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Characterization of greater yam (*Dioscorea alata* L.) genotypes by using morphological markers

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Abstract
The present investigation was undertaken to characterize the morphological traits among 27 genotypes of greater yam (*Dioscorea alata* L.) by using morphological markers in a randomized block design with three replications during kharif 2017-18 and 2018-19 at AICRP on tuber crops project, RHRS farm, ACHF, NAU, Navsari. The morphological characterization for 19 characters revealed high variation among the genotypes in terms of shape of leaf, position of leaf, distance between lobes, colour of wing, stem and leaf, pigmentation of petiole on leaf base, formation of aerial tuber, skin and flesh colour of underground tuber, shape of tuber, presence of hairiness on tuber and spines on stem.

Keywords: *Dioscorea alata*, greater yam, genotypes, characterization, and morphological markers

Introduction
Greater yam (*Dioscorea alata* L. 2n=4x=40), is polyploid known as purple yam, greater asiatic yam, ten months yam, water yam and winged yam belongs to the family Dioscoreaceae, originated in South East Asia. More than 600 *Dioscorea* species present in world and Africa, America, Asia and Polynesia are its main habitat, where some of the yam species are economically significant tuber crops (Coursey, 1967) [5]. The species of *Dioscorea* (yam) are regarded as a staple food crop for millions of people in the tropical and subtropical regions of the world. It is regarded as an important food crop next to cereals and grains due to high yield storage of carbohydrates. Greater yam is one of the largely cultivated yam species with the largest world distribution and one of the oldest cultivated yam species (Lebot, 2009) [7]. In India, greater yam is cultivated in the states of Andhra Pradesh, Kerala, West Bengal, Bihar, Odisha, North Eastern states, Uttar Pradesh, Tamil Nadu, Gujarat and Maharashtra (Chadha, 2002) [4]. In Gujarat, it is cultivated in Valsad, Navsari, Dangs, Panchmahals, Surat and Tapi districts.

In plant breeding, markers that are related to variation in shape, size, colour and surface of various plant parts are called morphological markers. Such markers refer to available gene loci that have obvious impact on morphology of plant. Genes that affect form, coloration, male sterility or resistance among others have been analyzed in many plant species. The objectives of this study were to determine the relationships between the genotypes, and to identify duplicates and groupings of genotypes in the germplasm of yams collected from different districts of Gujarat and CTCRI, Kerala. The exploitation of the genetic diversity so determined serves to facilitate the development of better varieties through combination and marker assisted breeding program.

Materials and Methods
The plant materials used for morphological studies comprises of twenty seven genotypes of *D. alata* conserved in the AICRP on tuber crops project at RHRS farm, NAU, Navsari, Gujarat. The details of materials used for the study is given in Table 1.

Table 1: Source of experimental material

S. No	Name of Genotypes	Place/Source of Collection
1	NGy-1	Pipalgabhan, Chikhli, Navsari, Gujarat
2	NGy-2	Pipalgabhan, Chikhli, Navsari, Gujarat
3	NGy-3	Local Vegetable Market, Navsari, Gujarat
4	NGy-4	Vasvari, Olpad, Surat, Gujarat
5	NGy-5	Rumla, Chikhli, Navsari, Gujarat
6	NGy-6	Kaliyari, Chikhli, Navsari, Gujarat
7	NGy-7	Ghej, Chikhli, Navsari, Gujarat
8	NGy-8	Boriyavi, Anand, Gujarat
9	NGy-9	Rambhas Farm, Waghai, Gujarat
10	NGy-10	Velvach, Killa-Pardi, Valsad, Gujarat
11	NGy-11	Navagam, Navsari, Gujarat
12	NGy-12	Nanidesad, Gandevi, Navsari, Gujarat
13	NGy-13	Manekpur, Gandevi, Navsari, Gujarat
14	NGy-14	Antroli, Surat, Gujarat
15	NGy-15	Bhilod, Valiya, Bharuch, Gujarat
16	NGy-16	Waghai, Gujarat
17	NGy-17	Netrang, Kamrej, Surat, Gujarat
18	IGDa-2	Raipur, Collected from CTCRI, Kerala
19	IGDa-3	Raipur, Collected from CTCRI, Kerala
20	IGDa-4	Raipur, Collected from CTCRI, Kerala
21	Da-11	CTCRI, Thiruvananthapuram, Kerala
22	Da-25	CTCRI, Thiruvananthapuram, Kerala
23	Sree Roopa	CTCRI, Thiruvananthapuram, Kerala
24	Sree Karthika	CTCRI, Thiruvananthapuram, Kerala
25	TRC	Port Blair, Collected from CTCRI, Kerala
26	Sree Kirthi	CTCRI, Thiruvananthapuram, Kerala
27	Konkan Ghorkand	Dapoli, Collected from CTCRI, Kerala

