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DEVELOPMENT OF DUS STANDARD FOR TARO [*Colocasia esculenta* var. *antiquirom* (L.) Schott.] USING DIGITAL MORPHOMETRICS

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ABSTRACT

The leaves, tubers and other morpho-culinary characters of nine taro [*Colocasia esculenta* var. *antiquirom* (L) Schott.] cultivars were considered for development of distinct, uniform and stable (DUS) standards using digital morphometrics and computational methods besides taking help from prototypes of hand-held digital field guides and various robotic systems to bring them under IPR-related regimes. Out of 48 morpho-culinary characters studied maximum were polymorphic in nature. Some cultivars possessed unique stable characters helpful for their identification. The study revealed that DUS descriptors using digital morphometrics can be used effectively for identification and grouping of taro germplasm.

Key words: Digital morphometrics, DUS, taro

INTRODUCTION

Among the tropical tuber crops, taro (*Colocasia esculenta* var. *antiquirom* (L.) Schott.) belonging to the family Araceae has high potential for food, feed and industrial uses. Taro is believed to have originated in South-East Asian region which includes India (Plucknett, 1976; Kuruvilla and Singh, 1981; Coates *et al.*, 1988). Thus rich genetic diversity is available for this aroid. The taro is evenly distributed with greater diversity in north eastern states of India (Mandal *et al.*, 2013). The genetic diversity of taro is concentrated in Western Ghats and in some pockets of Eastern and Western Peninsula. Research and development work on this crop has resulted in identifying location specific commercial cultivars. The improved released varieties are characterized through identification of their distinct, uniform and stable (DUS) characters. Extant varieties like farmer's varieties and varieties under public domain need to be protected for effective genetic resources management. At present, DUS standards are not available for taro as well as other tuber crops, except potato. Thus location-specific improved cultivars and many wild species of this high value crops need to be brought under DUS testing.

Morphometrics, the study of shape, has been applied to plants and their organs for many years (OED, 2014). Leaves are readily apparent structures on many plants which are readily available for examination around the active growth season in deciduous or annual plants or year the round in evergreen perennials, unlike more transient reproductive organs. As such, leaf characters, including those involving the shape have been used extensively in traditional text-based taxonomic keys for plant identification since the beginning of botany. In recent years, high quality digital

cameras have become ubiquitous and are instrumental in creating hand-held field guides. These are prototype-built-around smart phones or personal digital assistants (PDAs) designed to allow a user in the field to photograph a specimen of interest and instantly to receive information about it. One advantage of such systems is that they require little infrastructure at the point of use, so can be used even in the least developed and most remote parts of the world. However, the scope of such systems is currently very limited, restricting their practical use. A second consequence of cheap digital cameras and scanners is the creation of vast databases of plant images. For example, the Royal Botanic Gardens, Kew (UK) has provided a digital catalogue of over 200,000 high-resolution images, with more being added continuously as part of an on-going digitization project **(**James *et al.,* 2012). The morphological descriptors and their classes have reliably been used for DUS testing of potato varieties (Gopal *et al.,* 2007). The present study deals with the characteristics of leaf outlines, vein structures, leaf textures and corm morphology, etc. using modern technology including prototypes of hand-held digital field guides and various robotic systems used in agriculture so as to develop distinct, stable and uniform morphological characters for differentiating various varieties/clones of this aroid species**.**

MATERIALS AND METHODS

The work was carried out in the year 2012-2013 using nine varieties of taro, collected from different parts of India by All India Coordinated Research Project on Tuber Crops (AICRPTC), BCKV, West Bengal (India). The varieties BCC-1 (Bidhan Chaitanya), BCC-22, BCC-35, BCC-38 and BCC-39 were procured from AICRP TC, BCKV, West Bengal whereas varieties Sonajuly and Muktakeshi were obtained from Regional Centre of Central Tuber Crops Research Institute (RCCTCRI), Orissa and variety Telia from Central Tuber Crops Research Institute (CTCRI) Kerala. The experiment was laid out at the University Horticultural Research Station, Mondouri, West Bengal in a randomized complete block design with each treatment replicated thrice. The experimental site lies in Gangetic New Alluvial Plains of West Bengal at 9.75 m mean sea level elevation, 22°57` N latitude and 88°20`E longitude. The soil was sandy loam and slightly acidic in nature. Taro varieties were grown in field as per the standard agronomic practices (POP, 2006).

