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EVALUATION OF GENETIC DIVERSITY IN AERIAL YAM (*Dioscorea bulbifera* L) USING QUALITATIVE AND QUANTITATIVE MORPHOLOGICAL TRAITS.

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Abstract (sent to GSJ on1/11/2019)

A collection of twenty five aerial yam accessions from West African countries conserved by International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria was assessed for genetic diversity based on twenty five morphological traits. Analyses of Variance showed significant differences in internode length and number, leaf number and size, and stem number/ hill ($P \leq 0.001$). The accessions were not significantly different in number of veins/ per leaf and stem length ($P \geq 0.05$). Principal Component Analysis of eight quantitative morphological traits revealed three Principal components and explained 74.8% of the total variations observed, with the stem length, stem number per hill and stem diameter being the major contributors. PC 1 contributed 42.7% of the total variations with an Eigen value of 3.840. Cluster analysis revealed two clusters. Principal Component Analysis of sixteen qualitative morphological traits revealed six major components and explained 84.83% of the total variations observed, with leaf arrangement, leaf colour, absence /presence of bumps on bulbils, bulbil skin colour, surface texture and leaf size being the major contributors, with Eigen values of 3.745, 3.158, 2.292,

1.838, 1.430 and 1.100 respectively. Analyses of variance of the quantitative characters also revealed significant differences among the accessions. Cluster analysis revealed two clusters. These results are significant in the conservation and genetic improvement program of this crop.

Key words: Aerial yam, Genetic diversity, Morphology, Cluster analyses.

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Introduction

Dioscorea bulbifera is an edible yam species differentiated from every other species by the possession of specialized aerial bulbils, usually produced on the base of petioles (Martin, 1974). In addition to these bulbils, some varieties also have edible underground tubers. *D. bulbifera* is a vigorously growing dioecious, perennial crop having spineless twinning stem with simple broad leaves. The plant often grows up to 20m or more in length. The stems are round or slightly angled in cross section. The plant has axillary flowers which are diminutive and sessile inflorescence, usually white or greenish tinged (Miller, 2003). Flowers are often visited by bees, wasps and nocturnal insects because they produce a pleasant fragrance (Hammer, 1998). Reproduction in *D. bulbifera* is mainly vegetative (through the bulbils and underground tubers) and sometimes sexually by seed (Miller, 2003).

Several landraces of *D. bulbifera* are cultivated for human consumption and constitute an important food source for millions of people across different countries in the tropics and subtropical Asia, Africa and America. *D. bulbifera* has also been exploited in local medical practices across different regions of Asia, Africa and Latin America in the treatment of several ailments such as dysentery, diarrhoea, fatigue, conjunctivitis, diabetes and depression.

Despite their nutritional and economic importance, selection and breeding of these yam genotypes for improved traits is presently limited by lack of adequately characterised genotypes at both morphological and molecular levels (Asiedu *et al.*, 1998). This apparent lack of research into the diversity and utilization of this plant may lead to genetic erosion of this particular yam species particularly in Nigeria.

An understanding of the diversity and phylogenetic relationships in *D. bulbifera* will provide the requisite baseline data for efficient breeding scheme for the crop. In order to contribute to knowledge that can be useful for breeding and improvement of this plant species, the present study was designed to assess the genetic diversity of accessions of *D. bulbifera* using morphological attributes. The specific objectives were to characterise the variation in morphological traits among the 25 *D. bulbifera* accessions in IITA holding and identify the quantitative and qualitative traits contributing significantly to variation in morphology in this species. This will enable proper characterisation as well as the development of effective breeding strategies for this crop and further stimulate its domestication, cultivation, commercialization as well as its integration into cropping system.

LITERATURE REVIEW

D. bulbifera is among the yam species in the genus *Dioscorea*, with great potentials in agricultural productivity for food security, especially in sub-Saharan Africa. The genetic diversity present in *D. bulbifera* especially in the Nigerian land races has remained poorly understood. Limited efforts have however been made in genetic diversity studies in the genus Dioscorea, but knowledge of the association of the traits in relation to their inheritance is still incomplete.

Detailed analysis of genotypes based on morphological traits play a critical role in diversity studies, genetic improvements and conservation of crops Dansi *et al.* (2001) and Hasan *et al.* (2008) have carried out a number of morphological diversity studies between and within yam populations to document existing diversity. Norman *et al.* (2011) reported morphological diversity among 52 yam genotypes from Sierra Leone Beyene, (2013) reported genetic diversity of *D. bulbifera* accessions in Ethiopia based on morpho-agronomic traits. Jayeola and Oyebola (2013) also reported the characterization of 34 accessions of *D. bulbifera* from Nigeria using morphological traits and SSR markers.

