-3, DPU-36, DPU-42, DPU-51-3, DPU-57, DPU-59, DPU-72, DPU-75, DPU-76, DPU-79 and DPU-80 | |
| Fruit: Skin colour pattern | Uniform | DPU-1, DPU-4-2, DPU-6, DPU-21, DPU-32, DPU-36, DPU-41, DPU-51-3, DPU-56, DPU-71, DPU-75, DPU-76, DPU-79, DPU-80 and CM-350 | VG |
| | Mottled | DPU-2, DPU-3, DPU-4, DPU-5, DPU-5-2, DPU-5-3, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-33, DPU-35, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-52, DPU-53, DPU-54, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-72, DPU-73, DPU-74, DPU-77, Kashi Harit and Punjab Samrat | |
| | Striped | Pusa Vishwas | |
| Fruit: Shape at peduncle end | Raised | DPU-4, DPU-5-3, DPU-54, DPU-59, DPU-60, DPU-73 and Pusa Vishwas | VG |
| | Flat | DPU-2, DPU-6, DPU-8, DPU-9, DPU-10, DPU-15, DPU-17, DPU-18, DPU-19, DPU-23, DPU-25, DPU-26, DPU-30, DPU-57, DPU-63, DPU-74 and Punjab Samrat | |
| | Slightly depressed | DPU-1, DPU-16, DPU-21-3, DPU-22-3, DPU-24, DPU-35, DPU-44, DPU-45, DPU-51, DPU-51-3, DPU-52, DPU-56, DPU-58, DPU-61, DPU-62, DPU-66, DPU-67, DPU-69, DPU-70, DPU-71 and CM-350 | |
| | Moderately depressed | DPU-3, DPU-4-2, DPU-5, DPU-5-2, DPU-8-2, DPU-20-2, DPU-21, DPU-22, DPU-27, DPU-28, DPU-29, DPU-31, DPU-32, DPU-33, DPU-36, DPU-41, DPU-42, DPU-43, DPU-46, DPU-53, DPU-64, DPU-64-2, DPU-65, DPU-68, DPU-72, DPU-75, DPU-76, DPU-77, DPU-80 and Kashi Harit | |
| | Strongly depressed | DPU-79 | |
| Fruit: Shape at blossom end | Slightly depressed | DPU-1, DPU-15, DPU-16, DPU-20-2, DPU-21, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-27, DPU-28, DPU-29, DPU-31, DPU-32, DPU-36, DPU-41, DPU-43, DPU-45, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-56, DPU-62, DPU-64, DPU-64-2, DPU-65, DPU-69, DPU-70, DPU-72, DPU-75, DPU-77, CM-350 and Kashi Harit | VG |
| | Moderately depressed | DPU-3, DPU-5, DPU-22, DPU-33, DPU-35, DPU-42, DPU-68, DPU-71, DPU-76, DPU-79 and DPU-80 | |
| | Strongly depressed | DPU-44 | |
| | Flat | DPU-2, DPU-4, DPU-4-2, DPU-5-2, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-17, DPU-18, DPU-19, DPU-21-3, DPU-26, DPU-54, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-63, DPU-66, DPU-67, DPU-73, DPU-74 and Punjab Samrat | |
| | Raised | DPU-5-3, DPU -30 and Pusa Vishwas | |

*Contd.*

Table 2. (*Continued*)

