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Research Article

COMPARATIVE STUDIES ON MORPHOLOGY AND ANATOMY OF SELECTED SPECIES OF THE GENUS *AMARANTHUS* L. IN KERALA

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ABSTRACT
The genus *Amaranthus*, a widely cultivated taxonomic group, consists about 60–70 species. Collectively known as Amaranth, it is a cosmopolitan genus of herbs belonging to the family Amaranthaceae. Most of amaranth species are summer annual weeds and are commonly referred to as pig weed. The floral and vegetative characters of the genus are complicated and hence it is refered as a difficult genus. The paper attempts to understand in deep the morphological and anatomical characters of selected five species of *Amaranthus* viz of *A. caudatus, A. tricolor, A. viridis, A. blitum* and *A. hybridus*. An indended key is prepared on the anatomy and morphological characters reporting the new unnoticed traits which would help in the easy identification of the species. It also puts light into the evolutionary relationship of these species with respect to the taxonomical and anatomical traits.

Keywords: *Amaranthus, Morphology, Anatomy, Key to the Species*

INTRODUCTION
Under the traditional Bentham and Hooker system of classification (1862), the family Amaranthaceae comes under the series Curvembryae under the group Monochlamydae of Dicotyledons (Sambamurthy, 2010). Schinz, while dividing the family into two sub-families, viz. Amaranthoideae and Gomphrenoideae, included amaranths under the former group (Subfamily: Amaranthoideae; Tribe: Amarantheae (Vasishta, 1994). With time, this classical position has undergone several revisions. Currently, the APG III system of classification assigns the following hierarchal position to the genus (APG, 2009):- Super regnum: Eukaryota; Regnum: Plantae; Cladus: Angiosperms; Cladus: Eudicots; Cladus: Core eudicots; Order: Caryophyllales; Familia: Amaranthaceae; Subfamilia: Amaranthoideae; Genus: *Amaranthus*.

Sauer (1955) designated two subgenera: *Acnida* (which included the dioecious species) and *Amaranthus* (which included the monoecious species) (Sauer 1950, Modified in 1955). Mosyakin & Robertson (1996) recognized three subgenera, i.e. *Acnida*, *Amaranthus* and *Albersia* based on classical characters, such as inflorescence and floral characteristics. The differences observed in phyllotaxy, combined with the organization of the leaf vascular supply, support this classification (Costea & DeManson, 2001).

Taxonomically, the family Amaranthaceae comes under the series Curvembryae under the group Monochlamydae of Dicotyledons as per the traditional system by Bentham & Hooker (1862), Sambamurthy, (2010); Vasishta, (1994). With revisions in the systems of classification based on similarities and dissimilarities at the molecular level, the family, under the APG 3 system of classification was placed under the Order Caryophyllales (APG, 2009). Due to high levels of phenotypic plasticity, broad geographical distribution and other factors, the need for infra-generic classification were addressed (Achigan-Dako *et al.*, 2014). Sauer (1955) initially designated two subgenera: *Acnida* (which included the dioecious species) and *Amaranthus* (which included the monoecious species) (Sauer 1950, 1955). Infra-generic classification by Sauer focused on inflorescence, floral characters and if the flowers were monoecious or dioecious (Juan *et al.*, 2007). The leaves are alternate or opposite, exsipulate and simple. A branched tap root system is present. The stem is aerial, erect or straggling, branched, herbaceous or woody (Sambamurthy, 2010; Vasishta, 1994). Flowers are bracteate and bracteolate, small and inconspicuous and hypogynous. *Amaranthus* is a genus that includes annual more rarely perennial herbs that are glabrous or covered with short and gland-like or multi-cellular hairs. They can be monoecious or dioecious. Leaves are alternate with long petioles and entire or wavy. Flowers are unisexual and seeds are

usually compressed, black, and shiny. Many of the species in this genus are edible and some are cultivated for their leaves (Townsend, 1997).

The anatomical peculiarities of *Amaranthus* have been studied by many researchers. The members of the family Amaranthaceae, along with the members of Polygonaceae, Nyctaginaceae, Chenopodiaceae and Piperaceae are characterized by the presence of vascular bundles in the pith, known as medullary bundles, in addition to the normal ring of vascular bundles (Chandurkar, 1983). The presence of medullary bundles is an 'anomaly', which according to Esau is 'a growth pattern which occur less common' (Esau, 1965). These are 'leaf trace bundles', produced by leaf traces entering the node and running through several internodes before reaching the vascular system in the stem (Chandurkar, 1983).

