

Taxonomic significance of the epicalix in the genus *Hibiscus* (Malvaceae)

Taiwo A. Ayanbamiji¹, Oluwatoyin T. Ogundipe² & James D. Olowokudejo²

¹ Department of Biological Sciences, Bowen University, Iwo, Nigeria,
e-mail: taiwoayanbamiji@yahoo.com (corresponding author)

² Department of Botany, University of Lagos, Akoka-Yaba, Lagos, Nigeria.

Received: April 20, 2012 ▷ Accepted: July 06, 2012

Abstract. The epicalyx may be defined as a whorl of bracts below or beside the calyx, occasionally referred to as an extra calyx. Such structures attract little emphasis in floral morphology because they are absent in many flowering plants. A detailed study of the morphology of epicalyxes in some species of *Hibiscus* L. was carried out. The number, size, shape, structure and orientation of bracteoles of the epicalyx were found to be useful in the identification of species. On the basis of cohesion and adhesion of the epicalyx to the calyx, the species of *Hibiscus* can be divided into four major taxonomic groups. The morphological features of the epicalyx are suspected to be phylogenetic and, therefore, are seen as preliminary tools for the review of the sections in this genus. A dichotomous key for identification of the species is prepared, based exclusively on the reported features. The floral formulae are also presented for the first time.

Key words: adhesion, bracteoles of epicalyx, cohesion, *Hibiscus*, taxonomic groups.

Introduction

The genus *Hibiscus* L. belongs to the family Malvaceae. The family comprises 88 genera and 2300 species distributed across the world (Heywood 1978; Burkill 1997). Members of this family are found in all regions, except in the very cold ones, but are most numerous in the temperate warm and tropical countries. The family has four tribes, *Malopeae*, *Malveae*, *Ureneae* and *Hibisceae* (Hutchinson 1967; Willis 1973).

The species of *Hibiscus* are of great economic importance as sources of fibres, medicinal products, food, and cosmetics. They are used in the fashion industry and as agriculturally and ecologically beneficial plants (Dalziel 1937; Esau 1960; Metcalf & Chalk 1965; Hutchinson 1967; Ugborogho & Shofoyeke 1983; Burkill 1997; Akpan 2000).

The *Hibiscus* species are annual or perennial herbs, shrubs or trees. Leaves are often palmately lobed. Flowers showy, commonly solitary with five petals, five sepals and pedicels usually articulated. Epicalyx and calyx are occasionally persistent, inflated and enlarged in fruit. The ovary has five carpel and 5-capitate stigmas, which are essentially constant (Ghazanfar 1989; Hutchinson 1967). The epicalix is a ring of modified leaves/bracts that looks like an extra calyx below or adjacent to the proper calyx, and may resemble a calyx (Olorode 1984; Sharma 2008). The units in a flower are called bracteoles and all bracteoles in a flower make the epicalyx. According to Fryxell (1997) and Alam & al. (2006), the genus exhibits considerable taxonomic complexity and is so heterogeneous that it is hard to identify any distinguishing features between some species. The present study is aimed at using the characteristic features of the epicalyx as taxonomic tools in the genus *Hibiscus*.

Material and methods

The Herbarium of the Forestry Research Institute of Nigeria (FHI) Ibadan was visited to study the preserved specimens. Plants were also studied in their natural habitats across the country. Qualitative and quantitative characters of the epicalyx were assessed in detail for each collection (Stace 1989). The assessment included number, length, width, shape, orientation and structure of bracteoles of the epicalyx. Cohesion of bracteoles and adhesion to the sepals were also observed.