The data for forty eight traits were recorded to develop DUS testing criteria for this species. The data were recorded directly from the plants and theirs tubers. The data evaluated included plant span (maximum horizontal distance reached by leaves), plant height (vertical distance relative to ground level), number of stolons (side shoots), stolon length, number of suckers, leaf base shape, predominant position (shape) of leaf lamina surface, leaf blade margin, leaf blade colour, leaf blade margin colour, leaf lamina appendages, leaf lamina length/width ratio, petiole junction pattern, petiole junction colour, sap colour of leaf blade tip, leaf main vein colour, vein pattern, petiole/ lamina length ratio, petiole colour, petiole stripe, petiole stripe colour, petiole basal ring colour, cross section of lower part of petiole, ratio of sheath length/total petiole length, sheath length, sheath colour, sheath margin colour, leaf waxiness, corm manifestation, corm length, corm branching, corm shape, corm weight, corm cortex colour, corm flesh colour, corm flesh fibre colour, corm skin colour, corm skin thickness, degree of fibrousness of corm, bud colour, number of cormels, weight of cormels, shape of cormels, flesh colour of cormels, cormel acridity, palatability, taste, mealiness and softiness. Descriptor of taro developed by International Plant Genetic Resources Institute (IPGRI/IITA, 1999) was followed for the collection of both foliar and subterranean data. Foliar traits were scored at five months after planting, while subterranean traits were evaluated at harvest (8 months). Most of the data (qualitative and quantitative) were recorded on individual plant basis using sample averages of six plants selected at random from the row. The data was recorded using modern technology including prototypes of hand-held digital field guides and various robotic systems such as digital camera, mobile phone, computer, scanner and different

types of software (like Photoshop, Picasa, PhotoScape and Microsoft Office 2010, etc.). For culinary characterization opinion poll was carried out within a group of farmers against each of the culinary characters for nine varieties. The group of farmers consisting 47 males and 20 female, actively engaged in this crop cultivation, was selected of which 30% were women. Their liking and disliking levels with respect to culinary characters of the varieties were recorded on the basis of their personal preferences through consumption of boiled taro. Preference data were generated by scoring the sixty seven votes and computing thereafter. Acridity and calcium oxalate were estimated following the standard method (AOAC, 2012).

RESULTS AND DISCUSSION

All the morphometric data were recorded through digitalization using modern technology (Gardner *et al*., 2012; Benca *et al.*, 2014) to prepare digital herbarium (Fig. 1). Distinct characters were identified on the basis of digitalized morphometric characters in different varieties individually and group-wise. Architectures of leaf venation and leaf base are shown in Fig. 2 and 3, respectively. Cross section of lower part of petiole (Fig. 4) was image-processed through scanner and the image of corm flesh and cormels in different varieties have been presented in Fig. 5 and 6. Out of 48 morphological characters, maximum were polymorphic in nature. Nine taro cultivars were grouped on the basis of their individual characters using plant habit (Table 1), tuber characters and culinary characters (Table 2).

Fig. 1: Digital herbarium of taro varieties

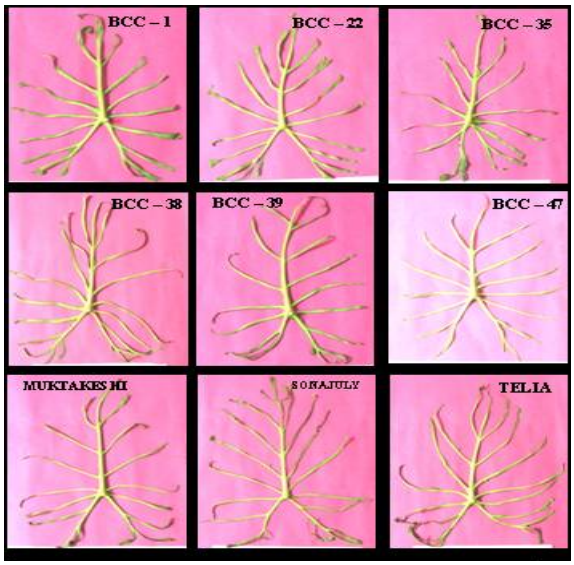

Fig. 2: Variation in leaf venation of taro varieties

BCC-1 was characterized by the largest plant span, light green corm skin colour and maximum corm length. Smallest plant-span and slide acridity were the unique characters of BCC-22. Heart-shaped corm with yellow corm flesh colour was the unique character of BCC-35. Violet petiole basal ring and highly coarse in mealiness in corm nature were the most unique characters of BCC-38. The unique characters of BCC-39 were highest number of suckers plant^{-1} and light green bud colour. Whereas light violet petiole junction colour and salty tuber taste were the important unique characters of BCC-47. Sonajuly had unique characters like irregular brown stripe on petiole, purple colour corm skin and bud. Yellowish green sap colour of leaf blade tip and greenish white corm skin colour were the unique characters of Muktakeshi. Telia had blackish yellow sap colour of

