Borneo Journal of Resource Science and Technology (2023), 13(1): 108-119
DOI: https:doi.org/10.33736/bjrst.5277.2023

Morphometric Studies of Accessions of *Duranta erecta* L. (Vebernaceae) Complex in Nigeria

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Received: 25 December 2022 Accepted: 10 April 2023 Published: 30 June 2023

ABSTRACT

Studies were conducted to broaden the systematic knowledge of the genus *Duranta erecta* L., to contribute a better understanding of their taxonomic and evolutionary relationships. Previous studies have pointed out complexity in the taxonomy and nomenclature of the species. A total of 224 samples were collected from six geo-political zones of Nigeria, and were grouped into 38 accessions. The plants were compared using 21 morphological characters involving qualitative and quantitative characteristics. Multivariate analyses such as Principal Component Analysis (PCA) and Cluster Analysis (CA) were employed to evaluate the intraspecific variabilities. The results showed that all the plants exhibited significant differences in all the quantitative attributes with the variegated type having the longest and widest leaves ranging from 12.20 cm and 5.08 cm, respectively. The qualitative characters delimited the plants accessions into distinctive groups of eight morphological forms namely; green bush, yellow bush, variegated yellow, variegated white, variegated yellow double, plain yellow, broad green, thorny green type. The PCA showed that leaf length, leaf width, internode length and length of inflorescence were some of the quantitative characters while leaf shape, leaf colour, leaf margin, flower colour and leaf apex are some of the qualitative traits that accounted for the delimitation. Unpaired Weighted Group Multivariate Analysis (UPGMA) using the Euclidian separated the 38 accessions into two major clusters; cluster I (flower producing) and cluster II (non-flower producing) *D. erecta*. Morphological variations and field observations suggested that there could be gene flow among the accessions of *D. erecta* studied and gene flow is an important factor in population genetics, shaping the diversity of species.

Keywords: *Duranta erecta*, morphometric, morphology, Nigeria, taxonomy, Verbenaceae

INTRODUCTION

Duranta L. is a wide and popular genus in the family Verbenaceae, they are mostly shrubs, often with climbing habit. They are well adapted to tropical and warm subtropical areas, broadly developed as a decorative plant for its smooth yellow edges around the 1-2 inch-long, serrated leaves, and also for its gaudy flower and fruits that make it an attractive addition to the garden. It can be propagated by either seeds or stem cuttings (Robbins & Evans, 2006). Over the years there have been several reports (Munir, 1995; Sander, 2001; Moroni *et al.*, 2019) on the variation and discrepancies of *D. erecta*. *Duranta erecta* is one of the most important species in the genus, with an attractive leaf that comes in different colours and pale blue-purple to purple blossoms and meaty, brilliant yellow-orange fruits (Judd & Sanders, 1986).

There are a lot of discrepancies in the number of species in the genus *Duranta.* For example, there are four according to Schauer (1847), ten according to Walpers (1845) and six by Aymard and Grande (2012). Also, Moldenke (1981) listed about 30 species and 12 infraspecific taxa of *Duranta*; Sanders (2001) listed 17 species and 19 natural hybrids, while 34 species of the genus were listed by Troncoso (1974). The wide variation in habit, thorns, leaf, flower colour and shape, and margins of the leaves in this species has led to the publication of about 20 intra and inter-generic synonyms such as *D. erecta* L., *D. repens* L., *D. plumieri* Jacq. and *D. xalapensis* Kunth., *etc* (Martinez & Múlgura, 1997; Sanders, 2001).

The choice of this plant, *D. erecta* is because of its availability, abundance, easy to cultivate and uses for ornamental purposes especially in urban areas where heavy metal pollution is prevalent due to high industrial activities. The plant also exists in many forms, therefore, there is a need to review the existing infra specific grouping/classification. Adequate taxonomic understanding of the species complex will enhance optimal utilisation of the various forms in medicine, horticulture, ecological services and reduction of pollution by heavy metals.

MATERIALS AND METHODS

Field Work and Collection of Plant Materials

Exploration trips was undertaken between August 2017 and September 2018 to six geo-political zones in Nigeria covering 10 states *viz.* Oyo, Ondo (South-west), Plateau, Kwara (North-centra), Kebbi, Sokoto (North-west), Gombe and Maiduguri (North-east), Enugu (South- east) and Edo (South-south) for collections of the available samples of *D. erecta* (Table S1). A total of 224 samples were collected and maintained as living germplasms in the screen house of University of Ilorin Botanical Garden. The samples were later grouped into 38 accessions after several sorting. Dry and wet herbarium specimens of the collected samples were prepared where possible, following standard methods (Kolawole *et al*., 2016). All descriptions were based on the author's collections. Additional identifications were done through a literature survey and consultation of references with various flora related experts in the Herbarium of the University of Ilorin, Forest Research Institute of Nigeria (FRIN) and Herbarium of University of Ibadan, Pl@ntNet application software version (3.0.0) and PlantSnap application software version (1.12) for further identification.

Morphological Studies

Selection and scoring of qualitative and quantitative characters

A total of 22 morphological features comprising 10 quantitative morphological data (Table 1) and 12 qualitative characters (Table 2) encompassing both vegetative and reproductive features were evaluated for all samples of *D. erecta* investigated. Qualitative characters were scored as continuous characters while quantitative characters were counted and measured manually, employing electronic digital callipers and the standard metre ruler.

