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Original Article

Morphometric Study of Several Species of the Genus *Jatropha* Linn. (Euphorbiaceae)

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Abstract

Morphological parameters of several *Jatropha* species, namely *Jatropha curcas* L., *Jatropha gossypifolia* L., *Jatropha podagrica* Hook., *Jatropha integerrima* Jacq. and *Jatropha multifida* L. were subjected to quantitative analysis within the present study. Twelve traits of the leaves, fruits and seeds were analysed: leaf length, leaf width, leaf length/width ratio, petiole length, petiole width, fruit length, fruit width, fruit length/width ratio, seed length, seed width, fruit stalk length and fruit stalk width were subjected to Principal Component Analysis (PCA) and cluster analysis. Highly significant positive correlations have been noted, while negative correlation was observed between leaf width and leaf length/width ratio, fruit width and leaf length/width ratio. Traits such as leaf length, leaf width and leaf length/width ratio contributed significantly along with other traits to discriminate the studied *Jatropha* species. *J. podagrica* and *J. integerrima* were found to have more similarities, with a stronger coefficient of agglomeration (69.072) than *J. curcas* and *J. podagrica* with 315.028 coefficient of agglomeration respectively. The generated dendrogram showed the relationship between the studied *Jatropha* species, whereas great affinity was noted between *J. podagrica* and *J. multifida* as compared with *J. gossypifolia* and *J. integerrima* which are distantly related. The closeness observed between *J. podagrica* and *J. multifida* is in line with their current sub-generic grouping.

Keywords: cluster analysis, fruits, *Jatropha* species, leaves, PCA, seeds, taxonomy

Introduction

Jatropha L. is a morphologically diverse and geographically widespread genus of 150-175 woody species (Dehgan, 1982). The genus *Jatropha* belongs to the family *Euphorbiaceae* and is a very diverse subtropics and tropical genus which includes succulent, caudiciform species, herbaceous perennial and woody species (Nwokocha *et al*., 2011).

Hutchinson and Dalziel (1958) recognized 8 species of *Jatropha* in West-Tropical Africa, while Ratha and Paramathma (2009) described 12 species of *Jatropha* in India, using morphological traits. A range of economic importance of *Jatropha* species has been reported, most especially *J. curcas* yields oil of highly marketable biodiesel value (Agarwal and Agarwal, 2007; Akbar *et al.,* 2009). The oil is used in the manufacture of candle, soap and cosmetics industry (Nwokocha *et al.*, 2011). *J. curcas* also has a great potentiality in the rehabilitation of degraded soil (Achten *et al.*, 2007; Damisa *et al.*, 2008; Kumar *et al.*, 2008; Koyejo *et al.*, 2010) and it is a drought resistant plant that has wide adaptability to varied climate and soils. In addition, *J. podagrica* Hook. seeds yield 40% of oil known as pinheon oil or "oil infernale" (Joubert *et al.*, 1984). *J. integerrima* Jacq. makes a delightful shrubs border plant with its eye catching red flowers (Oladipo and Illoh, 2012) and it contains a potential lethal toxin called curcin. A leaf decoction of *J. gossypifolia* is used routinely by herbalists in the urban areas to stop nose, gum and skin bleeding. Further, leaf decoction of *J. gossypifolia* has been used for bathing wounds, while its seeds are used as purgative and for treatment of body aches.

Morphometrics represent the quantitative analysis of biological form that has been widely used in a lot of discipline including systematics (Henderson, 2006). Morphometrics, known as numerical taxonomy, is the application of various mathematical procedures to encode characters. The practice of numerical taxonomy embraces numbers of fundamental assumptions and philosophical attitudes towards taxonomic work. It has the ability to integrate data from a variety of sources such as anatomy, cytology, ecology, genetics, geography, physiology, palynology, chemistry etc. (Soladoye *et al*., 2010b).