Table 1: Individual distinct characters (on the basis of plant habit) of taro varieties

Varieties	Individual distinct characters
BCC-1	Largest plant span (98.01 cm)*, largest petiole length (73.53 cm), lamina colour off-green, larger cross section area of lower part of plant and petiole basal ring (17.34 cm^2).
BCC-22	Smallest plant span (21.83 cm)*, shortest plant height (40.33 cm), lowest cross section area of lower part of plant (3.46 cm^2), largest ratio of sheath length and total petiole length (0.71).
BCC-35	Short plant height (40.67 cm) and plant span (25.5 cm), lowest sheath length (22.67 cm), deep green with gelatin type sap colour of leaf blade tip
BCC-38	Short plant height (48.93 cm) with high plant span (38.00), violet petiole basal ring colour*, deep violet sheath margin, deep green sap colour of leaf blade tip, lowest of petiole and lamina ratio (1.52).
BCC-39	Highest number of suckers (7.33)*, entire leaf blade margin, highest cross section area of lower part of petiole (18.85 cm^2).
BCC-47	Have no sucker*, largest ratio of leaf lamina length and width (1.51), light violet petiole junction colour*
Sonajuly	Tallest plant height (78.17cm) with high plant span (37.67 cm), lowest leaf ratio of lamina length (1.11) and width, irregular brown stripe on petiole*, smallest ratio of sheath length and total petiole length (0.49).
Muktakeshi	Largest sheath length (40.33 cm)*, larger plant span (36.67 cm), yellowish green sap colour of leaf blade tip*, high leaf waxiness
Telia	Medium plant height (65.83 cm), blackish yellow sap colour of leaf blade tip*, deep violet colour of sheath margin and petiole

*symbol represents the unique character

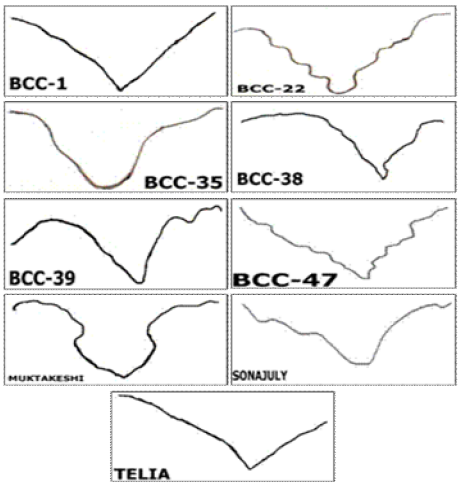

Fig. 3: Architecture of leaf basal portion of taro

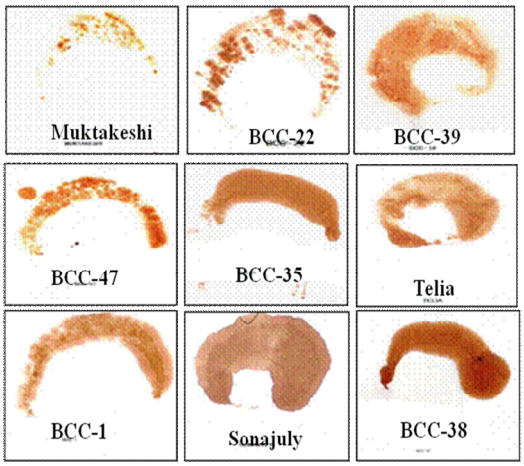

Fig.4: Cross section of lower part of petiole

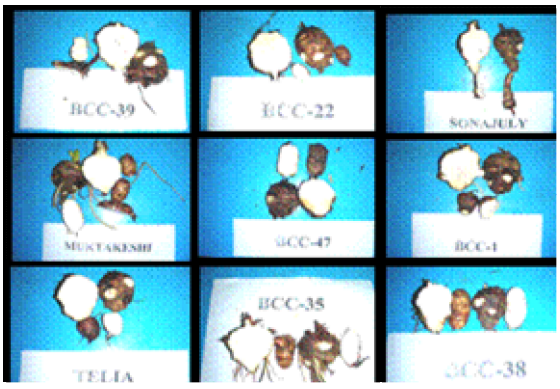

Fig. 5: Images of taro corm flesh

Fig. 6: Images of taro cormels

Table 2: Individual distinct characters (corm, cormel and culinary characters of boiled tubers)