Table 1. Quantitative characters of some accessions of *Duranta erecta* in Nigeria

Code	Quantitative Character	Description
A01	Leaf length (cm)	Length of leaf from the start of the peduncle to the leaf tip. Measured with metre rule
A02	Leaf width (cm)	Width of leaf at the maximum width in transvers. Measured with metre rule
A03	Petiole length (cm)	Length of petiole from the base to the beginning of the leaf blade. Measured with Electronic Digital calliper
A04	Petiole width (cm)	Width of petiole at the maximum width in transverse. Measured with Electronic Digital calliper
A05	Length of inflorescence (cm)	Length of inflorescence from the bottom-most bract to the tip of the topmost bract. Measured with metre rule
A06	Internode length (cm)	Length from the beginning of a node to the other. Measured with metre rule
A07	Petal lengths (cm)	Length of a petal lobe from the tip to the beginning of the corolla tube. Measured with metre rule
A08	Number of flowers per inflorescence	Total number of flowers on inflorescence. Manually counted
A09	Corolla tube length (cm)	Length from the top of the corolla tube to the point of attachment to the calyx. Measured with metre rule
A10	Calyx tube length (cm)	Length from the tip of the teeth to the base of the pedicel. Measured with metre rule

Table 2. Qualitative characters of some accessions of *Duranta erecta* in Nigeria

Code	Qualitative character states	Description
B01	Leaf shape	0 = Ovate; 1 = elliptic; 2 = elliptical to ovate
B02	Leaf colour	0 = Green; 1 = Yellow; 2 = Variegated Yellow; 3 = Variegated White; 4 = Variegated yellow with plain; 5= Plain yellow
B03	Leaf apex	0 = acute; 1 = acuminate;
B04	Leaf type	1 = simple
B05	Leaf arrangement	0 = opposite and superposed; 1 = opposite and whorled; 2 = Opposite and Decussate
B06	Leaf margin	0 = entire to serrate; 1 = serrate; 2 = dentate; 3= entire
B07	Flower colour	0 = white; 1 = lilac; 2 = Purple; 3 = Bluish Purple; 4 = Absent
B08	Thorn	0 = present and twig like; 1 =present and spine like; 2 = absent
B09	Leaf base type	0 = Attenuate; 1 = Oblique; 2 = obtuse;
B10	Inflorescence spike	0 = dense; 1 = moderate; 2 = lax; 3 = Nil
B11	Fruit colour	0 = light orange; 1 = deep orange
B13	Leaf indumenta	0 = coriaceous; 1 = chartaceous

Statistical Analysis

Data obtained were subjected to Analysis of Variance (ANOVA) to detect significant differences among means at a probability level of ($p \geq 0.05$). The computation was carried out using Statistical Package for Social Sciences (SPSS) Version 20.0 software. Clustering was conducted using Unweighted Pair Group Method (UPGMA) algorithm on standardized variables with average linkage and squared Euclidean distances (Lance & Williams, 1967). For consensus, dendrograms were constructed using combinations of linkage, distance, and standardised and unstandardised variables and the results were consistent.

RESULTS

Survey, Collection and Evaluation

Two unusual forms were found in the northern zone which were recognized and coded as, Thorny green (TG) and Broad green (BG). TG is restricted to the North west while BG is restricted to the North east and the rest are scattered all over the geo-political zones of the country except Green bush (GB) and Yellow bush (Yb) which have the widest distributional area covering all zones. Yb was observed to have the highest number of accessions and populations particularly because it is widely grown as a hedge plant due to its bright colour and ability to resist drought. Other than BG, all other forms are found in at least two states. BG is the rarest form as only one accession was collected in the entire survey.

Qualitative Characteristics of The Studied Accessions

Table 3 shows the qualitative characteristics of the studied accessions of *D. erecta.* The 38 accessions displayed the typical morphology of the species with simple leaf, attenuate base, glabrous to slightly hairy leaf surface, stipules with an appendage, and racemose inflorescence. Each flower has the calyx and the corolla with the anther buried inside the corolla tube. They exhibit, however, some differences in morphological characters (e.g. leaf margin, leaf apex, orientation and indumentum).

The plants are erect in habit with decussate-opposite in a branching pattern, except for BG which has a weak branching growth pattern. The leaf shape varies from elliptic to ovate (at the lower portion or as old leaves and ovate leaves at the upper portion or as young leaves) while some accessions studied have ovate and elliptic leaves in the both upper and lower portion of the stem or branches. Variations were observed in the flower colour with Green bush having lilac colour, Thorny green with whitish petals, Yellow bush with purple colour, and Variegated white with bluish purple colour, however, Variegated yellow, Plain yellow and Variegated yellow double accessions did not produce any flower throughout the research. Regarding leaf colour six different colour types were observed which are green, yellow, variegated yellow, variegated white, and variegated yellow with plain yellow leaves and plain yellow in all the accessions.

Table 3. Qualitative attributes of the *Duranta erecta* accessions

Accession	Leaf shape	Leaf colour	Leaf apex	Leaf type	Leaf arrangement	Leaf margin	Flower colour	Thorn	Leaf base type	Inflorescence spike	Fruit colour	Leaf indument
1	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Coriaceous
2	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
3	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
4	Elliptic	Variegated white	Acuminate	Pinnate	Opposite and decussate	Dentate	Bluish-purple	Absent	Attenuate	Moderate	Orange	Coriaceous
5	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Coriaceous
6	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
7	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
8	Elliptic	Variegated white	Acuminate	Pinnate	Opposite and decussate	Dentate	Bluish-purple	Absent	Attenuate	Moderate	Orange	Coriaceous
9	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartecous
10	Elliptic	Green	Acuminate	Pinnate	Opposite and decussate	Dentate	White	Spine-like	Attenuate		Orange	Sub-Coriaceous
11	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
12	Elliptic	Variegated yellow with plain	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
13	Elliptic	Green	Acuminate	Pinnate	Opposite and decussate	Dentate	White	Absent	Attenuate	Moderate	Orange	Sub-Coriaceous
14	Elliptic	Plain Yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
15	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
16	Elliptic	Variegated yellow with plain	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
17	Ovate	Green	Acute	Pinnate	Opposite and decussate	Serrate	Bluish purple	Absent	Attenuate		Orange	Coriaceous
18	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
19	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
20	Elliptic	Variegated white	Acuminate	Pinnate	Opposite and decussate	Dentate	Bluish purple	Absent	Attenuate	Moderate	Orange	Coriaceous
21	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Coriaceous
22	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
23	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
24	Elliptic	Variegated white	Acuminate	Pinnate	Opposite and decussate	Dentate	Bluish Purple	Absent	Attenuate	Moderate	Orange	Coriaceous
25	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Coriaceous
26	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
27	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
28	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Coriaceous
29	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
30	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
31	Elliptic	Variegated yellow with plain	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
32	Elliptic	Plain Yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
33	Elliptic to ovate	Green	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Lilac	Absent	Attenuate	Moderate	Orange	Chartaceous
34	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Coriaceous
35	Elliptic	Variegated yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
36	Elliptic	Plain Yellow	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous
37	Elliptic to ovate	Yellow	Acute	Pinnate	Opposite and Whorl	Entire to serrate	Purple	Absent	Attenuate	Dense	Orange	Chartaceous
38	Elliptic	Variegated yellow with plain	Acuminate	Pinnate	Opposite and decussate	Dentate	Absent	Spine-like	Attenuate	None	Nil	Chartaceous

