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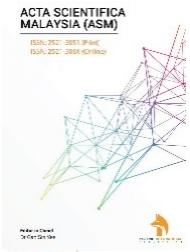

RESEARCH ARTICLE

TAXONOMIC REVISION OF NIGERIAN SPECIES OF *Capsicum* L. BASED ON SOME MORPHOLOGICAL CHARACTERS

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ABSTRACT

Species of *Capsicum* L. are closely related plants whose taxonomic status has remained controversial among different taxonomists. This study was designed to examine the taxonomic status of the species of *Capsicum* in Nigeria in order to establish the genetic variation between the species for the purpose of identification, as well as review the infrageneric classification (INC) of the members of the genus. Germplasm collection of the seeds of five cultivars of *Capsicum* were regenerated and nurtured to fruiting. Variations in their vegetative and reproductive morphology were macroscopically evaluated in replicates of 30 individuals per cultivar for each character, which equals 150 samples altogether. The cultivars of each species was hierarchically clustered as operational taxonomic units (OTUs) using Ward's method with squared Euclidean distance. Artificial key was also constructed for the identification of the species in the genus. The twenty-three (23) morphological characters adopted gave useful insights into the INC of the species and were sufficiently diagnostic of the species as evidenced by the artificial key. Through this study, some light has been shed on the delimitation of species and varieties of the Nigerian *Capsicum*.

KEYWORDS

Capsicum, Morphological Characters, Artificial key, Nigeria, Operational Taxonomic Units.

1. INTRODUCTION

The genus *Capsicum* in Nigeria has not been thoroughly revised, classified and identified especially using morphological characters. There is a dearth of information on the exact number of *Capsicum* species and varieties found in the country. At the moment, no satisfactory revision of the morphology of the Nigerian genera of *Capsicum* is available. Apart from this challenge, it has been observed that some authors have misrepresented some Nigerian species of *Capsicum* due to lack of proper identification. E.g. in Edeoga et al. (2010), 'tatashe' (local name for *C. annuum*) was regarded as a variety of *C. frutescens.* The boundaries between some of the species are still ill-defined, with many of the taxa proving to possess not more than slight morphological variations from those already described. Even where the revisions of the genera are in existence, the situation is further complicated by the researchers who always either treat different members of the genera as varieties of particular species or considered them as different species on the basis of morphological differences (Schilling and Andersen, 1990; Edmonds and Chweya, 1997; Grubben and El Tahir, 2004). Mainly, the disagreements among taxonomists on *Capsicum* taxonomy include species boundaries and importance of some morphological characters over others. It is agreeable that when classification is confused, so is nomenclature and literally any information about such taxa is unspecific and definitely, less useful.

Capsicum crops are perennial crops with densely branched stems and an average height of 0.5 – 1.0 meters, which are usually grown annually (Young and Tarawou, 2014). They are important crops not only because of their economic importance but also for the nutritional value of their fruits, being a major source of natural colours and antioxidant compounds (Ogunlade *et al.,* 2012). In fact, Iwegbue et al. (2011) stated that support for increased production and consumption of fresh vegetables such as *Capsicum annuum* is an important goal. Pepper is a largely widespread spice with annual world production in the year 2004 evaluated to 23 million tons from a total of 1.54 million ha (Djieto-Lordon *et al.,* 2014). Despite the importance of *Capsicum* spp (Adepoju et al., 2020), there is currently no consensus classification of *Capsicum* itself. The infrageneric taxa proposed by Kuntze (1891) and Bitter (1921) have later been recognised asthe segregate genera: *Witheringia, Brachistus, Saracha* Ruiz and Pav. *TuboCapsicum* (Wettst.) Makino, *Aureliana* (Hunziker, 2001). More recently, different classical and molecular cytogenetic analyses, crossing experiments, enzymatic studies, and chloroplast and nuclear DNA sequence studies (Scaldaferro *et al.*, 2006), have allowed considerable progress in the characterization of infrageneric groups in *Capsicum*.

