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Morphological Diversity of Edible Yam (*Dioscorea spp*) in Tablas, Island, Romblon, Philippines

Marjail I. Ferriol

ABSTRACT

Yam plants (*Dioscorea spp*), either wild or cultivated, propagate naturally and are highly productive crops even in marginal areas adapted to diverse conditions. This crop plays a vital role in the lives of many people, as a staple food, feedstuff to livestock/poultry and medicine. However, limited study was conducted on the morphological characterization of edible yams in Tablas Island, Romblon. This study was conducted to determine the morphological characteristics of the existing yam in the province. The different accessions from seven species were collected from cultivated and wild species and were assessed using the descriptors for yams proposed by International Plant Genetic Resources Institute and the National Plant Genetic Resources Laboratory to characterize the yam. Data on morphological diversity were analyzed using descriptive statistics such as percentage and frequency. Eighty-six morphological characters were used in morphological characterization and in assessing the genetic diversity of accessions using the Shannon-Weaver Index. Frequency distribution per trait was determined for the calculation of diversity. The mean H' of the qualitative and quantitative traits was high, H=0.62 and H=0.83, respectively. The qualitative and quantitative traits have shown normal frequency distribution indicating a wide variation of yam accessions in Tablas Island.

Keywords: *accession, characterization, Dioscorea spp., diversity index, morphological diversity*

INTRODUCTION

The Philippines has a diverse collection of Dioscorea species totaling about 600 accessions (Acedo & Arradaza, 2012). However, only two species are widely grown and cultivated for food, *D. alata* (purple yam) and *D. esculenta* (lesser yam). Other rarely cultivated species, *D. hispida* (Asiatic bitter yam) and *D. bubifera* (aerial yam) are grown mainly in the wild and forests at low to medium altitudes for medicinal purposes. The wild tubers also act as a "safety net" for local people during their critical time of drought and famine. Approximately 50 species are consumed as wild-harvested staples or famine food. The most well-known species is *Dioscorea villosa L*., also called wild yam, and is native to North America (Avula et al., 2014).

In the Philippines, the greater yam is widely known as *ube* and utilized as food delicacy, which is popular because of its purple color and exceptional taste. It is cooked as *halaya, puto, sagobe, halo halo*, among others. It has also become a great favorite for ice cream, tarts, cakes, bread, etc.

Romblon encompasses seven islands and has Tablas as the largest of nine municipalities. Topographically, extensive mountain ranges characterize the area, it has streams, gullies, creeks, and rivers draining into adjacent municipalities and finally to the lowlands. The island economy is agriculturally based and planted with varied crops and domesticated animals. Root crop production is grown on a small scale and frequently consumed for subsistence and if blessed with good harvest, farmers bring the product to the market.

Based on the report of the Philippine Statistics Authority (PSA, Romblon), as of 2018, the area harvested for yam is 19.85 hectares with a total production of 159.29 MT. In 2019, it had a production of only 157.19 MT. This shows that there was a decrease in production in the entire province.

Yam (*Dioscorea* species) is grown in most of Romblon province. It thrives well in all kinds of soil, is very productive, and needs a small number of inputs for cultivation and production. It is one of the leading high calorie-staple crops which is of great help when foods

marjailferriol@yahoo.com.ph/marjailferriol74@gmail.com
Romblon State University – College of Agriculture, Fisheries and Forestry, Odiongan, Romblon
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are insufficient. It is served as an alternative to rice, cooked with meat and other vegetables, and as dessert or snack. Yam is a source of industrial products like starch, feedstuff, and functional food. Worldwide, 55 percent of root crop production is utilized as food, and the rest is for feedstuff and industrial products. Olojede (2013), reported that root crops can increase the resources for consumption for food, food security, economic development, and poverty alleviation. According to Sheikh et al. (2009), in terms of utilization for food, *Dioscorea bulbifera*, and *Dioscorea pentaphylla* are popular to consume. The tubers and bulbils of *Dioscorea alata* are utilized as starch for cooking in various ways. They are processed as yam flakes or flour, and used as medicine and feedstuff in Southeast Asia. The species with purple flesh are used for manufacturing ice cream, cakes, and others (USDA-ARS, 2012).

The edible tuber species are an essential food source and have a significant place in the dietary lifestyle among marginal families during food scarcity (Ogbonna et al., 2017).

During scarce situations, stormy days and extreme conditions, people in the rural areas collect different wild corms, and tuber root crops to augment food supply. Sometimes they barter them to nearby barangays with some goods. They also mix tubers with rice (Medhi & Borthakur, 2011).

The traditional ways of preparing and consuming edible yams depend on the local traditions and available species (Idusogie and Olayide, 1977). Some of the *Dioscorea* species are bitter, and the local people are using traditional skills to remove its bitterness.

The *Dioscorea* species known locally by its vernacular name are *Binangkal*, *Burot* or *Yapisan*, *Palad amo, Namo, Patatas, Sap- ang*, *Sinawa, Ube, or Tapoy, Umag,* naturally grows at the mountainous or hilly part of the island and some are cultivated at the lowland areas. The occurrence of the same cultivar of yam having different local names is expected on the island. The exchange of planting materials or the casual transport from other places among farmers resulted in speciation and have been named differently or have changed its local name from its point of origin (Beyerlein & Dos Santos, 2018).

Massive production of yam is not in practice in the locality probably due to poor market access, lack of knowledge on diversity, potentials, and uses of this crop, but when given attention, it will form part of the sustainable program of the province.