The tubers of the collected genotypes were planted on the field at the end of May. Tuber cuttings were planted on mounds prepared at a spacing of 90 cm × 90 cm. The vines were supported on a stake of about 2m height. Harvest was done during February-March by manually digging out the tubers and the tubers were cleaned free of soil and kept in ventilated yam storage house till the next planting season.

The genotypes were characterized based on 19 morphological traits. Traits measurement and data collection procedure used was based on those presented in the International Plant Genetic Resources Institute's descriptor list for yam (IPGRI/ IITA, 1997) [6]. Only those descriptors or traits that discriminated between genotypes were used in this study.

Results and Discussion

Twenty seven genotypes of greater yam under investigation were characterized based on 19 morphological parameters and measured as per IPGRI (1997) [6] descriptors for greater yam and are presented in Table 2a & 2b.

Table 2a: Variation in morphological traits of greater yam genotypes

Characters Genotypes	Plant type	Shape of leaf	Leaf apex shape	Position of leaves	Distance between lobes	Direction of twining stem	Cross section of stem	Wing on stem	Wing colour	Colour of stem
NGy-1	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Green
NGy-2	Climbing	Cordate	Acute	Opposite	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-3	Climbing	Cordate	Acute	Alternate at base & opposite at above	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-4	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-5	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Green
NGy-6	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-7	Climbing	Cordate	Acute	Opposite	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-8	Climbing	Sagittate long	Acute	Opposite	Non-measurable	Clock wise	Square	Present	Purple	Purplish green

NGy-9	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Purplish green
NGy-10	Climbing	Sagittate long	Acute	Opposite	Intermediate	Clock wise	Square	Present	Purple	Green
NGy-11	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Purplish green
NGy-12	Climbing	Sagittate long	Acute	Opposite	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-13	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-14	Climbing	Sagittate long	Acute	Opposite	Non-measurable	Clock wise	Square	Present	Purple	Purplish green
NGy-15	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Green
NGy-16	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Purplish green
NGy-17	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Green
IGDa-2	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Purplish green
IGDa-3	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Purplish green
IGDa-4	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Purplish green
Da-11	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Green
Da-25	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Green
Sree Roopa	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purplish green	Green
Sree Karthika	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Green
TRC	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green with purple edge	Green
Sree Kirthi	Climbing	Sagittate long	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Green	Green
Konkan Ghorkand	Climbing	Cordate	Acute	Alternate at base & opposite at above	Intermediate	Clock wise	Square	Present	Purple	Purplish green

Table 2b: Variation in morphological traits of greater yam genotypes

Characters Genotypes	Colour of leaf	Pigmentation of petiole on leaf base	Formation of aerial tuber	Shape of aerial tuber	Skin colour of tuber	Shape of tuber	Flesh colour of underground tuber	Hairiness on tuber surface	Presence of spines on the stem
NGy-1	Purplish green	Present	Absent	Absent	Dark brown	Round	Light purple	Present	Absent
NGy-2	Dark green	Absent	Absent	Absent	Dark brown	Long	Purple	Present	Absent
NGy-3	Dark green	Absent	Absent	Absent	Dark brown	Long	Light purple	Present	Absent
NGy-4	Dark green	Absent	Absent	Absent	Dark brown	Long	Dark purple	Present	Absent
NGy-5	Purplish green	Present	Absent	Absent	Light brown	Round	Light purple	Absent	Absent
NGy-6	Dark green	Present	Absent	Absent	Dark	Long	Dark purple	Present	Absent

