

Research Article

Fruit Morphology as Taxonomic Features in Five Varieties of *Capsicum annuum* L. Solanaceae

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Received 12 November 2013; Accepted 31 December 2013; Published 17 February 2014

Academic Editor: Peter J. de Lange

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Variations in the fruit morphological features of *Capsicum annuum* varieties were studied. Varieties studied include var. *abbreviatum*, var. *annuum*, var. *accuminatum*, var. *grossum*, and var. *glabriusculum*. The fruit morphology revealed attenuated fruit shape with rounded surfaces in var. *glabriusculum*, and cordate fruit shape with flexuous surface in var. *annuum*, *abbreviatum* and *accuminatum*. The fruit is a berry and may be green, yellow, or red when ripe. The fruit epidermal cell-wall patterns are polygonal in shape with straight and curved anticlinal walls in all the five varieties. The fruit of var. *abbreviatum* and var. *grossum* is trilocular, while that of var. *accuminatum* and *annuum* is bilocular, and that of var. *glabriusculum* is tetralocular. *Capsicum annuum* var. *glabriusculum* had the highest mean number of seeds (108.4) and var. *annuum* had the lowest number of seeds (41.3) per fruit. The fruit is conspicuously hollowed in var. *glabriusculum*, *accuminatum*, and *annuum* but inconspicuously hollowed in var. *abbreviatum* and var. *grossum*. These features are shown to be good taxonomic characters for delimiting the five varieties of *Capsicum annuum*.

1. Introduction

Capsicum annuum L. is a domesticated species of the plant genus *Capsicum* in the family Solanaceae [1], native to southern North America and northern South America [2–4]. The fruit is a berry and may be green, yellow, or red when ripe [5]. There are more than 200 common names in use for this species. The most common include chilli pepper, paprika (sweet varieties); bell pepper, cayenne, jalapeños, chiltepin (hot varieties); Christmas peppers (ornamental) [4, 6]. In the past some woody forms of this species have been called *C. frutescens*, but the features that were used to distinguish those forms appear in many populations of *C. annuum* and there is no consistently recognizable *C. frutescens* species. [6]. *Capsicum annuum* can be difficult to separate from the cultivated *C. chinense* (the hottest pepper) and *C. frutescens* (tabasco pepper) and their morphological

features can overlap. These three species share the same ancestral gene pool and are sometimes called the “*annuum*-*chinense*-*frutescens* complex” [7]. *Capsicum* terminology is very confusing with pepper, chilli, chile, chili, aji, paprika, and capsicum all used interchangeably to describe the plant [8, 9]. There are many local cultivars grown in West Africa. Nigeria alone has more than 200 selections of pepper [10].

Sweet peppers are very often used as a bulking agent in ready-made meals and take-away food, because they are cheap, have a strong flavour, and are colourful (Janick & Paull, 2009); [11]. Its potential uses and benefits to mankind cover many areas such as food and nutrition, medicine, cosmetics, plant based insecticides (PBI), and income [12]. The colourful aspect of peppers increases the visual appeal of the food, making it more appetizing. Foods containing peppers, especially chili peppers, often have a strong aftertaste which is due to the presence of capsinoids in peppers [13].



FIGURE 1: Side view of the fruit of *Capsicum annuum* var. *glabriusculum*.



FIGURE 2: Side view of the fruit of *Capsicum annuum* var. *grossum*.

The fruits of nonpungent (sweet) varieties are eaten raw in salads or cooked as a vegetable [14]. They are rich sources of vitamin C (ascorbic acid) and vitamin A. The dried fruits are ground to a powder (paprika) and used as an ingredient in curry powder [8].

The varieties and cultivars of *Capsicum annuum* are classified on the basis of their fruit shapes. Fruits form as the result of the development and differentiation of the gynoecium after fertilization. They are therefore the product of late morphological and structural modifications in the carpels [15, 16]. The genus *Capsicum* (sweet and hot pepper) shows intra- and inter-specific diversity in fruit type, colour, shape, taste, and biochemical content [12]. The species encompass a wide variety of shapes and sizes of peppers, both mild and hot, ranging from bell peppers to chili peppers [6]. There has been much debate amongst botanists and taxonomists as to number and classification of *Capsicum* species; but it is now widely accepted that the genus *Capsicum* consists of five domesticated species and twenty-six wild species [7]. Fruit characters have been extensively used in the taxonomy of the family Solanaceae [17]. Excellent reviews of the application of morphological and anatomical features in systematic studies are shown in the works of Okwulehi and Okoli [18], Chakrabarty and Gupta [19], Olowokudejo [20], and Nwachukwu et al. [21].

The present study assessed fruit morphological features in five varieties of *C. annuum* in order to evaluate the reliability of these characters and their relevance to the taxonomic consideration of the *C. annuum* varieties studied.