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The products of such determinations are often considered to be unbiased indicators of the similarity or differences between the taxa, which are used to arrange taxa in hierarchy (Quike, 1993). The method of morphometrics or numerical taxonomy has been used in classifying many plants, as well as interpreting results of the taxonomic studies (Sonibare *et al*., 2004; Abu Zaida *et al*., 2008; El-Gazzar, 2008; Soladoye *et al.,* 2010b).

The present study has therefore aimed at using the morphometrics method to observe the differences and similarities in the morphological characters used to discriminate *Jatropha* species. The objective of the study is to determine the traits that would contributed strongly to the delimitation of the taxa based on their similarities.

Materials and Methods

Plant collection

Mature plant specimens from the field and herbarium were used for the study. The fresh specimens were collected in open vegetation, from roadsides and bushy areas in various parts of South-Western Nigeria, while herbarium specimens were accessions previously collected from different parts of Nigeria and preserved in the Forest Herbarium, Ibadan, FHI, Nigeria (Table 1). Upon collection of fresh plants, voucher specimens were prepared according to the established protocol of Soladoye *et al.* (2010a).

In this study, twenty-five accessions of each species were examined. Some traits which were difficult to assess accurately or were unsuitable for rapid and accurate scoring were eliminated. Thus, twelve traits were recorded as employed for the morphometric study: leaf length and width, leaf length/ width, petiole length, petiole width, fruit length, fruit length/width, seed length, seed width, fruit stalk length and fruit stalk width.

Morphometric and statistical analysis

Morphometric analysis was carried out on field and on herbarium specimens of each of the five species of the genus *Jatropha*. The measurements regarded the length and width of leaves, petiole, fruit, seed and fruit stalk using a line ruler and an electronic digital calliper graduated in millimetres (later converted to centimetres). The length of the leaf was obtained by spreading on a white sheet of paper on the laboratory bench and the longest part was measured; the same procedure was used for the width of vegetative parts. These measurements were then compiled for each Operational Taxonomic Unit (OTU).

Table 1. Voucher information and distribution of fresh and herbarium specimens of studied *Jatropha* species

Plant species	Herbarium specimen
Jatropha curcas L.	FHI 108927, FHI 109620, FHI 109865, FHI 86744, FHI 108432
Jatropha gossypifolia L.	FHI 108011, FHI 108195, FHI 83442, FHI 44937, FHI 109863
Jatropha podagrica Hook.	FHI 107676, FHI 64394, FHI 14509, FHI 43496, FHI 109871
Jatropha integerrima Jacq.	FHI 109864, IFE 16420
Jatropha multifilda L.	FHI 109458, FHI 108012, FHI 96651, FHI 31400, FHI 109872

The corresponding mean figures of the recorded measurements keyed into a Microsoft Excel spreadsheet and SPSS 16.0 statistical software analysis sheet. The Principal Components Analysis (PCA) and Cluster Analysis were computed based on the 12 selected quantitative traits measured.

Results

Morphological parameters of five *Jatropha* species (Table 1) were examined with numerical methods. The mean and standard deviation of the quantitative morphological traits employed are presented in Table 2. Similarities matrix on correlation of *Jatropha* species (Table 3) showed that close resemblance of species could be observed when certain characters are employed. For instance, when leaf length was correlated with leaf width, the degree of affinity was 0.816 and 0.338 when correlated with petiole width, but when leaf length was correlated against leaf length, it was 1,000. Similarly, when leaf width was correlated with leaf length/width ratio, the degree of resemblance was -0.317, whereas it was 0.380 when compared with fruit width and 1.000 when correlated against fruit width. The results revealed highly significant positive correlations among almost all the analysed traits. Negative correlation was observed between leaf width and leaf length/width ratio, fruit width and leaf length/width ratio.

The cumulative Principal Component Analysis is presented in Table 4. At least three of the traits (leaf length, leaf width and leaf length/width ratio) contributed greatly to the delimitation of the studied taxa.