Quantitative Characteristics of the Studied Accessions

Table 4 shows the quantitative morphology of the *D. erecta* accessions studied. The results showed that they exhibited significant differences in all the ten (10) attributes considered in this study.

Significant longest ($p<0.05$) leaf length was observed in MAI004 (10.67), while the significant shortest ($p<0.05$) leaf length was recorded in EDO002 (2.80). It was observed from the result that all the Yb (i.e., 002) are statistically similar to GB (i.e., 001) while the variegated types are also similar to thorny green accessions.

MAI004 (5.08) had the significant broadest ($p<0.05$) leaf width. The significant narrowest ($p<0.05$) leaf width was observed in POR002 with the range of 1.07. However, this was not statistically different from all other Yb, GB and one of the variegated forms collected from Edo state EDO003 (2.35), respectively.

The petiole length showed significant variation among the accessions collected. GOM002 (0.33) had the significant shortest ($p<0.05$) petiole length and was not statistically different from the rest of the accessions except GOM004 (1.60) which recorded the significant highest. The lowest value for petiole width of the *D. erecta* accession was observed in POR002 (0.05) while the highest significant value was recorded in GOM004 (0.17). Significant highest ($p<0.05$) internode length was observed in MAI004 (0.12) while the significant lowest was recorded in POR002 (1.23).

It can be observed that there is not much variation observed in the flowers of the accession of *D. erecta* studied for this work. Therefore, it was observed that there was no variation observed for number of flowers per inflorescence while the highest for petals length, length of inflorescence, corolla tube length and calyx tube length was recorded in accession (ILR002: 0.70, MAI001: 6.53, ILR001: 0.67 and ILR004: 0.63), respectively.

Classification of Accessions

Based on the qualitative and quantitative characters, the 38 accessions of *D. erecta* studied were classified into eight different Operational Taxonomic Units (OTU) (Table 5).

Delimitation of Taxa by Means of Multivariate Analyses

Five out of the 22 attributes were detected as characters by successive rounds of cluster analyses. With a phenom line of 9.8 similarity level, the 38 accessions can be delimited into eight (8) clusters, herein considered as accepted forms of *D. erecta*, each of them characterised by a unique combination of characters. The characters are: leaf shape, leaf colour, flower colour to absence of flower, leaf apex and leaf margin.

In Figure 1, the first cluster in the phenograms (cluster A) consists of mixed forms of accessions comprising four Variegated yellow double (KEB004, EDO003, SOK004 and GOM004) with one Plain yellow accession (SOK002) which stands as intermediate between the first-two and the latter two accessions. The second group, cluster B, comprises two Plain yellow (GOM005 and EDO001) accessions and are morphologically similar to cluster A by having yellow leaf, dentate leaf margin and acuminate apex. Cluster C is well defined by variegated yellow leaf, dentate margin and acuminate apex which are the major characters binding them to Clusters A and B. The cluster consists of eight similar accessions (IBA003, AKU003, SOK003, MAI003, GOM003, ILR003, KEB003 and ENU003).

Cluster D also consists of two TG accessions (KEB002 and SOK001) and are readily distinguished by the presence of whitish flower. The leaf colour placed the form closer to cluster E that consist of six similar Variegated white accessions (ILR004, IBA004, AKU004, POR003, MAI004) with single accession of BG form (MAI001) which is morphologically different from the other members of the cluster in having serrated leaf margin and glabrous leaf and stands as cluster F.