Yams share many morphological, physiological and chemical attributes. Since yams are heterogeneous perennial crops, the efficient utilization of large genetic variability can thus be optimized when it has been systematically evaluated, quantified and characterised (Amurrio *et al.,* 1995). The use of more systematic methods to determine the extent of variability in yam has provided better understanding in countries like Benin (Dansi *et al.,* 1997) and Cameroun (Mignouna *et al.,* 2002). The present study will throw some light on the diversity of the *D. bulbifera* accessions in the custody of IITA, Nigeria.

Materials and Methods

The research was carried out in the germplasm bank and the Bioscience Centre of the International Institute of Tropical Agriculture (IITA), Ibadan – Oyo State, Nigeria.

Morphological characterisation

Twenty five accessions of *Dioscorea bulbifera*, representing entries from eight countries and maintained in IITA germplasm bank were used for the study (Table 1). The accessions were planted in a Randomized Complete Block Design (RCBD) with three replicates. The spacing between plants and rows was 1.5m and 1m respectively. Cultural practices such as staking and weeding were done as at when due. The plants were raised to maturity and data collected on morphological traits.

Data collection

The International Plant Genetic Resources Institute (IPGRI, 1997) descriptors for yam (*Dioscorea* spp), were followed for data collection. Two sets of data (qualitative and quantitative) were collected from the 25 *D. bulbifera* accessions. Five measurements were taken for internode length, petiole length, stem diameter and stem length using a measuring tape and Vernier callipers respectively (in cm). The means of the measurements were determined accordingly. Manual counting was done for leaf number, number of veins per leaf, stem number per hill and internode number based on the yam descriptors for yam. The qualitative traits were also scored through visual observation based on the descriptors

Data analysis

Quantitative data collected were subjected to Analysis of Variance (ANOVA) and where necessary, means were separated using the Least Significance Difference (LSD) test. Cluster patterns for the quantitative and qualitative traits in the 25 accessions of *D. bulbifera* were generated from hierarchical cluster analysis using Ward's method. The quantitative and qualitative data were also subjected to Principal Component Analysis (PCA). The Genstat discovery Edition 4 and SPSS version 20.0 software were used in all the analyses.

Results and Discussion

Morphological characterization

Twenty-five (25) accessions of *Dioscorea bulbifera* (shown in Table 1) were characterised based on 24 morphological traits. Table 2 gives the means and standard errors of eight (8) quantitative morphological traits characterised in the 25 accessions. The results show significant differences in all the traits among the accessions except number of veins per leaf ($P>0.05$). Results of Analysis of Variance (ANOVA) tests are summarized in Table 3. The results show significant differences in internode length ($P<0.001$), leaf number, petiole length, stem length, stem diameter stem number per hill and internode number among the accessions (($p<0.001$). The accessions were however not significantly different in number of veins per leaf, and stem height at seedling stage ($P>0.05$).

Results of the principal component analysis of eight quantitative traits studied (Table 4), revealed three principal components and explained 74.8% of the total variation in these traits. PC 1 had an Eigen value of 3.840, contributing to 42.7% of the total variation. In the quantitative traits, stem length produced large loading values for the first component. Therefore, PC 1 was designated the "stem length component."

PC2 had an Eigen value of 1.891, contributing to 21.01% of the total variation, stem number per hill produced large loading values for this component, thus this array was designated the "stem number component."

Results of the principal component analysis of sixteen (16) qualitative traits studied (Table 5) revealed six principal components and explained 84.83% of the total variation in the qualitative traits. PC1 had an Eigen value of 3.745, contributing to 23.43% of the variation observed. Leaf arrangement produced large loading values

for the first component which was thus designated as leaf arrangement component. PC 2 had an Eigen value of 3.158, contributing to 19.74% of the variation observed. Leaf colour produced large loading values for this component. PC 3 had an Eigen value of 2.292, contributing to 14.33% of the variation observed. Absence/presence of bumps and spines on the bulbil produced large loading values for this component and was thus designated as "bump component." PC 4 had an Eigen value of 1.838, contributing to 11.49% of the total variation. Bulbil Skin colour produced large loading values for this component and was thus designated as "skin colour component".