MATERIALS AND METHODS

Species of *Amaranthus* available abundantly in Kerala viz. *A. viridis, A. spinosus, A. tricolor, A. blitum, A. caudatus* and *A.hybridus* were selected as the experimental plants. The plants, after identification from the Department of Botany, Mahatma Gandhi College, Trivandrum, were assigned with collection numbers and the following data regarding each plant were collected: Location of the plant, and notes on the immediate locality of the plant. The fresh plant within one week of flowering was collected and was subjected to taxonomical identification of different characters. The plants were worked out with the help of The Flora of The Presidency of Madras (Gamble) Volume 2. The characters and variations were noted for the preparation of key.

Anatomy

Some mature and fresh parts of the leaves, stems and roots of each species among the experimental plants were collected. With the help of a razor blade different transverse sections of stem and root were obtained by cutting along the radial plane of a cylindrical portion of the stem and root. Leaf was dissected with the help of papaya pith. All the fine dissections were kept in watch glass along with water (Baral M, 2013). The sections were mounted as performed by (Omosun, Markson and Mbanasor, 2008), with modifications. The obtained sections were mounted temporarily; photographed using Leica photomicroscope and the characters were noted. Safranin was used to stain the sections and Glycerine was used as the mountant. The sections were then photographed.

RESULTS AND DISCUSSION

The morphological characters of *A. caudatus, A. tricolor, A. viridis, A. blitum* and *A. hybridus* were studied in detail. Key based on the general distinguishable morphological characters was prepared. The general morphological characters are as have been summarised in Table 1 and a key for identification has been given in Table 2. The number of periyanth present in *A. tricolor* were reported as three (Das, 2012) which is varied in the present study. Periyanth *A. tricolor* is seen as 5 which can be used as a major lead in classifying the species. *A viridis* and *A.blitum* has 3 tepals which is similar to the previous reports. *A.hybridis* has an additional periyanth like structure apart from the 5 tepals which has been reported. The height thickness large leaves and branched spike makes its easy identification. *A. tricolor* is distinguished from the other species with the purple color and the globose inflorescence, in the present study it was also noticed that the bract was straight. *A.blitum* is distinguished by the prostrate appearance of its habit and the presence of small leaves, terminal spike and profuse branches. It is observed 5cm in length, on reaching a particular stage of growth the branches grow extensively in a decumbent prostrate manner which can be used as a key feature in identifying the species. The prostrate nature of the stem and reduced number of tepals suggests that among the species under study *A.blitum* is the most primitive one. The reproductive characters of the species is much complicated than the others. Apart from *A.blitum, A.viridis* also have 3 tepals but the nature of its stem and inflorescence resembles more to *A.caudatus* and *A.tricolor*. *A.caudatus* and *A. tricolor* are closely related in terms of their infloresence number of tepals and nature of stem and leaf. They differ in terms of the bract structure and color of stem and leaf. A. hybridus has many bracts and tepals. The size of the plant is also huge with respect to other species. Anomalous secondary thickening was shown by all the species under study. The result is in close

proximity with the findings of Esau, (1965). The presence of medullary bundle other than the V.B, presence of conjuctive tissues has been reported as anomaly though the number and position of the same varies with species. A.hybridus was separated by the presence of double layered epidermis, and the presence of large pith area. Shape of the stem cross section is also an important lead in identifying the species. It shows a great variance with the members. On the basis of the width of medullary rays in the root *A.tricolor* and *A caudatus* were separated. A key which is different from the one reported by A.A.L Ghamery in 2005, has been prepared incorporating the anatomy of leaf as well as petiole.