At present, there is no worldwide accepted formal infrageneric classification of *Capsicum.* Two attempts at grouping the species were made based on cytogenetic studies (Moscone et al., 2007), and a combination of data from enzyme, crossing and molecular studies (Walsh and Hoot, 2001). In both studies, the informal classification was still considered provisional despite more than 50% of the species having been analysed. Barboza (2011) designated lectotypes for 14 species names of

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the genus, and these were synonymised under their accepted names in *Capsicum*. In addition, a new name in *Capsicum* was proposed. In each case, the locality information given for the lectotype corresponded with the information found on the specimen itself.

Anatomy of *Capsicum* in Nigeria has been studied by Mbagwu et al. (2007), Nwachukwu et al. (2007), Adedeji et al. (2007) and Edeoga et al. (2010). Edeoga et al. (2010) studied the role of leaf exomorphology in the taxonomy of *Capsicum annum* and *C. frutescens* and reported the anatomical markers for only these two. *C. chinense* which is also a common species in Nigeria was not included in the study while the authors did not elucidate the details of the trichomes of the two taxa that they examined.

Adedeji et al. (2007) embarked on the study of the organographic distribution and taxonomic importance of trichomes in the family Solanaceae involving only six Nigerian species of t he family namely; *Capsicum frutescens* L., *Solanum pimpinellifolium* (Jusl.) Mill., *S. macrocarpon* Linn., *Solanum torvum* Sw., *Solanum nigrum* Linn. an d *Nicot-iana tabacum* Linn. based on the findings, these authors suggested that *lycopersicum* which had earlier been regarded as a species of *Solanum*, should be placed in a separate genus.

This study sought to undertake a vegetative and reproductive morphological revision of *Capsicum* species in Nigeria with a view to examining their taxonomic status as well as provide markers for their identification.

2. MATERIALS AND METHODS

2.1 Sample Collection and Regeneration of germplasm

Table 1: List of the species of *Capsicum* whose seeds were collected for the study

	Species name	Local/ cultivar name	Place of collection	GPS location
1	*C. fructescens* L.	*Ijosi*	Obbo road, Ilorin.	8.5° N; 4.55° E
2	*C. fructescens* L.	*Sombo*	Gbagba area, Ilorin	8.5° N; 4.55° E
3	*C. fructescens* L.	*Bawa*	Wazo Market, Ogbomoso	7.9° N; 4.32° E
4	*C. annuum* L.	*Tatashe*	NACGRAB, Ibadan	7.39° N; 3.9° E
5	*C. chinense* Jacq.	*Rodo*	Inisa, Osun state	7.85° N; 4.33° E

Source: Author Survey (2014)

Seed samples of three species of *Capsicum* were obtained from various locations in Nigeria as enumerated in Table 1. The seeds collected were grown at the Botanical Gardens of Ladoke Akintola University of Technology, Ogbomoso for the purpose of providing equal environmental conditions and to obtain the various vegetative and reproductive parts needed for morphological evaluation. The plants were authenticated at Obafemi Awolowo University Herbarium (OAUH), Nigeria by Prof. H.C. Illoh and were later documented at LAUTECH Herbarium, Ogbomoso (LHO), Nigeria.

2.2 Taxonomic Treatments of the Sample

A total of 23 characters were drawn out from the leaves, fruits and seeds of the five cultivars of *Capsicum*. The qualitative characters obtained were first quantified by scoring presence as "1" and absence as"0". Quantitative readings were taken in 30 replicates; one from each individual of a cultivar, which equals a total of 150 samples. Means and levels of significance (Duncan's) were determined by the use of SPSS statistical software, the 19.0 version. Thereafter, the scores of both qualitative and quantitative characters were used as characters to perform a cluster analysis on the five cultivars, each of which was taken as an operational taxonomic unit (OTU). A dendrogram was constructed using PAST statistical software (Hammer et al., 2001) by adopting a hierarchical cluster analysis using *Ward's method* applying *squared Euclidean Distance*. Using both the qualitative and quantitative morphological characters obtained, a dichotomous key was constructed for the purpose of diagnosing the five varieties.

3. RESULTS

3.1 Morphological characters in the *Capsicum* species studied.

Figure 1: Images of ripe fruits of five Nigerian cultivars of *Capsicum* spp (IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*).

