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Original Article

Contributions to the Classification of *Capsicum annuum* L. and *Capsicum frutescens* L. in West Africa Using Morphological Traits

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Abstract

In West Africa, the genus *Capsicum* is represented by two cultivated species namely *C. frutescens* and *C. annuum* with different varieties. However, the taxonomic identity of these two species has been unresolved because they are morphologically related. There has been considerable debate on their status as two separate species or just varieties of one species. The study was aimed at assessing the variability and relatedness among the four varieties of the two closely related *Capsicum* species in West Africa. The varieties used in this study are *C. annuum* var. *abbreviatum*, *C. annuum* var. *acuminatum*, *C. annuum* var. *grossum* and *C. frutescens* var. *baccatum*. The varieties were morphologically characterized using 80 quantitative and qualitative standard descriptors from seedling emergence to plant maturity. Data collected were subjected to statistical analysis using SPSS statistical package, descriptive statistics and cluster analysis. The results revealed overlapping similarities in the morphology of the four varieties. Classification analysis based on data collected showed two distinct clusters by grouping varieties sharing close phenotypic similarities into distinct cluster. The differences observed among the varieties majorly in flower and fruit traits do not provide enough evidence to conceive that the collections are two separate species. Our results therefore support the inclusion of *C. frutescens* var. *baccatum* as a variety of *C. annuum*. Additional comparative molecular profiling is needed to fully understand the phylogenetic relationship among the cultivated *Capsicum* species in this part of the world.

Keywords: *Capsicum*; descriptors; dendrogram; morphological characterization; similarity index

Introduction

The genus *Capsicum* commonly known as chilli or hot pepper belongs to the family Solanaceae. It originated from the Central and South America (Bosland and Votava, 2000). This genus consists of five domesticated and 22 wild species. The domesticated ones are *C. annuum* L., *C. chinenses* Jacqs., *C. frutescens* L., *C. pubescens* R. and *C. baccatum* L. (Bosland and Votava, 2000).

In West Africa, the genus is represented by two cultivated species namely *C. frutescens* and *C. annuum* with different varieties. However, the taxonomic identity of these two species has been unresolved because they are morphologically related. There has been considerable debate on their status as two separate species or just varieties of one species. Bosland and Votava (2000) defined species as a population or series of populations within which free gene flow occurs under natural conditions, with fertile and healthy progeny produced by interbreeding within the species whereas a botanical variety is a distinct morphological subgroup within a species. On the basis of the form as annual or perennial, *C. annuum* and *C. frutescens* respectively were first distinguished as the only two species in the genus *Capsicum* by Linneaus in 1825. However, in the study of South American pepper, Bukasow (1930) rejected Linneaus' classification and considered the annual form to be nothing more than a variety of *C. frutescens*. Up till today, the distinction of these two plants as separate species or varieties of one species is still unresolved.

Identification and classification of botanical species correctly is a crucial step for managing germplasm collection efficiently. It is the basis for improving any plant species (Moura *et al*., 2013). The first step in the description and classification of germplasm is morphological characterization. Evaluation of morphological traits contributes valuable information for the assessment of genetic relatedness and variability of any plant species (Franco *et al*., 2005; Laurentin, 2009). This allows the description, identification and differentiation of species (Carvalho *et al*., 2014). Generally, the identification of *Capsicum* genus is carried out by morphological traits that are observed majorly in the

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flowers and fruits (Sudré *et al*., 2010). However, a combination of several diagnostic morphological traits is necessary to identify and differentiate the *Capsicum* species.

