



Morphometric Studies of Representative Species in Three Tribes of Euphorbiaceae

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Abstract

Morphometric studies have been shown to be highly efficient in plant classification. A morphometric study was carried out to examine the phenetic relationships among and within representative species from three tribes of Euphorbiaceae in Nigeria using morphological characters. Fifteen samples of the species of Euphorbiaceae were collected from Ibadan representing the three tribes. Twenty six qualitative and quantitative morphological characters of the studied taxa were examined. Data recorded from the morphological characters were scored and converted to binary numbers necessary for generating clusters of the Operational Taxonomic Units (OTUs). PCA-biplot and cluster analysis were used to determine the relationships between the studied taxa. The result of the morphological study of the species of Euphorbiaceae revealed that all the species had simple leaves. The dendrogram generated from the cluster analysis of the studied taxa grouped the fifteen species into two main groups. Species within the same cluster display greater similarity when compared to those in the other cluster. *Acalypha hispida*, *A. indica*, *A. godseffiana*, *A. fimbriata*, *A. wilkesiana*, *Jatropha integerrima*, *J. gossypifolia*, *J. multifida*, *J. podagrica*, *J. curcas*, *Euphorbia heterophylla*, *E. graminea* in one group and *E. hyssopifolia*, *E. hirta* and *E. milii* in another main group. The stem, petiole and leaf surfaces played a significant role in the delimitation of the species. The results from this study have highlighted the existence of similarity and dissimilarity among the different species of Euphorbiaceae.

Key words: Euphorbiaceae, Dendrogram; morphometry; cluster analysis; PCA-biplot.

Introduction

Euphorbiaceae, also known as the spurge family, is a large family of flowering plants with over 300 genera and more than 7,500 species (Secco *et al.*, 2012; Webster, 1994). Euphorbiaceae is one of the most composite, large and diverse families among Angiosperms (Wurdack *et al.*, 2004). Members of the family show diverse growth forms ranging from small short-lived species to herbaceous annuals or herbaceous perennials, shrubs, small trees and cactus-like succulent species (Davis *et al.*, 2007). The species of Euphorbiaceae are dominant in the tropics. Nevertheless, some species are found in vegetations such as the Mediterranean sea, the Mid-East, South-Africa and southern America (Rahman and Akter, 2013; Davis *et al.*, 2007).

Plant species of remarkable economic value belong to this group. The utilization of species in this family is classified into varied forms. They are classified into food and fodder, medicine, hedges, ornamental, timber, fuel and others. Some of the species are still among the popularly known weeds of both the arable farmlands and forest plantation (Akobundu and Agyakwa, 1998). Examples of such plants species are cassava (*Manihot esculenta*), Rubber tree (*Hevea brasiliensis*), castor oil plant (*Ricinus communis*) and Physic nut (*Jatropha curcas*). Cassava ranks as the thirteenth most valuable staple crop in the world (Secco *et al.*, 2012). It ranks the fourth in terms of supply of carbohydrates for human consumption in the tropics, after rice, sugarcane and maize (Bellotti *et al.*, 1999). It serves as raw material for the production of starch, alcohol and biofuel (Jansson *et al.*, 2009). Rubber tree produces latex which forms the source of natural rubber. Castor oil plant produces tasteless and odorless vegetable oil. Physic nut is widely used to produce the non-edible *Jatropha* oil, for making candles and soap, and it is an important element in the production of biodiesel and various other natural products (Raja, 2011). Chenille plant (*Acalypha hispida*), copperleaf plant (*Acalypha wilkesiana*), Peregrina (*Jatropha integerrima*), crown of thorns (*Euphorbia milii*) etc are popularly used for ornamental beautification of landscapes (Mahendiran *et al.*, 2023; ASSEH Ebah Estelle *et al.*, 2025).

The leaves of the species of Euphorbiaceae are alternate and stipulate. They are rarely opposite. The leaves are simple. When the leaves are found to be compound, they are palmate but not pinnate. Stipules may be reduced to hairs, glands, or spines, or in succulent species are sometimes absent. The flowers are unisexual with a radial symmetrical. The species of Euphorbiaceae are either monoecious or dioecious. The androecium has about 1 to 10 numbers of stamen and sometimes more while the gynoecium has superior ovaries (Davis *et al.*, 2007).

Taxonomic studies provide a fast and accurate way to identifying plant species (Quicke, 1993). Morphometrics is a system whereby organisms are classified by numerical methods based on the organisms' character states. The character states are numerically encoded. It classifies organisms based on their affinity. It uses equally weighted characters and makes use of clustering and similar algorithms to achieve the objective classification. It has been widely utilized in many disciplines including systematic (Henderson, 2006). The outcome of morphometric analysis is usually considered to be unbiased marker of the similarity or difference between species. Furthermore, the outcome arranges the species in hierarchical order (Agbagwa, and Okoli, 2005; Quike, 1993). Morphometrics has previously been applied in the classification of a number of plant species (El-Gazzar, 2008; Dogan *et al.*, 2009; Soladoye *et al.*, 2010; Kolawole *et al.*, 2016).

The aim of this study is to contribute to the available knowledge on the taxonomic relationship of species within the family Euphorbiaceae.

The aim of this study is to quantitatively analyze and compare the morphological traits of representative species in three tribes of Euphorbiaceae. The major objective of the study was to confirm the phenetic relationships among some of the species and to determine taxonomic characters useful in the delimitation and identification of the species studied.

Materials and Methods

Selection and Collection of Plants Species

Three tribes (Acalypheae, Jatropheae and Euphorbieae) were selected in Euphorbiaceae s.s. for this study. Five species were sampled for each of the three subtribes making a total of fifteen species. Twigs bearing inflorescence from mature plants of the fifteen species from the three subtribes of Euphorbiaceae were collected from different locations in Oyo State, Nigeria. The different locations where samples were collected are shown in Table 1. The collections were identified at the Herbarium of the Department of Botany, University of Ibadan, Ibadan and at the Herbarium of the Forestry Research Institute of Nigeria (FHI), Ibadan. Voucher specimens of all the species were prepared.