PC5 had an Eigen value of 1.430, contributing to 8.94% of the total variation. Surface texture produced large loading values for this component and was thus designated as "surface texture component". PC6 had an Eigen value of 1.100, contributing to 6.91% of the variation observed. Leaf shape produced large loading values for this component and was thus designated as "leaf shape component." The predominant leaf arrangement among the accessions was alternate (72%) while seven accessions (TDb 4119, TDb 4120, TDb 4122, TDb 3431, TDb 2857, TDb 3045 and TDb 3049) had opposite leaf arrangement. 84% of the accessions had pale green leaves, TDb 2857 and TDb 4122 accessions had yellowish leaves while TDb 3431and TDb 3693 accessions had dark green leaves. 64% of the accessions had bulbils with bumps while accessions: TDb 3060, TDb 3064, TDb 3067, TDb 3069, TDb 4120 had no bumps. The predominant bulbil skin colour among the accessions was dark brown (48%). TDb 2857, TDb 3065, TDb 3070, TDb 3082, TDb 3085, TDb 3431 and TDb 3694 accessions had bulbils with light brown colour. TDb 3067, TDb 3069, TDb 3089 and TDb 4122 had greyish bulbils while TDb 3072 and TDb

4120 accessions had dark green bulbils. The predominant bulbil surface texture among the accessions was smooth (60%) while accessions TDb 2857, TDb 3072, TDb 3078, TDb 3083, TDb 3084, TDb 3085, TDb 3089, TDb 3694, TDb 3835 and TDb 4119 had rough bulbil surface texture. The predominant leaf shape among the accessions was cordate broad (88%) but accessions TDb 3045 and TDb 3049 had cordate leaves while TDb 3835 had sagitate broad leaves.

From the cluster pattern based on squared Euclidean distance 0.05 using Ward's method, two clusters were revealed for the eight quantitative morphological traits studied (Fig 1).The dendrogram generated showed that cluster 1 contained the following accessions: TDb- 4119, TDb- 4120, TDb -412 and TDb -2857. Cluster 2 contained the other 21 accessions. Cluster analysis of the sixteen (16) qualitative morphological traits (Fig 2) also revealed two clusters. Cluster 1 contained seven accessions: TDb 4119, TDb 4120, TDb 4122, TDb 2857, TDb 3049, TDb 3835 and TDb 3045. Cluster 2 contained the other 18 accessions.

Discussion

Significant variations were observed in the morphology of the 25 *D. bulbifera* accessions in internode length, stem number per hill and internode number. These traits are invaluable in varietal identification and the variations can play a significant role in the conservation, diversity analysis and genetic improvement of *D. bulbifera* as earlier articulated by Beyene, (2013). The variation in morphological traits among the accessions may be attributed to the fact that the crop under study came from various micro locations to which they may have become adapted through the process of genetic recombination as a response to genotype environment interactions. The results indicate the presence of a high degree of morphological polymorphisms

among the accessions, pointing to possibilities of obtaining desirable trait combinations in specific accessions. These results are consistent with the work of Norman *et al.* (2011) who reported morphological diversity among 52 yam genotypes from Sierra Leone with shoot traits (shoot growth rate, position, size and density) contributing significantly to variations. Jayeola and Oyebola (2013) reported significant variations in petiole length, leaf number and stem length and internode number among populations of *D. bulbifera* studied. Beyene (2013) also noted significant variations in stem length among *D. bulbifera* accessions in regions of Ethiopia. In the present study, a high degree of pleitropy of genes was observed as accessions with dark green coloured leaves also yielded dark coloured bulbils and the accessions with lighter coloured leaves yielded lighter coloured bulbils.

Principal component analysis (PCA) of eight quantitative morphological traits studied showed two principal components and explained 62.4% of the total variations in the traits studied. These confirms the analysis of variance (ANOVA) results and lends credence to the existence of a high degree of morphological polymorphisms possibly due to an interaction of genetic and environmental factors as earlier stated. These results made obvious the traits contributing to maximum variability among the accessions. The traits which had large loading values in the first two principal components should be made selection criteria in *D. bulbifera* - breeding programs emphasizing improvement for stem length and stem number per hill. The relative importance of each trait can be estimated by the rank order of their contribution (%) to the observed phenotypic variation. Stem length and stem number per hill were the major contributing variables.