Through morphological characterization of both cultivated and wild species, there is a need to differentiate various species to produce a great variant species that would be of great value in crop development and for its future potential use. Hence, this study was conducted.

Objectives of the Study

The general objective of the study is to evaluate the morphological diversity of edible yam (*Dioscorea* species) from the nine municipalities of Tablas Island. Specifically, the study aimed to analyze their morphological diversity and hierarchical clustering.

METHODOLOGY

Figure 1 shows the collection site of yam accessions. Highlighted in blue-violet in the northern part was the municipality of San Agustin, red for Calatrava, avocado green for San Andres in western part, pink for Odiongan, green for Ferrol, blue purple for Looc, in southern part, yellow green for Santa Fe, and for the eastern part, brown for Alcantara and red purple for Santa Maria.

The samples were taken either from the field or

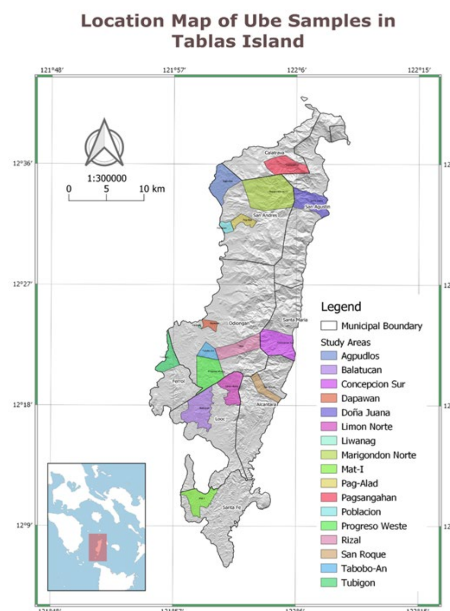

Figure 1. Location of various yam accessions and collection (*Dioscorea* species) in Tablas Island

farm or from uncultivated areas. The coordinates were taken using Geocam, and a location map was generated using GIS Software. A total of 70 yam population (comprising seven species) were randomly collected from the different collection sites on the Island.

On-site characterization of the accessions, specifically the stem, leaves, flower, fruit, and aerial tubers, was conducted during the field survey patterned on the descriptor proposed by International Plant Genetic Resources Institute's (IPGRI, 1997), and the National Plant Genetic Resources Laboratory (NPGRL) at the Los Banos Institute of Plant Breeding.

Eighty-six morphological traits (71 quantitative and 15 qualitative) were recorded). The quantitative measurements on 15 traits were taken for petiole, internode, stem, leaf size, length, and width using a meter ruler and caliper, while the 71 qualitative traits of yam were recorded directly upon measurement using scores of 1-11 scales or as a binary recording (1= Present and 0= Absent).

Data on morphological diversity were analyzed using descriptive statistics such as percentage and frequency. Seventy yam accessions were used to conduct the morphological characterization and assess the phenotypic diversity of the collection using Shannon Weaver Index.

The data on morphological characters were subjected to multivariate analysis and principal component analysis to identify the most discriminating morphological characters. The matrix of similarity was generated based on distance coefficients. The distance matrix was subjected to hierarchical cluster analysis using Euclidean distance.

To identify the similarity of the morphological characters of the collected accessions, the 70 yam accessions were clustered in groups based on their close relationships. The dendrogram of the hierarchical cluster analysis (HCA) is shown in Figure 6. The similarity pattern of clustering was determined to assess the accessions grouping in a cluster. This analysis was used to study the patterns of variation and relationships among each accession, where accessions with close genetic distances were placed near each other in the dendrogram.

RESULTS AND DISCUSSION

Collection Areas of Dioscorea spp in Tablas Island

Tablas is the largest island in the province of Romblon. IT is subdivided into nine municipalities, namely: Alcantara, Calatrava, Ferrol, Looc, Odiongan, San Agustin, San Andres, Santa Fe, and Santa Maria (Figure 1) wherein yam accessions were collected either from fields or farms as wild or cultivated. Most of the collection sites were highly elevated, the topography is somewhat hilly, steep, and slopey, and only a few are from flat areas.

The collected accessions were established in an off-campus area at 43.5 masl, at latitude 12˚24'21"N and longitude 121˚59'24"E. It is a flat well-drained area. The plants are watered daily or depending on the weather condition. Regular weeding was done by hand weeding to minimize the growth of the weeds. Later, a bamboo stake was set up to train the growing yams and to avoid creeping on the land.

Morphological Characterization and Diversity of Yam (Dioscorea spp.)

As shown in Table 1, out of the 71 selected qualitative traits of *Dioscorea spp.* no variation (H=0) was found in the presence of waxiness, barky patches, flowering, sex, inflorescence position, flower's color, inflorescence type, and absence or presence of corms of yam.

The presence of wings, hairs, spines and wing color of the young stem had low diversity (H=0.43, 0.46, 0.41, and 0.58, respectively), while the stem color had high diversity (H=0.76) where most of the accessions (71.5%) had purple stem color.

The presence of waxiness on the mature stem had low diversity (H=0.22), while the vigor, stem color, wing color, and spines on the stem base had high diversity (H=0.72, 1.0, and 0.78, respectively). The majority of the accessions (75.7%) had an intermediate vigor stem, had shown purplish-green stem color (60%), possessed purple wing color (52.9%), and few accessions (24.3%) did not have wings. Most of the accessions (78.6%) do not display spines on the stem, and only a few (11.4%) exhibited an intermediate spine on the stem.