Results

The quantitative and qualitative features of calyxes in the *Hibiscus* species are presented in Tables 2 and 3, respectively, while the shapes and structures are illustrated in Figs A-R. The number of bracteoles of the epicalyx varied from five in *H. congestiflorus*, *H. lunarifolius* and *H. owariensis*, to 13 in *H. rostellatus* (Table 1). The number was stable in *H. asper* (9), *H. congestiflorus* (5), *H. lunarifolius* (5), *H. vitifolius* (8), and *H. rosa-sinensis* (6), while it varied between six and 13 among the other species. In the present study, *H. schizopetalus* was recorded with the smallest bracteole (0.1 cm × 0.1 cm), while *H. owariensis* (2.56 cm) and *H. sabdariffa* (0.82 cm) have shown the greatest length and width respectively. Bracteoles

were fused (cohesion) at the base and divided towards the apex in *H. articulatus*, *H. scotellii*, *H. sterculiifolius*, and *H. tiliaceus*. The division was below half of the length in *H. tiliaceus* (Fig. N) and above half of the length in *H. articulatus* and *H. sterculiifolius* (Figs B, L), respectively. The bracteoles were totally free from each other (no cohesion) in the other species. The bracteoles/epicalyx were attached to the sepals/calyx (adhesion) in *H. asper*, *H. sabdariffa* and *H. scotellii*, and unattached in the others. The bracteoles were spatular in shape and with foliaceous appendages in *H. acetosella*, *H. rostellatus* and *H. surattensis* (Table 2). Those of *H. physaloides* and *H. vitifolius* were filiform; they were densely hairy and with a coiling apex in *H. physaloides* (Figs H, O). In *H. asper* and *H. sabdariffa*, the bracteoles of the epicalyx were succulent and robust.

Discussion

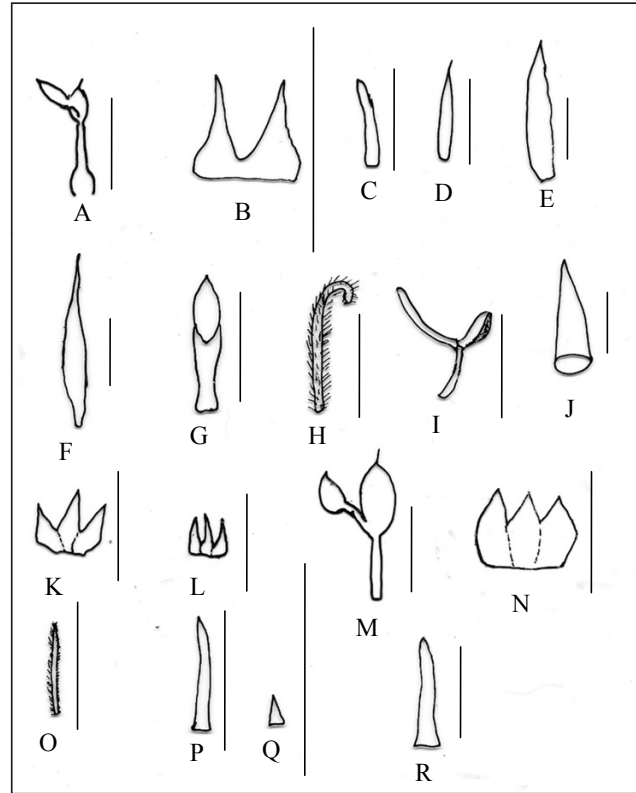
On the basis of the cohesion of bracteoles and adhesion of bracteoles of the epicalyx to the sepals, the species of *Hibiscus* can be divided into four groups. In the first group, the bracteoles of the epicalyx are free from each other and from the sepals, thus there is no cohesion and no adhesion. The group floral formula is $Epk_{5-13}K_{(5)}C_5A_{(\infty)}G_{(5)}$. The members are: *H. acetosella*, *H. congestiflorus*, *H. lunarifolius*, *H. physaloides*, *H.*