| Characteristics | State of expression | Example genotypes | Type of assessment* |
|---|---|---|---|
| Fruit: Surface grooves | Superficial | DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-17, DPU-18, DPU-21-3, DPU-24, DPU-25, DPU-27, DPU-29, DPU-30, DPU-31, DPU-32, DPU-35, DPU-41, DPU-45, DPU-46, DPU-54, DPU-59, DPU-66, DPU-73, DPU-74, DPU-77, CM-350 and Pusa Vishwas | VG |
| | Intermediate | DPU-1, DPU-5, DPU-5-2, DPU-5-3, DPU-15, DPU-16, DPU-20-2, DPU-21, DPU-22, DPU-23, DPU-26, DPU-28, DPU-33, DPU-36, DPU-42, DPU-43, DPU-44, DPU-51, DPU-51-3, DPU-56, DPU-57, DPU-58, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-67, DPU-68, DPU-69, DPU-71, DPU-72, DPU-75 and Kashi Harit | |
| | Deep | DPU-19, DPU-22-3, DPU-52, DPU-53, DPU-70 and DPU-79 | |
| | Very deep | DPU-76 and DPU-80 | |
| | Absent | Punjab Samrat | |
| Fruit : Marbling (immature stage) | Absent | DPU-1, DPU-4-2, DPU-6, DPU-8-2, DPU-17, DPU-21, DPU-32, DPU-41, DPU-51-3, DPU-59, DPU-71, DPU-75, DPU-76, DPU-79, DPU-80 and CM-350 | VG |
| | Weak | DPU-2, DPU-3, DPU-4, DPU-5, DPU-5-2, DPU-5-3, DPU-8, DPU-9, DPU-10, DPU-15, DPU-16, DPU-18, DPU-19, DPU-20-2, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-33, DPU-36, DPU-42, DPU-43, DPU-44, DPU-46, DPU-51, DPU-52, DPU-54, DPU-56, DPU-57, DPU-58, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-72, DPU-73, DPU-74, DPU-77 and Pusa Vishwas | |
| | Medium | DPU-35, DPU-45, DPU-53, DPU-65, Kashi Harit and Punjab Samrat | |
| | Strong | None | |
| Fruit: Length (mature stage) | Short (<12 cm) | DPU-21, DPU-21-3, DPU-22, DPU-27, DPU-31, DPU-32, DPU-41, DPU-43, DPU-45, DPU-61, DPU-65, DPU-66, DPU-67, DPU-69, DPU-70, DPU-76, DPU-77, CM-350 and Punjab Samrat | MS |
| | Medium (12-20cm) | DPU-1, DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-9, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-22-3, DPU-24, DPU-28, DPU-29, DPU-30, DPU-33, DPU-35, DPU-36, DPU-42, DPU-44, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-56, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-68, DPU-71, DPU-72, DPU-73, DPU-74, DPU-79, DPU-80, Kashi Harit and Pusa Vishwas | |
| | Long (21-30cm) | DPU-5-3, DPU-8, DPU-8-2, DPU-10, DPU-15, DPU-23, DPU-25, DPU-26, DPU-54, DPU-57, DPU-58, DPU-59, DPU-60 and DPU-75 | |
| | Very Long (>30 cm) | DPU-6 | |
| Fruit diameter (mature stage) | Small (<15 cm) | DPU-2 and DPU-21-3 | MS |
| | Medium (15-30cm) | DPU-1, DPU-3, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-5-3, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-35, DPU-36, DPU-41, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-56, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-72, DPU-73, DPU-74, DPU-75, DPU-76, DPU-77, DPU-79, DPU-80, CM-350, Kashi Harit, Pusa Vishwas and Punjab Samrat | |
| | Large (>30 cm) | DPU-6 | |
| Fruit Shape | Heart shaped | DPU-80 | VG |
| | Round flat | DPU-3, DPU-9, DPU-16, DPU-17, DPU-21, DPU-22-3, DPU-24, DPU-28, DPU-29, DPU-67 and DPU-69 | |
| | Oval | DPU-4, DPU-15, DPU-25 and DPU-59 | |
| | Oblong | DPU-2 and DPU-8 | |
| | Oval spherical | DPU-52, DPU-57 and DPU-74 | |
| | Oval/ oblong | DPU-5-3, DPU-8-2, DPU-30, DPU-54, DPU-60 and Pusa Vishwas | |
| | Oblong/ oval | DPU-10 | |