Cluster analysis has been used by several researchers to identify and distinguish accessions from each other and group accessions of plants based on their similarities (Sivaraj *et al*., 2012; Bibi *et al.,* 2013; Tyagi *et al.,* 2014; Dikshita and Sivarajb, 2015). On the basis of fruit form and size, four varieties of the cultivated species of *Capsicum* are recognized in West Africa. These are *C. annuum* var. *abbreviatum*, *C. annuum* var. *acuminatum*, *C. annuum* var. *grossum* and *C. frutescens* var. *baccatum* which are locally known as rodo, sombo, tatase and wewe respectively. The present study aimed to evaluate and characterize the commonly cultivated varieties of the *Capsicum* species using standard morphological descriptors and cluster analysis in order to assess their specific and varietal delineations.

Materials and Methods

Description of the study area

This study was carried out at the green house of University of Fort Hare, Alice, South Africa. University of Fort Hare lies between 32^{0}47'1.23"S, 26^{0}51'9.85"E.

Collection of plant materials

Nigeria is a major producer and consumer of the cultivated varieties of *Capsicum* species in West Africa, therefore, mature fruits of the four varieties of *C. annuum* and *C. frutescens* were obtained from markets in major geographical zones in Nigeria. Seeds in the fruits were first removed, sun-dried and stored at room temperature of about 15-25 °C in paper bags and were later used for Planting. The voucher specimens of each variety was collected and deposited at the University of Ilorin's herbarium.

Growth of plant materials and experimental design

Planting was done in labelled plastic pots in the green house of the University of Fort Hare between September 2017 and February, 2018. The layout in the green house was a completely randomized design with 10 replications for each variety. The plastic pots were perforated to avoid water logging and to prevent fungal growth; they were filled with loamy soil and watered before sowing. Seeds of each variety were sown in their labelled plastic pots and covered with thinnest possible layer of soil. Watering was done based on climatic conditions with a fine watering can and weeding was done frequently as per the emergence of weeds.

Data collection

Data were collected from the four *Capsicum* varieties using 80 standard morphological traits as defined by the International Board for Plant Genetic Resources Descriptors for *Capsicum* (IPGRI, 1995). Genotype characteristics were recorded as quantitative or qualitative values as required. The methodology used to record qualitative values from seedling to harvest followed the descriptor for *Capsicum.*

Statistical analysis

Data were subjected to Analysis of Variance (ANOVA) using SPSS statistical package version 16.0. Mean comparison was carried out using Duncan's multiple range test at 5% probability level. A dendrogram was generated using the Pair-Group Correlation Analysis (PGCA) clustering method to determine the relationship among the varieties.

Results

Variation in seedling/ vegetative qualitative traits

Morphological characterization of the four varieties of the cultivated *Capsicum* species revealed little variation in qualitative agronomic traits. Among the agronomic seedling traits (juvenile traits), all the *Capsicum* varieties examined had white hypocotyls with no pubescence. The cotyledon leaf colour ranged from green to dark green, the shape of which was lanceolate, ovate and deltoid. Stem colour was green for all varieties; all stem are angular in shape and pubescence was sparse (Table 1). Of the 19 qualitative vegetative traits examined, a major variation was observed in the nodal anthocyanin pigmentation. Nodal pigmentation was purple in *C. annuum* var. *abbreviatum*, *C. annuum* var. *acuminatum*, and *C. annuum* var. *grossum* while the node color was green in *C. frutescens* var. *baccatum* till maturity (Fig. 1).