As to young leaves, the first leaf emergence and hairiness surface of leaves had low density (H=0.50 and H=0.43), while the leaf color, leaf margin color, vein color, petiole color, and petiole wing color had high diversity (H=1.19, H=0.69, H=0.86, H=0.87, and H=0.64, respectively). Most of the accessions (41.4%) displayed purple leaf color, with purple leaf margin color (75.7%), and displayed pale green vein color (65.7%). The majority of the accessions (70%) displayed all purplish-green with purple at both ends petiole color, possessed purple petiole wing color (72.9%), and some did not have a wing (25.7%).

The leaf color, vein color, margin color, distance between lobes, and tip color of mature leaves had low density (H=0.48, H=0.38, H=0.38, H=0.26, and H=0.22, respectively), while the position of leaves, leaf density, leaf vein color upper surface, and position of the broadest part high diversity (H=0.97, H=0.89, H=0.62, and H=0.69, respectively). Most of the accessions (48.6%) had an opposite position of leaves, displayed intermediate leaf density, exhibited green leaf vein color on the upper surface of the leaves, and the position of the widest part of leaves was found in the middle. The leaf shape and petiole color had a very high density (H=1.25 and H=1.09, respectively).

On the other hand, different types of leaf shapes were noticed where most of the accessions (44.3%) had a cordate leaf shape, cordate broad (34.28%), sagittate long (35.71%), while two accessions had trilobed (2.9%) and only one with compound leaves (1.4%). Also, variation in petiole color was recognized wherein most of the accessions (42.9%) possessed all purplish-green with a purple base. The rest are having all purplish-green with purple at both ends, green, all green with a purple base, brownish-green, and all green with purple at both sides (20%, 18.6%, 10%, 5.7%, and 2.8%, respectively).

Table 1. Diversity indices (H') of 70 qualitative traits in yam.

TRAIT DESCRIPTOR	COLLECTION SHOWING THE TRAIT		
	No.	%	H'
YOUNG STEM			
1. Stem color			**0.76**
Green	12	17.1	
Purplish Green	7	10	
Brownish Green	1	1.4	
Purple	50	71.5	
2. Presence of Waxiness			**0**
Absent	0	0	
Present	70	100	
3. Presence of Wings			**0.43**
Absent	11	15.17	
Present	59	84.3	
4. Presence of Hairs			**0.46**
Absent	58	82.9	
Present	12	17.1	
5. Presence of Spines			**0.41**
Absent	60	85.7	
Present	10	14.3	
6. Presence of Barky Patches			**0**
Absent	70	70	
Present	0	0	
7. Wing Color After 20 days of Emergence			**0.58**
Green with purple edges	51	72.9	
None	19	27.1	
MATURE STEM			
8. The vigor of mature stem			**0.72**
Low	9	12.9	
Intermediate	53	75.7	
High	8	11.4	
9. Stem Color			**1**
Green	8	11.4	
Purplish Green	42	60	
Brownish Green	12	17.1	
Dark Brown	8	11.4	
10. Presence of waxiness			**0.22**
Absent	66	94.3	
Present	4	5.7	
11. Wing color			**0.78**
Green	1	1.4	
Green with Purple Edge	14	20	
Purple	37	52.9	
Mixture	1	1.4	
No Response	17	24.3	
12. Spines on stem base			**0.78**
Few	5	7.1	
Intermediate	8	11.4	
Many	2	2.9	
None	55	78.6	
13. First leaf emergence			**0.5**
Early	14	20	
Late	56	80	
14. Leaf color			**1.19**
Pale Green	4	5.7	
Dark Green	11	15.7	
Purplish Green	26	37.1	
Purple	29	41.4	
15. Leaf margin color			**0.69**
Green	13	18.6	
Purple	53	75.7	
Purple Green	4	5.7	
16. Vein color			**0.86**
Green	16	22.9	
Pale Green	46	65.7	
Purple	8	11.4	
17. Petiole color			**0.87**
All Green with Purple at Both Ends	3	4.3	
All Purplish Green with Purple Base	4	5.7	
All Purplish Green with Purple at Both Ends	49	70	
Green	14	20	
18. Petiole wing color			**0.64**
Green with Purple Edges	1	1.4	
Purple	51	72.9	
No Response	18	25.7	
19. Hairiness surface of leaves			**0.43**
Both	11	15.7	
none	59	84.3	
MATURE LEAVES			
20. Position of leaves			**0.97**
Alternate	28	40	
Opposite	34	48.6	
Alternate at Base/Opposite above	8	11.4	
21. Leaf density			**0.89**
Low	10	14.3	
Intermediate	45	64.3	
High	15	21.4	
22. Leaf color			**0.48**
Pale Green	13	18.6	
Dark Green	57	81.4	
23. Leaf vein color (upper surface)			**0.62**
Yellowish	1	1.4	
Green	55	78.6	
Pale Green	13	18.6	
Purple Green	1	1.4	
24. Leaf vein color (lower surface)			**0.38**
Green	61	87.1	
Purple	9	12.9	
25. Leaf margin color			**0.38**
Green	61	87.1	
Purple	9	12.9	
26. Leaf shape			**1.25**
Cordate	18	25.71	
Cordate Broad	24	34.29	
Sagitate Long	25	35.71	
Trilobe	2	2.8	
Compound	1	1.4	
27. Distance between lobes			**0.26**
No Measurable Distance	5	7.1	
Intermediate	65	92.9	
28. Position of the widest part			**0.69**
Third Upper	33	47.1	
Middle	37	52.9	
29. Tip color			**0.22**
Light Green	66	94.3	
Purple/Green	4	5.7	
30. Petiole color			**1.09**
All Green with Purple Base	7	10	
All Green with Purple at Both Sides	2	2.8	