Differences based on morphometry of *Jatropha* species are noted in Table 5, representing the agglomeration schedule of the studied *Jatropha* species as viewed from the perspective of cluster.

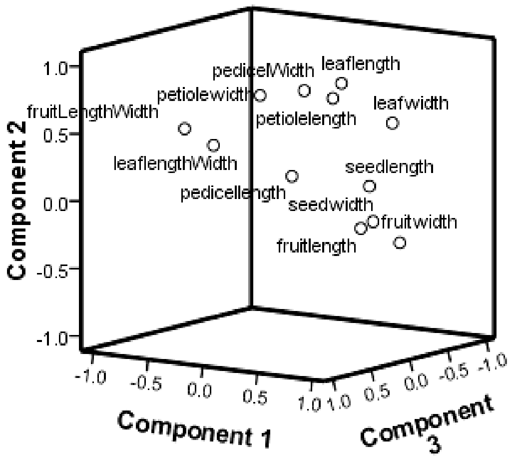

Fig. 1. Component plot in rotated space for the twelve morphological traits examined among *Jatropha* species; Component 1: petiole width; Component 2: fruit length/ width; Component 3: leaf length/ width

Table 2. Quantitative traits of *Jatropha* species scored for leaves, petiole, seeds and fruits

Plant species	Leaf length (mm)	Leaf width (mm)	Leaf length/width	Petiole length (cm)	Petiole width (cm)	Fruit length (cm)	Fruit width (cm)	Fruit length/width	Seed length (cm)	Seed width (cm)	Fruit stalk length (cm)	Fruit stalk width (cm)
Jatropha curcas L.	14.34±2.14	13.71±2.52	15.65±3.95	15.65±0.12	0.310±0.06	2.87±0.21	2.59±0.24	1.11±0.051	1.60±0.149	1.10±0.138	3.71±2.16	0.294±0.10
Jatropha gossypifolia L.	8.04±2.16	10.04±2.3	0.80±0.050	7.51±2.30	0.44±0.27	1.39±0.31	1.408±0.34	0.98±0.13	0.62±0.02	0.41±0.08	0.89±0.30	0.52±0.20
Jatropha podagrica Hook.	21.62±4.48	22.32±4.930	0.975±0.06	20.49±3.05	0.771±0.27	1.763±0.17	1.52±0.19	1.17±0.06	1.20±0.39	0.642±0.24	2.26±0.92	0.97±0.04
Jatropha integerrima Jacq.	13.04±2.34	9.80±3.326	1.461±0.47	9.037±2.56	0.204±0.05	1.83±0.02	1.84±0.03	1.19±0.02	0.58±0.02	0.38±0.03	0.45±0.01	0.12±0.02
Jatropha multifilda L.	15.58±1.42	24.25±2.63	0.646±0.056	15.32±2.42	0.281±0.10	2.814±0.22	1.78±1.55	0.947±0.34	1.63±0.534	1.28±0.036	2.09±0.26	0.79±0.01

Mean ± Standard deviation

Table 3. Correlation matrix based on quantitative traits of the studied *Jatropha* species