Table 1. List of taxa and voucher numbers of the used herbarium specimens

No	S	Taxa	Herbarium No
1		<i>H. acetosella</i>	FHI 103047, FHI 96892, FHI 2323
2		<i>H. articulatus</i>	FHI 39805, FHI 42094, FHI 65056, FHI 24859, FHI 40187, FHI 82265, FHI 44234, FHI 88239
3		<i>H. asper</i>	FHI 9998, FHI 71452, FHI 51359, FHI 36725, FHI 36726
4		<i>H. congestiflorus</i>	FHI 68106, FHI 43573, FHI 77667, FHI 66296, FHI 84722, FHI 15689, FHI 8163, FHI 62504, FHI 96468, FHI 25646, FHI 63550, FHI 86862, FHI 55670,
5		<i>H. lunarifolius</i>	FHI 54399, FHI 59710, FHI 23835, FHI 113650, FHI 55446, FHI 145308,
6		<i>H. owariensis</i>	FHI 57190, FHI 73414
7		<i>H. panduriformis</i>	FHI 64628, FHI 64759, FHI 71443, FHI 98980, FHI 9137
8		<i>H. physaloides</i>	FHI 88106, FHI 69914, FHI 90247
9		<i>H. rostellatus</i>	FHI 94415, FHI 68362, FHI 67996, FHI 68142
10		<i>H. sabdariffa</i>	FHI 84454, FHI 68039, FHI 55447, FHI 43908, FHI 27046, FHI 50273, FHI 94067, FHI 88456
11		<i>H. scotellii</i>	FHI 64799, FHI 48035, FHI 96461, FHI 35934
12		<i>H. surattensis</i>	FHI 82604, FHI 82604, FHI 2398, FHI 77532, FHI 64874, FHI 88832, FHI 89771
13		<i>H. sterculiifolius</i>	FHI 63138
14		<i>H. tiliaceus</i>	FHI 64020, FHI 19411, FHI 43286
15		<i>H. vitifolius</i>	FHI 45716, FHI 67458, FHI 29473, FHI 57708, 86583
16		<i>H. rosa-sinensis</i>	FHI 42907

Table 2. Quantitative features of the epicalyx in the *Hibiscus* species

S No	Taxa	Number of bracteoles per flower	Size of bracteoles (cm)
1	<i>H. acetosella</i>	8–10	1.19 × 0.19
2	<i>H. articulatus</i>	6–7	0.46 × 0.26
3	<i>H. asper</i>	9	0.9 × 0.6
4	<i>H. congestiflorus</i>	5	1.09 × 0.16
5	<i>H. lunarifolius</i>	5	2.19 × 0.19
6	<i>H. owariensis</i>	5–6	2.56 × 0.55
7	<i>H. panduriformis</i>	8–9	1.1 × 0.3
8	<i>H. physaloides</i>	7–9	1.12 × 0.11
9	<i>H. rostellatus</i>	8–13	1.31 × 0.2
10	<i>H. sabdariffa</i>	8–10	1.89 × 0.82
11	<i>H. scotellii</i>	9–10	0.54 × 0.24
12	<i>H. surattensis</i>	9–11	1.81 × 0.7
13	<i>H. sterculiifolius</i>	9–11	0.48 × 0.17
14	<i>H. tiliaceus</i>	10–11	0.69 × 0.21
15	<i>H. vitifolius</i>	8	0.76 × 0.6
16	<i>H. rosa-sinensis</i>	6	0.85 × 0.17
17	<i>H. schizopetalus</i>	7–8	0.1 × 0.1
18	<i>H. variegata</i>	6–7	1.23 × 0.19

**Figs A-R:** Line drawings of the bracteoles of epicalyx of species of *Hibiscus*. Scale: bar = 1 cm. A, *H. acetosella*; B, *H. articulatus*; C, *H. asper*; D, *H. congestiflorus*; E, *H. lunarifolius*; F, *H. owariensis*; G, *H. panduriformis*; H, *H. physaloides*; I, *H. rostellatus*; J, *H. sabdariffa*; K, *H. scotellii*; L, *H. sterculiifolius*; M, *H. surattensis*; N, *H. tiliaceus*; O, *H. vitifolius*; P, *H. rosa-sinensis*; Q, *H. schizopetalus*; R, *H. variegata*.**Table 3.** Qualitative features of epicalyx in *Hibiscus* species.