TRAIT DESCRIPTOR	COLLECTION SHOWING THE TRAIT		
	No.	%	H’
All Purplish Green with Purple Base	30	42.9	
All Purplish Green with Purple at Both Ends	14	20	
Green	13	18.6	
Brownish Green	4	5.7	
31. Flower			**0**
Flowering in some years	2	2.85	
No Response	68	97.15	
32. Sex			**0**
Female			
Male	2	2.85	
No Response	68	97.15	
33. Inflorescence position			**0**
Pointing Upwards			
Pointing Downwards	2	2.85	
No Response	68	97.15	
34. Average of Inflorescence flower			**0**
<10			
11-29	2	2.85	
>30			
No Response	68	97.15	
35. Flower color			**0**
Purplish			
White	2	2.85	
Yellowish			
No Response	68	97.15	
36. Inflorescence type			**0**
Spike			
Raceme	2	2.85	
Panicle			
No Response	68	97.15	
37. Fruit formation			**0.62**
No	9	12.9	
Yes	32	45.7	
No Response	29	41.4	
38. Fruit development			**0.63**
Mostly Well-Developed	23	32.9	
Mostly Poorly Developed	9	12.9	
No Response	38	54.3	
39. Fruit position			**0.46**
Pointing Upward	2	2.9	
Pointing Downward	30	42.9	
No Response	38	54.3	
40. Hairiness			**0.66**
Sparse	20	28.6	
Dense	12	17.1	
No Response	38	54.3	
41. Absence/presence of waxiness in fruit			**0.5**
Absent	29	41.4	
Present	3	4.3	
No Response	38	54.3	
42. Absence/presence of dark spot inside fruits			**0.36**
Absent	32	45.7	
Present			
No Response	38	54.3	
43. Absence/presence of seeds			**0.36**
Absent	32	45.7	
Present			
No Response	38	53.3	
44. Seed shape			**0.36**
None	32	45.7	
No Response	38	54.3	
45. Seed wing structure			**0.36**
None	32	45.7	
No Response	38	54.3	
46. Absence/ presence of aerial tubers			**0.42**

TRAIT DESCRIPTOR	COLLECTION SHOWING THE TRAIT		
	No.	%	H’
Absent	1	1.4	
Present	31	44.3	
No Response	38	54.3	
47. Surface texture			**0.67**
Wrinkled	18	25.7	
Rough	14	20	
No Response	38	54.3	
48. Aerial tuber shape			**0.74**
Oval	3	4.3	
Oval-Oblong	2	2.9	
Flattened	3	4.3	
Irregular	24	34.3	
No Response	38	54.3	
49. Flesh color			**0.62**
Light Purple	2	2.9	
Purple	10	14.3	
White with Purple	6	8.6	
Outer Purple/Inner Yellowish	3	4.3	
No Response	49	70	
50. Skin color			**0.73**
Greyish	2	2.9	
Light Brown	9	12.9	
Dark Brown	21	30	
No Response	38	54.3	
51. Relationship of tubers			**0.76**
Completely Separate and Distant	1	1.4	
Completely Separate but Close Together	33	47.1	
Fused at Neck	36	51.4	
52. Absence/presence of corms			**0**
Present	70	100	
Absent	0		
53. Corm size			**1.09**
Small	23	32.9	
Intermediate	28	40	
Large	19	27.1	
54. Sprouting at harvest			**0.23**
No	66	94.3	
Yes	4	5.7	
55. The tendency of tubers to branch			**0.99**
Unbranched	7	10	
Slightly Branched	16	22.9	
Branched	44	62.9	
Highly Branched	3	4.3	
56. Place where tubers branches			**0.39**
Upper Third	63	90	
Middle	3	4.3	
Lower Third	4	5.7	
57. Tuber shape			**1.38**
Oval	7	10	
Oval-Oblong	9	12.9	
Cylindrical	8	11.4	
Irregular	35	50	
Elongated	11	15.7	
58. Roots on the tuber surface			**1.13**
Few	21	30	
Intermediate	30	42.9	
Many	18	25.7	
System	1	1.4	
59. Place of roots on the tuber			**0.15**
Upper	1	1.4	
Entire Tuber	68	97.1	
No Response	1	1.4	
60. Absence/presence of cracks on the tuber surface			**0.26**
Absent	65	92.9	