*Contd.*

Table 2. (*Continued*)

| Characteristics | State of expression | Example genotypes | Type of assessment* |
|---|---|---|---|
| | Oblong cylindrical | DPU-26 | |
| | Spherical | DPU-1, DPU-4-2, DPU-5, DPU-5-2, DPU-6, DPU-18, DPU-19, DPU-20-2, DPU-31, DPU-32, DPU-33, DPU-46, DPU-51-3, DPU-53, DPU-61, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-68, DPU-71, DPU-72, DPU-75, DPU-79, CM-350 and Punjab Samrat | |
| | Flattish | DPU-22, DPU-27 and DPU-76 | |
| | Flattish round | DPU-21-3, DPU-23, DPU-36, DPU-41, DPU-42, DPU-43, DPU-44, DPU-45, DPU-51, DPU-56, DPU-62, DPU-70, DPU-73, DPU-77 and Kashi Harit | |
| | Club shaped | DPU-35 | |
| | Cylindrical | DPU-58 | |
| Fruit main colour of skin (mature stage) | Creamy brown | DPU-32 | |
| | Brown | DPU-1, DPU-5, DPU-5-2, DPU-10, DPU-15, DPU-16, DPU-17, DPU-21-3, DPU-23, DPU-25, DPU-27, DPU-29, DPU-30, DPU-31, DPU-33, DPU-35, DPU-42, DPU-43, DPU-45, DPU-46, DPU-51-3, DPU-52, DPU-56, DPU-57, DPU-58, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-73, DPU-74, DPU-77, DPU-80, Kashi Harit, Pusa Vishwas and Punjab Samrat | VG |
| | Yellow brown | DPU-44 and CM-350 | |
| | Dark brown | DPU-51 | |
| | Light yellow | DPU-19 | |
| | Orange | DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-18, DPU-20-2, DPU-21, DPU-22, DPU-22-3, DPU-24, DPU-26, DPU-28, DPU-36, DPU-41, DPU-53, DPU-54, DPU-59, DPU-64-2, DPU-72 and DPU-76 | |
| | Dark orange | DPU-75 and DPU-79 | |
| Fruit: Waxiness of skin (at mature fruit stage) | Light | DPU-3, DPU-4, DPU-5-2, DPU-8, DPU-15, DPU-17, DPU-18, DPU-21-3, DPU-28, DPU-29, DPU-30, DPU-32, DPU-35, DPU-36, DPU-46, DPU-67, DPU-68, DPU-71, Kashi Harit and Pusa Vishwas | VG |
| | Medium | DPU-1, DPU-4-2, DPU-5, DPU-6, DPU-9, DPU-10, DPU-20-2, DPU-21, DPU-22, DPU-22-3, DPU-23, DPU-25, DPU-26, DPU-31, DPU-33, DPU-41, DPU-42, DPU-51, DPU-54, DPU-58, DPU-64-2, DPU-66, DPU-69, DPU-72, DPU-73, DPU-74 and Punjab Samrat | |
| | High | DPU-5-3, DPU-8-2, DPU-16, DPU-24, DPU-27, DPU-43, DPU-44, DPU-45, DPU-51-3, DPU-52, DPU-53, DPU-56, DPU-57, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-65, DPU-70, DPU-75, DPU-76, DPU-77 and DPU-80 | |
| | Very high | DPU-79 | |
| | Absent | DPU-2, DPU-19 and CM-350 | |
| Fruit main colour of flesh | Creamy white | DPU-3, DPU-19 and DPU-44 | VG |
| | Light orange | DPU-2, DPU-4-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-16, DPU-20-2, DPU-22, DPU-23, DPU-24, DPU-25, DPU-26, DPU-29, DPU-30, DPU-32, DPU-33, DPU-35, DPU-36, DPU-41, DPU-43, DPU-56, DPU-58, DPU-67, DPU-68, DPU-70, DPU-73, DPU-74, DPU-76 and DPU-79 | |
| | Orange | DPU-1, DPU-4, DPU-5, DPU-5-2, DPU-17, DPU-18, DPU-22-3, DPU-28, DPU-31, DPU-45, DPU-52, DPU-54, DPU-64-2, DPU-65, DPU-72, DPU-77 and Pusa Vishwas | |
| | Dark orange | DPU-51, DPU-61 and DPU-62 | |
| | Yellowish orange | DPU-10, DPU-15, DPU-21, DPU-21-3, DPU-27, DPU-53, DPU-66, DPU-69, CM-350 and Kashi Harit | |
| | Orange yellow | DPU-80 | |
| | Dark orange yellow | DPU-60 | |
| | Light orange with green overcast | DPU-42 | |
| | Orange with green overcast | DPU-46, DPU-57 and DPU-59 | |