Table 4. Quantitative attributes of the *Duranta erecta* accessions

Accession Name	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole width (cm)	Internode length (cm)	Petal length (cm)	Length of inflorescence (cm)	No. of flower per infloresence	Corolla tube length (cm)	Calyx tube length (cm)
ILR001	$5.37\pm0.07^{f-j}$	$2.32\pm0.24^{e-l}$	$0.77\pm0.15^{b-g}$	0.13 ± 0.03^{ab}	$2.73\pm0.89^{b-l}$	0.60 ± 0.06^{abc}	5.13 ± 0.35^{abc}	4.33 ± 0.33^{a}	0.67 ± 0.03^{b}	0.53 ± 0.03^{ab}
ILR002	3.90 ± 0.06^{ij}	1.48 ± 0.07^{kl}	$0.70\pm0.30^{b-g}$	0.10 ± 0.00^{abc}	1.43 ± 0.47^{kl}	0.70 ± 0.15^{a}	5.90 ± 0.38^{abc}	5.33 ± 1.45^{a}	0.60 ± 0.06^{bc}	0.47 ± 0.03^{ab}
ILR003	$9.60\pm0.35^{a-d}$	$3.30\pm0.12^{b-h}$	$1.00\pm0.21^{a-g}$	0.15 ± 0.03^{ab}	4.63 ± 0.47^{ab}	-	-	-	-	-
ILR004	$5.65\pm1.26^{e-i}$	$3.20\pm0.25^{b-i}$	$0.83\pm0.17^{a-g}$	0.12 ± 0.02^{abc}	$4.27\pm0.37^{a-e}$	0.43 ± 0.03^{efg}	6.37 ± 1.32^{ab}	4.67 ± 0.88^{a}	0.63 ± 0.03^{bc}	0.63 ± 0.09^{a}
IBA001	$5.70 \pm 0.20^{e-i}$	$2.22 \pm 0.16^{f-l}$	$0.73 \pm 0.15^{b-g}$	0.12 ± 0.02^{abc}	$1.80 \pm 0.70^{i-l}$	0.37 ± 0.03^{fg}	6.00 ± 0.53^{abc}	3.33 ± 0.88^{a}	0.57 ± 0.03^{c}	0.63 ± 0.03^{a}
IBA002	4.50 ± 0.51^{hij}	1.83 ± 0.15^{jkl}	$0.53 \pm 0.09^{d-g}$	0.08 ± 0.02^{bc}	$1.70 \pm 0.46^{i-l}$	$0.53 \pm 0.07^{b-e}$	4.50 ± 0.32^{bc}	3.00 ± 0.58^{a}	0.57 ± 0.03^{c}	0.57 ± 0.03^{a}
IBA003	9.27 ± 0.47^{abcd}	$3.03 \pm 0.18^{c-j}$	$1.10 \pm 0.30^{a-g}$	0.10 ± 0.00^{abc}	$3.83 \pm 0.03^{a-h}$	-	-	-	-	-
IBA004	9.20 ± 0.51^{abcd}	4.07 ± 0.03^{abc}	$1.20 \pm 0.27^{a-d}$	0.15 ± 0.03^{ab}	4.50 ± 0.15^{abc}	0.47 ± 0.03^{def}	5.30 ± 1.36^{abc}	4.33 ± 0.33^{a}	0.63 ± 0.03^{bc}	0.60 ± 0.06^{a}
KEB001	3.87 ± 0.27^{ij}	$1.93 \pm 0.12^{i-l}$	1.43 ± 0.07^{ab}	0.12 ± 0.02^{abc}	$2.00\pm0.29^{g-l}$	$0.53 \pm 0.03^{b-e}$	4.37 ± 0.33^{c}	3.33 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.50 ± 0.06^{ab}
KEB002	$7.10\pm0.15^{d-h}$	$3.03\pm0.29^{c-j}$	$0.77\pm0.09^{b-g}$	0.15 ± 0.03^{ab}	$3.63\pm0.68^{a-i}$	0.63 ± 0.03^{ab}	4.63 ± 0.64^{abc}	3.67 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.57 ± 0.07^{a}
KEB003	10.60 ± 1.99^{a}	$3.50\pm 0.79^{b-e}$	$0.87\pm0.20^{a-g}$	0.17 ± 0.03^{a}	$4.333\pm0.88^{a-d}$	-	-	-	-	-
KEB004	$8.10\pm0.47^{a-e}$	$2.28\pm0.67^{e-l}$	$0.53\pm0.19^{d-g}$	0.12 ± 0.02^{abc}	$1.97\pm0.59^{h-l}$	-	-	-	-	-
SOK001	$9.50\pm2.52^{a-d}$	4.22 ± 0.74^{abc}	0.40 ± 0.15^{efg}	0.17 ± 0.03^{a}	4.77 ± 1.52^{a}	0.47 ± 0.07^{def}	4.77 ± 0.55^{abc}	3.67 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.57 ± 0.03^{a}
SOK002	$7.63\pm0.87^{b-g}$	$2.58\pm0.22^{d-k}$	$0.62\pm0.10^{c-g}$	0.15 ± 0.03^{ab}	$3.20\pm0.81^{a-k}$	-	-	-	-	-
SOK003	$9.07\pm1.03^{a-d}$	$3.20\pm0.51^{b-i}$	$1.00\pm0.23^{a-g}$	0.15 ± 0.03^{ab}	$3.63\pm0.49^{a-i}$	-	-	-	-	-
SOK004	$7.90\pm1.40^{a-g}$	$3.017\pm0.36^{c-j}$	$0.67\pm0.09^{b-g}$	0.17 ± 0.04^{a}	$3.87\pm0.95^{a-h}$	-	-	-	-	-
MAI001	$8.87\pm0.23^{a-d}$	4.23 ± 0.03^{abc}	$1.33\pm0.0.29^{abc}$	0.12 ± 0.02^{abc}	4.53 ± 0.48^{abc}	0.43 ± 0.03^{dfg}	6.53 ± 1.53^{a}	3.67 ± 0.33^{a}	0.57 ± 0.03^{c}	0.37 ± 0.03^{b}
MAI002	4.50 ± 0.45^{hij}	1.83 ± 0.24^{jkl}	0.40 ± 0.06^{efg}	0.12 ± 0.02^{abc}	$2.07\pm0.37^{g-l}$	$0.53 \pm 0.03^{b-e}$	4.37 ± 0.33^{c}	3.33 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.50 ± 0.06^{ab}