TRAIT DESCRIPTOR	COLLECTION SHOWING THE TRAIT		
	No.	%	H'
Present	5	7.1	
61. Tuber skin color (beneath the bark)			**1.36**
Light Marron	14	20	
Dark Maroon	29	41.4	
Greyish	1	1.4	
Light Yellow	2	2.9	
Yellow Orange	3	4.3	
Yellow	7	10	
Off White	9	12.9	
Orange	2	2.9	
White	2	2.9	
No Response	1	1.4	
62. Hardness of tuber			**0.61**
Hard	48	68.6	
Easy	21	30	
No Response	1	1.4	
63. Uniformity of flesh color in cross-section			**0.71**
No	24	34.3	
Yes	45	64.3	
No Response	1	1.4	
64. Texture of flesh			**0.97**
Smooth	42	60	
Grainy	19	27.2	
Very Grainy	8	11.4	
No Response	1	1.4	
65. Flesh oxidation color			**1.4**
Grey	1	1.4	
Purple	30	42.9	
Orange	15	21.4	
Off-White	11	15.7	
Brown	3	4.3	
Light Brown	2	2.9	
Light Purple	2	2.9	
Light Yellow	1	1.4	
Purplish Brown	1	1.4	
White	1	1.4	
Yellow	2	2.9	
No Response	1	1.4	
66. Skin color at the head of the tuber			**1.3**
Yellowish White or Off White	9	12.9	
Yellow	5	7.1	
Orange	6	8.6	
Light Purple	6	8.6	
Purple	30	42.9	
Purple with White	3	4.3	
White with Purple	6	8.6	
Yellow with Purple	1	1.4	
Outer Purple/Inner Yellowish	1	1.4	
No Response	3	4.3	
67. Flesh color at a central transverse cross-section			**1.63**
White	3	4.3	
Yellowish White or Off White	11	15.7	
Yellow	5	7.1	
Orange	8	11.4	
Light Purple	5	7.1	
Purple	19	27.1	
Purple with White	7	10	
White with Purple	10	14.3	
White with Pink	1	1.4	
No Response	1	1.4	
68. Flesh color at the lower part of a tuber			**2.02**
Yellowish White or Off White	16	22.9	
Yellow	4	5.7	
Orange	3	4.3	
Light Purple	6	8.6	
Purple	18	25.7	
Purple with White	6	8.6	
White with Purple	9	12.9	
White with Pink	3	4.3	
69. Tuber skin thickness (mm			**0.74**
< 1mm	27	38.6	
> 1mm	42	60	
No Response	1	1.4	
70. Time for flesh oxidation after cutting			**0.47**
<1 min	12	17.1	
1-2 min	57	81.4	
No Response	1	1.4	
Mean			**0.62**

As to fruit, the fruit position, absence/presence of waxiness, dark spots inside fruits, absence/presence of seeds, seed shape, and seed wing structure had low density (H=0.46, H=0.50, H=0.36, 0.36, 0.36, and 0.36, respectively). In contrast, fruit formation, fruit development, and hairiness had high diversity (H=0.62, H=0.63, and H=0.66, respectively).

Most accessions (45.7 %) manifested fruit formation, and only 12.9 percent were non-bearing fruit. Also, 32.9 percent of the accessions showed well-developed fruits, and 12.9 percent had poorly developed fruits and evidence of sparse hairiness (28.6%) on the fruit.

The absence/presence of aerial tubers had a low diversity (H=0.42), while the surface texture, aerial tuber shape, flesh color, and skin color had high diversity indices (H=0.67, H=0.74, H=0.62, and H=0.73, respectively). Among the accessions (25.7%) had manifested wrinkled surface texture, with rough surface texture (20.0%), and irregular tuber shape (34.3%).

The dominant flesh color was purple (14.3%), followed by white with purple (8.6%), outer purple/inner yellowish flesh color (4.3 %), and light purple (2.9%). Similarly, most of the accessions (30%) had dark brown skin color, others had light brown skin color (12.9%) and a few had a greyish skin color (2.9%).

As to underground tubers, sprouting at harvest, the place where tubers branch, place of roots on the tuber, absence/presence of cracks on the tuber surface, and time for flesh oxidation after cutting had low density (H=0.23, H=0.39, H=0.15, H=0.26, and H=0.47, respectively) while the tendency of tubers to branch, hardness of tuber, uniformity of flesh color in cross-section, the texture of flesh, and tuber skin thickness had high diversity (H=0.99, H=0.61, H=0.71, H=0.97, and H=0.74, respectively) and the corm size, tuber shape, roots on the tuber surface, tuber skin color (beneath the bark), flesh oxidation color, skin color at the head of the tuber, flesh color at a central transverse cross-section,

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and flesh color at the lower part of a tuber had a very high density (H=1.09, H=1.38, H=1.13, H=1.36, H=1.40, H=1.30, H=1.63, and H=2.02, respectively).

Most of the tubers' accessions (62.9%) had branched, hard when cut (68.6%), displayed uniformity on its flesh color in cross-section (64.3%), and had smooth texture flesh when cut across (60.0%). The highest variation was observed in the flesh color at the lower part of a tuber (H=2.02), flesh color at a central transverse cross-section (H=1.63), flesh oxidation color (H=1.40), tuber shape (H=1.38), tuber skin color (beneath the bark) (H=1.36), skin color at the head of the tuber (H=1.30), roots on the tuber surface (H=1.13), and the corm size (H=1.09).

Most of the accessions (40.0%) had intermediate corm size, had an irregular shape (50%), and manifested intermediate roots on the tuber surface (42.9%). Variation in tuber skin color has been recorded, wherein most of the accessions (41.4%) had dark maroon skin color beneath the bark, displayed purple skin color at the head (42.9 %), manifested purple flesh color at the central transverse cross-section (27.1 %), displayed purple flesh color at the lower part of tuber (25.7 %), and had observed purple flesh oxidation color (42.9%).

Diversity Indices of 15 Quantitative Traits in Yam

No variation (H =0.0) was found in the average number of inflorescence/flowers of the fifteen quantitative traits measured. The time for flesh oxidation had a relatively low diversity (H= 0.47). Tuber length had the highest diversity index (H=1.34); most of the accessions (30%) measured 21 cm to 30 cm long. Similarly, the number of days to emergence of the young stem and the number of internodes had the highest diversity (H=1.29 and 1.08, respectively).

Table 2. Diversity indices (H') of 15 quantitative traits in yam.