Varieties	Individual distinct characters
BCC-1	Maximum corm weight (100 g) and cormels weight (267.67g), corm flesh colour creamy, corm skin colour light green*, maximum corm length (7.43 cm)*, degree of fibrousness of corm high and bud colour creamy, highly palatable, sweet in taste, very soft, very fine coarse in mealiness acridity very low.
BCC-22	Round shaped corm with very high degree of fibrousness of corms and minimum number of cormels (8.33). hard, highly coarse in mealiness and slidely acrid*
BCC-35	Heart shaped corm with yellow corm flesh colour* and higher degree of fibrousness and bud colour light green, softiness medium hard, medium coarse in mealiness with low acidity
BCC-38	White corm flesh colour, corm skin colour and high degree of fibrousness of corms, minimum corm weight (5.57 g) and less number of cormels (9.01) very hard, highly coarse in mealiness* with low acridity
BCC-39	Corm skin colour, corm flesh colour and cormels flesh colour off white but corm flesh fibre yellowish and bud colour light green*, soft, very fine coarse in mealiness and acridity low
BCC-47	Minimum cormels weight (60 g), corm flesh colour white, corm flesh fibre colour yellow, corm skin colour off white, bud colours light green*, palatable and taste light salty*
Sonajuly	Corm flesh colour purple, corm flesh fibre colour yellow, corm skin colour purple, bud colour purple*, softiness medium hard, medium coarse in mealiness and acridity very low, highly palatable and taste sweet
Muktakeshi	Corm shape round flat, corm skin colour greenish white*, maximum number of cormels (17), degree of fibrousness of corm medium, corm fibre colour yellowish green and bud colour creamy, softiness very hard, highly coarse in mealiness and acridity low
Telia	Corm skin colour, corm flesh colour, corm flesh fibre colour and bud colour white, high degree of fibrousness* soft in nature, mealiness low and acridity low, highly palatable, taste sweet

* represents the unique character

Table 3: Group distinct characters of taro varieties (on the basis of plant habit)

Characters	Groups	Name of varieties
Vegetative growth (plant span and plant height)	Low vegetative growth	None
	Medium vegetative growth (plant span: 20-30 cm; plant height: 40-65 cm)	BCC-22, BCC-35, BCC-47, BCC-38
	High vegetative growth (plant span: >30 cm; plant height:> 65 cm)	Telia, Muktakeshi, BCC-39, BCC-1, Sonajuly
Number of sucker	Low (0-2)	BCC-47, BCC-22, BCC-35
	Medium (> 2 to 5)	BCC-38, Telia
	Higher (>5)	Sonajuly, BCC-1, Muktakeshi, BCC-39
Sap colour of leaf blade tip	Deep Green	BCC-47, BCC-38
	Green	BCC-39,Sonajuly, BCC-35, BCC-22
	Yellowish Green	Muktakeshi, BCC-1
	Blackish Yellow	Telia
Cross section area	Small (2-5 cm^2)	Telia, BCC-22, BCC-38, Sonajuly
	Medium (>5-10 cm^2)	Muktakeshi, BCC-47
	Large (>10-15 cm^2)	BCC-35
	Extra Large (>15cm^2)	BCC-39, BCC-1
Sheath length	Medium (>20-30 cm)	BCC-38,BCC-47,BCC-35,BCC-22
	High (> 30 cm)	Muktakeshi, BCC-1, BCC-39, Telia, Sonajuly
Predominant position of leaf lamina surface	Toward Base:	BCC-1, BCC-22, Sonajuly, BCC-39, BCC-47
	Toward the Middle of Leaf	Telia, BCC-38, Muktakeshi, BCC-35
Leaf blade margin	Wavy	BCC-47
	Entire	BCC-39,BCC-38
	Undulate	Muktakeshi, Sonajuly, Telia, BCC-35, BCC-22, BCC-1