Variation in quantitative vegetative traits

According to analysis of variance (Table 2), the varieties of the cultivated *Capsicum* species differed significantly ($p<0.05$) for all the quantitative vegetative traits examined. The plant height at maturity ranged from 17.57- 59.9 cm. The highest plant height was recorded from *C. frutescens* var. *baccatum* while the lowest height at maturity was recorded in *Capsicum annuum* var. *grossum.* Highest total leaf length was recorded in *C. frutescens* var. *baccatum* with the least recorded in *C. annuum* var. *grossum*. However, *C. annuum* var. *acuminatum* and *C. frutescens* var. *baccatum* were found to be statistically the same. Furthermore, there was no statistical difference in *C. annuum* var. *abbreviatum* in comparism with *C. annuum* var. *acuminatum* and *C. frutescens* var. *baccatum* (Table 2). The widest leaf was obtained from *C. annuum* var. *abbreviatum* with *C. frutescens* var. *baccatum* recording the smallest leaf breadth. Highest stem girth was recorded in *C. frutescens* var. *baccatum* and the lowest was recorded in *Capsicum annuum* var. *grossum* (Table 2). With respect to the number of leaves, the highest number of leaves was recorded from *C. frutescens* var. *baccatum* with a mean value of 73.40. The least number of leaves was obtained from *C. annuum* var. *grossum*. The highest leaf area was found in *C. annuum* var. *abbreviatum*, followed by *C. annuum* var. *acuminatum* and *C. frutescens* var. *baccatum*, while the least was recorded in *C. annuum* var. *grossum.* However, *C. annuum* var. *acuminatum* and *C. frutescens* var. *baccatum* were found to be statistically the same (Table 2).

Table 1. Observed seedling and vegetative traits classified according to IPGRI, 1995

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* var. *baccatum*
Hypocotyl color	1(White)	1(White)	1(White)	1(White)
Hypocotyl pubescence	3(Sparse)	3(Sparse)	3(Sparse)	3(Sparse)
Cotyledon leaf color	2(Green)	3(Dark green)	2(Green)	2(Green)
Cotyledon leaf shape	1(Deltoid)	3(Lanceolate)	7(Ovate)	3(Lanceolate)
Stem color	1(Green)	1(Green)	1(Green)	1(Green)
Nodal pigmentation	5(Purple)	5(Purple)	5(Purple)	5(Purple)
Stem shape	2(Angled)	2(Angled)	2(Angled)	2(Angled)
Stem pubescence	3(Sparse)	3(Sparse)	3(Sparse)	3(Sparse)
Plant growth habit	7(Erect)	7(Erect)	7(Erect)	7(Erect)
Branching habit	5(Intermediate)	5(Intermediate)	3(Sparse)	7(Dense)
Leaf density	7(Dense)	7(Dense)	5(Intermediate)	7(Dense)
Leaf color	2(Green)	2(Green)	2(Green)	2(Green)
Leaf shape	1(Deltoid)	3(Lanceolate)	2(Ovate)	3(Lanceolate)
Leaf margin	1(Entire)	1(Entire)	1(Entire)	1(Entire)
Leaf base	7(Oblique)	7(Oblique)	7(Oblique)	7(Oblique)
Leaf venation	2(Pinnate)	2(Pinnate)	2(Pinnate)	2(Pinnate)
Leaf apices	2(Acuminate)	2(Acuminate)	2(Acuminate)	2(Acuminate)
Leaf type	1(Simple)	1(Simple)	1(Simple)	1(Simple)
Leaf arrangement	1(Alternate)	1(Alternate)	1(Alternate)	1(Alternate)
Leaf pubescence	3(Sparse)	3(Sparse)	5(Intermediate)	3(Sparse)
Leaf variegation	1(Not variegated)	1(Not variegated)	1(Not variegated)	1(Not variegated)
Life cycle	1(Annual)	1(Annual)	1(Annual)	1(Annual)
Plant habit	1(Shrub)	1(Shrub)	1(Shrub)	1(Shrub)

Fig. 1. Variation in nodal pigmentation in the four varieties of *Capsicum* species. Arrow points to nodal pigmentation (A) purple in *C. annuum* var. *abbreviatum*; (B) purple in *C. annuum* var. *acuminatum*; (C) purple in *C. annuum* var. *grossum* ; (D) green in *C. frutescens* var. *baccatum*

Table 2. Vegetative growth performance of the four varieties of *Capsicum* species. Data in mean ± standard error