A total of twenty six characters were selected for the morphological study. The characters were both quantitative (10) and qualitative (16). Quantitative characters were measured using line ruler and the Vernier caliper. The quantitative morphological measurements were done using a minimum of five samples for each species studied. Observations and measurements for each Operational Taxonomic Unit (OTU) on quantitative and qualitative characters were compiled and recorded. Quantitative characters recorded are: Leaf length, Petiole length, Leaf width, Petiole width, Internodes length, Blade length, Peduncle length, Inflorescence length, Leaf length/blade length ratio, Leaf length/leaf width ratio. Qualitative characters recorded are: Plant habit, Leaf colour, Leaf arrangement, Leaf shape, Leaf surface, Leaf apex, Leaf base, Leaf margin, Flower colour, Inflorescence type, Leaf venation, Inflorescence position, Stem surface, Petiole surface, Stem outgrowth, Petiole colour.

Morphometric Analysis

Morphometric analysis was performed on each of the species under study. The raw data recorded for the qualitative and quantitative morphological characters were coded to allow for cluster analysis. The mean and standard error were calculated for all the quantitative characters. The principal component analysis (PCA) and cluster analysis (Unweighted Pair Group Method with Arithmetic mean) were computed based on the data recorded in order to show the phenetic relationships among and between the species studied. The analysis was performed on the data using Palentological Statistics, ver. 2.17c (PAST).

Table 1: Collection Sites and voucher information of the Species Of Euphorbiaceae studied

Species/ V.No	Place of Collection	Coordinates
<i>Acalypha hispida</i> Burm. F/FHI 112822	Botanical garden, University of Ibadan	N7°27'28; E3°53'49
<i>A. indica</i> Forssk./FHI 112821	Botanical garden, University of Ibadan	N7°26'35; E3°54'9
<i>A. godseffiana</i> Mast./FHI112828	Along Balewa way, University of Ibadan	N7°26'37; E3°53'46
<i>A. fimbriata</i> Schumach. & Thonn./FHI 112820	Forestry Research Institute of Nigeria, Jericho, Ibadan	N7°23'14; E3°52'10
<i>A. wilkesiana</i> Mull.Arg./ FHI 112819	Botanical garden, University of Ibadan	N7°27'28; E3°53'49
<i>Jatropha integerrima</i> Jacq./ FHI 112813	Microbiology dept, University of Ibadan	N7°26'32; E3°53'51
<i>J. gossypifolia</i> L./ FHI112815	Nursery Unit, Botany Dept, University of Ibadan	N7°26'32; E3°53'51
<i>J. multifida</i> L./ FHI 112817	Microbiology dept, University of Ibadan	N7°26'32; E3°53'51
<i>J. podagrica</i> Hook./ FHI 112816	Nursery Unit, Botany Dept, University of Ibadan	N7°26'32; E3°53'51
<i>J. curcas</i> L./ FHI 112810	Botanical garden, University of Ibadan	N7°27'28; E3°53'49
<i>Euphorbia hyssopifolia</i> L./ FHI 112823	Beside Gate car park, University of Ibadan	N7°26'32; E3°54'11
<i>E. hirta</i> L./ FHI 112818	Botanical garden, University of Ibadan	N7°27'28; E3°53'49
<i>E. milii</i> Des Moul./ FHI 112814	Microbiology dept, University of Ibadan	N7°26'37; E3°53'46
<i>E. heterophylla</i> L./ FHI 112812	Crop protection dept., University. of Ibadan	N7°26'56; E3°53'48
<i>E. graminea</i> Jacq./ FHI 112811	Botanical garden, University of Ibadan	N7°27'28; E3°53'49

Results

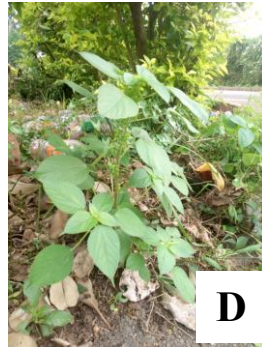


Plate 1 (A-E): Images of *Acalypha* species

- A: *A. hispida*
- B: *A. indica*
- C: *A. godseffiana*
- D: *A. fimbriata*
- E: *A. wilkesiana*



Plate 2 (A-E): Images of *Jatropha* species

- A: *J. integerrima*
- B: *J. gossypifolia*
- C: *J. multifida*
- D: *J. podagrica*
- E: *J. curcas*