The principal component analysis of sixteen qualitative morphological traits studied showed six principal components and explained 84.83% of the total variation in the

qualitative traits. The traits with large loading values in the first six principal components should be considered in selection for breeding and genetic improvement programs in *D. bulbifera.* The major contributing variables from the results are leaf arrangement, leaf colour, absence /presence of bumps, bulbil skin colour, surface texture and leaf shape. Again, the high degree of phenotypic variation may be due to high gene recombination rate in response to diverse environmental conditions to which they had become adapted. The traits identified will be invaluable in varietal identification, conservation, diversity analysis, selection, breeding and genetic improvement of *D. bulbifera.*

Two clusters were revealed for the eight quantitative morphological traits studied in the 25 accessions of *D. bulbifera* (Fig 1). The dendrogram showed that Cluster 1 contained four accessions: TDb 4119, TDb 4120, TDb 4122, TDb 2857, TDb 3049, TDb 3835 and TDb 3045, while cluster 2 contained the remaining eighteen accessions. The accessions were not differentiated according to countries or ecological regions of collection, much like the results obtained by Beyene, (2013). The clustering pattern shows that many of the accessions are related to each other, possibly due to exchange of planting materials across and between countries. The maintenance of stable phenotypic variability in the crop irrespective of source of collection could be attributed to continuous vegetative propagation and selection.

The dendrogram however showed low variation on morphological traits studied and this could be an indication of limitations in using only morpho-agronomic characters for diversity studies. The genetic control of polygenic morpho-agronomic characters is a complex process and is affected also by genotype-environment interaction as noted by Sanou, (1993) and also in the present study. The use of DNA marker

system for diversity study in addition to morpho-agronomic traits in this crop is hereby advocated.

Conclusion

Twenty-five (25) accessions of *D. bulbifera* were characterised based on 24 morphological traits. The results showed significant variations in internode length, leaf number, petiole length, stem diameter, stem length, stem number per hill and internode number.

The results of principal component analysis of 8 quantitative morphological traits and 16 qualitative morphological traits studied revealed two and six principal components, respectively which explained 62.4% and 84.8% of the total variations in the morphological traits studied, with stem length, stem number per hill, leaf arrangement, leaf colour, absence/presence of bumps on the bulbils, bulbils peel colour, surface texture and leaf shape as the major contributing variables to the variation observed. Cluster patterns based on squared Euclidean distance, 0.05, using Ward's method revealed two clusters for each set of morphological traits studied.

Principal component analysis of the morphological traits studied showed stem length, stem number per hill, stem diameter, leaf arrangement, leaf colour, bulbil surface texture and leaf shape were found to be the major traits contributing to variation in this crop. Ultimately, this research has provided information on genetic diversity of *D. bulbifera* accessions using morphological attributes.

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TABLE 1

Accessions of *D. bulbifera* used in the study, their origin and ecological zone

S/N	Accessions	Origin	Ecological zone
1	TDb-2857	Equatorial Guinea	Forest
2	TDb-3045	Nigeria	Forest
3	TDb-3049	Benin	Savannah
4	TDb-3058	Togo	Savannah
5	TDb-3060	Togo	Savannah
6	TDb-3064	Togo	Savannah
7	TDb-3067	Togo	Savannah
8	TDb-3068	Togo	Savannah
9	TDb-3069	Togo	Savannah
10	TDb-3070	Togo	Savannah
11	TDb-3072	Nigeria	Forest
12	TDb-3078	Nigeria	Forest
13	TDb-3082	Nigeria	Forest
14	TDb-3083	Gabon	Savannah wood land
15	TDb-3084	Gabon	Forest
16	TDb-3085	Nigeria	Forest
17	TDb-3089	Equatorial Guinea	Forest
18	TDb-3431	Nigeria	Forest
19	TDb-3512	Togo	Forest
20	TDb-3693	Congo	Forest
21	TDb-3694	Congo	Forest
22	TDb-3835	Nigeria	Swampy with tall tree and grasses
23	TDb-4119	Guinea	Savannah
24	TDb-4120	Sierra Leone	Savannah
25	TDb-4122	Sierra Leone	Savannah

TABLE 2

Means (± SE) of 8 Morpho- agronomic (Quantitative) Traits Studied in 25 Accessions of Aerial Yam