Traits	Leaf length	Leaf width	Leaf length/ width	Petiole length	Petiole width	Fruit length	Fruit width	Fruit length/ width	Seed length	Seed width	Fruit stalk length	Fruit stalk width
Leaf length	1.000											
Leaf width	0.816[ab]	1.000										
Leaf length/width	0.258[a]	-0.317[ab]	1.000									
Petiole length	0.671[ab]	0.553[ab]	0.187[a]	1.000								
Petiole width	0.338[ab]	0.129	0.240[a]	0.352[ab]	1.000							
Fruit length	0.158	0.287[ab]	0.017	0.240[a]	-0.401[ab]	1.000						
Fruit width	0.033	0.380[ab]	-0.483[ab]	0.006	-0.325[ab]	0.448[ab]	1.000					
Fruit length/width	0.150	-0.268[ab]	0.613[ab]	0.135	0.377[ab]	-0.357[ab]	-0.947[ab]	1.000				
Seed length	0.445[ab]	0.522[ab]	0.071	0.470[ab]	-0.266[ab]	0.889[ab]	0.383[ab]	-0.238[a]	1.000			
Seed width	0.224[a]	0.415[ab]	-0.092	0.270[ab]	-0.420[ab]	0.915[ab]	0.484[ab]	-0.391[ab]	0.929[ab]	1.000		
Fruit stalk length	0.241[a]	0.085	0.348[ab]	0.283[ab]	-0.059	0.469[ab]	-0.010	0.129	0.502[ab]	0.424[ab]	1.000	
Fruit stalk width	0.527[ab]	0.422[ab]	0.010	0.370[ab]	0.580[ab]	-0.459[ab]	-0.091	0.127	-0.208[a]	-0.373[ab]	-0.140	1.000

Superscript **a** represents significantly different at P < 0.05; Superscript **b** represents significantly different at P < 0.01

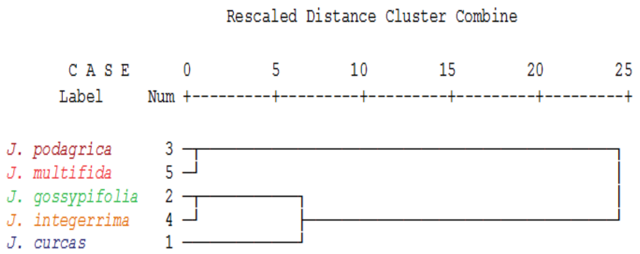

Fig. 2. Cluster analysis showing the relationship among *Jatropha* species based on quantitative morphological traits [Using Average Linkage]

The cluster that exists between species 3 (*J. podagrica*) and species 5 (*J. multifida*) had a coefficient of 69.072, whereas between species 1 (*J. curcas*) and species 3 (*J. podagrica*) it was 315.025, showing a great degree of variation within their morphometry.

Table 6 showed the factor loading of the twelve quantitative morphological characters and it also reveals that some traits are more valuable comparing with others in the genus variation. Fig. 1 shows the components plots on rotated axis for the twelve quantitative morphological traits employed; it was noted that petiole width, fruit length/width and leaf length/width were contributing most to the separation among species.

The dendrogram showing the relationships established among the studied species, based on the quantitative morphological characters within the study, underlined a great affinity that exists between *J. podagrica* and *J. multifida* opposite to the one between *J. gossypifolia* and *J. integerrima* which were distantly related (Fig. 2).

Table 5. Agglomeration schedule of the *Jatropha* species as viewed from the perspective of clusters

Stage	Cluster combined		Coefficients	Stage clusters first appears		Next stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	3	5	69.072	0	0	4
2	2	4	71.562	0	0	3
3	1	2	129.327	0	2	4
4	1	3	315.025	3	1	0

Note: 1. *J. curcas* L.; 2. *J. gossypifolia* L.; 3. *J. podagrica* Hook.; 4. *J. integerrima* Jacq.; 5. *J. multifilda* L.

Table 6. Factor loading of the *Jatropha* species quantitative traits

Component Matrix	Components		
	1	2	3
Leaf length	0.669	-0.063	0.688
Leaf width	0.860	-0.386	0.063
Leaf length/width	-0.550	0.494	0.656
Petiole length	0.859	-0.147	0.489
Petiole width	0.270	-0.734	0.479
Fruit length	0.734	0.623	-0.215
Fruit width	0.330	0.920	0.062
Fruit length/width	-0.329	0.459	0.825
Seed length	0.960	0.255	-0.115
Seed width	0.880	0.344	-0.315
Fruit stalk length	0.815	0.370	0.088
Fruit stalk width	0.627	-0.778	0.037