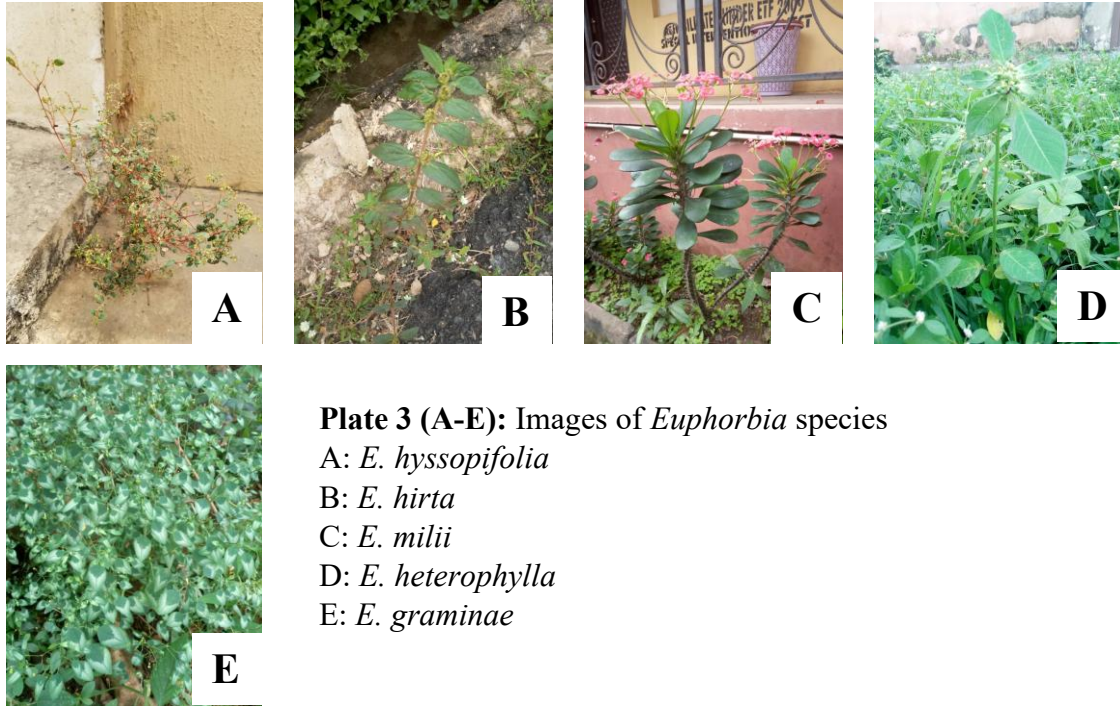


Plate 3 (A-E): Images of *Euphorbia* species

A: *E. hyssopifolia*

B: *E. hirta*

C: *E. milii*

D: *E. heterophylla*

E: *E. graminea*

Qualitative morphological characters studied are shown in Table 2 (A and B). The species of Euphorbiaceae may be shrubs e.g. *Acalypha hispida*, *A. godseffiana*, *A. wilkesiana*, *Jatropha integerrima*, *J. gossypifolia*, *J. multifida*, *J. podagrica*, *J. curcas* and *Euphorbia milii* or herbs e.g. *A. indica*, *A. fimbriata*, *E. hyssopifolia*, *E. hirta*, *E. heterophylla* and *E. graminea*. The species are characterized by simple leaves which may be ovate, elliptic-ovate, orbicular, peltate, oblong and ovate-lanceolate; and may be pubescent or glabrous on their leaf, stem and petiole surfaces.

The leaf apex may be acuminate, attenuate, acute and obtuse with leaf base that may be cuneate, cordate, peltate, oblique or attenuate and leaf margins that is serrate, crenate, dentate entire or lobed. The inflorescence may be a spike or a cyme with a terminal or axillary position. Flowers may be red, green, greenish yellow or pink. The stems of the species studied are without outgrowth except for *E. milii* with projected spines. Petioles may be green, purple, copper-red with leaf venation that is either pinnate or palmate. The leaves have spiral, alternate or opposite arrangement. *E. heterophylla* and *E. graminea* show both opposite and alternate arrangement.

Table 2A: Qualitative Morphological Characters of the Species of Euphorbiaceous studied

S/N	Species/Character	Plant Habit	Leaf Color	Leaf Arrangement	Leaf Shape	Leaf Surface	Leaf Apex	Leaf Base	Leaf Margin
1	<i>Acalypha hispida</i>	Shrub	Green	Alternate	Ovate	Pubescent	Acuminate	Cuneate	Serrate
2	<i>A. indica</i>	Herb	Green	Alternate	Ovate	Pubescent	Acuminate	Cuneate	Serrate
3	<i>A. godseffiana</i>	Shrub	Green/white margin	Alternate	Elliptic-Ovate	Pubescent	Acuminate	Cuneate	Crenate
4	<i>A. fimbriata</i>	Herb	Green	Alternate	Ovate	Pubescent	Acuminate	Cuneate	Serrate
5	<i>A. wilkesiana</i>	Shrub	Copper red	Alternate	Ovate	Pubescent	Acuminate	Cuneate	Dentate
6	<i>Jatropha. integerrima</i>	Shrub	Green	Alternate	Ovate	Pubescent	Acuminate	Cordate	Entire
7	<i>J. gossypifolia</i>	Shrub	Green	Alternate	Ovate	Pubescent	Acuminate	Cordate	Lobed
8	<i>J. multifida</i>	Shrub	Green	Alternate	Orbicular	Glabrous	Attenuate	Cordate	Lobed
9	<i>J. podagrica</i>	Shrub	Green	Alternate	Peltate	Glabrous	Acute	Peltate	Lobed
10	<i>J. curcas</i>	Shrub	Green	Alternate	Ovate	Glabrous	Acute	Cordate	Lobed
11	<i>Euphorbia hyssopifolia</i>	Herb	Green	Opposite	Oblong	Glabrous	Acute	Oblique	Serrate
12	<i>E. hirta</i>	Herb	Green	Opposite	Ovate-lanceolate	Pubescent	Acuminate	Oblique	Serrate
13	<i>E. milii</i>	Shrub	Green	Spiral	Obovate	Glabrous	Obtuse	Attenuate	Entire
14	<i>E. heterophylla</i>	Herb	Green	Alt/Opp	Ovate	Pubescent	Acute	Attenuate	Entire
15	<i>E. gramineae</i>	Herb	Green/white patch	Alt/Opp	Ovate	Pubescent	Acute	Attenuate	Entire

Table 2B: Qualitative Morphological Characters of the Species of Euphorbiaceae studied