S/No	Accessions	Stem length (cm)	Internode number	Stem No. per hill	Stem diameter (cm)	Internode length (cm)	Leaf number	Number of veins per leaf	Petiole length (cm)
1	TDb-2857	147.00o±0.58	18.00j ± 0.58	1.33d± 0.33	6.00fghi ± 0.58	17.00i ± 0.58	13.67ij± 0.33	7.00a ± 0.00	2.00a ± 0.00
2	TDb-3045	53.00e ± 0.58	5.67f ± 0.33	2.67c± 0.33	2.67ab ± 0.33	6.67a ± 0.33	10.33gh±0.33	7.00a ± 0.00	2.00a ± 0.00
3	TDb-3049	96.00n ± 0.58	8.00g ± 0.58	1.00a± 0.00	9.33m ± 0.67	13.00def ± 0.58	13.00ij± 0.58	7.00a ± 0.00	2.00a ± 0.00
4	TDb-3058	52.00f ± 0.58	3.00bcd± 0.58	1.00a± 0.00	4.67cdefg±0.33	14.33cdefg±0.33	6.67de± 0.33	10.00a ± 0.00	2.67b ± 0.33
5	TDb-3060	52.00e ± 0.58	3.33cd ± 0.33	1.00a± 0.00	3.33bcd ± 0.33	12.67cde± 0.33	7.33ef ± 0.67	10.00a ± 0.00	2.67b ± 0.33
6	TDb-3064	38.00a ± 0.58	1.67a ± 0.33	1.00a± 0.00	7.00ghijk± 0.58	13.33ef ± 0.33	4.00ab± 0.58	11.00a ± 0.00	2.67b ± 0.33
7	TDb-3067	49.67l ± 0.88	2.67abcd±0.33	2.00b±0.00	6.00fghi ± 0.58	11.33bc ± 0.67	3.00a ± 0.00	10.00a ± 0.00	2.67b ± 0.33
8	TDb-3068	48.00k ± 0.58	3.00bcd± 0.58	2.00b ± 0.00	7.33hijkl± 0.67	12.00bcd± 0.58	3.00a ± 0.00	10.00a ± 0.00	3.00b ± 0.00
9	TDb-3069	44.00bc±0.58	1.67a ± 0.33	1.00a ± 0.00	6.67ghij ± 0.88	12.67bcde±0.33	4.67bc± 0.33	10.00a ± 0.00	2.67b ± 0.33
10	TDb-3070	45.00cd±0.58	1.67a ± 0.33	1.00a ± 0.00	3.67bcde± 0.33	14.00efg ± 0.58	8.00f ± 0.58	10.00a ± 0.00	3.00b ± 0.00
11	TDb-3072	43.00b ± 0.58	2.00ab ± 0.00	1.00a ± 0.00	4.00cdef ± 0.00	11.67bcd ± 0.33	8.00f ± 1.00	10.00a ± 0.00	2.67b ± 0.33
12	TDb-3078	43.00b ± 0.58	5.00f ± 0.00	1.00a ± 0.00	8.00ijkl ± 0.58	16.67bcd ± 0.33	3.67ab± 0.33	10.00a ± 0.00	2.67b ± 0.33
13	TDb-3082	48.00j ±	2.00ab ±	1.00a ±	7.00ghijk± 0.58	16.67hi ± 0.33	3.67ab± 0.33	10.00a ±	2.67b ±

		0.58	0.58	0.00				0.00	0.33
14	TDb-3083	45.00cd±0.58	2.00ab ± 0.00	1.00a ± 0.00	3.67bcde± 0.33	12.67bcde± 0.33	5.67cd± 0.33	10.00a ± 0.00	2.67b ± 0.00
15	TDb-3084	59.67f ± 0.88	3.67de ± 0.00	1.00a ± 0.00	4.67cvdefg±0.33	12.67cde ± 0.33	4.67bc± 0.33	10.00a ± 0.00	2.00a ± 0.00
16	TDb-3085	57.67m±0.88	3.00cd ± 0.33	1.00a ± 0.00	8.33jklm± 0.67	13.67f ± 0.67	17.00k ± 0.58	10.00a ± 0.00	3.00b ± 0.33
17	TDb-3089	38.67a ± 0.33	2.33abc ± 1.00	1.00a ± 0.00	7.00ghijkl±0.58	12.00bcde± 0.00	10.67h ± 0.33	10.00a ± 0.00	2.67b ± 0.33
18	TDb-3431	16.00g ± 0.58	5.00f ± 0.33	1.00a ± 0.00	4.00cdef ± 0.00	7.00a ± 0.58	9.33g ± 0.67	10.00a ± 0.00	2.00b ± 0.33
19	TDb-3512	38.67a ± 0.33	3.00bcd± 0.58	1.00a ± 0.00	7.00ghijk± 0.00	11.00b ± 0.58	8.00f ± 0.58	11.00a ± 0.00	2.00a ± 0.33
20	TDb-3693	24.67h ± 0.33	15.00h ± 0.58	1.00a ± 0.00	3.00abc ± 0.00	7.67a ± 0.33	9.33g ± 0.67	10.00a ± 0.00	2.00a ± 0.00
21	TDb-3694	32.33i ± 0.67	7.00g ± 0.58	2.00b ± 0.00	4.00cdef ± 0.00	11.00b ± 0.58	8.00f ± 0.58	10.00a ± 0.00	2.00a ± 0.00
22	TDb-3835	45.33cd±0.88	4.67ef ± 0.58	2.00b ± 0.00	2.00a ± 0.00	11.00b ± 0.58	10.00gh±0.00	7.00a ± 0.00	2.00a ± 0.00
23	TDb-4119	243.67r±1.45	2.3.00i ± 0.33	1.00a ± 0.00	4.67cdefg±0.67	15.33gh ± 0.88	14.00j ± 0.58	11.00a ± 0.00	3.00b ± 0.00
24	TDb-4120	174.33p±1.20	15.33h ± 0.58	2.00b ± 0.00	5.00efgh ± 0.00	16.0hi ± 0.58	12.67i ± 0.33	8.00a ± 0.00	2.67b ± 0.00
25	TDb-4122	223.33q±1.20	22.67i ± 0.33	1.00a ± 0.00	7.69hijkl± 0.33	24.00j ± 0.58	15.667v±0.33	8.00a ± 0.00	2.67b ± 0.00