Extraction method: Principal Component Analysis; 3 components (studied traits) extracted: petiole width, fruit length/width and leaf length/width

Table 4. Variance in the observed traits using Principal Component Analysis

Trait (Component)	Initial Eigen values			Extraction sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.329	36.072	36.072	43.29	36.072	36.072
2	3.140	26.169	62.241	3.140	26.169	62.241
3	2.211	18.427	80.668	2.211	18.427	80.668
4	0.640	5.334	86.003			
5	0.500	4.166	90.169			
6	0.471	3.924	94.093			
7	0.339	2.825	96.913			
8	0.237	1.977	98.895			
9	0.074	0.615	99.511			
10	0.32	0.204	99.775			
11	0.022	0.179	99.954			
12	0.005	0.046	100.00			

Note: traits respect the order given in Table 3

Discussion

Generally, morphometrics add a quantitative element to species descriptions, allowing more rigorous comparisons within a genus. In the numerical analysis of five *Jatropha* species using twelve quantitative morphological traits, the results revealed that variations in the vegetative parts and fruit traits are important. Of the quantitative parameters used, leaf length, leaf width and leaf length/width ratio had the highest values compared with the others traits, confirming their usefulness for species identification purposes. Same trends had been observed by previous studies on *Ficus* species (Sonibare *et al*., 2004), *Acalypha* in South-Western Nigeria (Soladoye *et al*., 2008), *Senna* species in South-Western Nigeria (Soladoye *et al*., 2010a) and *Indigofera* species (Soladoye *et al*., 2010b).

The studied *Jatropha* species exhibited variations based on samples collected from different locations. The size of the fruit and bud length was dependent on the age of plants as earlier confirmed by other reports (Irvine, 1961; Burkill, 1995). Leaf shape and size may vary within the same plant. Previous studies suggested that light intensity may affect the carbohydrate balance, which could affect the length of the cells in the direction of the long axis, thereby leading to differences in the length, shapes and width of the leaves (Soladoye *et al*., 2010b). Such variations observed may be due to environmental, as well as genetic factors, and the interaction among them (Nwachukwu and Mbagwu, 2006).

The closeness observed between *J. podagrica* and *J. multifida* is in line with their current subgeneric and sectional delimitations based on their vegetative morphology, epidermal and petiole anatomy (Dehgan and Webster, 1979; Dehgan, 1980, 1982). Both species belong to the subgenus *Jatropha*, section *Peltatae*. Generally, the pattern of clustering observed in dendogram using average linkage within groups was in line with the current sub generic delimitation of the taxa. Under the current classification, only *J. curcas* belongs to the subgenus *Curcas*, while the remaining taxa belong to the subgenus *Jatropha*. In the dendogram it can be observed that there was a close relationship between *J. gossypifolia* and *J. integerrima* in their quantitative morphological traits, although they have different sectional delimitation in taxonomy (Dehgan and Webster, 1979; Dehgan, 1980, 1982); nevertheless, Oladipo and Illoh (2012) on their research on the comparative wood anatomy on genus *Jatropha* underlined same findings as the current study did.

The chemotaxonomic method of using quantitative phytochemical constituent differences can also be employed in further investigation on the taxonomy of the genus *Jatropha,* thereby adding to the existing information on the taxonomic results of stomata parameters (Abdulrahaman and Oladele, 2010), leaf electrophoresis (Oladipo and Illoh, 2012), crude seed electrophoresis (Oladipo *et al*., 2008) and wood anatomy (Oladipo and Illoh, 2012) on the genus *Jatropha*.

Conclusions

Conclusively, numerical taxonomy provided a greater discrimination along the spectrum of taxonomic differences among *Jatropha* species and was also more sensitive in the delimitation of the studied taxa. The closeness observed between *J. podagrica* and *J. multifida* is in agreement with their current sub-generic grouping. In addition, the study hereby revealed more detailed information on the level of relationship within the genus *Jatropha*.

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