S/N	Species/Character	Flower Colour	Inflorescence Type	Leaf Venation	Inflorescence Position	Stem Surface	Petiole Surface	Stem Outgrowth	Petiole Colour
1	<i>Acalypha hispida</i>	Red	Spike	Pinnate	Axillary	Pubescent	Pubescent	Absent	Green
2	<i>A. indica</i>	Green	Spike	Pinnate	Axillary	Pubescent	Pubescent	Absent	Green
3	<i>A. godseffiana</i>	Green	Spike	Pinnate	Axillary	Pubescent	Pubescent	Absent	Green
4	<i>A. fimbriata</i>	Green	Spike	Pinnate	Axillary	Pubescent	Pubescent	Absent	Green
5	<i>A. wilkesiana</i>	Red	Spike	Pinnate	Axillary	Pubescent	Pubescent	Absent	Copper red
6	<i>Jatropha. integerrima</i>	Red	Cyme	Pinnate	Terminal	Pubescent	Pubescent	Absent	Purple
7	<i>J. gossypifolia</i>	Red	Cyme	Palmate	Terminal	Pubescent	Pubescent	Absent	Purple
8	<i>J. multifida</i>	Red	Cyme	Pinnate	Terminal	Glabrous	Glabrous	Absent	Green
9	<i>J. podagrica</i>	Red	Cyme	Palmate	Terminal	Glabrous	Glabrous	Absent	Green
10	<i>J. curcas</i>	Greenish yellow	Cyme	Palmate	Terminal	Glabrous	Pubescent	Absent	Green
11	<i>Euphorbia hyssopifolia</i>	Green	Cyathium	Pinnate	Axillary	Glabrous	Glabrous	Absent	Purple
12	<i>E. hirta</i>	Green	Cyathium	Pinnate	Axillary	Pubescent	Pubescent	Absent	Purple
13	<i>E. milii</i>	Pink	Cyathium	Pinnate	Axillary	Glabrous	Glabrous	Present	Green
14	<i>E. heterophylla</i>	Greenish yellow	Cyathium	Pinnate	Terminal	Pubescent	Pubescent	Absent	Green
15	<i>E. gramineae</i>	Green	Cyathium	Pinnate	Axillary	Glabrous	Glabrous	Absent	Green

Quantitative morphological characters in the species of Euphorbiaceae s.s studied are shown in Tables 3 (A and B). The mean leaf length and the mean petiole length ranged from 2.36 cm to 36.96 cm and 0.13 cm to 21.78 cm in all the species with the lowest mean recorded in *E. hyssopifolia* and the highest mean in *J. podagrica* respectively. The lowest mean leaf width (0.31 cm) was recorded in *E. hyssopifolia* and the highest mean leaf width (26.34 cm) was recorded in *J. multifida*. The lowest petiole width mean (0.10 cm) was recorded in *E. gramineae*, *E. hyssopifolia*, *E. hirta* and *A. fimbriata* while the highest mean petiole width (0.65 cm) was recorded in *J. podagrica*.

The lowest mean internode length (0.54 cm) was recorded for *J. multifida* and the highest internode length's mean (6.22 cm) was recorded for *E. heterophylla*. The species showing the lowest mean blade length (2.27 cm) in all the samples studied was *E. hyssopifolia* and the highest mean (19.54 cm) was recorded for *A. hispida*. The mean peduncle length (0.10 cm) was recorded for *E. hyssopifolia* and *E. heterophylla* as the lowest mean while *J. podagrica* recorded the highest mean (28.06 cm). The lowest mean inflorescence length (0.42 cm) was recorded by *E. heterophylla*, while the highest mean (32.40 cm) was recorded by *J. podagrica*. *J. podagrica* recorded the highest ratio of mean leaf length and mean blade length (2.56) while the lowest mean ratio (1.06) was recorded by *E. hyssopifolia* and *E. milii*. The ratio of the mean leaf length

to mean leaf width ranges from 1.24 cm to 7.90 cm. The lowest mean leaf length to mean leaf width ratio was recorded by *A. godseffiana* and the highest mean was recorded by *E. hyssopifolia*.

Table 3A: Quantitative Morphological Characters of the Species of Euphorbiaceae studied

S/N	SPECIES	Lowest (Mean ± Standard error mean) Highest (cm)				
		LL (cm)	PL (cm)	LW (cm)	PW (cm)	INL (cm)
1	<i>Acalypha hispida</i>	29.90(32.10±0.76)34.30	10.60(12.56±0.57)13.80	15.00(15.26±0.15)15.80	0.30(0.31±0.01)0.33	1.20(2.50±0.56)3.90
2	<i>A. indica</i>	8.80(9.40±0.23)10.20	4.30(5.14±0.27)5.70	3.20(3.50±0.13)3.80	0.10(0.12±0.01)0.14	1.10(1.42±0.14)1.80
3	<i>A. godseffiana</i>	13.90(15.78±1.00)18.40	2.10(2.92±0.45)4.60	11.50(12.74±0.55)14.60	0.45(0.46±0.01)0.49	2.00(2.42±0.24)3.30
4	<i>A. fimbriata</i>	10.60(11.62±0.40)12.40	3.90(4.90±0.31)5.50	3.60(3.90±0.10)4.20	0.10(0.10±0.00)0.11	2.30(2.56±0.07)2.70
5	<i>A. wilkesiana</i>	15.20(17.84±1.20)21.60	3.00(4.64±0.50)6.00	6.50(7.78±0.74)10.60	0.29(0.30±0.00)0.31	1.20(1.46±0.09)1.70
6	<i>Jatropha. integerrima</i>	14.20(18.34±1.42)22.20	5.90(7.68±0.67)8.90	5.20(8.24±0.48)11.80	0.20(0.22±0.01)0.24	1.30(1.42±0.03)1.50
7	<i>J. gossypifolia</i>	25.20(27.04±0.82)29.60	10.90(12.84±0.58)14.40	15.50(16.42±1.11)18.10	0.33(0.35±0.01)0.38	1.70(1.98±0.09)2.20
8	<i>J. multifida</i>	26.00(35.50±3.43)45.40	14.60(18.42±1.96)25.50	22.50(26.34±1.43)29.90	0.35(0.37±0.01)0.40	0.40(0.54±0.50)0.70
9	<i>J. podagrica</i>	32.20(36.96±2.00)41.90	17.00(21.78±2.21)29.50	21.20(24.72±1.46)28.60	0.61(0.65±0.01)0.68	0.70(1.00±0.24)1.20
10	<i>J. curcas</i>	27.00(29.18±0.82)31.50	14.50(16.12±0.63)18.00	14.70(16.20±0.49)17.50	0.20(0.26±0.02)0.31	1.20(2.16±0.36)3.00
11	<i>Euphorbia hyssopifolia</i>	2.00(2.36±0.07)2.60	0.10(0.13±0.02)0.20	0.26(0.31±0.02)0.40	0.10(0.10±0.00)0.10	2.20(2.50±0.13)2.90
12	<i>E. hirta</i>	3.20.90(3.68±0.18)4.10	0.27(0.29±0.01)0.30	1.10(1.60±0.13)1.80	0.09(0.10±0.00)0.11	1.20(2.52±0.48)3.90
13	<i>E. milii</i>	10.40(11.38±0.28)12.10	0.60(1.06±0.12)1.30	4.10(4.42±0.10)4.60	0.27(0.28±0.00)0.30	0.60(0.73±0.01)0.90
14	<i>E. heterophylla</i>	10.90(12.06±0.30)12.60	2.00(3.42±0.56)5.10	4.60(5.12±0.24)6.00	0.10(0.11±0.00)0.12	4.90(6.22±0.48)7.20
15	<i>E. graminea</i>	6.00(6.62±0.22)6.62	2.20(2.40±0.08)2.60	2.00(2.66±0.17)2.90	0.10(0.10±0.00)0.10	3.90(4.50±0.33)5.40