Traits with similar lower case letters are not significantly different (P>0.05)

TABLE 3

Summary of Analysis Of Variance of Qualitative Morphological traits in 25 D. bulbifera

Morphological traits studied	DF	SUM OF	MEAN	VARIANCE	L. S.

Accessions studied

		SQUARES	SQUARE	RATIO	D
Internode length	74 2 24 48	983.55 4.19 947.55 31.81	 2.09 39.48 0.66	 3.16 59.57***	1.34
Leaf number	74 2 24 48	1236.48 8.00 1201.15 27.33	 4.00 50’05 0.57	 7.02 87.89***	1.24
Number of veins/leaf	74 2 24 48	120.72 0.00 120.00 0.00	 0.00 5.03 0.00	 0.00^{ns}	
Petiole Length	74 2 24 48	18.72 1.28 10.72 6.72	 0.64 0.45 0.14	 4.57 3.19**	0.61
Stem diameter	74 2 24 48	316.67 9.71 284.67 22.29	 4.85 11.86 0.46	 10.45 25.54***	1.12
Stem height	74 2 24 48	31.68 0.00 31.68 0.00	 0.00 1.32 0.00	 0.00^{ns}	–
Stem length	74 2 24 48	260644.32 19.52 260562.99 61.81	 9.76 10856.79 1.29	 7.58 8430.64***	1.86
Stem number/hill	74 2 24 48	19.12 0.00 17.79 1.33	 0.00 0.74 0.03	 0.00 26.68**	0.27
Internode number	74 2 24 48	3208.35 10.91 3171.01 26.43	 5.45 132.13 0.55	 9.91 239.99**	1.22

TABLE 4

Eigen vectors and Eigen values for Principal Components (PC) based on Eight Quantitative Morphological traits in 25 Accessions of *D. bulbiferous*

Quantitative traits	Communalities	Components	
		PC 1	PC 2
Stem length	.865	.930	.030
Internode no	.784	.863	-.198
Stem no. per hill	.485	-.069	-.693
Stem diameter	.397	.302	.553
Internode length	.778	.734	.490
Leaf no.	.642	.759	-.257
No. of veins per leaf	.591	-.527	.560
Petiole length	.452	.089	.666
Eigen values		3.105	1.890
% variation		38.806	23.621
Cumulative variation		38.806	62.427

TABLE 5

Eigen vectors and Eigen values for principal components based on sixteen qualitative morphological traits in 25 accessions of *D. bulbiferous*