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* var. *baccatum*
Plant height(cm)	23.70±2.28^{b}	43.50±3.45^{a}	17.57±1.79^{b}	55.96±6.52^{a}
Total leaf length (cm)	8.79±0.8^{ab}	9.63±0.57^{a}	7.09±0.63^{b}	9.73±0.59^{a}
Leaf lamina length (cm)	6.73±0.62^{ab}	7.22±0.45^{a}	5.84±0.44^{b}	7.02±0.40^{ab}
Leaf breadth (cm)	3.74±0.37^{a}	3.23±0.26^{ab}	2.37±0.26^{b}	2.54±0.10^{b}
Stem girth (cm)	2.09±0.17^{ab}	2.48±0.20^{a}	1.77±0.09^{b}	2.26±0.23^{ab}
Petiole length (cm)	2.05±0.26^{ab}	2.38±0.18^{a}	1.59±0.20^{b}	2.81±0.23^{a}
Number of leaf	32.3±3.72^{bc}	45.0±3.51^{b}	20.40±2.70^{c}	73.40±7.63a
Leaf area (cm^2)	16.04±2.67^{a}	14.92±2.13^{ab}	7.87±1.89^{b}	10.65±1.11^{ab}
Leaf index(cm)	1.29±0.02^{b}	1.33±0.02^{ab}	1.27±0.03^{b}	1.39±0.03^{a}
Number of branches	3.60±0.72^{b}	4.90±0.78^{b}	2.20±0.70^{b}	14.10±1.85^{a}
Days to seedling emergence (days)	7.00±0.0^{b}	7.00±0.0^{b}	7.00±0.0^{b}	9.00±0.00^{a}

Means in the same row with the same superscript are not significantly different at $p<0.05$.

Table 3. Observed inflorescence traits classified according to IPGRI, 1995

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* ar. *baccatum*
Pedicel position	3(Pendant)	3(Pendant)	3(Pendant)	3(Pendant)
Corolla color	1(White)	1(White)	1(White)	1(White)
Corolla shape	1(Rotate)	1(Rotate)	1(Rotate)	1(Rotate)
Anther color	5(Purple)	5(Purple)	5(Purple)	6(Green)
Filament color	1(White)	6(Purple)	1(White)	1(White)
Stigma exertion	5(Same level)	7(Exerted)	5(Same level)	7(Exerted)
Calyx pigmentation	1(Present)	1(Present)	1(Present)	1(Present)
Calyx margin	3(Dentate)	3(Dentate)	3(Dentate)	3(Dentate)
Calyx anular constriction	1(Present)	1(Present)	1(Present)	1(Present)
Inflorescence type	4(Cyme)	4(Cyme)	4(Cyme)	4(Cyme)
Type of symmetry	2(Actinormorphic)	2(Actinormorphic)	2(Actinormorphic)	2(Actinormorphic)
Flower position	3(Pendant)	3(Pendant)	3(Pendant)	7(Erect)

Variation in qualitative inflorescence traits

Flower position was found to be the most useful diagnostic character that distinguished the two cultivated *Capsicum* species. Among the four varieties of the cultivated *Capsicum* species, the character erect flower position was present only in *Capsicum frutescens* var. *baccatum* while *Capsicum annuum var. abbreviatum, Capsicum annuum* var. *acuminatum* and *Capsicum annuum* var. *grossum* produced pendant flowers (Fig. 2). Other inflorescence characters varied considerably among the *Capsicum* varieties. Anther colour was predominantly purple as found in *C. annuum* var. *abbreviatum*, *C. annuum* var. *acuminatum* and *C. annuum* var. *grossum*, while the anther color in *C. frutescens* var. *baccatum* was green. Regarding the corolla colour, they all had white corolla the shape of which was rotate in all. Filament colour varied from white to purple, white being the predominant colour. The petals and sepals are five and six in number respectively in all the varieties. Flowers are borne singly on the node. Anular constriction in the calyx was present in all the pepper varieties with a dentate calyx margin (Table 3).

