RESEARCH ARTICLE

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

Adeyinka O. Adepoju¹, Tunde J. Ogunkunle² and Abiola G. Femi-Adepoju³

¹Department of Biological Sciences, Fourah Bay College, University of Sierra Leone, Freetown, Sierra Leone
²Department of Pure and Applied Biology, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria
³Department of Plant and Environmental Biology, Kwara State University, PMB 1530, Malete, Nigeria
*Corresponding Author e-mail: adeyinka.adepoju.phd@gmail.com

This is an open access article distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:
Received 01 February 2021
Accepted 17 March 2021
Available online 26 March 2021

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 revisited, 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 Cheweya, 1997; Grubb and El Tahri, 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 Tanwou, 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 as the segregate genera: Witheringia, Brachistus, Sarachru Ruix and Pav. Tubocapiscum (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...
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 annuum 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 the family namely; Capsicum frutescens L., Solanum pimpinellifolium (Jusl.) Mill., S. macrocarpon Linn., Solanum torvum Sw., Solanum nigrum Linn. and Nicotiana tabacum Linn. Based on the findings, these authors suggested that hypocersicum 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. frutescens L.    | Ijosi               | 8.5° N; 4.55° E |
| 2            | C. frutescens L.    | Sombo               | 8.5° N; 4.55° E |
| 3            | C. frutescens L.    | Bowa                | 7.9° N; 4.32° E |
| 4            | C. annuum L.        | Tatashie            | 7.39° N; 3.9° E  |
| 5            | C. chinense Jacq.   | Rodo                | 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. frutescens var. ijosi, SOM= C. frutescens var. sombo, BAW= C. frutescens var. bawa, ANN= C. annuum and CHI= C. chinense).](image1)

![Figure 2: Seeds of the five cultivars of Capsicum in Nigeria (IJO= C. frutescens var. ijosi, SOM= C. frutescens var. sombo, BAW= C. frutescens var. bawa, ANN= C. annuum and CHI= C. chinense).](image2)

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    | Straw/smooth               |
| SOM      | Elongate    | Red                      | Discoid    | Creamish-brown/ fairly smooth |
| BAW      | Elongate    | Dark red                 | Discoid    | Straw/smooth               |
| ANN      | Blocky      | Dark red                 | Discoid    | Straw/smooth               |
| CHI      | Campanulate | Red                      | Discoid    | Brown/rough                |

![Table 3: Mean quantitative leaf morphological characters of the cultivars of Capsicum in Nigeria.](image3)

| Taxa | Lamina length (cm) | Petiole length (cm) | Lamina length/ Width ratio |
|------|---------------------|---------------------|---------------------------|
| IJO  | 6.61±0.56           | 1.51 ± 0.01         | 1.87 ± 0.02               |
| SOM  | 7.88±0.67           | 3.64 ± 0.46         | 1.54 ± 1.12               |
| BAW  | 8.92±1.22           | 4.44 ± 1.01         | 2.02 ± 0.12               |
| ANN  | 7.51±0.65           | 4.03 ± 0.55         | 1.92 ± 0.01               |
| CHI  | 8.22±1.11           | 4.44 ± 0.57         | 1.88 ± 0.01               |

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. ijosí) and 9.82 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 different among the cultivars of Capsicum studied. C. fructescens var. ijosí 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. annum, which along with that of C. chinense were significantly wider than the other fruits observed. Lastly, C. fructescens var. ijosí 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).

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. annum; a middle branch containing C. chinense alone; and a first branch of C. fructescens var. sombo and C. fructescens var. ijosí. The dendrogram is suggestive of some closeness in distance between C. chinense, C. fructescens var. bawa, and C. annum as compared to C. chinense and the other two cultivars.