MAI003	$8.80\pm0.20^{a-d}$	$3.48\pm0.09^{b-f}$	$0.75\pm0.09^{b-g}$	0.13 ± 0.02^{ab}	$3.77\pm0.46^{a-h}$	-	-	-	-	-
MAI004	10.67 ± 0.94^{a}	5.08 ± 0.60^{a}	$0.87\pm0.13^{a-g}$	0.12 ± 0.02^{abc}	4.87 ± 0.27^{a}	0.47 ± 0.03^{def}	5.97 ± 0.87^{abc}	4.67 ± 0.67^{a}	0.60 ± 0.00^{bc}	0.60 ± 0.06^{a}
AKU001	$5.70\pm0.20^{e-i}$	$2.22\pm0.16^{f-l}$	$0.63\pm0.15^{c-g}$	0.12 ± 0.02^{abc}	$1.80\pm0.75^{i-l}$	0.33 ± 0.03^{g}	5.87 ± 0.57^{abc}	2.67 ± 0.33^{a}	0.57 ± 0.03^{c}	0.60 ± 0.06^{a}
AKU002	4.47 ± 0.41^{hij}	$1.97\pm0.15^{i-l}$	$0.50\pm0.10^{d-g}$	0.08 ± 0.02^{bc}	1.67 ± 0.47^{jl}	0.47 ± 0.03^{def}	4.43 ± 0.39^{c}	4.67 ± 0.88^{a}	0.57 ± 0.03^{c}	0.50 ± 0.06^{ab}
AKU003	$9.15\pm0.53^{a-d}$	$3.03\pm0.23^{c-j}$	$1.07\pm0.32^{a-g}$	0.10 ± 0.00^{abc}	$3.80\pm0.06^{a-h}$	-	-	-	-	-
AKU004	$9.13\pm0.54^{a-d}$	4.03 ± 0.07^{abc}	$1.17\pm0.35^{a-e}$	0.13 ± 0.03^{ab}	4.60 ± 0.06^{ab}	0.43 ± 0.03^{efg}	5.07 ± 1.47^{abc}	4.00 ± 0.58^{a}	0.63 ± 0.03^{bc}	0.60 ± 0.10^{a}
POR001	$5.70\pm0.27^{e-i}$	$2.07\pm0.04^{h-l}$	$0.60\pm0.15^{c-g}$	0.10 ± 0.00^{abc}	$2.37\pm0.13^{e-l}$	0.60 ± 0.60^{abc}	4.70 ± 0.15^{abc}	3.00 ± 0.58^{a}	0.57 ± 0.03^{c}	0.53 ± 0.03^{ab}
POR002	3.07 ± 0.23^{ij}	1.07 ± 0.07^{k}	0.37 ± 0.07^{fg}	0.05 ± 0.00^{c}	1.23 ± 0.35^{l}	0.47 ± 0.03^{def}	4.43 ± 0.39^{c}	4.67 ± 0.88^{a}	0.57 ± 0.03^{c}	0.50 ± 0.06^{ab}
POR003	$8.35\pm1.75^{a-d}$	3.67 ± 0.44^{bcd}	$1.13\pm0.24^{a-f}$	0.15 ± 0.03^{ab}	$3.40\pm0.35^{a-j}$	0.47 ± 0.03^{def}	5.07 ± 0.38^{abc}	3.67 ± 0.67^{a}	0.67 ± 0.03^{b}	0.57 ± 0.03^{a}
GOM001	$5.67\pm0.33^{e-i}$	$2.10\pm0.12^{h-l}$	$0.57\pm0.03^{c-g}$	0.08 ± 0.02^{bc}	$2.93\pm0.35^{a-l}$	0.57 ± 0.03^{bcd}	5.50 ± 1.04^{abc}	5.00 ± 2.08^{a}	0.60 ± 0.00^{bc}	0.57 ± 0.03^{a}
GOM002	4.17 ± 0.33^{ij}	1.82 ± 0.06	0.33 ± 0.03^{g}	0.10 ± 0.00^{abc}	$2.03\pm0.42^{g-l}$	0.63 ± 0.03^{ab}	4.63 ± 0.64^{abc}	3.67 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.57 ± 0.07^{a}
GOM003	$9.50\pm1.40^{a-d}$	$3.53\pm0.57^{b-e}$	1.33 ± 0.17^{abc}	0.15 ± 0.03^{ab}	$3.93\pm0.30^{a-g}$	-	-	-	-	-
GOM004	$8.23\pm0.75^{a-e}$	$3.42\pm0.07^{b-g}$	1.60 ± 0.50^{a}	0.17 ± 0.02^{a}	$4.13\pm0.38^{a-f}$	-	-	-	-	-
GOM005	$9.40 \pm 0.81^{a-d}$	4.37 ± 0.72^{ab}	$1.00 \pm 0.10^{a-g}$	0.13 ± 0.02^{ab}	$2.60 \pm 0.70^{c-l}$	-	-	-	-	-
ENU001	$5.20\pm0.72^{g-j}$	$2.20\pm0.35^{g-l}$	$0.53\pm0.03^{d-g}$	0.10 ± 0.00^{abc}	$2.30\pm0.74^{f-l}$	$0.53 \pm 0.03^{b-e}$	4.37 ± 0.33^{c}	3.33 ± 0.88^{a}	0.60 ± 0.00^{bc}	0.50 ± 0.06^{ab}
ENU002	3.45 ± 0.13^{ij}	1.50 ± 0.00^{kl}	0.40 ± 0.06^{efg}	0.10 ± 0.00^{abc}	$1.70\pm0.30^{i-l}$	0.57 ± 0.03^{bcd}	5.77 ± 1.01^{abc}	5.00 ± 2.08^{a}	0.60 ± 0.00^{bc}	0.60 ± 0.06^{a}
ENU003	10.17 ± 0.58^{abc}	3.70 ± 0.15^{bcd}	$1.03\pm0.03^{a-g}$	0.15 ± 0.03^{ab}	$4.07\pm1.05^{a-f}$	-	-	-	-	-
EDO001	10.43 ± 1.28^{ab}	4.27 ± 0.67^{abc}	$1.00\pm0.12^{a-g}$	0.15 ± 0.03^{ab}	$2.60\pm0.70^{c-l}$	-	-	-	-	-
EDO002	2.80 ± 0.46^{j}	$2.27\pm0.97^{e-l}$	$1.23\pm0.88^{a-d}$	0.13 ± 0.03^{ab}	$1.93\pm0.64^{h-l}$	0.50 ± 0.06^{cde}	5.17 ± 0.49^{abc}	6.00 ± 0.58^{a}	0.57 ± 0.03^{c}	0.57 ± 0.03^{a}
EDO003	$7.40\pm0.58^{c-g}$	$2.35\pm0.54^{e-k}$	$0.97\pm0.03^{a-g}$	0.15 ± 0.03^{ab}	$2.50\pm0.00^{d-l}$	-	-	-	-	-