Variations in quantitative inflorescence traits

Morphological characterization of the four varieties of the cultivated Capsicum species revealed considerable variation in quantitative inflorescence traits. The earliest number of days to 50% flowering was observed in *C. annuum* var. *acuminatum* (57 days), while the longest day to attain 50% flowering was recorded from *C. annuum* var. *grossum* (72 days) (Table 4). Number of flowers per plant significantly varied among the varieties ($p<0.05$). The highest number of flowers per plant was recorded from *C. annuum* var. *abbreviatum* with a mean value of (37.80), followed by *C. frutescens* var. *baccatum* (23.20) and *C. annuum* var. *acuminatum* (19.60). The least number of flowers per plant was recorded in *C. annuum* var. *grossum* (14.70). However, there was no statistical difference among *C. annuum* var. *acuminatum*, *C. annuum* var. *grossum* and *C. frutescens* var. *baccatum* (Table 4). The longest anther length was recorded in *C. annuum* var. *grossum*, followed by *C. annuum* var. *acuminatum* and *C. frutescens* var. *baccatum*. The shortest anther length was recorded in *C. annuum* var. *abbreviatum*. The widest corolla was found in *C. annuum* var. *grossum* while the longest corolla was found in *C. annuum* var. *acuminatum*. Filament length varied significantly among the varieties ($p<0.05$). *C. annuum* var. *grossum* had the highest filament length, followed by *C. annuum* var. *acuminatum* and *C. annuum* var. *abbreviatum*, while *C. frutescens* var. *baccatum* recorded the least filament length (Table 4).

Fig. 2. Flower positions on the four varieties of *Capsicum* species. (A) pendant on *C. annuum var. abbreviatum* (B) pendant on *C. annuum* var. *acuminatum* (C) pendant on *C. annuum* var. *grossum* (D) erect on *C. frutescens* var. *baccatum*

Table 4. Inflorescence growth performance of the four varieties of *Capsicum* species. Data in mean ± standard error

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* var. *baccatum*
Number of flowers per plant	37.70±3.28^{a}	19.60±2.09^{b}	14.70±1.36^{b}	23.20±2.44^{b}
Anther length(cm)	0.23±0.02^{c}	0.30±0.00^{ab}	0.32±0.01^{a}	0.27±0.01^{bc}
Filament length(cm)	0.22±0.01^{b}	0.26±0.02^{ab}	0.31±0.02^{a}	0.21±0.01^{b}
Corolla width(cm)	0.38±0.03^{b}	0.41±0.03^{b}	0.57±0.03^{a}	0.33±0.02^{b}
Corolla length(cm)	0.85±0.05^{ab}	0.96±0.03^{a}	0.91±0.05^{ab}	0.80±0.3^{b}
Days to 50% flowering(days)	67.00±0.0	57.00±0.0	72.00±0.0	64.00±0.0

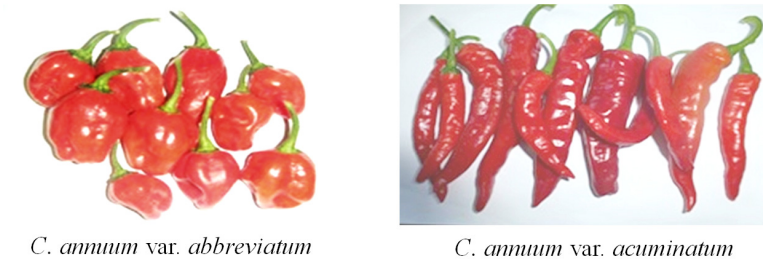
Means in the same row with different superscript are significantly different at $p<0.05$.