					brown				
NGy-7	Dark green	Absent	Absent	Absent	Dark brown	Long	Dark purple	Present	Absent
NGy-8	Dark green	Absent	Absent	Absent	Dark brown	Long	Dark purple	Present	Absent
NGy-9	Purplish green	Present	Absent	Absent	Light brown	Round	Light purple	Present	Absent
NGy-10	Purplish green	Present	Absent	Absent	Light brown	Round	Light purple	Absent	Absent
NGy-11	Pale green	Present	Absent	Absent	Light brown	Round	Light purple	Present	Absent
NGy-12	Dark green	Absent	Absent	Absent	Dark brown	Long	Dark purple	Present	Absent
NGy-13	Dark green	Absent	Absent	Absent	Dark brown	Long	Dark purple	Present	Absent
NGy-14	Dark green	Present	Absent	Absent	Dark brown	Long	Light purple	Present	Absent
NGy-15	Yellowish green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
NGy-16	Dark green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
NGy-17	Dark green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
IGDa-2	Pale green	Absent	Absent	Absent	Dark brown	Long	White	Present	Absent
IGDa-3	Dark green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
IGDa-4	Dark green	Present	Absent	Absent	Dark brown	Long	Light purple	Present	Absent
Da-11	Dark green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
Da-25	Yellowish green	Absent	Absent	Absent	Dark brown	Long	White	Present	Absent
Sree Roopa	Pale green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
Sree Karthika	Pale green	Present	Absent	Absent	Dark brown	Long	White	Present	Absent
TRC	Pale green	Present	Absent	Absent	Light brown	Long	White	Present	Absent
Sree Kirthi	Yellowish green	Absent	Absent	Absent	Light brown	Long	White	Present	Absent
Konkan Ghorkand	Dark green	Absent	Present	Round	Dark brown	Round	Light purple	Present	Present

Plant type

The result revealed that all twenty seven genotypes exhibited climbing type growth habit.

Shape of leaf

Among the twenty seven genotypes under study, fifteen genotypes *viz*., NGy-1, NGy-4, NGy-5, NGy-6, NGy-8, NGy-10, NGy-11, NGy-12, NGy-13, NGy-14, NGy-15, IGDa-4, Sree Roopa, TRC and Sree Kirthi had sagittate long leaf shape whereas, cordate leaf shape was observed in twelve genotypes *viz*., NGy-2, NGy-3, NGy-7, NGy-9, NGy-16, NGy-17, IGDa-2, IGDa-3, Da-11, Da-25, Sree Karthika and Konkan Ghorkand.

Leaf apex shape

The results revealed that all the twenty seven genotypes exhibited acute leaf apex shape.

Position of leaves

Twenty one genotypes *viz*., NGy-1, NGy-3, NGy-4, NGy-5, NGy-6, NGy-9, NGy-11, NGy-13, NGy-15, NGy-16, NGy-17, IGDa-2, IGDa-3, IGDa-4, Da-11, Da-25, Sree Roopa, Sree Karthika, TRC, Sree Kirthi and Konkan Ghorkand had showed alternate at base and opposite at above type of leaves arrangement on stem whereas six genotypes *viz*., NGy-2, NGy-7, NGy-8, NGy-10, NGy-12 and NGy-14 exhibited opposite type of leaves arrangement.

Distance between lobes

Among twenty seven genotypes, eighteen genotypes *viz*., NGy-1, NGy-5, NGy-9, NGy-10, NGy-11, NGy-15, NGy-16, NGy-17, IGDa-2, IGDa-3, IGDa-4, Da-11, Da-25, Sree Roopa, Sree Karthika, TRC, Sree Kirthi and Konkan Ghorkand showed intermediate type while, nine genotypes *viz*., NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-12, NGy-13 and NGy-14 exhibited non-measurable type of distance between lobes.

Direction of twining stem

All the twenty seven genotypes expressed clock wise direction of twining stem.

Cross section of stem

It is evident from the data that all the twenty seven genotypes showed square type of stem in cross section.

Wing on stem

All the twenty seven genotypes exhibited wing on stem under the study.

Wing colour

Eighteen genotypes *viz*., NGy-1, NGy-2, NGy-3, NGy-4, NGy-5, NGy-6, NGy-7, NGy-8, NGy-9, NGy-10, NGy-11, NGy-12, NGy-13, NGy-14, NGy-16, IGDa-4, Da-11 and Konkan Ghorkand were exhibited purple colour wing on stem. Seven genotypes *viz*., NGy-15, NGy-17, IGDa-2, IGDa-3, Da-25, Sree Karthika and TRC had green with purple edge type of wing colour on stem whereas, Sree Roopa and Sree Kirthi had purplish green and green wing colour respectively.