Cluster G consists of six similar GB accessions (IBA001, POR001, ENUOO1, AKU001, GOM001 and ILR001). They are defined by presence of serrate to entire leaf margin, acute apex lilac flower colour and elliptical leaf shape.

Cluster H share a common clade with cluster F in having elliptical leaf, acute apex, serrate to entire margin but produced a deeper purple flower colour and chartaceous indumentum. It consists of nine similar Yb accessions (IBA002, AKU002, MAI002, GOM002, KEB001, POR002, ILR002, ENU002 and EDO002). The dendrogram presents three broader groups which are designated herein as the sections of *D. erecta*. The first section consists of three major forms which are made up of the Variegated yellow, Variegated yellow double and Plain yellow. They are characterised as non-flower producing form (i.e., did not flower throughout the work), dentate margin and distinct golden yellow leaf colour. The second section is similar to the first in habit, shape and structure and consists of three different forms namely; TG, variegated white and BG accessions. They are characterised by distinct green leaf colour with wide internode. The third section is characterised by elliptical to ovate leaf shape, acute apex, and smaller leaf size. The section includes GB and Yb.

The plot of component 1 (PC1) versus component 2 (PC2) separated the 38 *Duranta erecta* accessions into five groups (Figure 2). PC1 higher scores are correlated with leaf length, leaf colour, flower colour, leaf margin, internode length and leaf width while lower scores are correlated with other characters. PC2 showed that the majority of the quantitative characters are positively correlated while the leaf type mainly characterised the variation that exist among the accessions. Six characters are negatively correlated which includes leaf shape, leaf colour, leaf type, flower colour, leaf base type, fruit colour and indumentum.

The first cluster is a mixture of Variegated white, TG and BG which are closely related. Cluster II is of different morphological forms which include ILR004 (Variegated white) and KEB002 (TG), closely joined together by reproductive parts which include length of florescence, numbers of flower per inflorescence, corolla tube length, calyx tube length, *etc*. Clusters III and IV consist GB and Yb, respectively. Cluster V revealed the largest group comprises of 15 mixed accessions of Variegated yellow *Duranta*, Variegated yellow double and Plain yellow.

Table 6 shows the eigenvalues and the percentage of the total variance calculated in the Principal Component Analysis (PCA) for the characters in the data matrix. All the vectors with an eigenvalue greater than one explained 97.44% of the total observed variations. The first six axes explained 70.48%, 15.88%, 6.41%, 1.82%, 1.43% and 1.42%, respectively.

Table 5. Qualitative and quantitative classification of accessions of *Duranta erecta*

Duranta form	Accession number	Place of collection
Green bush (GB) OTU1	1, 5, 21, 25, 28, and 33	Kwara, Oyo, Ondo, Plateau, Gombe, and Enugu
Yellow bush (YB) OTU2	2, 6, 9, 18, 22, 26, 29, 34 and 37	Kwara, Oyo, Kebbi, Bornu, Ondo, Gombe, Enugu, Edo and Plateau
Variegated yellow (VY) OTU3	3, 7, 11, 15, 19, 23, 30 and 35	Kwara, Oyo, Kebbi, Sokoto, Bornu, Ondo, Plateau, Gombe and Enugu
Variegated white (VW) OTU4	4, 8, 20, 24 and 27	Kwara, Oyo, Bornu and Ondo
Variegated yellow double (VYD) OTU5	12, 16, 31 and 38	Kebbi, Sokoto, Gombe and Edo
Plain yellow (YV) OTU6	14, 32 and 36	Sokoto, Gombe and Edo
Thorny green (TG) OTU7	10 and 13	Kebbi and Sokoto
Broad green (BG) OTU8	17 only	Bornu