TRAIT DESCRIPTOR	COLLECTIONS SHOWING THE TRAIT		
	No.	%	H'
1. Number of days to emergence of young stem			**1.29**
0 and below	9	12.9	
51 to 100	24	34.3	
101 to 125	26	37.1	
125 and above	11	15.7	
2. Stem Length			**0.76**
30 to 50	49	70	
51 to 70	17	24.3	
71 and above	4	5.7	
3. Number of internodes (no) – young stem			**1.08**
5 and below	19	27.1	
6	30	42.9	
7 and above	21	30	
4. Stem height (m)			**0.62**
2 to 10 meters	22	31.4	
More Than 10 meters	48	68.6	
5. Number of internode to the first branching			**0.86**
5 and below	17	24.3	
6 to 9	47	67.1	
10 and above	5	7.1	
No Response	1	1.4	
6. Length of internode (cm)			**0.91**
10 and below	15	21.4	
11 to 13	46	65.7	
14 and above	8	11.4	
System	1	1.4	
7. Wing size (mm)			**0.61**
Less Than 1mm	16	22.9	
1 to 2 mm	53	75.7	
More than 2 mm	1	1.4	
8. Number of leaves (30 days after emergence)			**0.89**
7 and below	27	38.6	
8 to 10	38	54.3	
11 and above	5	7.1	
9. Leaf width (cm)			**0.94**
9 and below	21	30	
10 to 14	40	57.1	
15 to 20	9	12.9	
10. Leaf length (cm)			**1.21**
9 and below	9	12.9	
10 to 14	29	41.4	
15 to 20	26	37.1	
20 and above	6	8.6	
11. Average of Inflorescence flower			**0**
<10			
11-29	2	2.85	
>30			
No Response	68	97.15	
12. Fruit size (cm)			**0.61**
< 3 cm	8	11.4	
> 3 cm	24	34.3	
No Response	38	54.3	
13. The number of tubers per hill (no.)			**0.73**
One	26	37.1	
Few (2-5)	43	61.4	
Several (>5)	1	1.4	
14. Tuber length (cm)			**1.34**
10 and below	18	25.7	
11 to 20	22	31.4	
21 to 30	21	30	
31 and above	9	12.9	
15. Tuber width (cm)			**0.99**
10 and below	36	51.4	
11 to 15	23	32.9	
16 and above	11	15.7	
Mean			**0.86**

Most accessions (37.1%) had been observed to emerge from 101 to 125 days after planting with six internodes. Also, the leaf length of the mature stem had the highest genetic diversity (H= 1.21) where most accessions (41.4%) measure 10 to 14 cm long. The stem length of the young stem had high diversity index (H= 0.76), whereas most of the accessions (70%) had a stem length of 30 to 50 cm long. Similarly, the stem height, number of internodes to first branching, internode length, and wing size of the mature stem had high genetic diversity (H=0.62, 0.86, 0.91, and 0.61, respectively). The majority of the accessions (68.6%) had a height of more than 10 meters, with 6 to 9

Table 3. Principal component scores (PCn) of 62 traits of 70yam (*Dioscorea spp.*) accessions.