Colour of stem

Among 27 genotypes under study, sixteen genotypes *viz*., NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-9, NGy-11, NGy-12, NGy-13, NGy-14, NGy-16, IGDa-2, IGDa-3, IGDa-4 and Konkan Ghorkand had exhibited purplish green colour stem. Eleven genotypes *viz*., NGy-1, NGy-5, NGy-10, NGy-15, NGy-17, Da-11, Da-25, Sree Roopa, Sree Karthika, TRC and Sree Kirthi had exhibited green colour stem.

Colour of leaf

The results related to mature leaf colour revealed that fifteen genotypes *viz*., NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-12, NGy-13, NGy-14, NGy-16, NGy-17, IGDa-3, IGDa-4, Da-11 and Konkan Ghorkand were exhibited dark green colour leaves. Four genotypes *viz*., NGy-1, NGy-5, NGy-9 and NGy-10 had exhibited purplish green colour leaves while, Three genotypes *viz*., NGy-15, Da-25 and Sree Kirthi have showed yellowish green colour. Five genotypes *viz*., NGy-11, IGDa-2, Sree Roopa, Sree Karthika and TRC were exhibited pale green colour leaves (Plate 2).

Pigmentation of petiole on leaf base

Among 27 genotypes in the study only 10 genotypes *viz*., NGy-1, NGy-5, NGy-6, NGy-9, NGy-10, NGy-11, NGy-14, IGDa-4, Sree Karthika and TRC had showed pigmentation of petiole on leaf base.

Formation of aerial tuber

The formation of aerial tuber was observed only in genotype Konkan Ghorkand under study (Plate 3).

Shape of aerial tuber

Among 27 genotypes, only one genotype Konkan Ghorkand produced aerial tuber with round shape.

Skin colour of tuber

Fifteen genotypes *viz*., NGy-1, NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-12, NGy-13, NGy-14, IGDa-2, IGDa-4, Da-25, Sree Karthika, and Konkan Ghorkand were exhibited dark brown skin colour tubers. Twelve genotypes *viz*., NGy-5, NGy-9, NGy-10, NGy-11, NGy-15, NGy-16, NGy-17, IGDa-3, Da-11, Sree Roopa, TRC, and Sree Kirthi had shown light brown skin coloured tubers, respectively (Plate 1).

Shape of tuber

The results obtained on shape of the tuber revealed that twenty one genotypes *viz*., NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-12, NGy-13, NGy-14, NGy-15, NGy-16, NGy-17, IGDa-2, IGDa-3, IGDa-4, Da-11, Da-25 and Sree Roopa, Sree Karthika and TRC are having long type tuber shape. Six genotypes *viz*., NGy-1, NGy-5, NGy-9, NGy-10, NGy-11 and Konkan Ghorkand were exhibited round type tubers (Plate 1).

Plate 1: Variations observed in tuber shape, size, skin and flesh colour of greater yam genotypes

Flesh colour of underground tuber

The white coloured flesh was observed in eleven genotypes *viz*., NGy-15, NGy-16, NGy-17, IGDa-2, IGDa-3, Da-11, Da-25, Sree Roopa, Sree Karthika, TRC and Sree Kirthi. Nine genotypes *viz*., NGy-1, NGy-3, NGy-5, NGy-9, NGy-10, NGy-11, NGy-14, IGDa-4 and Konkan Ghorkand are having

light purple flesh whereas six genotypes *viz*., NGy-4, NGy-6, NGy-7, NGy-8, NGy-12 and NGy-13 were showed dark purple colour flesh. The genotype NGy-2 expressed purple coloured flesh (Plate 1).

Hairiness on tuber surface

Presence of hairiness on tuber surface was observed in 25 genotypes *viz*., NGy-1, NGy-2, NGy-3, NGy-4, NGy-6, NGy-7, NGy-8, NGy-9, NGy-11, NGy-12, NGy-13, NGy-14, NGy-15, NGy-16, NGy-17, IGDa-2, IGDa-3, IGDa-4, Da-11, Da-25, Sree Roopa, Sree Karthika, TRC, Sree Kirthi and Konkan Ghorkand under the study. The presence of hairiness on tuber surface was absent in two genotypes NGy-5 and NGy-10 (Plate 1).