Table 1: Morphological Characters of the Species under Study

Species	Habit	Stem	Leaf	Inflorescence	Flower
A.blitum	Decumbent annual herb	Dark purple, extensively branched, glabrous	Alternate, small, wavy margin, ovate,	Terminal, green & small	Male flowers on top, female flowers on bottom, periyanth 3-5, bract length greater than periyanth length
A.tricolor	Erect annual herb	Erect, branched, glabrous, dark purple	Alternate, slightly pubescent, margin entire	Terminal/ nodal spike, globose cluster, purple colour	Male & female flower intermixed, periyanth 5
A.caudatus	Erect annual herb	Erect, branched, green, slightly pubescent	Obovate ,acute base, recurvate bract	Terminal & nodal, green	Male flowers in terminal spike & female only in nodes, periyanth 5 lobed, bract length = periyanth length
A.hybridus	Erect annual herb	Erect, green, thick, heavily branched	Large, glabrous, wavy margin, round apex	Spike green ,branched.	Male and female flowers intermixed, bract lessthanperiyanth.
A.viridis	Erect annual herb	Erect, branched, green.	Ovate, truncate apex, petiole	Axillary & terminal spike.	Male & female flower intermixed, tepals 3.

Key Based on Morphology

1. Habit erect shrub. . . . . [2]

1. Habit prostrate decumbent herb; Branches profuse; Bract length greater than perianth length. . . . . *A. blitum*

2. Terminal spike heavily branched and prominent; Leaves large. . . . . *A. hybridus*

2. Terminal spike unbranched or sparcely branched; Leaves moderately sized. [3]

3. Perianth three in number; Leaf margin wavy; Bract length lesser than perianth length . . . . . [4]

3. Perianth five in number; Leaf margin entire; Bract length equal to perianth length . . . . . [5]

4. Stem purple coloured; Inflorescence as aggregation of globose clusters; Bract straight. . . . . *A. tricolor*

4. Stem green coloured; Inflorescence as a single unit; Bract recurvated. . . . . *A. caudatus*

5. Spike green coloured; Stem green coloured; Leaf with truncate apex. . . *A.viridis*

Table 2: Anatomical Characters of the Selected Species

Species	Stem	Leaf	Petiole	Root
A.tricolor	Epidermis: single layered round cells Cortex:3-9 layered collenchyma, 3 layers of chlorenchyma present V.B scattered	Epidermal hair multicellular, lower epidermis has crystals.	2 notches in lateral pattern 1-7 layered collenchyma Arc shaped V.B	Secondary xylem 1- 7 and arranged in two groups. Distribution of parenchyma between secondary vessels only. Medullary ray wide and long 2 anomalous ring
A.caudatus	Epidermis: single layered round cells Cortex:5-9 layered collenchyma, medullary bundles occupies pith	Epidermal hair multicellular, lower epidermis has crystals	1-7 layered collenchyma Arc shaped V.B with on bundle large on apical region	Secondary xylem more than 7 and arranged in two groups.. Medullary ray narrow and long 1 anomalous ring
A,blitum	Irregular outline Epidermis: single layered Sclerenchymatous hypodermis Endodermis in patches medullary bundles 22	Epidermal hair multicellular on both sides	Epidermis single layered 2-3 patches of xylem near epidermis	Anomalous cambium product is lignified parenchyma only, Sand crystals present 2 anomalousrings present
A.viridis	Wavy in outline Single layered epidermis 5 layers of sclerenchyma present Chlorenchyma in patchesconjuctive tissue forms a continuous ring	Epidermal hairs 3 – 6 celled, thick cuticle present Hairs present in mid rib region	8 C shaped V.B Epidermis followed by chlorenchyma patches and collenchyma	Secondary xylem more than 7 and arranged in two groups.. Medullary ray narrow and long 1 anomalous ring Anomalous cambium product is lignified parenchyma only
A.hybridus	Circular in cross section Epidermis 2 layered, pappilose shaped cells 6-7 layers of collenchyma	Epidermal hair absent C shaped V.B	Petiole has thick cuticle 12 V.B present	Secondary xylem ranges from 1-7 No of anomalous ring-1

Key Based on Anatomy

1. Stem epidermis multi-layered; Pith covers more than 50% of the cross section. . . . . *A. hybridus*

1. Stem epidermis single layered; Pith covers less than 50% of the cross section. . . . . [2]

2. Stem hypodermis distinguished into concentric zones of single type of cells. . . . . [3]

2. Stem hypodermis with patches of chlorenchyma at regular intervals. . . . . [4]

3. Stem cross section irregular; Sandy crystals in pith present. . . . . [5]

3. Stem cross section orbicular; Sandy crystals in pith absent. . . . . [5]

4. Stem endodermis in patches; Leaf hairs present; Lignified parenchyma in anomalous ring of root in discontinuous ring. . . . . *A. blitum*