*Contd.*

Table 2 (*Concluded*)

| Characteristics | State of expression | Example genotypes | Type of assessment* |
|---|---|---|---|
| | Yellowish orange with green overcast | DPU-51-3, DPU-63, DPU-64, DPU-71, DPU-75 and Punjab Samrat | |
| Fruit thickness of flesh | Thin ( <2.5 cm) | DPU-2, DPU-3, DPU-8, DPU-21-3, DPU-59, DPU-66, DPU-74, Pusa Vishwas and Punjab Samrat | MS |
| | Medium (2.5-4.5cm) | DPU-1, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-5-3, DPU-6, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-35, DPU-36, DPU-41, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-57, DPU-58, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-72, DPU-73, DPU-75, DPU-76, DPU-77, DPU-79, DPU-80, CM-350 and Kashi Harit | |
| | Thick ( >4.5 cm) | DPU-56 | |

*MS: Measurement of a number of individual plants or parts of plants. VG: Visual assessment by a single observation of a group of plants or parts of plants.

Table 3 Characterization of pumpkin genotypes based on seed characters

| Characteristics | State of expression | Example genotypes | Type of assessment |
|---|---|---|---|
| Seed: length | Small ( <1.2 cm) | None | MS |
| | Medium (1.2-1.6 cm) | DPU-1, DPU-2, DPU-3, DPU-4, DPU-5, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-16, DPU-19, DPU-20-2, DPU-26, DPU-30, DPU-31, DPU-32, DPU-33, DPU-36, DPU-42, DPU-45, DPU-51, DPU-52, DPU-56, DPU-59, DPU-61, DPU-63, DPU-65, DPU-66, DPU-67, DPU-68, DPU-72, DPU-73, DPU-74, DPU-75, DPU-79, DPU-80, Kashi Harit and Punjab Samrat | |
| | Long (>1.6 cm) | DPU-4-2, DPU-5-2, DPU-5-3, DPU-10, DPU-15, DPU-17, DPU-18, DPU-21, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-27, DPU-28, DPU-29, DPU-35, DPU-41, DPU-43, DPU-44, DPU-46, DPU-51-3, DPU-53, DPU-54, DPU-57, DPU-58, DPU-60, DPU-62, DPU-64, DPU-64-2, DPU-69, DPU-70, DPU-71, DPU-76, DPU-77, CM-350 and Pusa Vishwas | |
| Seed: width | Small ( <0.6 cm) | None | MS |
| | Medium (0.6-0.9 cm) | DPU-1, DPU-2, DPU-3, DPU-4, DPU-5, DPU-5-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-16, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-21-3, DPU-23, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-36, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-52, DPU-54, DPU-56, DPU-58, DPU-59, DPU-61, DPU-62, DPU-63, DPU-64, DPU-64-2, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-72, DPU-73, DPU-74, DPU-75, DPU-77, DPU-80, CM-350, Kashi Harit, Pusa Vishwas and Punjab Samrat | |
| | Large (>0.9cm) | DPU-4-2, DPU-10, DPU-15, DPU-17, DPU-22, DPU-22-3, DPU-24, DPU-35, DPU-41, DPU-51-3, DPU-53, DPU-57, DPU-60, DPU-71, DPU-76 and DPU-79 | |
| Seed: colour of coat | Cream | DPU-1, DPU-2, DPU-3, DPU-4, DPU-4-2, DPU-5, DPU-5-2, DPU-5-3, DPU-6, DPU-8, DPU-8-2, DPU-9, DPU-10, DPU-15, DPU-16, DPU-17, DPU-18, DPU-19, DPU-20-2, DPU-21, DPU-21-3, DPU-22, DPU-22-3, DPU-23, DPU-24, DPU-25, DPU-26, DPU-27, DPU-28, DPU-29, DPU-30, DPU-31, DPU-32, DPU-33, DPU-35, DPU-36, DPU-41, DPU-42, DPU-43, DPU-44, DPU-45, DPU-46, DPU-51, DPU-51-3, DPU-52, DPU-53, DPU-54, DPU-56, DPU-57, DPU-58, DPU-59, DPU-60, DPU-61, DPU-62, DPU-63, DPU-64, DPU-65, DPU-66, DPU-67, DPU-68, DPU-69, DPU-70, DPU-71, DPU-72, DPU-73, DPU-74, DPU-75, DPU-76, DPU-77, DPU-79, DPU-80, CM-350, Kashi Harit, Pusa Vishwas and Punjab Samrat | VG |
| | Yellow | DPU-64-2 | |
| | White | None | |
| | Brown | None | |