Qualitative traits	Communalities	Components					
		1	2	3	4	5	6
Coloured spot at spine base	.963	-.621	.708	.092	-.165	.205	.020
Young stem colour	.963	.621	-.708	-.092	.165	-.205	-.020
Waxiness	.621	-.024	.020	-.570	.372	-.397	.107
Adult hairiness	.797	.669	.232	-.059	-.448	.250	.112
Absence or presence of wings	.751	-.580	.031	.382	-.502	-.180	.326
Leaf arrangement	.931	-.857	.051	.158	.225	-.338	-.054
Leatheriness	.873	.620	.710	-.099	.153	.025	-.045
Leaf colour	.806	.325	.812	-.004	-.127	.036	.191
Absence or presence of spines	.744	-.384	-.003	-.632	.139	.463	.097
Leaf shape	.347	.409	-.369	.063	-.151	.181	.692
Plant vigor	.746	.429	-.285	.631	-.106	-.335	-.132
Inflorescence type	.701	.013	.323	.529	.318	-.266	.453
Peel colour	.780	.111	.314	-.110	.763	-.125	.306
Surface texture	.882	.177	-.327	.422	.464	.593	-.011
Absence or presence of bumps	.834	-.342	-.065	.635	.369	.420	-.080
	.655	.555	.632	.304	.121	-.072	-.349
Eigen values		3.749	3.158	2.292	1.838	1.430	1.106
% variation		23.430	19.736	14.327	11.489	8.936	6.912
Cumulative variation		23.430	43.165	57.492	68.981	77.911	84.829

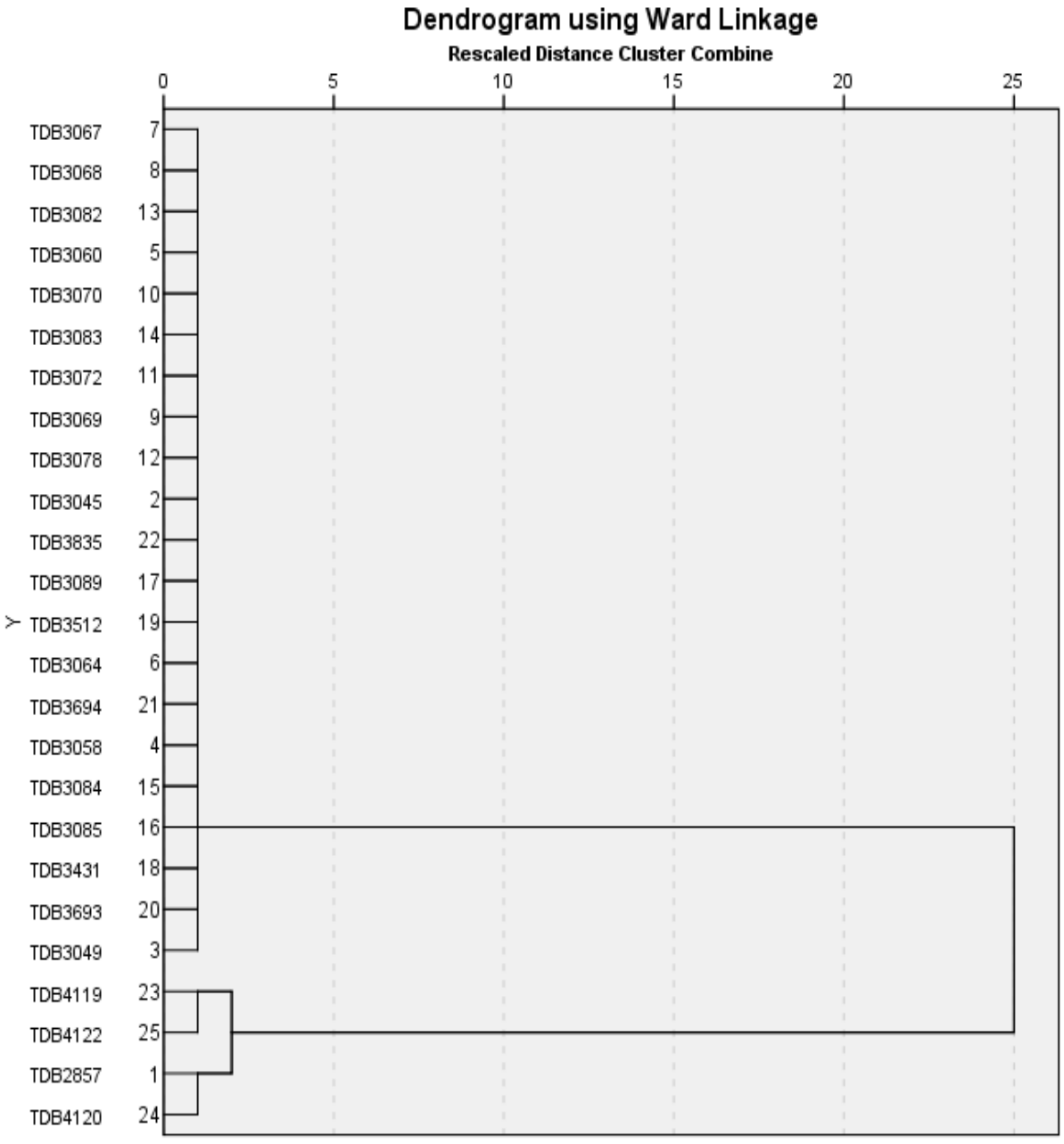

Figure 1: Cluster pattern for nine quantitative morphological traits in 25 accessions of *D. bulbifera* generated from hierarchical cluster analysis using Ward's method