Keys:

LL: Leaf length LW: Leaf width
 PL: Petiole length INT: Internode length
 PW: Petiole width

Table 3B: Quantitative Morphological Characters of the Species of Euphorbiaceae studied

S/N	SPECIES	Lowest (Mean ± Standard error mean) Highest (cm)				
		BL (cm)	PDL (cm)	IL (cm)	LL/BL	LL/LW
1	<i>Acalypha hispida</i>	17.80(19.54±0.49)20.50	1.40(1.68±0.12)2.10	25.00(30.98±2.53)37.00	1.66(1.68±0.01)1.69	2.00(2.11±0.05)2.29
2	<i>A. indica</i>	3.50(4.08±0.21)4.60	0.60(0.94±0.10)1.20	2.90(3.24±0.12)3.50	1.96(2.33±0.11)2.63	2.50(2.70±0.07)2.88
3	<i>A. godseffiana</i>	11.40(12.90±0.86)15.90	3.80(4.26±0.12)4.50	7.20(8.44±0.41)9.60	1.14(1.22±0.03)1.33	1.05(1.24±0.08)1.52
4	<i>A. fimbriata</i>	6.20(6.72±0.15)7.10	0.25(0.35±0.0)0.40	2.10(2.36±0.09)2.60	1.57(1.73±0.04)1.82	2.55(3.00±0.17)3.39
5	<i>A. wilkesiana</i>	10.70(13.20±0.83)15.60	1.90(2.54±0.30)3.30	7.20(8.80±0.67)10.40	1.23(1.35±0.03)1.42	2.04(2.30±0.10)2.52
6	<i>Jatropha. integerrima</i>	13.60(14.40±0.29)15.30	11.90(14.14±0.97)16.70	16.10(19.96±1.39)24.40	1.44(1.64±0.05)1.74	1.77(2.31±0.16)2.73
7	<i>J. gossypifolia</i>	8.30(10.78±0.87)13.30	4.50(5.56±0.59)7.20	11.60(13.80±0.83)15.70	1.74(1.89±0.04)2.00	1.49(1.63±0.04)1.70
8	<i>J. multifida</i>	11.40(15.98±1.65)20.90	13.20(16.18±1.34)20.80	16.40(19.92±1.43)24.70	1.98(2.18±0.07)2.40	1.16(1.30±0.06)1.46
9	<i>J. podagrica</i>	12.00(14.78±1.16)18.90	24.40(28.06±1.71)33.50	27.50(32.40±2.47)41.10	2.12(2.56±0.23)3.46	1.41(1.50±0.04)1.65
10	<i>J. curcas</i>	12.50(13.06±0.37)14.30	3.80(3.94±0.07)4.20	7.90(8.42±0.25)9.20	2.11(2.24±0.05)2.36	1.59(1.81±0.08)2.01
11	<i>Euphorbia hyssopifolia</i>	2.10(2.27±0.06)2.40	0.10(0.10±0.00)0.10	0.61(0.69±0.02)0.81	1.05(1.06±0.01)1.08	6.50(7.90±0.36)8.46
12	<i>E. hirta</i>	2.90(3.38±0.19)3.80	0.80(1.00±0.07)1.20	1.10(1.36±0.08)1.60	1.08(1.09±0.00)1.10	1.83(2.41±0.35)3.73
13	<i>E. milii</i>	9.80(10.72±0.35)11.80	7.10(9.44±0.62)10.40	10.00(12.12±0.55)13.00	1.01(1.06±0.02)1.11	2.53(2.57±0.02)2.63
14	<i>E. heterophylla</i>	6.90(8.64±0.93)10.00	0.10(0.010±0.00)0.10	0.32(0.42±0.04)0.53	1.20(1.42±0.10)1.70	2.00(2.49±0.18)3.02
15	<i>E. graminea</i>	2.80(4.02±0.34)4.70	1.00(1.48±0.24)2.30	1.20(1.68±0.24)2.50	1.48(1.69±0.14)2.25	2.25(2.51±0.13)3.00