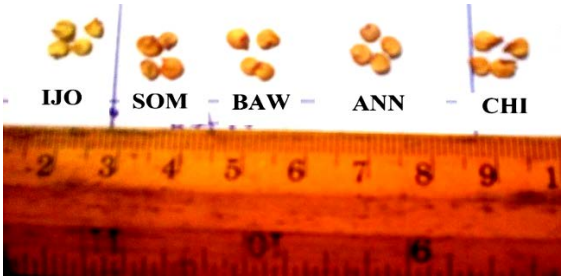

Figure 2: Seeds of the five cultivars of *Capsicum* in Nigeria (IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*).

Qualitative leaf morphological features in the five cultivars of *Capsicum* studied were fairly constant, all the leaves being simple, lanceolate in shape with sparse to fair pubescence, entire margin, pinnate venation, acuminate tip, and oblique-cuneate to cuneate base. On the other hand, the features of the fruits and the seeds (Figure 1 and 2; Table 2) were fairly diagnostic. While the seed shape was generally discoid and flattened, the fruit shape ranged from campanulate in *C. chinense* to blocky in *C. annuum* and elongate in the other three cultivars of *C. fructescens*. The seed colour observed for most of the cultivars was straw, with those of *C. annuum* and *C fructescens* var. *sombo* being brown and cream-brown respectively. Surface texture was generally smooth except for the seeds of *C. annuum* which had rough texture (Table 2).

Table 2: Qualitative fruit and seed morphological characters of the cultivars of *Capsicum* in Nigeria.

Taxa	Fruit shape	Fruit colour at maturity	Seed shape	Seed colour/surface texture
IJO	Elongate	Pale orange	Discoid, flattened	Straw/smooth
SOM	Elongate	Red	Discoid, flattened	Creamish-brown/ fairly smooth
BAW	Elongate	Dark red	Discoid, flattened	Straw/smooth
ANN	Blocky	Dark red	Discoid, flattened	Brown/rough
CHI	Campanulate	Red	Discoid, flattened	Straw/smooth

(IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*).

Table 3: Mean quantitative leaf morphological characters of the cultivars of *Capsicum* in Nigeria.

Taxa	Lamina length (cm)	Lamina width (cm)	Petiole length (cm)	Petiole length/ Lamina length ratio	Lamina Length/ Width ratio
IJO	$6.61^{b} \pm 0.56$	3.64 ± 0.46	1.51 ± 0.01	0.23 ± 0.00	1.87 ± 0.02
SOM	$7.88^{ab} \pm 0.67$	4.54 ± 1.12	3.44 ± 0.67	0.38 ± 0.00	1.82 ± 0.02
BAW	$8.92^{a} \pm 1.22$	4.44 ± 1.01	2.40 ± 0.56	0.30 ± 0.02	2.02 ± 0.12
ANN	$7.51^{ab} \pm 0.65$	4.03 ± 0.55	1.84 ± 0.10	0.25 ± 0.01	1.92 ± 0.01
CHI	$8.22^{ab} \pm 1.11$	4.44 ± 0.57	2.40 ± 0.12	0.29 ± 0.02	1.88 ± 0.01

(IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*). Mean values in columns with differing alphabet superscripts are significantly different at P≤0.05 while those without alphabets are not significantly different at P≤0.05.

The quantitative results of leaf morphology are presented in Table 3 while those of the fruits and seeds are in Table 4. Mean lamina length which ranged between 6.61 cm (in *C. fructescens* var. *ijosi*) and 8.92 cm (in *C. fructescens* var. *bawa*), showed a significant difference across the five cultivars studied, but this was not observed for the other four leaf morphological features (Table 4). The mean fruit length and width were also observed to be diagnostic among the cultivars of *Capsicum* studied. *C. fructescens* var. *ijosi* had the shortest fruit length (i.e. 1.21 cm), a mean value which was significantly shorter than the fruits in the others, while *C. fructescens* var. *bawa* with mean fruit length of 10.70 cm was significantly longer than the fruits of the others. The highest fruit width with the mean value of 3.20 cm was observed in *C. annuum*, which along with that of *C. chinense* were significantly wider than the other fruits observed. Lastly, *C. fructescens* var. *ijosi* which recorded the shortest mean fruit value (0.60 cm) was also next to *C. fructescens* var. *sombo* (0.58 cm), the fruits of both, being significantly narrower than the other three (Table 4).