TRAITS	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
SC	0.235	-0.112	0.04	-0.156	-0.007	-0.017	0.016	-0.008	-0.018	-0.046
APW	0.19	0.06	0.129	0.075	0.14	0.043	0.072	-0.136	-0.063	0.087
APH	-0.214	-0.024	-0.062	-0.036	-0.167	-0.026	-0.092	0.106	0.016	0.009
APS	**-0.253**	-0.103	0.079	-0.047	-0.076	-0.006	-0.021	0.017	0.061	-0.025
WC	-0.246	0.161	-0.05	0.049	-0.006	-0.069	-0.031	0.018	-0.05	0.047
V	0.046	0.08	0.125	0.098	0.026	**0.254**	-0.237	0.126	0.23	0.041
SC1	-0.16	-0.083	0.129	0.003	-0.048	0.099	-0.2	-0.176	-0.022	-0.036
APWx1	-0.03	0.168	-0.016	-0.07	-0.04	-0.199	0.107	0.034	-0.21	-0.205
WS	0.229	-0.154	0.086	-0.031	-0.039	-0.009	0.094	0.033	0.055	-0.002
WC1	-0.246	0.133	-0.028	0.046	0.007	-0.062	0.008	-0.005	-0.033	0.02
SSb	-0.242	-0.102	0.123	-0.043	-0.036	-0.027	-0.008	0.012	0.039	-0.048
FLE	0.036	-0.069	-0.174	0.186	0.214	0.144	-0.128	-0.002	0.078	**0.266**
LC	0.185	0.085	-0.011	-0.107	-0.129	0.136	-0.01	**-0.251**	-0.033	-0.121
LMC	**0.256**	0.045	-0.077	0.032	0.056	0.043	0.009	-0.003	-0.04	0.014
VC	0.185	0.001	0	0.052	-0.178	-0.062	0.038	0.035	-0.118	0.146
PC	-0.125	-0.053	0.02	-0.117	-0.008	0.21	0.091	-0.126	0.142	-0.162
PWC	-0.247	0.138	-0.045	0.029	-0.007	-0.071	0	0.089	-0.046	0.027
HULSL	-0.205	-0.109	0.069	-0.108	-0.057	-0.046	-0.018	0.002	0.063	0.04
PL	0.159	-0.076	0.086	-0.062	0.002	0.134	-0.025	-0.02	0.041	-0.24
LD	0.154	0.129	0.005	-0.001	0.021	0.043	0.171	0.023	-0.068	0.092
LC1	-0.021	0.127	-0.106	0.067	**-0.258**	0.123	-0.104	0.034	-0.133	**-0.261**
LVC(us)	0.078	-0.175	-0.085	-0.092	0.04	**-0.289**	**-0.254**	-0.122	0.077	-0.03
LVC(ls)	0.049	-0.127	0.048	-0.033	-0.051	**-0.332**	**-0.299**	0.019	0.104	-0.008
LMC1	0.057	-0.084	0.079	0.112	0.064	-0.078	**-0.252**	0.185	0.098	0.007
LS	0.069	**0.254**	-0.023	0.048	-0.1	-0.077	**-0.255**	0.054	-0.06	0.041
DBL	-0.033	0.035	-0.118	**-0.28**	0.158	-0.187	0.132	-0.148	0.115	0.046
PWPL	-0.055	-0.055	0.077	-0.099	-0.162	0.214	-0.148	0.215	-0.025	0.011
TC	0.034	-0.056	0.001	-0.227	-0.085	0.113	0.15	-0.047	-0.147	0.122
PC1	-0.166	0.031	0.035	0.004	-0.175	-0.075	-0.056	-0.214	-0.138	-0.04
RT	0.047	0.222	-0.137	0.036	-0.003	-0.119	-0.054	0.042	**0.33**	-0.103
APC	-0.052	0.022	-0.19	**-0.258**	0.132	0.107	-0.095	-0.192	0.025	-0.14
CS	0.086	0.082	0.202	-0.174	-0.051	-0.007	0.077	0.139	0.239	**-0.253**
SH	0.03	-0.019	-0.191	0.126	-0.178	-0.002	0.189	-0.049	0.237	-0.113
TTB	0.004	**-0.258**	0.074	-0.093	0.123	0.242	-0.159	-0.064	-0.186	-0.151
PTB	0	-0.048	-0.011	0.216	-0.214	-0.063	**0.347**	-0.023	**0.278**	0.036
TS	0.175	-0.129	0.092	0.033	-0.187	0.022	0.035	0.056	0.024	-0.023
RTS	0.016	0.04	0.231	-0.049	0.197	-0.087	-0.071	-0.171	-0.077	-0.166
PRT	-0.016	0.073	0.101	0.042	0.015	0.063	0.021	-0.096	-0.217	0.162
APCTS	0.034	-0.061	0.111	**0.289**	-0.093	0.226	-0.052	-0.041	-0.089	-0.107
TST(mm)	-0.05	-0.035	-0.173	-0.177	0.107	0.043	0.138	**0.266**	-0.172	0.135
TSC(bb)	-0.159	0.145	0.205	0.015	0.149	0.172	-0.032	0	0.161	-0.009
HT	0.018	-0.109	0.013	**0.317**	-0.071	0.03	-0.001	**-0.328**	0.16	0.018
UFCCS	-0.094	-0.063	-0.01	**0.288**	0.032	0.013	-0.018	-0.104	-0.168	0.176
TF	0.055	0.246	0.16	-0.094	0.069	-0.04	0.013	-0.001	-0.101	0.057
FOC	-0.155	-0.132	0.107	0.072	-0.119	0.043	0.087	0.022	0.044	0.103
SCHT	0.026	-0.002	0.022	-0.03	0.163	0.062	-0.115	0.01	0.224	-0.072
FCCTCS	0.033	-0.165	**-0.346**	0.096	0	0.027	-0.071	0.165	-0.159	-0.21
FCLPT	0.023	-0.169	**-0.358**	0.11	-0.071	-0.02	0.013	0.109	-0.153	-0.209
DE	0.069	-0.132	-0.187	0.04	**0.306**	-0.003	-0.003	0.001	0.16	0.146
SL (cm)	0.012	0.001	-0.062	-0.24	-0.221	0.069	-0.035	-0.162	0.104	**0.364**
SH (m)	-0.041	0.164	-0.082	-0.156	0.031	0.227	0.027	0.073	0.037	-0.132
IN	-0.065	-0.168	-0.063	-0.094	-0.03	0.106	-0.047	**0.347**	0.107	0.077
IL(cm)	-0.027	0.134	-0.082	0.035	**0.258**	**0.264**	0.171	0.093	-0.016	0.04
Nl	0.109	0.03	-0.082	-0.133	**-0.279**	0.102	-0.077	-0.163	-0.077	0.113
LW(cm)	0.066	**0.334**	-0.009	0.148	-0.023	0.085	-0.206	0.069	-0.036	0.05
LL(cm)	0.159	0.145	-0.041	0.003	0.01	-0.096	-0.249	0.05	-0.059	0
NTH	-0.033	**-0.299**	0.169	-0.009	0.166	-0.028	-0.027	-0.006	-0.191	0.044
TL	0.098	-0.046	**0.262**	0.008	-0.143	0.057	0.089	**0.275**	-0.011	0.028
TW	0.091	0.004	0.219	-0.059	-0.034	-0.217	0.033	0.23	-0.054	0.125

Note: Values in bold indicate the most important traits (>0.25) that had large contributions to the total variance of a particular principal component.

internodes to first branching, an internode length of 11 cm to 13 cm, and a wing size of less than 1- 2 mm. The number of young leaves had high diversity (H= 0.89), whereas most accessions (54.3%) had 8 to 10 leaves at 30 days after emergence.

The leaf width of the mature stem also had high diversity (H= 0.94), where most of the accessions (57.1%) measure 10 cm to 14 cm wide. The fruit size also had high diversity (H=0.61) where most accessions (34.3%) had a measurement of greater than 3 cm. Likewise, the number of tubers per hill and width had high diversity (H= 0.73, and 0.99, respectively). Most accessions (61.4%) had a few tubers per hill and a width of 10 cm wide and below.