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

| Taxa   | Fruit length (cm) | Fruit width (cm) | Seed length (mm) | Seed weight per 100 (mg) |
|--------|------------------|------------------|------------------|--------------------------|
| IJO    | 1.21±0.09        | 0.60±0.02        | 2.87±0.12        | 0.36±0.02                |
| SOM    | 3.82±0.45        | 0.58±0.01        | 3.01±0.12        | 0.35±0.01                |
| BAW    | 10.70±0.97       | 1.71±0.06        | 3.61±0.12        | 0.51±0.02                |
| ANN    | 7.50±0.67        | 3.20±0.01        | 3.70±0.22        | 0.50±0.12                |
| CHI    | 3.72±0.09        | 2.86±0.02        | 3.67±0.12        | 0.46±0.01                |

**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 S
1b. Shape of leaf base, cuneate; shape of mature fruit, not elongate; usually blocky or campanulate ................. 3
2a. Colour of mature seed, yellow; texture, smooth ......................................................................................... 3 S
2b. Colour of mature seed, creamish-brown; Seed surface texture, fairly smooth; mean fruit length, 3.82 cm ........................................................................................................................................... 4 S
3a. Colour of leaf 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. ijosí.
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. annum.
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 morphology 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. fructescens while some other taxonomists proposed that all other purportedly recognized species were forms of either C. annum or C. fructescens.

It can be deduced from Figure 1 that morphological variations between the cultivars studied may have some relation to their quality of Capsaicine 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. annum, C. fructescens var. bawa, C. chinense, C. fructescens var. sombo and C. fructescens var. ijosí (Nwokem et al, 2010) Interestingly, the cluster obtained is in line with this arrangement (Figure 1) with ijosí and sombo clustering as hot-taste cultivars, bawa and C. annum clustering as mid-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 var. ijosí 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. annum 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. annum was distinct. However, contrary to the findings of McLeod et al. (1982), this study reveals that C. annum may be closer to C. chinense than to C. fructescens, two varieties which clustered far away from C. annum.

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 in 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. frutescens 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.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Gloria Barboza, for providing some useful insights on Capsicum taxonomy.

REFERENCES

Adepoju, A.O., Adepoju, G.A. 2021. Taxonomic Revision of Nigerian Species of Capsicum L. Based on Some Morphological Characters. Acta Scientifica Malaysia (ASM) 5(2): 43-46.

Adejei, O., Ajewun, O.Y., Babawale, O.O. 2007. Foliar Epidermal Studies. Organographic Distribution and Taxonomic Importance of Trichomes in the Family Solanaceae. Int. J. Bot. 3, 276-282. DOI:10.3923/ijb.2007.276.282.

Adjei, O.O., Okonkwo, A.T.J., Azeez, M.A., Femi-Adepoju, A.G. 2019. Value of Seed Protein Profile in the taxonomy of cultivars of Capsicum in Nigeria. Nig. J. Biotech. 36(2), 1 - 8. DOI: https://dx.doi.org/10.4314/njb.v36i2.1

Adjei, O.O., Otomo, A.O., Femi-Adepoju, A.G., Karim, A.B. 2020. Comparative studies on the Antimicrobial, Chemical and Biochemical contents of Capsicum frutescens L.varieties. Afr. J. Biotech. 19(12), 836-845. DOI: https://doi.org/10.5897/AJB2020.17258

Barboza, G.E. 2011. Lectotypifications, synonymy, and a new name in Capsicum. Int. J. Plant Taxon. 4, 6-10. DOI: 10.17660/ActaHortic.2011.845. DOI:10.5897/ActaHortic.2007.74.5.5

Bitter. G.1921. Solana africana III. Bot. Jb. 57, 248-286.

Djieto-Lordon, C., Heumou, C.R., Elono-Azang, P.S., Alene, C.D., Ngassam, P. 2014. Assessment of pest insects of Capsicum frutescens L. Tiliaceae, New Bot. 25, 87 – 101.

Edmonds, J.M., Chweya, J.A. 1997. Black nightshades. Solanum nigrum L. and related species. Promoting the conservation and use of underutilised and neglected crops 15, Institute of Plant Genetics and Crop Plant Research, Gatersleben, Germany/International Plant Genetic Resources Institute, Rome, Italy, 5-113.

Grubben, G.J.H., El Tahir, I.M. 2004. Capsicum annuum L. Internet Record from PROTA4U, PROTA (Plant Resources of Tropical Africa/Ressources végétales de l’Afrique tropicale), Wageningen, Netherlands. Viewed 11 May, 2019 from http://www.prota4u.org/search.asp.

Hammer, O., Harper, D.A.T., Ryan, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis, Palaeo.