Variation in qualitative fruits and seeds traits

Variations were observed on fruit related traits such as shape, size and the position of fruit on the plant. Fruit shape was determined based on comparison with the shape proposed in the lists of descriptors of IPGRI. The four characteristic fruit shape recorded were campanulate in *C. annuum* var. *abbreviatum*, blocky type in *C. annuum* var. *acuminatum*, triangular in *C. annuum* var. *grossum* and the elongate fruit shape in *C. frutescens* var. *baccatum* (Fig.3). All the cultivated *Capsicum* varieties produced shiny fruits. The fruit position was pendant in *Capsicum annuum* var. *abbreviatum*, *Capsicum annuum* var. *acuminatum* and in *Capsicum annuum* var. *grossum* while *Capsicum frutescens* var. *baccatum* produced erect fruits on the plant (Fig.4). Fruit colour at intermediate maturation stage varied from light yellow to green, whereas at the mature stage, all the fruits turned red. Fruit shape at pedicel attachment varied from lobate to cordate and truncate and mature fruits on the pedicel were found to be persistent in all the *Capsicum* varieties studied (Table 5). Fruit outline was found to be slightly corrugated to corrugated and neck at the base of the fruit was either present or absent. The seeds of the *Capsicum* varieties were similar in shape and structure; they are all ellipsoid and oval in longitudinal section. The seed colour ranged from cream to light yellow and all had a wrinkled seed surface with intermediate seed size.

Variation in quantitative fruit and seed characters

Differences in mean performance of quantitative fruit and seed traits in the four varieties of cultivated *Capsicum* species are presented in Table 6. The shortest number of days to first fruiting was recorded in *Capsicum annuum* var. *grossum* while the longest days to first fruiting was recorded in *Capsicum annuum* var. *abbreviatum*. Analysis of variance indicated significant difference ($p<0.05$) among the varieties on number of fruits per plant. *C. annuum* var. *abbreviatum* produced the highest number of fruits per plant while the least number of fruits per plant was recorded in *C. annuum* var. *grossum* (Table 6). With respect to the number of days to first fruit ripening, *C. annuum* var. *acuminatum* took the least number of days to ripen (96 days), followed by *C. annuum* var. *abbreviatum* and *C. annuum* var. *grossum* (98 days) and *C. frutescens* var. *baccatum* maturing latest (109 days). The highest number of seeds per fruit was recorded from *C. annuum* var. *grossum* while the least number of seeds was recorded from *C. annuum* var. *abbreviatum*. The maximum weight per 1000 seeds (7.09 g) was recorded from *C. annuum var. acuminatum* followed by *C. annuum* var. *grossum* (6.03g) and *C. annuum* var. *abbreviatum* (6.01 g). The least seed weight was registered from *C. frutescens* var. *baccatum* (4.10 g).



C. annuum var. *abbreviatum* *C. annuum* var. *acuminatum*

C. annuum var. *grossum* *C. frutescens* var. *baccatum*

Fig. 3. Variation in size and shape of mature fruits of the *Capsicum* varieties

Fig. 4. Variation in fruit positions of the varieties of the cultivated *Capsicum* species. (A) Pendant in *C. annuum* var. *abbreviatum* (B) Pendant in *C. annuum* var. *acuminatum* (C) Pendant in *C. annuum* var. *grossum* (D) Erect in *C. frutescens* var. *baccatum*

