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RESEARCH ARTICLE

MORPHOLOGICAL AND STEM ANATOMICAL DESCRIPTION OF 6 *AMARANTHUS* L. SPECIES
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ABSTRACT

Stem anatomy, stomatal types and stomatal index in addition the morphological characters for 6 species of genus *Amaranthus* named *A. caudatus*, *A. graecizens*, *A. hybridus*, *A. retroflexus*, *A. spinosus* and *A. viridis* are collected from Jazan, Saudi Arabia. Two types of stomata are recognized; anomocytic and anisocytic. Anomocytic type found only in *A. graecizens* while anisocytic found in the remainder. The different stem anatomical characters are discussed and revealed a distinct characters for each species. Both Leaf epidermal and anatomical features revealed a great taxonomical values which in turn will be used for the correct identification of each species. An artificial key is provided for the identification of the studied species.

INTRODUCTION

Although genus *Amaranthus* (Amaranthaceae) has been the subject of many taxonomic treatments, it is still poorly understood and is widely considered a difficult genus. It consists of about 70 species that are distributed worldwide. They are mostly native, weeds or cultivated ornamentals, pseudo cereals or vegetables (Costea, et al., 2001). In Jazan, nine species of *Amaranthus* are recorded by Alfarhan et al. (2005). The *Amaranthus* species can be divided into two subgenera; *Amaranthus* and *Albersia* based on flowering morphology (Göpf, 1986; Horak et al., 1994; Robertson, 1981 and Wax, 1995). Mosyakian and Robertson (1996) proposed the subgeneric rank [subgenus *Albersia* (Kunth) Gren. & Godr.] for the section *Blitopsis* sensu lato. This infrageneric classification with 3 subgenera (*Albersia*, *Amaranthus* and *Albersia*) is based on classical characters, such as those of inflorescence and floral characteristics, and it would be interesting to see if other characters support it too. Caroline et al., 1978, reported the anatomy of some species of *Amaranthus* have bundle sheath. Leaf epidermal features in *Amaranthus* are considered to be taxonomically important (Abdulrahman and Oladele, 2010). Schinz (1893) stated that secondary growth in *Amaranthus* derived from successive cambia which are permanently active.

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Sandy crystals are common in the family Amaranthaceae (Metcalf and Chalk, 1950). Viana (1993) described some general aspects of anatomy in *A. viridis*. Aim of the work is to investigate the different anatomical features of the taxa of *Amaranthus* in Jazan.

MATERIALS AND METHODS

The collection of the botanical material and the field observations of the studied taxa were collected from Abu-Arish. Taxa are identified according to Alfarhan et al. (2005) and Masrahi (2012). Materials and habits of *Amaranthus* are listed in Table 1. The morphological description of the studied plants are carried out from fresh plants. Stem cross sections have been carried out using freshly collected materials which are fixed in ethanol 70 % and carried out according to methods of Johansen (1940).

Table 1. Provenance of the studied taxa of genus *Amaranthus*

No.	Species	Subgenus	Section	Habit
1	<i>A. caudatus</i>	<i>Amaranthus</i>	<i>Amaranthus</i>	Cultivated
2	<i>A. graecizens</i>	<i>Albersia</i>	<i>Blitopsis</i>	wild
3	<i>A. hybridus</i>	<i>Amaranthus</i>	<i>Amaranthus</i>	wild
4	<i>A. retroflexus</i>	<i>Amaranthus</i>	<i>Amaranthus</i>	wild
5	<i>A. spinosus</i>	<i>Amaranthus</i>	<i>Amaranthus</i>	wild
6	<i>A. viridis</i>	<i>Albersia</i>	<i>Blitopsis</i>	wild

This material was cut free hand or in semi-rotative microtome to make semi-permanent and permanent slides for the microscopic slides, carried out according to the usual techniques. Sections were stained in safranin and light green. Stomata epidermal cells and stomatal index are carried out according to methods of Ahmad *et al.* (2010). The stomatal index (SI) was calculated using the formula described by Salisbury (1972) that is:

$$SI = \frac{S}{S + E} \times 100$$

Where S donates the number of stomata per unit area and E the number of epidermal cells in the same unit area.

RESULTS AND DISCUSSION

Macromorphological Characters

1-*A. caudatus*: Annual, erect herb, erect branched herb, up to 30-40 cm, red in colour, stem slender stout, branched, with glandular trichomes. Leaf alternate, lanceolate, 2-5-3.0 cm, petiole long. Inflorescence yellowish to reddish or purplish in axillary and terminal spikes of cymose clusters.

2-*A. graecizans*: Annual, erect herb, erect branched herb, up to 30-40 cm, reddish green in colour, stem slender stout, branched, with glandular trichomes. Leaf alternate, lanceolate, 2-5-3.0 cm, petiole long, 3-4 cm long. Inflorescence yellowish to reddish or purplish in axillary and terminal spikes of cymose clusters.