Table 4: Group distinct characters of taro varieties (on the basis of corm, cormel and culinary characters of boiled tubers)

Character	Groups	Names of varieties
Corm weight	Low (20-50 g)	BCC-38, BCC-22
	Medium (> 50-80 g)	BCC-35, BCC-39, BCC-47, Sonajuly
	High (> 80 g)	BCC-1, Telia, Muktakeshi
Corm length	Low (1-6)	Sonajuly, BCC-22, BCC-38,
	Medium (>6)	BCC-1, BCC-35,BCC-39, BCC-47, Muktakeshi, Telia
Cormels weight	Low (20-100 g)	BCC-38, BCC-22, BCC-35, BCC-47
	Medium (> 100-200 g)	BCC-39, Sonajuly, Muktakeshi
	High (> 200 g)	BCC-1, Telia
Number of cormels	Low (5-10)	BCC-35, BCC-47
	Medium (>10-15)	BCC-38, BCC-22, BCC-39, Sonajuly
	High (> 15)	BCC-1, Telia, Muktakeshi
Bud colour	Cream	BCC-1, BCC-38, Muktakeshi
	White:	BCC-22, BCC-47, Telia
	Light green	BCC-35, BCC-39
	Purple	Sonajuly
Corm flesh colour	Cream	BCC-1
	White	BCC-22, BCC-35, BCC-38, BCC-39, BCC-47,
	Purple	Muktakeshi, Telia, Sonajuly
Corm flesh fibre color	Yellow	BCC-39, BCC-47, SONAJULY, BCC-35,
	Light yellow	BCC-1, BCC-22
	Cream	BCC-38
	Yellowish green	Muktakeshi
	White	Telia
Degree of fibrousness of corm	Very high	BCC-22
	High	BCC-1, BCC-38, BCC-39, Sonajuly
	Medium	BCC-35, Muktakeshi
	Low	BCC-47, Telia
Corm skin colour	Purple	Sonajuly
	White	BCC-22, BCC-38, BCC-35, BCC-47, Telia
	Off-white	BCC-39
	Light green	BCC-1, Muktakeshi
Palatabitity	Highly palatable	BCC-1, Sonajuly, Telia
	Moderate palatable	BCC-39, Muktakeshi
	Palatable	BCC-22, BCC-35, BCC-39, BCC-47
Taste	Sweet	BCC-1, Sonajuly, Telia
	Light salty	BCC-35, BCC-39, BCC-47, Muktakeshi
	Taste-less	BCC-22, BCC-38
Mealiness	Highly coarse	BCC-22, BCC-38, Muktakeshi
	Medium coarse	BCC-35, Sonajuly
	Fine coarse	BCC-47, Telia
	Very fine coarse	BCC-1, BCC-39
Softiness	Very soft	BCC-1
	Soft	BCC-39, BCC-47, Telia
	Medium hard	Sonajuly, BCC-35
	Hard	BCC-22
	Very hard	BCC-38, Muktakeshi
Acridity (mg 100^{-1} g dry tuber)	Very low (10-20 mg	BCC-1, BCC-39, Sonajuly, Telia
	Low (>20-50 mg)	BCC-35, BCC-38, BCC-47, Muktakeshi
	Slightly Acrid (> 50 mg)	BCC-22

leaf blade tip and high degree of corm fibrousnesses. Group distinct characters are in Table 3 and 4.

Digital morphometrics is the important tool for DUS characterization. Morphological characters especially the shape and size cannot be stored in living stage but with the help of digitalization technique it has now been possible to prepare digital herbarium for all the morphological characters which can be stored easily. It has become possible to identify the individual, unique and group character using this digital herbarium (Jelínková *et al*., 2014) except the culinary characters. In omega it may be concluded that morphological DUS descriptors using digital morphometrics can be used effectively for identification and grouping of the taro varieties and varieties satisfying the DUS criteria for these descriptors could be registered under the PPV&FR Act for obtaining Plant Breeders and Farmers' Rights. However, morphological descriptors used in the present study alone may be limiting for the DUS criteria for establishment of distinctness of taro varieties. Hence, some other markers/descriptors may be considered for complementing the morphological DUS descriptors to establish distinctness of closely related varieties. Molecular characterization may be one of the modern digital tools which can be a help to DUS characterization in future.

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