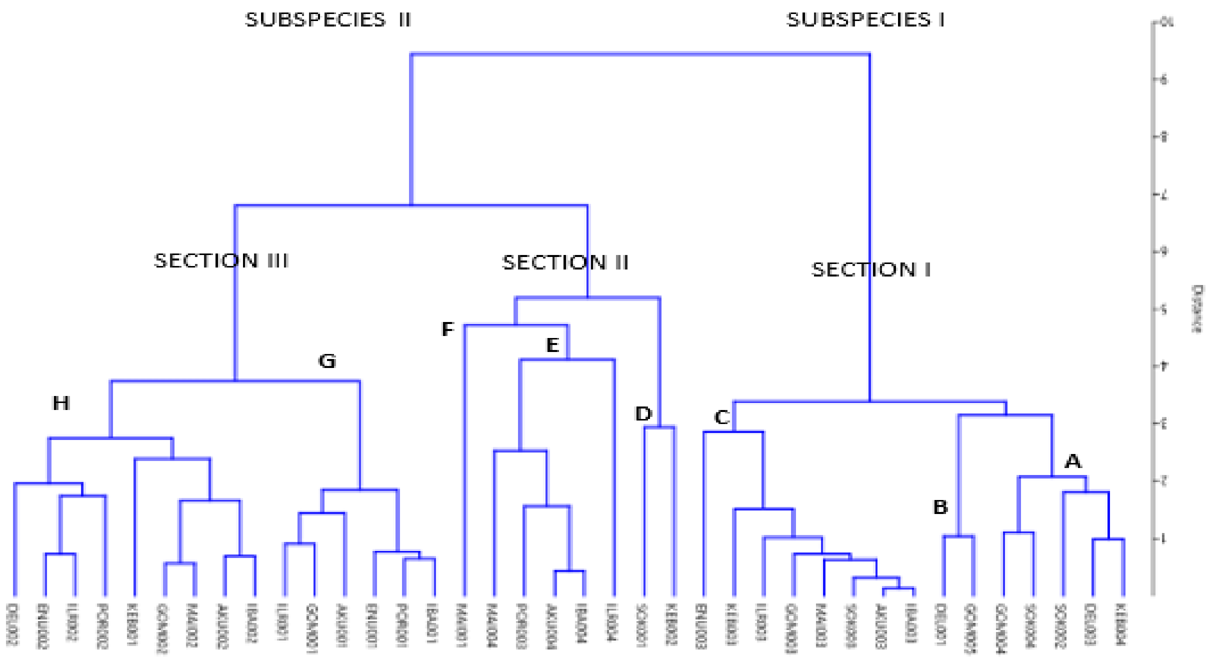

Figure 1. Dendrogram using average linkage between groups of morphological traits of the accessions of *Duaranta erecta*

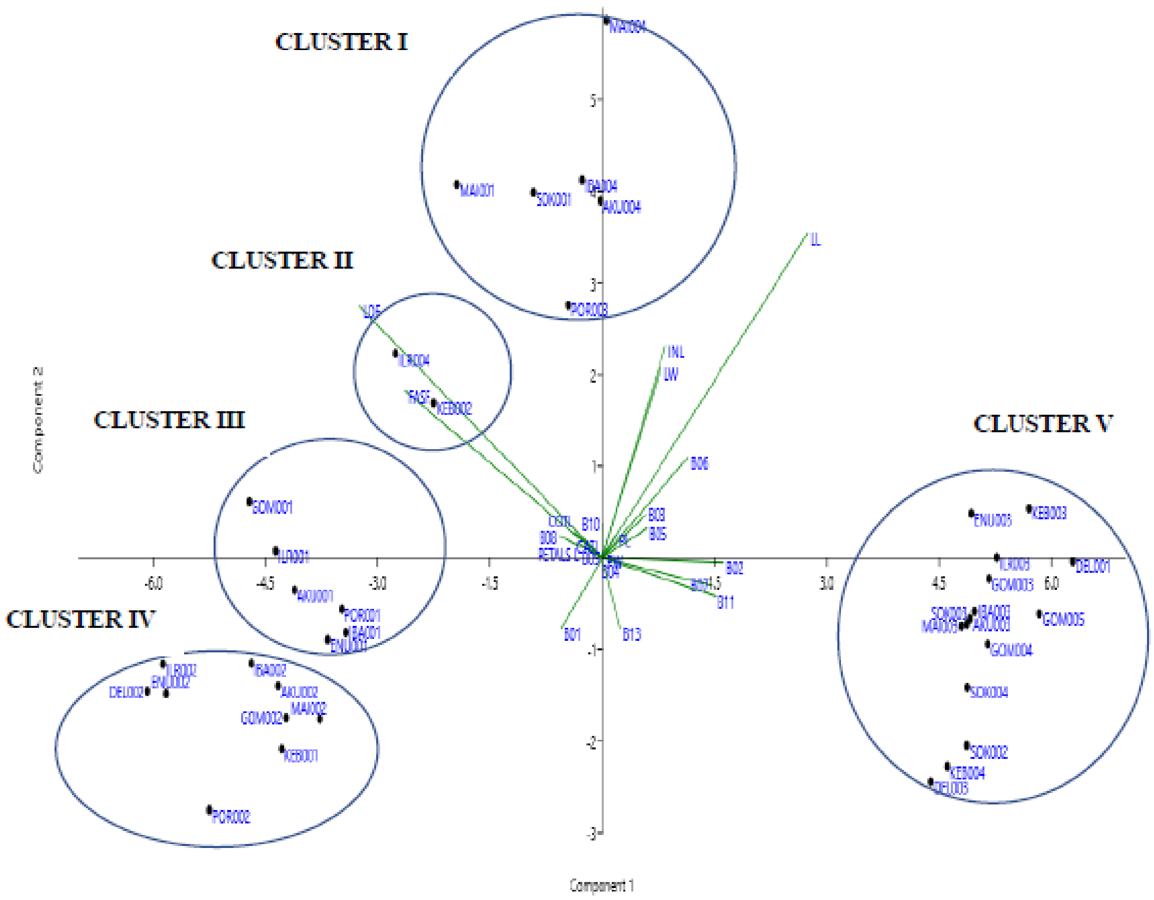

Figure 2. Ordination of the 38 accessions of *Duranta erecta* on principal component axes 1 vs 2

Table 6. Eigenvalues and percentages of the Principal Coordinates Analysis

PC	Eigenvalue	% variance	Cumulative %
1	19.8129	70.482	70.48
2	4.46305	15.877	86.36
3	1.80163	6.409	92.77
4	0.512011	1.8214	94.59
5	0.403069	1.4339	96.02
6	0.3984	1.4173	97.44
7	0.232241	0.82616	
8	0.176235	0.62693	
9	0.131794	0.46884	
10	0.0671645	0.23893	
11	0.0550755	0.19592	
12	0.0338551	0.12043	
13	0.0143262	0.050963	
14	0.0049608	0.017647	
15	0.00243971	0.0086789	
16	0.000965566	0.0034349	
17	0.000385836	0.0013726	
18	0.00022761	0.00080969	
19	3.78E-32	1.35E-31	
20	1.60E-32	5.69E-32	
21	6.15E-33	2.19E-32	

DISCUSSSION

Edmund *et al.* (2004) stated that the phenotype of members of the same species may vary continuously while their genotype is relatively stable throughout the life of the organisms because of the impact of the environment. For taxonomic purposes, variation based on the genetic makeup of the organisms is more reliable than variation induced by changes in environmental factors (Akinyele & Temikotan, 2005).