4. Stem endodermis in continuous ring; Leaf hairs absent; Lignified parenchyma in anomalous ring of root in continuous ring. . . . . *A. viridis*

5. Stem medullary bundles occupy most of the pith; Starch grains in root absent; Medullary rays of anomalous ring in root narrow. . . . . *A. caudatus*

5. Stem medullary bundles does occupy most of the pith (pith prominent); Starch grains in root present; Medullary rays of anomalous ring in root wide. . . . . *A. tricolor*

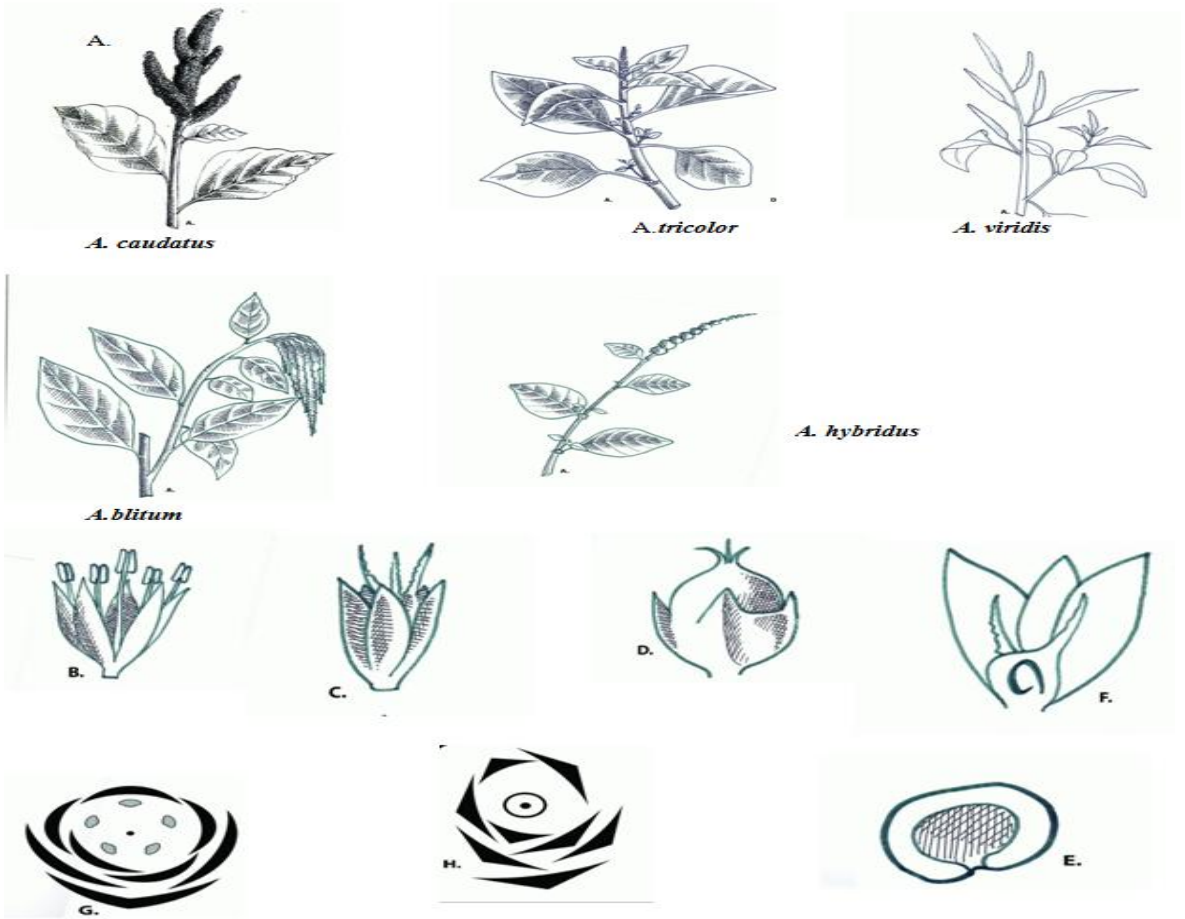

Figure 1: Morphological Variations

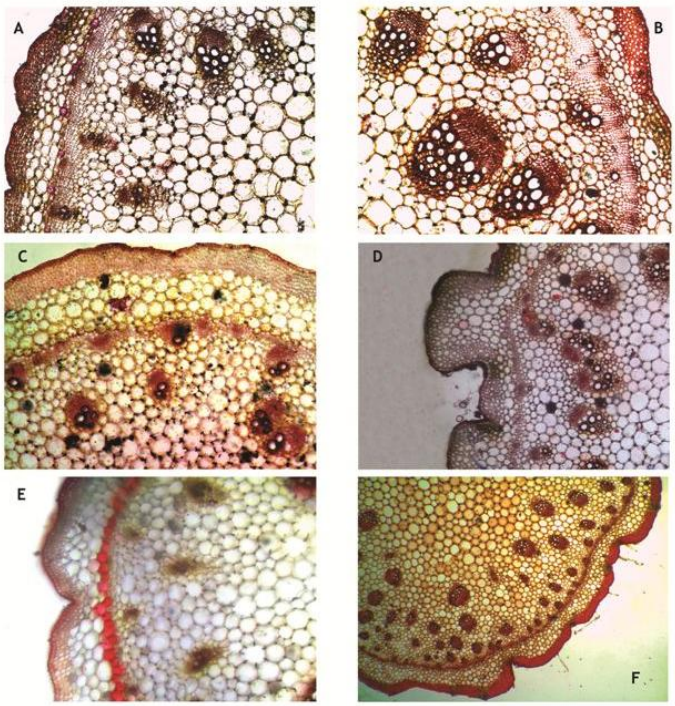

Figure 1: STEM T.S. A. *Amaranthus Blitum* B. *A. Viridis* C. & D. *A.caudatus* E. *A.Hybridus* F. *A.tricolor*

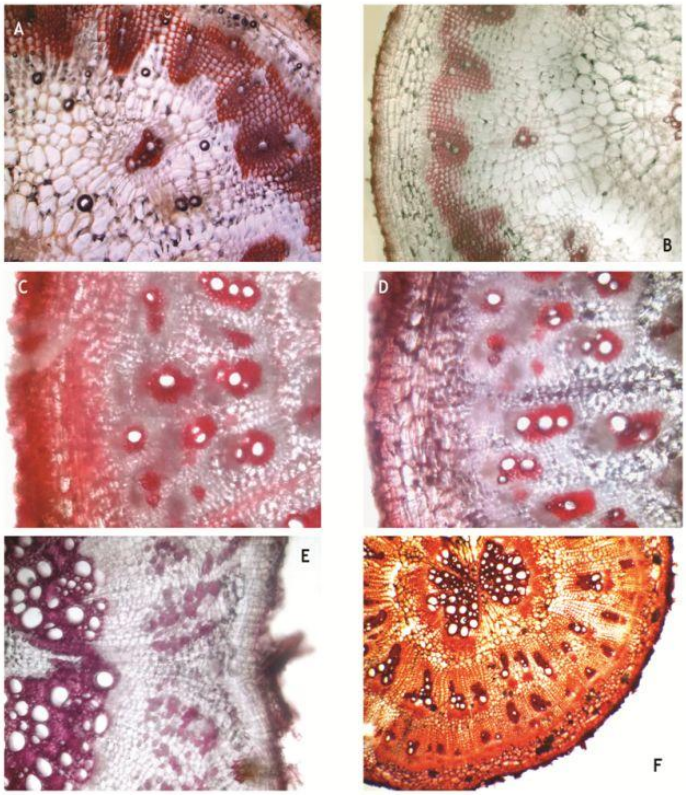

Figure 3: ROOT T.S. A. *Amaranthus Blitum* B. *A. Viridis* C. & D. *A. Caudatus* E. *A. Hybridus* F. *A. Tricolor*

Conclusion

The different morphological and Anatomical characters of the 5 species of Amaranthus under study helps in the easy identification of the Spinach. Certain characters which were unnoticed by the others such as the shape of bract infloresence and tepals are also included in the key. The species shows primitive characters to complicated ones in the order *A. blitum, A.viridis, A.caudatus, A.tricolor, A.hybridus* suggesting an evolutionary relationship between them. The anatomical characters in conjunction with morphology reveals identification of the species more reliable.

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