S No	Taxa	Shape of bracteoles	Cohesion of bracteoles	Adhesion of bracteoles with sepals	Orientation to Receptacle	Structure of bracteoles
1	<i>H. acetosella</i>	Spatular	Free	Free	Perpendicular	Compound
2	<i>H. articulatus</i>	Lanceolate	Fused	Free	Erect	Simple
3	<i>H. asper</i>	Lanceolate	Free	Fused	Perpendicular	Simple
4	<i>H. congestiflorus</i>	Oblong	Free	Free	Erect	Simple
5	<i>H. lunarifolius</i>	Elliptic	Free	Free	Erect	Simple
6	<i>H. owariensis</i>	Elliptic	Free	Free	Erect	Simple with linear appendage
7	<i>H. panduriformis</i>	Spatular	Free	Free	Erect	Simple
8	<i>H. physaloides</i>	Filiform	Free	Free	Perpendicular	Simple
9	<i>H. rostellatus</i>	Spatular	Free	Free	Perpendicular	Compound
10	<i>H. sabdariffa</i>	Lanceolate	Free	Fused	Perpendicular	Simple
11	<i>H. scotellii</i>	Lanceolate	Fused	Fused	Perpendicular	Simple
12	<i>H. surattensis</i>	Spatular	Free	Free	Perpendicular	Compound
13	<i>H. sterculiifolius</i>	Oblong	Fused	Free	Erect	Simple
14	<i>H. tiliaceus</i>	Oblong	Fused	Free	Erect	Simple
15	<i>H. vitifolius</i>	Filiform	Free	Free	Perpendicular	Simple
16	<i>H. rosa-sinensis</i>	Lanceolate	Free	Free	Perpendicular	Simple
17	<i>H. schizopetalus</i>	Lanceolate	Free	Free	Perpendicular	Simple
18	<i>H. variegata</i>	Lanceolate	Free	Free	Perpendicular	Simple

rostellatus, *H. owariensis*, *H. surattensis*, *H. rosa-sinensis*, *H. schizopetalus*, and *H. variegata*. In *H. physaloides* and *H. vitifolius* the bracteoles are filiform. *H. physaloides* can be separated by bracteoles with a densely hairy and coiling apex. *H. rosa-sinensis*, *H. schizopetalus* and *H. variegata* are similar to *H. physaloides* and *H. vitifolius* in their perpendicular bracteoles but are differentiated by their lanceolate shape. In *H. schizopetalus*, the bracteoles are distinctly below 0.5 cm long, in *H. rosa-sinensis* they exceed 0.5 cm but are under 1cm, while they exceed 1 cm in *H. variegata*. *H. acetosella*, *H. rostellatus* and *H. surattensis* have compound bracteoles. *H. acetosella* has one foliaceous appendage, while the others have two. In *H. surattensis*, the bracteoles have recorded the highest number of 11, whereas they number up to 13 in *H. rostellatus*. The remaining members in this first group have erect bracteoles. *H. owariensis* has the longest bracteoles (2.56 cm) with a linear appendage, *H. congestiflorus* and *H. lunarifolius* have five bracteoles per flower; in *H. congestiflorus* they are under 2 cm in length, but exceed 2 cm in *H. lunarifolius*. The bracteoles in *H. lunarifolius* are about twice as long as in *H. congestiflorus*. In *H. panduriformis*, the bracteoles number eight to nine and are spatulate in shape.

In the second group, the bracteoles of the epicalyx are free from each other but are attached to the calyx, and thus there is cohesion but no adhesion. The group floral formula is $\text{Epk}_{8-10}\text{K}_{(5)}\text{C}_5\text{A}_{(\infty)}\text{G}_{(5)}$. (App. 1) The species in this group are *H. asper* and *H. sabdariffa*. In *H. asper* the bracteoles are under 1 cm long, but in *H. sabdariffa* exceed 1 cm.

The bracteoles of the third group are fused but unattached to the sepals, thus there is cohesion but no adhesion. The group is also characterized with relatively small bracteoles, less than 1 cm in length. The group floral formula is $\text{Epk}_{(6-11)}\text{K}_{(5)}\text{C}_5\text{A}_{(\infty)}\text{G}_{(5)}$ and the members are *H. articulatus*, *H. sterculiifolius* and *H. tiliaceus*. In *H. articulatus*, the bracteoles are under eight in number but exceed eight in others. they are under 0.5 cm long in *H. sterculiifolius* but exceed 0.5 cm in *H. tiliaceus*.