Table 5. Observed fruit and seed traits classified according to IPGRI, 1995

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* var. *baccatum*
Fruit color at immature stage	2(Green)	2(Green)	2(Green)	2(Green)
Fruit color at intermediate stage	3(Yellow)	2(Green)	2(Green)	2(Green)
Fruit color at mature stage	4(Red)	4(Red)	5(Dark red)	5(Dark red)
Anthocyanin stripe	0(Absent)	0(Absent)	0(Absent)	0(Absent)
Fruit set	7(High)	5(Intermediate)	3(Low)	7(High)
Fruit shape	4(Campanulate)	5(Blocky)	3(Triangular)	1(Elongate)
Fruit shape at pedicel attachment	5(Lobate)	4(Cordate)	4(Cordate)	3(Truncate)
Neck at base of fruit	0(Absent)	1(Present)	1(Present)	1(Present)
Fruit shape at blossom end	3(Sunken)	1(Pointed)	3(Sunken)	1(Pointed)
Fruit blossom end appendage	0(Absent)	0(Absent)	0(Absent)	0(Absent)
Fruit cross-sectional corrugation	7(Corrugated)	3(Slightly corrugated)	7(Corrugated)	3(Slightly corrugated)
Fruit surface	3(Wrinkled)	1(Smooth)	1(Smooth)	2(Semi-wrinkled)
Pedicel with fruit	7(Persistence)	7(Persistence)	7(Persistence)	7(Persistence)
Pedicel with stem	7(Persistence)	7(Persistence)	7(Persistence)	7(Persistence)
Seed color	4(Cream)	4(Light –yellow)	4(Cream)	4(Yellow)
Seed surface	3(Wrinkled)	3(Wrinkled)	3(Wrinkled)	3(Wrinkled)
Seed size	5(Intermediate)	5(Intermediate)	5(Intermediate)	5(Intermediate)
Persistence of matured fruit on the pedicel	7(Persistence)	7(Persistence)	7(Persistence)	7(Persistence)

Table 6. Fruit and seed growth performance of the four varieties of *Capsicum* species; data in mean ± standard error

Traits	*C. annuum* var. *abbreviatum*	*C. annuum* var. *acuminatum*	*C. annuum* var. *grossum*	*C. frutescens* var. *baccatum*
Number of fruits per plant	28.30±3.28^{a}	12.50±0.58^{bc}	7.80±0.96^{c}	15.20±2.19^{b}
Fruit length (cm)	3.90±0.18^{c}	7.83±0.51^{a}	7.73±0.55^{a}	5.81±0.49^{b}
Fruit diameter (cm)	2.09±0.08^{b}	1.15±0.05^{c}	2.88±0.21^{a}	0.67±0.05^{d}
Length of pedicel (cm)	2.22±0.21^{c}	3.70±0.09^{a}	3.48±0.38^{ab}	2.68±0.12^{bc}
Fruit pericarp thickness (cm)	0.24±0.02^{bc}	0.63±0.05^{a}	0.28±0.03^{b}	0.15±0.01^{c}
Weight of fruit (g)	5.14±0.42^{bc}	8.75±0.85^{b}	20.97±2.69^{a}	1.83±0.25^{c}
Number of seeds per fruit	18.70±2.54^{b}	103.63±13.2^{a}	118.50±14.91^{a}	24.10±2.20^{b}
Seed diameter (cm)	0.26±0.03^{a}	0.26±0.03^{a}	0.27±0.01^{a}	0.23±0.03^{a}

Means in the same row with different superscript are not significantly different at $p<0.05$.

Cluster analysis

The dendogram separated the four *Capsicum* varieties studied into two distinct clusters by grouping varieties sharing close phenotypic similarities into distinct cluster. Consequently, *C. frutescens* var. *baccatum* and *C. annuum* var. *abbreviatum* were classified into the first cluster at 89% in the similarity matrix, while *C. annuum* var. *grossum* and *C. annuum* var. *acuminatum* were classified in the second cluster at 83% in the similarity matrix, indicating their close genetic affinities and phenotypic relationship (Fig. 5).

Discussion

Several researchers have stressed the importance of morphological characterization as a basic step towards the resolution of taxonomic conflicts in many plant species (Gerrano *et al*., 2017; Ranjit *et al*., 2013; Laurentin, 2009). According to Adebola and Morakinyo (2006), it is essential to use morphological descriptors first before the use of advanced biochemical and molecular techniques in resolving taxonomic problems because morphological characterization allows thorough investigation and provides basic information on existing genetic variability in the plant.