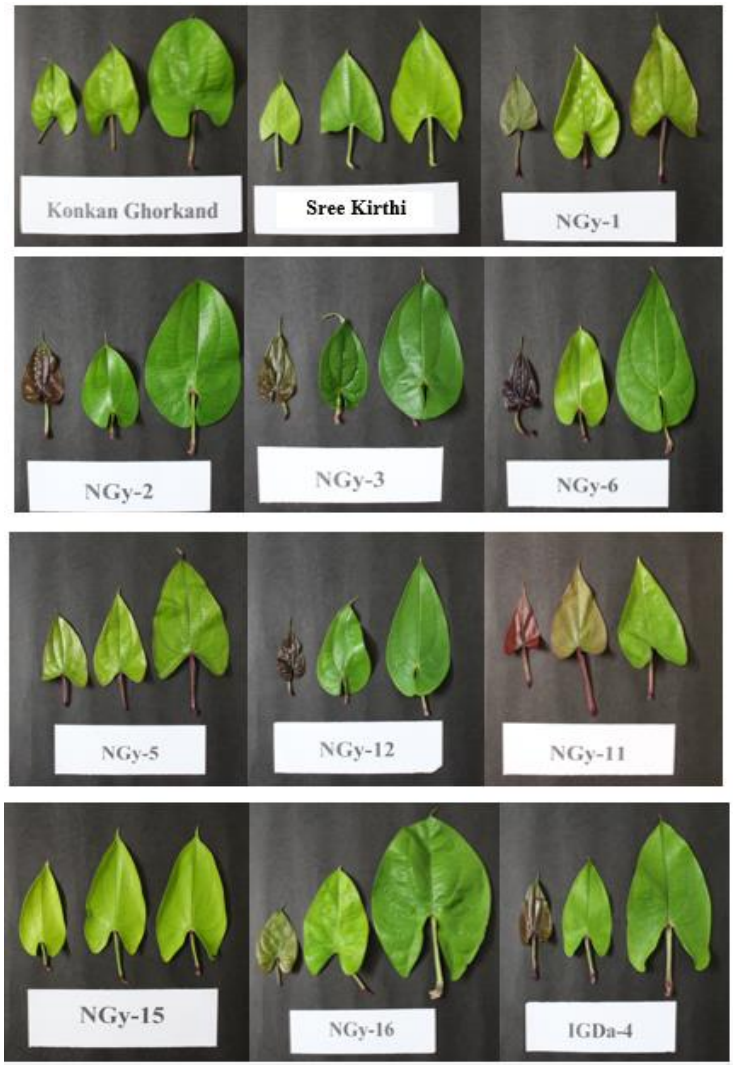

Plate 2: Variations observed in leaf shape, size, apex shape, distance between lobes and leaf colour of greater yam genotypes

Plate 3: Formation of aerial tubers in Konkan Ghorkand

Presence of spines on the stem

The presence of spines on the stem was observed in genotype Konkan Ghorkand under study.

A genotype is considered to be distinct if observations differ consistently from all others. Hence, the study is of significance in morphological characterization of genotypes.

A wide range of variations existing for various morphological traits has also been reported in greater yam by various workers. Athira *et al.*, 2017 [3] evaluated 45 accessions of greater yam for various morphological traits like tuber shape, tuber flesh colour, tuber skin texture, tuber cortex colour, leaf shape and young leaf colour were all found to be of great importance in distinguishing the accessions. Sayed *et al.*, 2008 [9] reported morphological variation among 70 accessions of greater yam for shape, size and flesh colour of underground tubers, shape and colour of aerial tubers and position, shape, size and vein colour of the leaves. Other authors *viz*., Anokye *et al*., 2014 [1]; Otoo *et al*., 2015 [8]; Anwar *et al*., 2016 [2]; Tiama *et al*., 2016 [11]; Sheikh and Kumar, 2017 [10] reported similar results for various traits in yam.

Conclusion

In the present study, 27 genotypes of greater yam collected were morphologically analyzed using the descriptors of yam and there were no duplicate accessions identified based on the morphological classification and it can be maintained as core collection because it depicts wide spectrum of variability. Morphological traits like shape of leaf, position of leaf, distance between lobes, colour of wing, stem and leaf, pigmentation of petiole on leaf base, formation of aerial tuber, skin and flesh colour of underground tuber, shape of tuber, presence of hairiness on tuber and spines on stem were all found to be of great importance in distinguishing the genotypes in greater yam.

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