Electr. 4(1), 1-9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Hunziker, A.T. 2001. The genera of Solanaceae. Ruggel, Lichtenstein: A.R.G. Gantner Verlag.

Iwegbue, M.A., Oparah, C.L., Ebigwai, J.K., Nwozo, S.O., Nwajei, G.E., Eguavoen, O. 2011. Heavy Metal Contamination of some vegetables and spices in Nigeria. Int. J. Biol. Chem. Sci. 5(2), 766-773. DOI: 10.4314/ijbcs.v5i2.72150

Kuntze, O. 1891. Revista Generum Plantarum, part II. Commissionen. A. Felix, Leipzig, 377-1011.

McLeod, M.J., Gutman, S.I., Edsbjerg, W.H. 1982. Early evolution of chili peppers (Capsicum). Econ. Bot. 36, 361-368. DOI:10.10108/IF02862689.

Mbagwu, F.N., Ngwachukwu, C.I., Okoro, O.D. 2007. Root Anatomical Studies on Solanum macrocarpon and Solanum nigrum (Solanaceae). J. Amer. Sci. 3(3), 1-4. DOI: 10.5923/jr.j.2008.04.48

Moscone, E.A., Scaldaferro, M.A., Gabriele, M., Cecchini, N.M., Sánchez, G.Y., Daviña, J.R., Ducasse, D.A., Barboza, G.E., Ehrendorfer, F. 2007. The evolution in chili peppers (Capsicum Solanaceae), a cytogenetic perspective, Acta Horticulturae (ISHS). 745, 137-140. DOI: 10.17660/ActaHortic.2007.74.5.5

Ngwachukwu, C.I., Mbagwu, F.N., Oneyi, A.N. 2007. Morphological and Leaf Epidermal features of Capsicum annum and Capsicum frutescens Solanaceae, Nat. Sci., 5(3), 54-60.

Nwokem, C.O., Agbajah, E.B., Agbajah, J.A., Ekanem, E. 2010. Determination of Capsaicin Content and Pungency Level of Five Different chili Peppers Grown in Nigeria, New York Sci. J., 3(9), 17-21.

Ogunlade, L.A., Abebiosu, A.A., Osasola, A.I. 2013. Proximate, mineral composition, antioxidant activity and total phenolic content of some pepper varieties (Capsicum species). Int. J. Biol. Chem. Sci. 6, 1-7. DOI: https://doi.org/10.4314/ijbcs.v6i5.28

Okike, S.E., Ngwachukwu, C.I. 2001, Characterization of Maesobotra barterii var. barteri. Nig. J. Bot. 13: 70-80.

Okwuleh, I.C., Okoli, B.E. 1999. Morphological and palynological studies in some species of Corchorus L. Tiliaceae, New Bot. 25, 87 – 101.

Scaldaferro, M.A., Seijo, J.G., Acosta, M.C., Barboza, G.E., Ducasse, D.A., Moscone, E.A. 2006. Gymnoschara characterisation of the germplasm in peppers (Capsicum- Solanaceae) by fluorescent in situ hybridization. Plant Sci. (Sofia), 43, 291-297. https://www.researchgate.net/publication/240054461

Schilling, E.E., Andersen, R.N. 1990. The black nightshades (Solanum section Solanum) of the Indian subcontinent. Bot. J Linn. Soc. 102, 253-259. DOI: 10.1111/j.1095-8339.1990.tb01879.x

Walsh, B.M., Hoot, S.B. 2001. Phylogenetic Relationships of Capsicum (Solanaceae) using DNA sequence from two Noncoding Regions: The atpB rbcL spacer Region and Nuclear introns. Int. J. Plant Sci. 162(4), 1409-1418. DOI: 10.1086/323275

Wilson, J.Y. 1959. A third species of pepper in West Africa. Nature. 183, 1142-1149. DOI: 10.1038/1831142a0

Wilson, J.Y. 1961. The Capsicum peppers of West Africa 1; The species and range of variation, West Afr. Sci. Asso. J., 6, 7895.

Young, E., Tarawu, T. 2014. Determination of metals in pepper by flame atomic absorption spectroscopy. Int. J. Biol. Chem. Sci. 8(6): 2891-2895. DOI: http://dx.doi.org/10.4314/ijbcs.v8i6.45