3-*A. hybridus*: Annual or biennial, erect branched herb, up to 140-180 cm, green in colour, stem semi solid, branched, angular, greenish or reddish in colour, glabrous. Leaf alternate, broadly lanceolate to ovate, 20-25 cm, petiole 4-6 cm long. Inflorescence yellowish to reddish or purplish in spike axillary and terminal spikes of cymose clusters, 4-6 cm in length.

4-*A. retroflexus*: Annual, erect, branched herb, up to 100-120 cm, pale green in color, leaf alternate, ovate to rhomboid-ovate; 12-15 cm, petiolated, 5-7 cm. Each leaf axil bears a pair of stout, slender spines. Inflorescence axillary and terminal spike like slender axillary clusters.

5-*A. spinosus*: annual, erect, branched herb, up to 100-120 cm, green in colour, leaf alternate, with two opposite axial spines, Ovate to rhomboid; 12-15 cm, petiolated, cm. Each leaf axil bears a pair of stout, slender spines. Inflorescence terminal spike like slender axillary clusters.

6-*A. viridis*: Annual, rarely ascending herb, erect branched herb, up to 1 m, pale green in color, stem stout, branched, angular, with glandular hairs, in colour, glabrous. Leaf alternate, lanceolate, 4-5 cm, petiole long, 1-4 cm. Inflorescence yellowish to reddish or purplish in axillary and terminal spikes of cymose clusters. Inflorescence terminal, spike like slender axillary clusters.

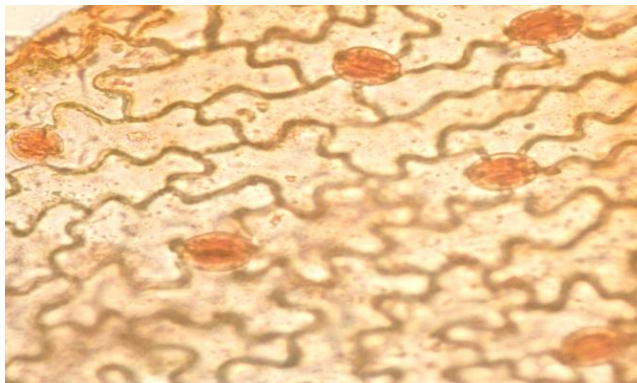
Micromorphological characters

A. Stomatal characters

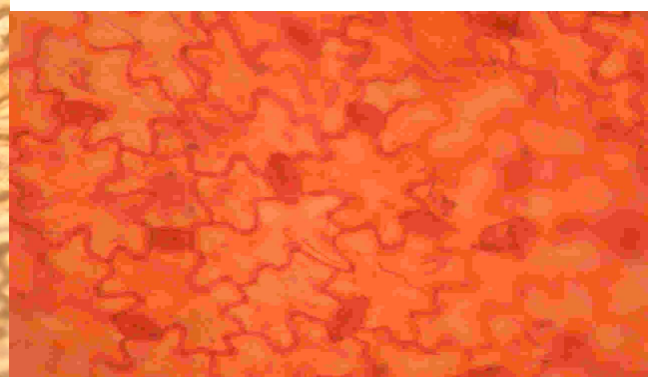
According to Table 2, types and stomatal number in addition to stomatal index seem to be important differences between the taxa. Stomatal types and index are observed in all the studied species of *Amaranthus* and illustrated in Plate 1. Leaf epidermal cells are differed between the different species; where undulated, straight or wavy are noticed. Two types of stomata are examined; anomocytic and anisocytic type which is common in the five species of *A. caudatus*, *A. hybridus*, *A. retroflexus*, *A. spinosus* and *A. viridis* while anomocytic type found only in *A. graecizans* (Plate 1).

Table 2. Quantitative data of leaf epidermal cells of *Amaranthus* sp.

No.	Species	No. of epidermal cells		No. of stomata		Stomatal index		Stomatal Types
		A	L	A	L	A	L	
1	<i>A. caudatus</i>	68	52	12	19	15	26.76	anisocytic
2	<i>A. graecizans</i>	50	41	8	15	13.79	26.78	anomocytic
3	<i>A. hybridus</i>	71	60	13	17	15.47	22.77	anisocytic
4	<i>A. retroflexus</i>	65	49	12	18	15.58	26.86	anisocytic
5	<i>A. spinosus</i>	57	48	11	20	16.17	29.41	anisocytic
6	<i>A. viridis</i>	38	32	19	26	33.33	44.82	anisocytic