Keys:

BL: Blade length LL/BL: Ratio of leaf length and blade length
 PDL: Peduncle length LL/LW: Ratio of leaf length and leaf width
 IL: Inflorescence length

The results of hierarchical clustering analysis are presented in the form of dendrograms, which are diagrams of relationship. Figure 1 shows the dendrogram of the combination of quantitative and qualitative morphological characters made up of twenty six characters. Two major clusters are recognized. The first group 1 is made up of a combination of *Jatropha* species, *Acalypha* species and two *Euphorbia* species (*E. heterophylla* and *E. graminea*). Group 1 is divided into two clusters. The *Euphorbia* species formed the first sub-group while *Jatropha* species and *Acalypha* species formed the second sub-group. Group two is made up of the remaining three species; *E. hyssopifolia*, *E. milii* and *E. hirta*. It is interesting that the *Euphorbia* species are dispersed in to the two major groupings. The *Euphorbia* species are dispersed to the two groupings on the basis of their leaf arrangement.

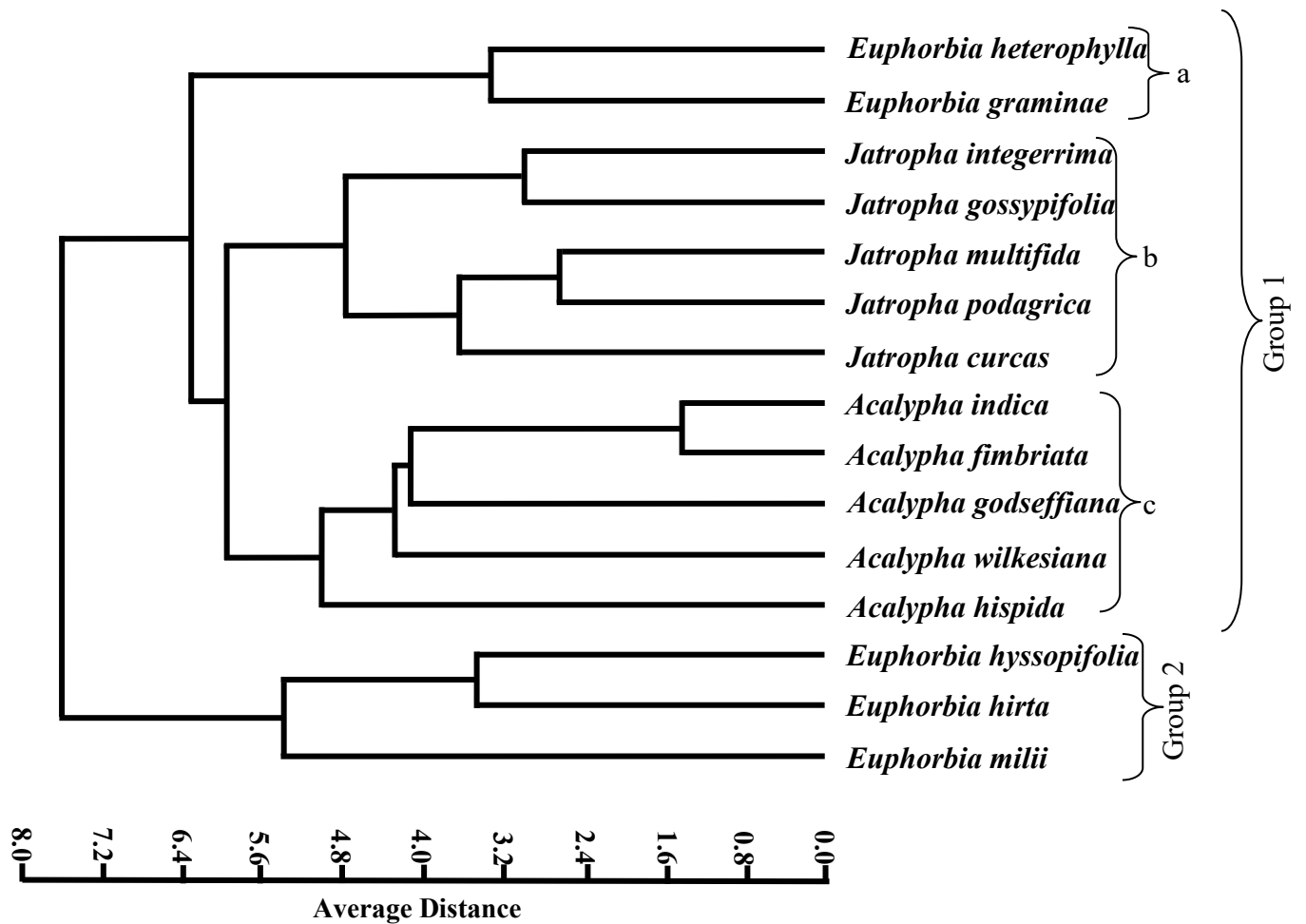


Fig. 1: Dendrogram showing the relationship among some species of the Euphorbiaceae s.s based on morphological characters.

The scree plot in Fig. 2, shows the number of principal components (PC) that can be retained for the principal component analysis (PCA). The first PC had 37.06% while the second PC contained 25.23% of the total variance. An assumption was reached that the two-component solution with a cumulative variance of 62.29 % was adequate for circumscribing the species of Euphorbiaceae for the analysis of the principal components.