The initial level of differences in quantitative characters among the 38 *D. erecta* germplasms, therefore, may have been exaggerated by variation in the conditions obtainable in their places of cultivation. This will no doubt make some of these differences to be of no taxonomic value. Mahajan *et al.* (2007) reported that varieties selected from local landraces generally are adapted to the environments from which they were derived.

Since this study has eliminated the environmentally induced variations by bringing all the *D. erecta* accessions into cultivation under the same environmental factors, any character or trait that now shows significant variation is most likely to have a taxonomic value and genetic bearing on the plants.

The use of plant diagnostic characteristics to identify a variety has been a classical taxonomic approach for both varietal purity and variety identification (Suhasini, 2006; Pandey & Misra, 2009). The variation in size, structure and pubescence of the leaves is supported by the work of Markus (2011), who reported that cultivation of species within different temperature ranges (hot weather in the northern part and moderate temperature in the southern part) may lead to changes in flower, leaf shape and size between different seasons. The flower colour also varied from purple in GB to lilac in Yb, bluish-purple in BG and Variegated white, and white in TG. The Golden yellow types did not flower throughout the work and this was in tandem with the observation made by Jerry (2005) who reported that variegated *Duranta* are mostly cultivated for their foliage display (i.e., they rarely bloom or set fruit).

Depending on the species and their natural habitat, leaves in the dry season tend to be smaller, more coriaceous and covered with trichomes and stinging setae, while rainy season leaves are larger, less pubescent and carnose (e.g., Yb, GB, TG and the variegated types). This indicates that specimens collected during different seasons may appear quite different at first glance. Several observations by Sanders (2001) confirm this ontogenetic variability. Temperature, solar radiation, soil composition and water availability influence plant growth, but this may not explain the large morphological variability observed in *D. erecta* accessions since they were subjected to the same condition.

In taxonomic studies, diagnostic characters are characters that are constant within a group but vary between groups. Such characters could be used to identify natural plant groups from several others of similar ranking (Davis & Heywood, 1963; Crovello, 1974; Dunn & Everitt, 1982; Kent & Cooke, 1992). In numerical analysis, diagnostic characters exhibit high and absolute factor scores and are also capable of separating accessions under study into distinctive groups of eight morphological forms in the same species *D. erecta*. Though, the taxonomic affinities of the species in the genus *Duranta* have been variously reported (Walpers, 1845; Schauer, 1847; Troncoso, 1974; Moldenke, 1981; Sanders, 1984, 2001; Aymard & Grande, 2012) its complexity had left many taxonomic issues in the genus unraveled. From the PCA of the rotated factor score characters, the qualitative and quantitative characters were identified as diagnostic which grouped and separate the forms.

It was also observed that most of these diagnostic characters that had high influence on the separation of the groups were mostly quantitative. The quantitative diagnostic characters identified in this study could be described as not being always reliable taxonomic characters. Davis and Heywood (1963) reported that quantitative characters are easily modified by environmental factors. Nevertheless, such taxonomic characters could still be utilized in any taxonomic studies or considerations provided their genetic bases have been ascertained through a series of transplant experiments. In fact, according to Essilfie and Oteng-Yeboah (2013), there are some instances where quantitative morphological characters have been proven to have genetic bases. In related work, Popoola *et al*. (2015) also observed that some species in the genus *Vigna* are morphologically very variable but much of its variation is genetic.

By raising the accessions in the same location and subjected them to the same environment, the effects of the environment on their phenotypic expressions would have been removed or reduced, hence the variabilities observed are largely due to genetic factors and phenotypic similarities will be an indication of genetic relationships. Thus, the phenotypic groupings arising from the analysis reflect the closeness of the accessions in each group/cluster which suggests the potential cross ability of the members of the same group.

It can also be observed from the clustering of the PCA that the GB form a distinct cluster, so as the Yb (clusters III and IV respectively) while cluster I consist of mixed accessions. The BG (MAI001) with Variegated white (IBA004, AKU004 and POR003) and SOK001, all form a separate cluster. This shows that the accessions studied may be of hybrid origin while the GB may stand as the ancestor. Also, in cluster V, all the Variegated yellow clustered with variegated yellow double (GOM005, KEB004 and SOK004) and Plain yellow (EDO001). This is in correlation with the findings of Sander (1984) that *D. repens* collected from different localities could stem from a hybrid origin.

Cluster analysis on the basis of morphological attributes revealed the presence of genetic diversity and therefore indicated that there is an opportunity to maximize the expression of heterosis among the studied *D. erecta* complex. The wide genetic similarity coefficient implied that there is a great scope for improvement in breeding programmes on the eight clusters designated as forms.

Moroni *et al.* (2018) reported that the different *Duranta* accessions studied consist of almost identical habit sketches of branches with flowers and fruits. However, the pattern of variability among the accessions could be attributed to the phenotypic plasticity of the morphological characters studied. Generally, morphological features of plant species are significantly influenced by both intrinsic and extrinsic factors and, therefore, the wide morphological differences observed among the individual plants could be attributed to either environmental or genetic differences which are corroborated by the report of Singh *et al*. (2010) that differences observed among organisms are caused by three factors: variation that occurs as a result of developmental processes; variation in their genetic make-up; and variation due to environmental influences.

Morphological variation in length, width, orientation, apex and margin of the leaves and field observations suggest that there is gene flow among all the *D. erecta* accessions studied. Gene flow is an important factor in population genetics, shaping the diversity of species. More so, the similarity in the base of the leaf, inflorescent type, indumentum and present or absent of thorn clearly differentiate the *D. erecta.*

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the curator of Department of Plant Biology, University of Ilorin Herbarium and the laboratory technologists for the facilities provided and time given during the research works.

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