2. Materials and Methods

Living fresh materials were used in this study. The fruits of *Capsicum annuum* varieties were obtained from plant stands and Ipata markets in Ilorin, Kwara State, Nigeria. Photographs of all the specimens collected were taken with digital camera during the field trips. The specimens were identified at the herbarium of the Department of Plant



FIGURE 3: Side view of the fruit of *Capsicum annuum* var. *abbreviatum*.



FIGURE 4: Side view of the fruit of *Capsicum annuum* var. *accuminatum*.

TABLE 1: Fruits morphological parameters in the varieties of *Capsicum annuum*.

Taxa	Fruit length (mm)	Fruit breadth (mm)	Fruit stalk length (mm)	Fruit shape	Fruit surface	Fruit colour
<i>C. annuum</i> var. <i>abbreviatum</i>	42.35 ± 3.15	35.57 ± 4.12	27.94 ± 3.46	Cordate	Flexuous	Red or yellow
<i>C. annuum</i> var. <i>annuum</i>	70.98 ± 1.08 ^a	19.85 ± 0.54 ^a	36.59 ± 1.68 ^a	Cordate	Flexuous	Green or red
<i>C. annuum</i> var. <i>accuminatum</i>	71.36 ± 1.75 ^a	45.37 ± 0.91	36.58 ± 1.69 ^a	Cordate	Flexuous	Green
<i>C. annuum</i> var. <i>grossum</i>	114.10 ± 1.58	65.32 ± 4.05	43.78 ± 1.12 ^{ab}	Attenuate	Rounded	Red
<i>C. annuum</i> var. <i>glabriusculum</i>	126.69 ± 4.05	19.51 ± 2.05 ^a	44.94 ± 3.68	Cordate	Rounded	Red

Means with similar indices in each column are not significantly different ($P \leq 0.05$).

TABLE 2: Fruits epidermal characters in the varieties of *Capsicum annuum*.

Taxa	Length (μm)	Breadth (μm)	Epidermal cell characteristics		
			Size (μm)	Shape	Anticlinal wall
<i>C. annuum</i> var. <i>abbreviatum</i>	15 (23.00) 31	13 (18.08) 25	328.51	Polygonal	Straight, curve
<i>C. annuum</i> var. <i>Annuum</i>	11 (20.00) 30	10 (14.92) 20	235.74	Polygonal	Straight, curve
<i>C. annuum</i> var. <i>accuminatum</i>	13 (18.42) 24	10 (14.58) 21	212.17	Polygonal	Straight, curve
<i>C. annuum</i> var. <i>Grossum</i>	38 (41.90) 45	13 (16.75) 21	554.44	Polygonal	Straight, curve
<i>C. annuum</i> var. <i>glabriusculum</i>	18 (21.67) 30	15 (16.50) 28	282.47	Polygonal	Straight, curve



FIGURE 5: Side view of the fruit of *Capsicum annuum* var. *annuum*.



FIGURE 6: Transverse section of the fruit of var. *annuum* showing it inconspicuously hollowed.

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Both qualitative and quantitative characters of fruits were used. The fruits were carefully observed for qualitative characters such as fruit type, shape, apex, surface, base,

TABLE 3: Characteristics of the fruit interior in *Capsicum annuum* varieties.

Taxa	Characteristics of the fruits interior			
	Locule	Placentation	Number of Seeds	Hollow
<i>C. annuum</i> var. <i>abbreviatum</i>	trilocular	Axile	43 (60.4) 81	less hollowed
<i>C. annuum</i> var. <i>Annuum</i>	bilocular	Axile	39 (41.3) 44	hollowed
<i>C. annuum</i> var. <i>accuminatum</i>	bilocular	Axile	58 (73.8) 88	hollowed
<i>C. annuum</i> var. <i>Grossum</i>	trilocular	Axile	61 (68.5) 70	less hollowed
<i>C. annuum</i> var. <i>glabriusculum</i>	tetralocular	Axile	97 (108.4) 122	hollowed



FIGURE 7: Fruit of var. *accuminatum* showing two fused carpels with axile placentation (bilocular).



FIGURE 9: Fruit of three fused carpels with axile placentation (trilocular).

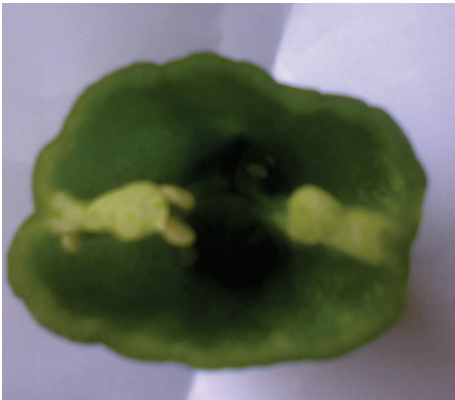


FIGURE 8: Transverse section of the fruit var. *accuminatum* showing it conspicuously hollowed.

and colour and quantitative features such as fruit length, width, stalk length, and fruit index measured and recorded using standardized electronic digital callipers. The fruits were observed, measured, and recorded using 30 randomly selected fruits as suggested by Radford et al., [22]. And the

ranges of variations of these characters were also noted. Terminologies used throughout were those of Pandey and Misra [23] and Olorode [24].