The mean H' of the qualitative and quantitative traits was high (H= 0.62 and H=0.86, respectively). All the quantitative traits had high and very high morphological diversity. This means that diverse yam accessions still exist on Tablas Island, comparable to the study of Ngompe-Deffo et al. (2017) with a diversity index (H'= 0.61) for cultivated cowpea. And incongruence to the statement of Beyene (2013) that the higher the diversity index, the more diversity among germplasm.

Wide variation was observed in various qualitative characters used in the morphological characterization of yam accessions, such as stem color, the vigor of the mature stem, stem color, wing color, spines on the stem base, leaf color, leaf margin color, vein color, petiole color, petiole wing color, the position of leaves, leaf density, leaf vein color (upper surface), leaf shape, fruit formation, fruit development, hairiness, surface texture, aerial tuber shape, flesh color, skin color, the relationship of tubers, tendency of tuber to branch, tuber shape, roots on the tuber surface, tuberkin color, hardness of tuber, uniformity of flesh color in cross-section, the texture of flesh, flesh oxidation, skin color at the head of the tuber, flesh color at the central transverse section, flesh color at the lower part of a tuber and tuber skin thickness. Similar observations were reported in the studies by Anokye et al. (2014); Demuyakor et al. (2013); Islam et al. (2012); Bressan et al. (2011). As Velayudhan et al. (1989) mentioned, continued selection within germplasm has contributed to a variation on the species.

Correlation and Principal Component Analysis

Correlation analysis was critical in determining the interrelationship of the traits that are essential in designing a breeding strategy. In the PCA, eigenvalues and load coefficient values were generated from the data set. The PCs with eigenvalues > 0.7 were selected, and those traits with load coefficient values > 0.25 were considered as relevant scores for the PC, significantly contributing to distinguishing between the genotypes (Jeffers, 1967).

The principal component scores (PC1 – PC10) are the eigenvectors (latent vectors) for each of the 62 morphological traits (Table 4). The multivariate analysis based on the 62 morphological traits revealed great diversity among the 70 accessions of Dioscorea spp.

Each of the first 10 PCs had an eigenvalue greater than 1.0 and explained 61.4%of the total variance in the data set (Table 4). Scores of PC1, which accounted for 0.83%of the total variation, were correlated (r > 0.25) with traits related to the stem (absence or presence of spines and leaf margin color.

Scores of PC2, which explained 7.60% of the total variation, were correlated (r > 0.25) with related to leaves and underground tubers, such as leaf shape, leaf width, the tendency of tubers to branch, and the number of tubers per hill.

Table 4. Eigenvalues, percentage variation, and accumulated variation explained by each component of the first 10 principal components

Principal Component	Eigen-values*	Each Component	Accumulated Variation (%)
1	12.912	20.83	20.83
2	4.711	7.6	28.43
3	3.764	6.07	34.5
4	2.906	4.69	39.19
5	2.66	4.29	43.48
6	2.525	4.07	47.55
7	2.386	3.85	51.4
8	2.193	3.54	54.94
9	2.039	3.29	58.23
10	1.966	3.17	61.4

The scores of PC3, which explained 6.07% of the total variation, were correlated (r>0.26) with underground tubers, such as flesh color at the central transverse cross-section, flesh color at the lower part of the tuber, and tuber length. The scores of PC4, which explained .69% of the variation, were mainly correlated (r>0.25) with leaves (distance between lobes) and underground tuber traits such as the absence or presence of corm, absence or presence of cracks on the tuber surface, hardness of tubers, and the uniformity of flesh color in the cross-section. The scores of PC5, which explained 0.29% of the total variation, were correlated (r>0.25) with leaf color, days to emergence, internode length, and the number of internodes. The scores of PC6, which explained 4.07% of the total variation, were correlated (r>0.25) with the vigor of mature stem and traits of leaves such as leaf vein color of the upper and lower surface.

The scores of PC7, which explained 3.85% of the total variation, were correlated (r>0.25) with days to emergence, leaf apex shape, leaf shape, petiole, and petiole wing color. The scores of PC8, which explained 3.54% of the total variation, were correlated (r>0.25) with leaf color, tuber skin thickness, hardness of tubers, internode number, and tuber length. The scores of PC9, which explained.29% of the total variation, were correlated (r>0.27) with underground tubers (the place where tuber branches and the relationship of tubers). The scores of PC10, which explained 3.17% of the total variation, were correlated (r>0.25) with first leaf emergence, leaf color, corm size, and stem length.

The study revealed positive correlations between first leaf emergence, leaf margin color, leaf shape, absence/presence of crack on tuber surface, hardness of tubers, uniformity of flesh color in cross-section, tuber skin thickness, days to emergence, internode length, internode number, stem length, number of leaves, number of tubers per hill and tuber length. Some of the traits, such as the number of days to emergence, number of tubers per hill, and tuber length, were considered in the selection for better yield in Dioscorea spp.

The first ten principal components explained 61.4% of the total variation in the number of clusters. This means there was a high level of diversity on the existing yam on the island, which was confirmed by principal component analysis.

CONCLUSION

Variations in the morphological characters of Dioscorea species exist in Tablas Island indicating species diversity and possible endemism. Also, the diversity index on both qualitative and quantitative traits among yam (*Dioscorea spp*) accession in Tablas Island are relatively higher. Additionally, the results of PCA have shown that several traits have considerably contributed to the variation within and between yam accessions.

AUTHOR'S CONTRIBUTIONS

The author confirms sole responsibility for the whole manuscript and study.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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