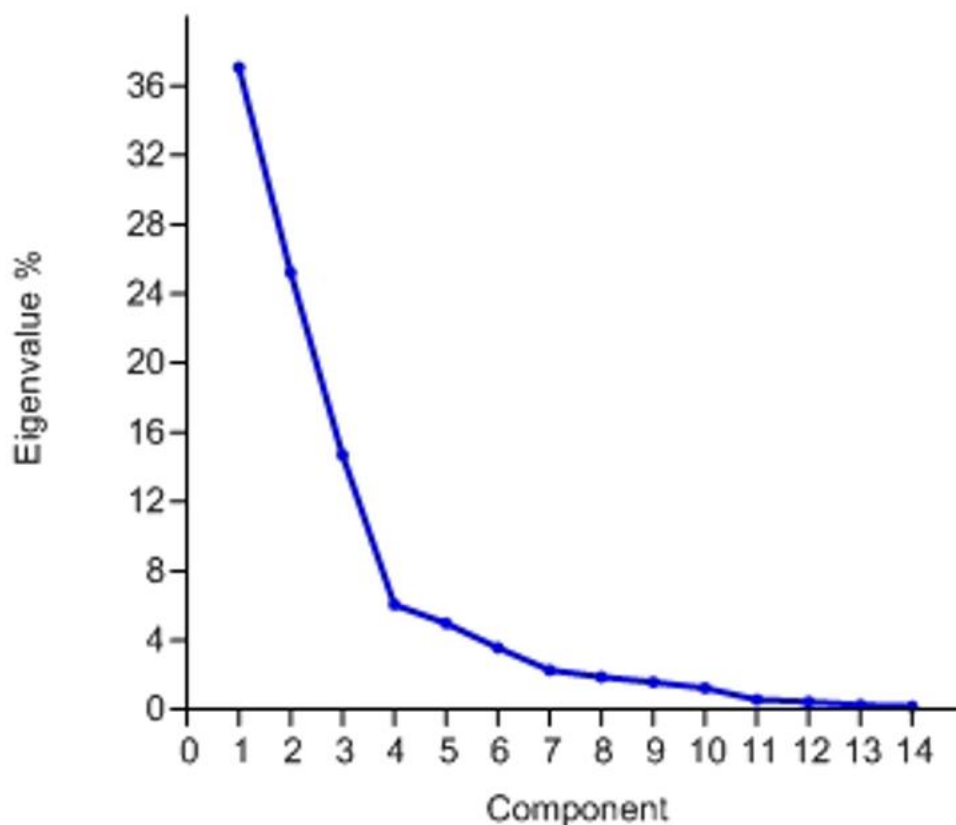


Fig. 2: Scree plot for the morphological characters of the species of Euphorbiaceae

The clustering of the 15 species against 26 characters was performed to show the underlying relationships among the species. The principal component biplot of PC 1 against PC 2 (Fig. 3) showed the joint performances of the species. Species 2 (*A. indica*) and 4 (*A. fimbriata*) showed strong similarities among the species across traits. Strong relationship was also shown between species 8 (*J. multifida*) and 10 (*J. curcas*), between species 11 (*E. hyssopifolia*) and 12 (*E. hirta*) and between species 14 (*E. heterophylla*) and 15 (*E. gramineae*). Weak similarities were observed between species 6 (*J. integerrima*) and 7 (*J. gossypifolia*) and also between species 1 (*A. hispida*) and 5 (*A. wilkesiana*). Species 13 (*E. milii*) was observed to be an outlier. The principal component biplot showed that there was strong correlation between stem surface (W), petiole surface (X) and leaf surface (O) in the circumscription of the species of Euphorbiaceae studied.

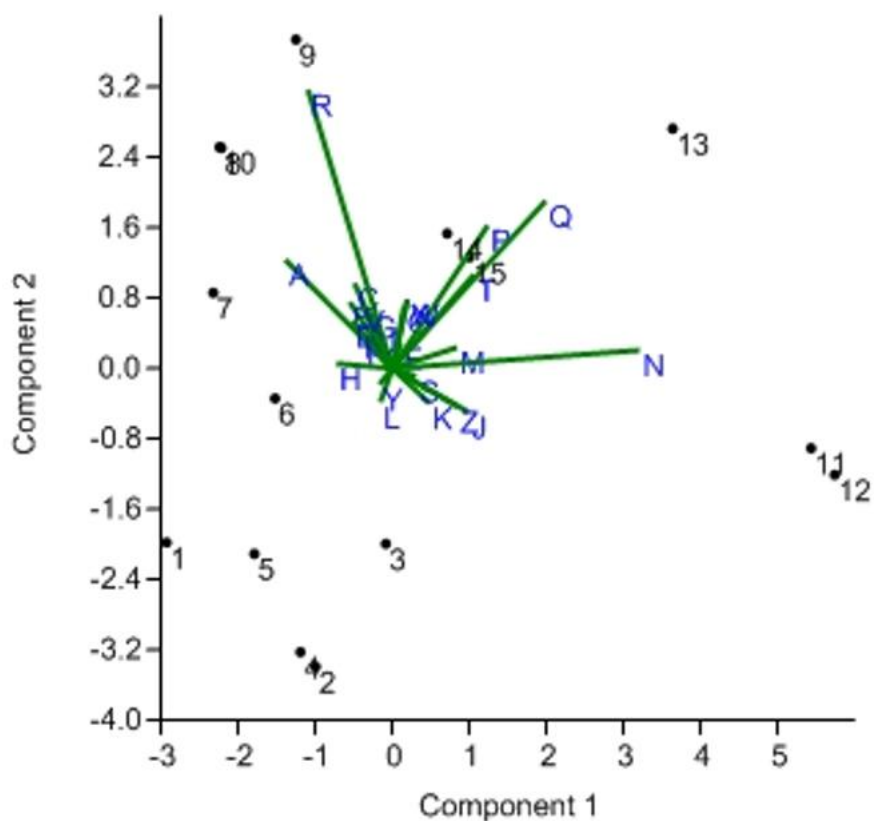


Fig. 3: PCA biplot for the morphological characters of the species of Euphorbiaceae

Discussion

Plant morphological characters are utilized for the identification, classification and description of plants, thereby resolving taxonomic problems (Cope, 2012). Taxonomy depends significantly on morphological characters to delimit groups. Leaf morphological characters are essential to Plant taxonomists and Systematics (Viscosi and Cardini, 2011). The taxonomic use of leaf morphological characters has been reviewed by several researchers (Ayodele and Olowokudejo, 1997; Ogundipe and Ayodele, 2000; Kadiri *et al.*, 2012). Particularly, leaf morphological characters have been utilized in delimiting the species of Euphorbiaceae (Soyewo *et al.*, 2015; Essiett *et al.*, 2012; Kadiri *et al.*, 2009). The value of flowers and inflorescences in taxonomic delimitation of species cannot be overemphasized. Many researchers have also highlighted the usefulness of inflorescences in characterizing plants species (Kaya, 2003; Celep and Dogan 2010; Kahraman and Dogan, 2010).