All data were processed using Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT). Computer software used was SPSS version 17. A probability value of 0.05 was used as a bench mark for significant difference between parameters.

3. Results and Discussion

The fruit length is one of the important characteristics, which help in differentiating the varieties as small, medium, and large. The *Capsicum* varieties exhibited significant variability in fruit length ranging from 42.35 mm (var. *abbreviatum*) to 126.69 mm (var. *glabriusculum*). Based on this variation in fruit length, the five varieties under study were grouped into small (<50 mm) as recorded by var. *abbreviatum*, medium (51–100 mm) as recorded by var. *annuum* and *accuminatum*, and large (>101 mm) as recorded by var. *grossum* and *glabriusculum*. Similar classification was reported by Surendra and Singhal [25] in peas, Ravi [26] in soybean, Jain et al. [27] in



FIGURE 10: Fruit of four fused carpels with axile placentation (tetralocular).

mung bean, and Mate and Shelar [28] in sorghum varieties. The wide variation in fruit length might be due to variation in genetic constitution of the varieties as the fruit length is controlled by three to ten pairs of genes with heritability value of 40 to 50 per cent in *Capsicum* [29]. The fruit length might have also been influenced by agronomic and environmental conditions. Moreover, Duncan Multiple Range Test (DMRT)—one-way ANOVA—revealed the fruit length of *C. annuum* var. *accuminatum* and var. *annuum* to be not significantly different, while the fruit breadths of *C. annuum* var. *glabriusculum* and var. *annuum* are also not significantly different (Table 1). The fruit shape of *C. annuum* var. *grossum* was attenuated, that is, pointed toward the apex with rounded surfaces, while *C. annuum* var. *annuum*, var. *accuminatum*, var. *glabriusculum*, and var. *abbreviatum* are cordate or truncated and have flexuous (wavy) surfaces (Table 2 and Figures 1, 2, 3, 4, and 5). This difference in the shape and surface of variety *glabriusculum* as suggested by Singh [30] is the most likely progenitor of the domesticated *C. annuum* var. *annuum*. Serebryanaya and Shipunov [31] reported that changes in plant morphological features in terms of variation have been attributed to small-scale evolutionary processes in different varieties of plants. The variability in fruits colour may be used to establish phylogenetic relationship among the varieties. Colour has been a major basis of differentiating *Capsicum annuum* varieties. The green colour in var. *accuminatum* does not change even in mature fruits (Abdul, pers. comm.).

A wide range of variability in morphology was observed in the transverse sections of these varieties (Table 3 and Figures 6–10). The fruit of var. *abbreviatum* and var. *grossum* is trilocular (Figure 9), var. *accuminatum* and var. *annuum* is bilocular (Figure 7), and var. *glabriusculum* is tetralocular (Figure 10). This heterogeneity in the ovary chambers suggests phylogenetic diversity among these varieties. The axile placentation in all the varieties indicates that the carpel sides are fused together in septa and the ovary in *Capsicum annuum* is plurilocular. There are diagnostic features in the number of seeds per fruit in the varieties of *Capsicum annuum*. Var. *grossum* recorded the highest mean number of

seeds (108.4) and var. *annuum* recorded the lowest number of seeds (41.3) per fruit. The fruit is conspicuously hollowed (Figure 8) in var. *grossum*, *accuminatum*, and *annuum* but inconspicuously hollowed in var. *abbreviatum* and var. *glabriusculum* (Figure 6). These variations in the fruit internal structure are probably due to the length and/or size of the fruits.

These distinguishing fruit morphological features observed in these investigations are of systematic value because they are consistently different in the taxa studied. Furthermore, the use of fruit features in systematics is an important taxonomic tool at the levels of family, genus, species, and variety. Works of Mulla et al. [32], Filippa and Bernardello [33], Olmstead et al. [34], Cutler et al. [15], and Pabón-Mora and Litt [17] are typical examples.

Based on the features observed above, the following dichotomous key has been developed to allow for separation of the five varieties of *Capsicum annuum* studied in this work:

- (1a) fruit shape cordate, fruit internal structure, conspicuously hollowed,—2
- (2a) fruit surface flexuous, fruit small or medium,—3
- (3a) fruit colour red or yellow, fruit small, trilocular,—*abbreviatum*
- (3b) fruit colour green or red, fruit medium, bilocular,—*annuum*
- (2b) fruit surface rounded, fruit large,—*grossum*
- (1b) fruit shape attenuate, fruit internal structure inconspicuously hollowed,—4
- (4a) fruit colour green, number of seeds low,—*accuminatum*
- (4b) fruit colour red, number of seeds high,—*glabriusculum*

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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