Table 4: Mean quantitative fruit and seed morphological characters of the cultivars of *Capsicum* studied.

Taxa	Fruit length (cm)	Fruit width (cm)	Seed length (mm)	Seed weight per 100 (mg)
IJO	$1.21^{d} \pm 0.09$	$0.60^{b} \pm 0.02$	2.87 ± 0.12	0.36 ± 0.02
SOM	$3.82^{c} \pm 0.45$	$0.58^{b} \pm 0.01$	3.01 ± 0.12	0.35 ± 0.01
BAW	$10.70^{a} \pm 0.97$	$1.71^{ab} \pm 0.02$	3.61 ± 0.12	0.51 ± 0.02
ANN	$7.58^{b} \pm 0.67$	$3.20^{a} \pm 0.01$	3.70 ± 0.22	0.50 ± 0.12
CHI	$3.72^{c} \pm 0.09$	$2.86^{a} \pm 0.022$	3.67 ± 0.12	0.46 ± 0.01

(IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*). Mean values in columns with different superscripts of alphabets are significantly different at P≤0.05 while those without alphabets are not significantly different at P≤0.05.

Figure 1 shows the dendrogram obtained when a cluster analysis was performed on the morphological characters from leaves, fruits and seeds of the five cultivars of *Capsicum* studied. From this dendrogram, three groupings are evident at 66.67% distance as follows: a direct (same level) cluster of *C. fructescens* var. *bawa* and C annuum; a middle branch containing *C. chinense* alone; and a first branch of *C. fructescens* var. *sombo* and *C. fructescens* var. *ijosi*. The dendrogram is suggestive of some closeness in distance between *C. chinense*, *C. fructescens* var. *bawa* and *C. annuum* as compared to *C. chinense* and the other two cultivars.

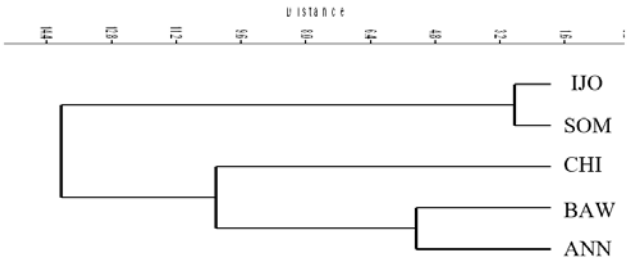

Figure 3: Dendrogram based on cluster analysis of leaf, fruit and seed morphological data recorded on the five Nigerian cultivars of *Capsicum* (IJO= *C. fructescens* var. *ijosi*, SOM= *C. fructescens* var. *sombo*, BAW= *C. fructescens* var. *bawa*, ANN= *C. annuum* and CHI= *C. chinense*).

4. Discussion

4.1 Biosystematic implications of the morphological features observed in *Capsicum*

Relatively little work had been carried out on the morphology of the Nigerian species of *Capsicum*. Evaluation of the morphological and leaf epidermal features of *C. annum* and *C. frutescens* carried out by Nwachukwu et al. (2007) showed certain characteristics that were of some taxonomic value. According to these authors, the vegetative features of habit and height of *C. annum* separated it from *C. frutescens*. Okwulehi and Okoli (1999) and Edeoga and Eboka (2000) had earlier used comparative morphology of different species of *Capsicum* in establishing relationship among various taxa while Okeke and Nwachukwu (2001) reported morphological markers in the family Euphorbiaceae. The results of the present study are partly at variance to those of Nwachukwu et al. (2007) because the authors described the leaf tips and leaf bases of *C. annuum* and *C. fructescens* as mucronate and round respectively. This probably may be as a result of misidentification or use of improper description chart.

Table 5: A morphology-based dichotomous key for identification of five cultivars of *Capsicum* in Nigeria.