The species of the family showed uniformity in the leaf type but are varied in plant habit. Most species of *Acalypha* and *Jatropha* are shrubs with the exceptions of *A. indica* and *A. fimbriata*. The species of *Euphorbia* are herbaceous with the exception of *E. milii* being a shrub. Leaf arrangement was predominantly alternate across all the species of *Jatropha* and *Acalypha* but opposite among the species of *Euphorbia* with the exceptions of *E. milii*, *E. graminea* and *E. heterophylla*. *Euphorbia heterophylla* and *E. graminea* had opposite arrangement clustered at the upper layer while alternate arrangements were formed in the lower layer. All the species have ovate, orbicular, peltate, obovate, ovate-lanceolate or elliptic ovate leaf shape; axillary or terminal inflorescence position; acuminate, acute, attenuate or obtuse leaf apex; cuneate, cordate, peltate, oblique or attenuate leaf base; serrate, dentate, crenate, lobed or entire leaf margin.

Morphological characters can be susceptible to environmental factors. Leaf shapes and sizes have been reported by different authors to vary within the same plant as influenced by light intensity interacting with the leaves, thereby affecting the carbohydrate balance. The imbalance in the carbohydrate content affects the length of the cells in the direction of the long axis. This process gives rise to the differences in the length, shapes and width of the leaves (Campey *et al.*, 2000; Wilson *et al.*, 1998). Even though characters that are easily influenced by the environment constitute bad characters, they can still be used in taxonomical studies in as much as the genetic bases for such plasticity are ascertained through a series of transplant experiment (Essilfie and Oteng-Yeboah, 2013).

The biological circumscription of plant species with a high speculative measure is based on the correlation between two or more characters (Goldman *et al.*, 2004). The Principal component analysis allows for the selection of the most significant characters in the discrimination of study groups (Kucharczyk, 2010). The Principal component analysis compares sample groups, taking into consideration the value of their characters. Diagnostic characters exhibit high and absolute factor scores which are capable of separating taxa under study into distinctive groups.

From the principal component analysis, it was observed that *A. indica* and *A. fimbriata* showed strong similarities. Strong relationship was also shown between *J. multifida* and *J. curcas*, between species *E. hyssopifolia* and *E. hirta* and between *E. heterophylla* and *E. graminea*. Weak similarities were observed between *J. integerrima* and *J. gossypifolia* and also between *A. hispida* and *A. wilkesiana*. *E. milii* was observed to be an outlier. The biplot component of the PCA indicated that characters such as stem surface, petiole surface and leaf surface were identified as diagnostic. It was also observed that these characters were qualitative in nature.

The dendrogram of the cluster analysis highlighted a strong relationship among the species based on the 26 morphological characters. The morphological tree topology showed a close relationship among the species under study. The species were clustered into two main groups. A close relationship was observed between the pair of *J. integerrima* and *J. gossypifolia*. They were delimited by pubescent leaf, stem and petiole surfaces. This relationship was collaborated by Opeyemi *et al.* (2014), who worked on the quantitative phytochemical constituents of the genus *Jatropha* and Opeyemi *et al.* (2016), who did a morphometric study of several species of the genus *Jatropha*. However, Oladipo and Illoh (2012) carried out a comparative wood anatomy study of five *Jatropha* species including *J. integerrima* and *J. gossypifolia*. They discovered differences in wood anatomical features such as vessel and ray cell characteristics. Although they observed a close relationship in the wood anatomy, they emphasized that these two species are classified differently based on vegetative morphology and epidermal characters.

The close relationship between the pair of *J. multifida* and *J. podagrica* was as a result of their glabrous leaf, stem and petiole surfaces. This relation is in line with their fruit, seed, and pollen morphology, which highlights relatedness thereby differentiating them from other *Jatropha* species (Abdulrahman *et al.*, 2014). *Acalypha fimbriata* and *A. indica* formed a close relationship. **Leong-Škorničková & Chase (2012)** studied sequences from nuclear ribosomal ITS and plastid regions (such as trnL-F) to reconstruct a molecular phylogeny of *Acalypha*. They confirmed that *A. fimbriata* and *A. indica* show close taxonomic relationship.

Euphorbia hirta and *E. hyssopifolia* showed a close relationship. The two species were included in the clade Hypericifolia (Yang and Berry, 2011). Kursat *et al.*, 2016 studied the cytological aspect of the two species and discovered differences in their genome size and chromosomes numbers. They speculated that the difference could be as a result of their individual evolution.

Conclusion

The quantitative morphometric analysis carried out on representative species across three tribes of Euphorbiaceae successfully confirmed the phenetic relationships among the species studied. The research identified distinct morphological features that proved valuable as taxonomic characters for

species delimitation and accurate identification. These findings do not only enhance understanding of the morphological variation within Euphorbiaceae but also provide a reliable framework for future taxonomic revisions and systematic studies within the family. In general, the study underscores the effectiveness of morphometric analysis in resolving taxonomic relationships and improving species classification in complex plant groups such as Euphorbiaceae.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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