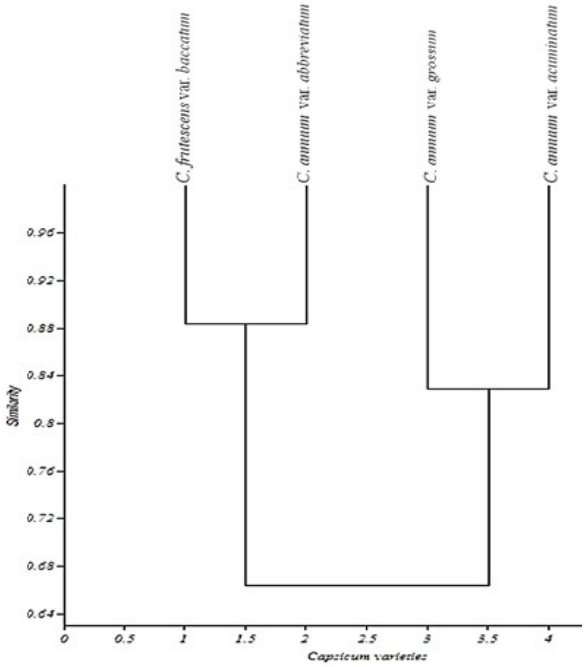


Fig. 5. Dendogram constructed from quantitative morphological data using PGCA clustering method

The detailed morphological characterization of the four varieties of the cultivated *Capsicum* species in this study revealed that they are relatively uniform in gross morphology but considerable variations still exist. The four species showed overlapping similarities in qualitative and quantitative traits. In general, *Capsicum annum* and *Capsicum frutescens* could be distinguished by four diagnostic qualitative traits: nodal pigmentation, anther color, flower position and fruit position. All the three varieties of *Capsicum annuum* had purple nodal color and white anthers. Flowers and fruits were in pendant position on the plant in the three varieties *of Capsicum annuum*. *C. frutescens* var. *baccatum* had white nodal color, purple anthers and flowers and fruit stood erect on the plant. Similar findings was reported by Baral and Bosland, (2004) where pendant flower and fruit position separated accessions of *C. frutescens* from *C. chinense* in their study. The variations observed in nodal pigmentation, anther color, flower and fruit position are inherent as all the varieties examined were grown and characterized in the same controlled environment. Thus, these four qualitative traits may be of taxonomic importance and may be used to delimit these varieties.

The high overlapping similarities in most of the morphological traits examined is a reflection of their phylogenetic relationship. However, the significant differences in most quantitative characters among the four varieties of the cultivated *Capsicum* species suggest that there is a store of genetic variability in these species. Such variability could be harnessed for informed breeding and improvement programmes in these species (Saleh *et al*., 2016; Ince *et al*., 2009; Sudré *et al*., 2006; Guzmán *et al*., 2005).

The information gathered from cluster analysis are useful to identify genetic variability among plants. Clustering of genotypes signifies close genetic affinity between/among species and can be used in resolving taxonomic complexities (Maity *et al*., 2009). The result from the cluster analysis indicated that there was considerable variability among the varieties of the cultivated *Capsicum* species which allowed them to be separated into distinct group. The cluster analysis from all the morphological traits examined did not separate *Capsicum frutescens* into a distinct cluster. Thus, the result does not support the distinction of *Capsicum frutescens* as a separate species. Based on the distance between species of different clusters, contrasting parents may be identified and used in hybridization programme for generating wider variability for selection and crop improvement.

Conclusions

The data set presented in this study is about the first report of morphological characterization of the varieties of the cultivated *Capsicum* species in West Africa, towards understanding their taxonomic complexities using the comprehensive descriptors provided by IPGRI. In general, the results from this study revealed overlapping similarities in the morphology of the varieties of the cultivated *Capsicum* species which justify the evolutionary and phylogenetic relatedness among them. However, the differences observed among the varieties majorly in flower and fruit traits do not provide enough evidence to conceive that the collections are two separate species. Our results therefore support the inclusion of *Capsicum frutescens* var. *baccatum* as a variety of *Capsicum annuum*. Additional comparative molecular profiling is needed in the on-going effort to fully understand the phylogenetic relationship among the cultivated *Capsicum* species in this part of the world.

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