*MS: Measurement of a number of individual plants or parts of plants. VG: Visual assessment by a single observation of a group of plants or parts of plants.

yellow in DPU-80; dark orange yellow in DPU-60; light orange with green overcast in DPU-42; orange with green overcast in DPU-46, DPU-57, DPU-59; yellow orange with green overcast in DPU-51-3, DPU-63, DPU-64, DPU-71, DPU-75 and Punjab Samrat.

Peduncle length in all genotypes was grouped into short, medium and long groups. Punjab Samrat was observed to have shortest peduncle while, other 67 and eight genotypes were grouped in medium and long group, respectively. For fruit length very long (>30cm) fruits were observed in DPU-6 genotype while other 19, 42, 14 genotypes were grouped into short (<12cm), medium (12-20cm) and long (21-30cm) group, respectively. DPU-6 was observed to have large fruit diameter (>30cm) while DPU-2, DPU-21-3 and remaining 73 genotypes were observed to have small (<15cm) and medium (15-30cm) fruit diameter, respectively. Fruit thickness of flesh was observed thin (<2.5 cm) in nine genotype including two check cultivar Punjab Samrat and Pusa Vishwas, medium (2.5-4.5 cm) in 66 genotype including check Kashi Harit and CM-350 and in DPU-56 thick flesh (>4.5 cm) was observed. The characteristics viz. main color of fruit skin at immature harvest stage, fruit surface grooves, fruit length, fruit diameter and fruit shape were used for grouping the genotypes.

Similar variations for different morphological traits in pumpkin had also been reported earlier by Tsivelikas *et al.* (2009) for marbling, intensity of main color of fruit skin and fruit shape; Ndoro *et al.* (2007) for fruit shape; Marek *et al.* (2008) for flesh colour; Balkaya *et al.* (2009) for fruit grooves, flesh colour and main colour of skin; Ahmed *et al.* (2011) for fruit shape and flesh colour; Aliu *et al.* (2011) for fruit shape, colour and size and Onyishi *et al.* (2013) for fruit colour, fruit shape and fruit fresh colour.

*Seed characters*

Seed is the most important input factor in any crop production programme, as the success or failure of any crop solely depends on the quality and potential performance of seed. In the present investigation, seed coat colour was recorded as cream in 75 genotypes and yellow in DPU-64-2. Seed length in all studied genotypes was grouped into two groups i.e. medium (1.2-1.6cm) and long (>1.6cm) with 38 genotypes in each while no genotype falls into small (<1.2cm) group whereas for seed width, 60 genotypes were grouped into medium (0.6-0.8cm) while 16 in large (>0.9cm) group and no genotypes falls in small group. Lebeda *et al.* (2010) and Mladenovic *et al.* (2012) had also reported significant variations for the seed traits.

In the present investigation 76 pumpkin genotypes were grouped into different categories for 21 traits. This characterization may be utilized for maintaining the genetic purity of a genotype. Among all genotypes many showed uniformity and stable in expression of the DUS characteristics at a particular state. It is applicable for the qualitative characteristics which are least influenced by environmental conditions. It is concluded that for identification and grouping of varieties above developed DUS descriptors can be effectively used by comparing candidate varieties for registration under PPV and FR Act to protect the right of farmers and plant breeders. The descriptor will be helpful in measuring diversity of a crop in terms of economic and social values to different plant genetic resources users. According to Singh *et al*. (2005) DUS testing of different pumpkin characters is useful for identification of varieties, registration of varieties and plant variety protection (PVP), varietal information system and classification of varieties into different groups, and for developing database for plant.

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