In the fourth group, the bracteoles of the epicalyx are fused and attached to the sepals, thus manifesting both cohesion and adhesion. *H. scotellii* belongs to this group with the formula

$$\text{♂ Epk}_{(9-10)}\text{K}_{(5)}\text{C}_5\text{A}_{(\infty)}\text{G}_{(5)}$$

The flowers of the *Hibiscus* species are pentamerous, with five stigma, five fused carpels, five petals adhered to the staminal tube, five sepals free at the apex and fused at the base, varying number of persistent bracteoles of the epicalyx which may be free or fused, and adhered to the calyx or not (Fryxell 1997; Alam & al. 2006; Ayanbamiji 2010). The differences in the floral formulae of all species resulted mainly from the features of epicalyx. It is therefore clear that quantitative description of the flowers would be impossible without the presence and thorough understanding of the epicalyx in each species. The characteristic features in the above groupings are suspected to be phylogenetic and, therefore, are seen as preliminary tools for the review of the sections in this genus. An indented dichotomous key and floral formulae based on the reported results are presented for identification of the *Hibiscus* species.

Identification key to the species of *Hibiscus* based on the features of epicalyx.

1. Bracteoles unfused:
 2. Bracteoles unattached to sepals:
 3. Bracteoles without foliaceous appendages:
 4. Bracteoles orientation to ovary perpendicular:
 5. Bracteoles pubescent and filiform:
 6. Bracteoles densely hairy, apex coiling *physaloides*
 6. Bracteoles sparsely hairy, apex uncoiling *vitifolius*
 5. Bracteoles glabrous and not filiform:
 7. Bracteole length under 0.5 cm *schizopetalus*
 7. Bracteole length exceeding 0.5 cm:
 8. Bracteoles number per flower 6, length under 1cm *rosa-sinensis*

8. Bracteoles number per flower 6 or more, length above 1cm *variegata*
4. Bracteoles orientation to ovary erect:
9. Bracteoles number per flower not more than 6, shape elliptic or oblong:
10. Bracteoles number 5–6, with appendage on the apex *owariensis*
10. Bracteoles number 5, without appendage on the apex:
11. Bracteoles length exceeding 2 cm *lunarifolius*
11. Bracteoles length under 2 cm *congestiflorus*
9. Bracteoles number per flower exceeding 6, shape spatular *panduriformis*
3. Bracteoles with foliaceous appendages:
12. Bracteoles with one foliaceous appendage, number exceeding 12 *rostellatus*
12. Bracteoles with two foliaceous appendages, number under 12:
13. Bracteoles number under 11, length under 1.5 cm *acetosella*
13. Bracteoles number may be up to 11, length exceeding 1.5 cm *surattensis*
2. Bracteoles attached to sepals:
14. Bracteoles length exceeding 1 cm *sabdariffa*
14. Bracteoles length under 1 cm *asper*
1. Bracteoles fused:
15. Bracteoles attached to sepals *scotellii*
15. Bracteoles unattached to sepals:
16. Bracteoles number per flower under 8 *articulatus*
16. Bracteoles number per flower exceeding 8:
17. Bracteoles length under 0.5 cm, division over half of length *sterculiifolius*
17. Bracteoles length exceeding 0.5 cm, division under half of length *tiliaceus*

Appendix 1. Floral formulae for the *Hibiscus* species.

Group 1 – bracteoles of the epicalyx are free

- (i) *H. acetosella* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{8-11} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (ii) *H. congestiflorus* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_5 \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (iii) *H. lunarifolius* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_5 \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (iv) *H. owariensis* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{5-6} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (v) *H. panduriformis* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{8-9} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (vi) *H. physaloides* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{7-9} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (vii) *H. rostellatus* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{8-13} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (viii) *H. surattensis* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{9-11} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$
- (ix) *H. vitifolius* $\oplus \overset{\circlearrowright}{\text{♀}} \text{Epk}_{9-10} \text{K}_{(5)} \overline{\text{C}_5\text{A}}_{(\infty)} \underline{\text{G}}_{(5)}$

Appendix 1. Continuation.