1a. Shape of leaf base, Oblique-cuneate; shape of fruit, elongate ..... 2.
2a. Colour of mature seed, yellow; texture, smooth ..... 3.
3a. Colour of fruit at maturity, dark red; mean fruit length, 10.7 cm ..... *C. fructescens.* var. *bawa.*
3b. Fruit colour at maturity, pale orange; mean fruit length, 1.21 cm ..... *C. fructescens.* var *ijosi.*
2b. Colour of mature seed, creamish-brown; Seed surface texture, fairly smooth; mean fruit length, 3.82 cm ..... C. fructescens. var sombo.
1b. Shape of leaf base, cuneate; shape of mature fruit, not elongate; usually blocky or campanulate ... . 4.
4a. Shape of mature fruit, blocky; fruit colour at maturity, dark red; colour of mature seed, brown; seed surface texture, rough; fruit length, 7.58 cm ..... *C. annuum.*
4b. Shape of mature fruit, campanulate; fruit colour at maturity, red; colour of seed, straw; seed surface texture, smooth; mean fruit length, 3.72 cm ..... *C. chinense.*

Some taxonomists are of the opinion that much of the proliferation of synonyms in *Capsicum* had been due to differences in fruit characters. The findings of the present study with regard to morphological features appear to be in consonance with this position. There seems to be no agreement yet with regard to the number of species of *Capsicum* present in West Africa. Wilson (1959, 1961) agreed to the presence of only two species, *C. annum* and *C. frutescens* while some other taxonomists proposed that all other purportedly recognized species were forms of either *C. annum* or *C. frutescens*.

It can be deduced from Figure. 1 that morphological variations between the cultivars studied may have some relation to their quality of Capsaicin contents. Based on their fruit taste (hotness), the five cultivars can be listed in increasing order of their hotness (and hence, capsaicin content) as *C. annuum*, *C. fructescens* var. *bawa*, *C. chinense*, *C. fructescens* var. *sombo* and *C. fructescens* var. *ijosi* (Nwokem *et al.,* 2010) Interestingly, the cluster obtained followed this arrangement (Figure 1) with *ijosi* and *sombo* clustering as hot-taste cultivars, *bawa* and *C. annuum* clustering as mild-taste cultivars while *C. chinense* alone clustered as a cultivar with intermediate taste. This finding supports that of Adepoju et al. (2019) in which two Nigerian pepper varieties of *C. fructescens* (*ijosi* and *sombo*) formed a taxonomic cluster, different from the cluster formed by *bawa, annuum* and *chinense*, based on their seed protein profiles.

The infrageneric classification of *Capsicum* proposed by McLeod et al. (1982) based on isozyme data and flower colour suggested two groups; *C. annuum* as one; and other species (*fructescens* and *chinense*) as the other. This study partly agrees with the findings of McLeod et al. (1982) in that *C. chinense* clustered separately as a species and with just one of the varieties of *C. fructescens*, while *C. annuum* was distinct. However, contrary to the findings of McLeod et al. (1982), this study reveals that *C. annuum* may be closer to *C. chinense* than to *C. fructescens*, two varieties which clustered far away from *C. annuum*.

Based on the morphological results obtained, from this study, qualitative and quantitative features of the fruits and seeds in particular can be said to be of some value for both classificatory and diagnostic purposes in the genus *Capsicum*. Table 5 is a morphology-based key, usable for the identification of the five cultivars studied.

5. Conclusion

Evaluation of vegetative and reproductive morphological features of Nigerian *Capsicum* has perfectly confirmed extant clusters of taxa based on their fruit capsaicin content (which is responsible for fruit hotness). It has thus assisted to reaffirm earlier taxonomic groupings of *C. chinense* as a separate species from *C. annuum* but not *C. fructescens* from the two. This study has established some concordance between fruit capsaicin content in *Capsicum* and infrageneric taxonomic groupings based on conventional morphological characters. Variations in vegetative and reproductive morphological features in Nigerian species of *Capsicum* have hereby been documented in form of unambiguous artificial key for proper identification of the taxa.

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