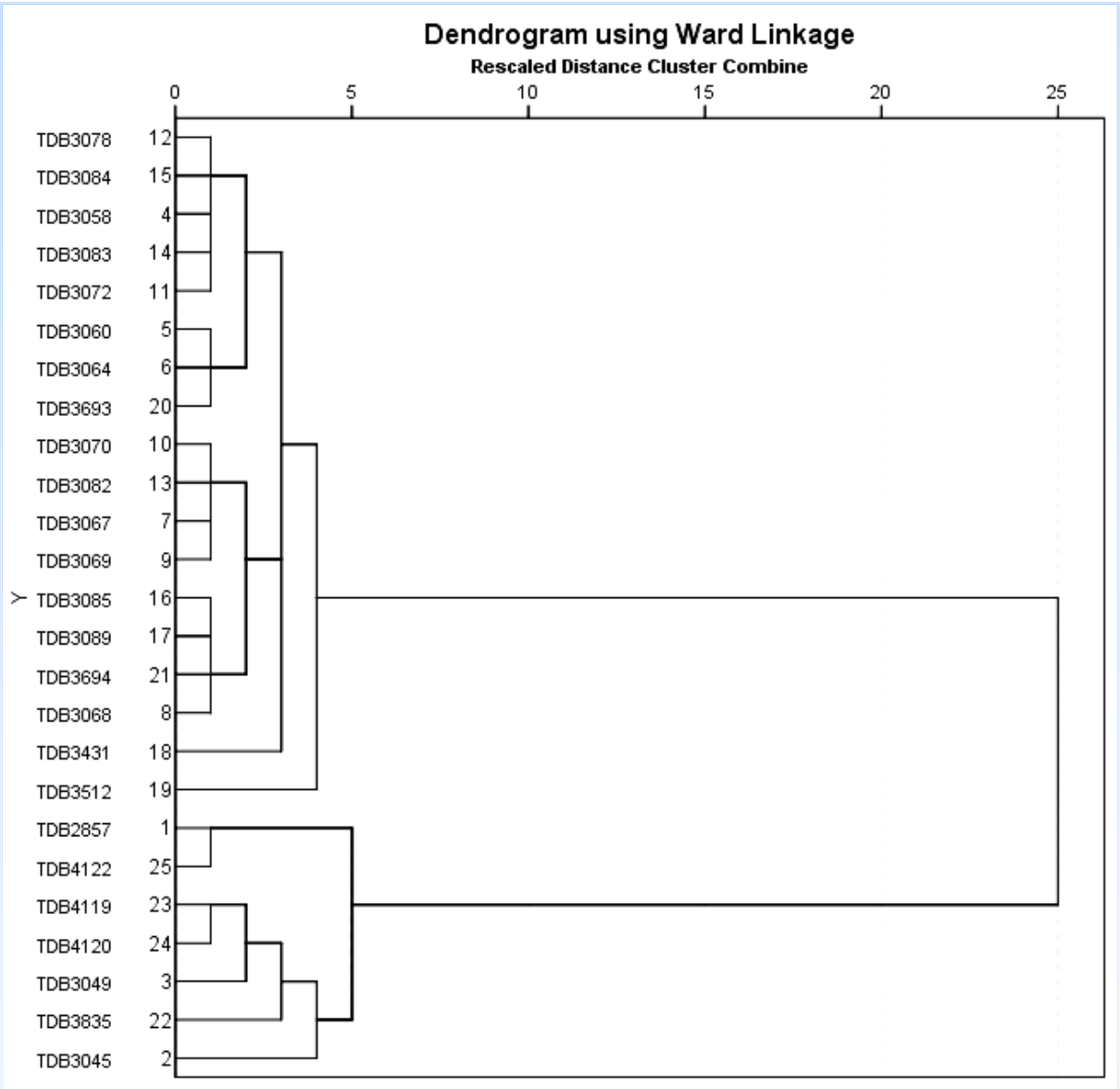

Figure 2: Cluster Pattern for Sixteen Qualitative Morphological Traits in 25 Accessions of *D. bulbifera* generated from Hierarchical Cluster Analysis using Ward's Method.