- (x) *H. rosa-sinensis* $\oplus \text{♀ Epk}_6\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$
 (xi) *H. schizopetalus* $\oplus \text{♀ Epk}_{7-8}\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$
 (xii) *H. variegata* $\oplus \text{♀ Epk}_{6-7}\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$

Group 2 – bracteoles of the epicalyx are free but attached to the calyx

- (xiii) *H. asper* $\oplus \text{♀ Epk}_9\overline{\text{K}}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$
 (xiv) *H. sabdariffa* $\oplus \text{♀ Epk}_{8-10}\overline{\text{K}}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$

Group 3 – bracteoles of epicalyx are fused but unattached to the calyx

- (xv) *H. articulatus* $\oplus \text{♀ Epk}_{(6-7)}\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$
 (xvi) *H. sterculifolius* $\oplus \text{♀ Epk}_{(9-11)}\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$
 (xvii) *H. tiliaceus* $\oplus \text{♀ Epk}_{(10-11)}\text{K}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$

Group 4 – bracteoles of epicalyx are fused and attached to the calyx

- (xviii) *H. scotellii* $\oplus \text{♀ Epk}_{(9-10)}\overline{\text{K}}_{(5)}\overline{\text{C}_5\text{A}_{(\infty)}}\underline{\text{G}}_{(5)}$

Acknowledgements. The authors are grateful to the staff and management of the Herbarium of Forestry Research Institute of Nigeria (FHI) Ibadan visited to study the preserved specimens.

References

- Akpan, G.A.** 2000. Cytogenetic characteristics and the breeding system in six *Hibiscus* species. – *Theor. Appl. Genet.*, **100**(2): 315-318.
- Alam, N.; Pasha, M.K. & Ahmad, S.** 2006. Identification of some *Hibiscus* germplasm through numerical analysis. – *Bangladesh J. Pl. Taxon.*, **13**: 49-54.
- Ayanbamiji, T.A.** 2010. Taxonomic study of *Hibiscus L. species* (*Malvaceae*) in Nigeria. PhD Thesis, University of Lagos, Nigeria.
- Burkill, H.M.** 1997. *The Useful Plants of West Tropical Africa*. Vol. 4. Royal Botanic Garden, Kew.
- Dalziel, J.M.** 1937. *The Useful Plants of West Tropical Africa*. Vol. 4. Crown Agents for the Colonies, London.
- Esau, K.** 1960. *Anatomy of Seed Plants*. John Wiley & Sons Inc., NY.
- Fryxell, P.A.** 1997. The American genera of *Malvaceae*-II. – *Brittonia*, **49**: 204-269.
- Ghazanfar, S.A.** 1989. *Savanna Plants: An Illustrated Guide*. Macmillan Publ., London.
- Heywood, V.H.** 1978. *Flowering Plants of the World*. Oxford Univ. Press, Oxford, London.
- Hutchinson, J.** 1967. *The Genera of Flowering Plants (Angiospermae)*. Vol. 2. Oxford Univ. Press.
- Metcalf, C.R. & Chalk, L.** 1965. *Anatomy of the Dicotyledons*. (Second edition). Vol. 1, Oxford Univ. Press.
- Olorode, O.** 1984. *Taxonomy of West African Plants*. Longman Group Ltd, England.
- Sharma, O.P.** 2008. *Plant Taxonomy*. Tata McGraw-Hill Publ. Co. Ltd, New Delhi.
- Stace, C.A.** 1989. *Plant Taxonomy and Biosystematics*. Edward Arnold Ltd, London.
- Ugborogho, R.E. & Shofoye, B.A.** 1983. Observations on the morphology, reproductive biology and economic importance of *Hibiscus esculenta* and *Hibiscus sabdariffa* (*Malvaceae*) in Nigeria. – *Nigerian Field*, **48**(1-4): 79-90.
- Willis, J.C.** 1973. *A Dictionary of Flowering Plants and Ferns*. 8th ed. rev. by Airyshow, H.K. Cambridge Univ. Press, Cambridge.