1- *A. caudatus*



2- *A. graecizans*

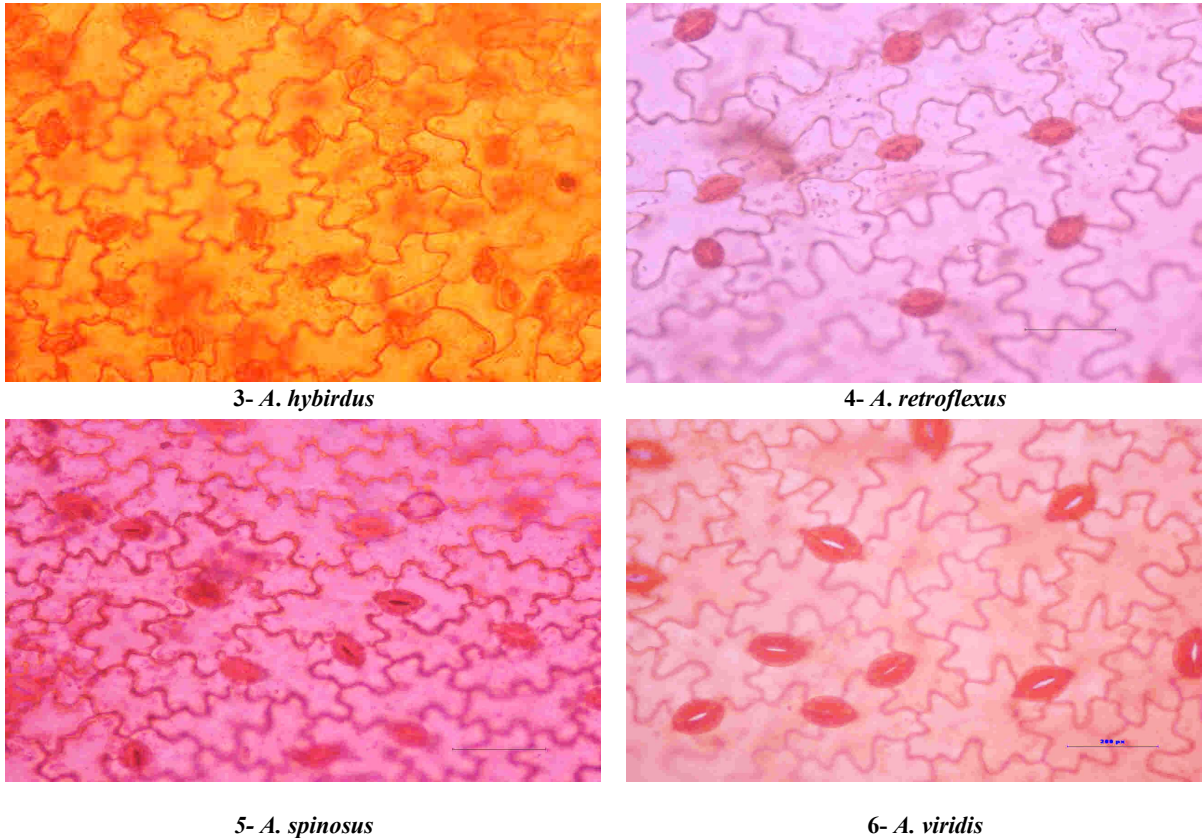


Plate 1. Leaf Surface views of the studied species

B. Stem Anatomy

1- *Amaranthuscaudatus*: Orbicular in cross section, solid, outer cortical zone has papillose single layer of collenchyma cells. The inner zone consists of 2-4 layers of parenchyma cells, Meristematic zone of the cortex has cambial ring which in turn surround the outer zone of collateral vascular bundles. The medullary bundles are few and scattered gives patches of secondary xylem element alternating with patches of sclerified tissues. One ring of vascular bundle is present and some of bundles moves inward to the pith. Druses and sandy crystals are present in the pith, stomata in this species is anisocytic with (Plate 2).

2- *Amaranthusgraecizans*: Quadrate to circular in outline, solid, outer cortical zone consists of 2-4 layer of collenchyma, inner zone consists of 2-4 layers of parenchyma, The cambial ring of meristematic tissues gives patches of secondary xylem element alternating with patches of sclerified tissues which has sclerified parenchyma. Medullary bundles are numerous, and arranged specially at the periphery of pith which represent narrow zone of polygonal parenchyma cells. Sandy crystals are present in pith, stomata in this species is anisocytic in which the subsidiary cells are 3-4 kidney shaped (Plate 2).

3- *Amaranthus hybridus*: Circular in cross section, solid, epidermis has two layers of papillose shaped cells. Cortical

zone consist of 6-8 layers of collenchymatous cells, scattered collateral primary vascular bundles separated by outer heterogeneous parenchyma cells and sclerified parenchyma. Pith occupies a vast area containing numerous scattered medullary bundles. Sclerified homogenous parenchyma cells are present. A few sandy crystals are recorded in cortex and pith. Stomata in this type is anisocytic type, stomata are surrounded by undulated subsidiary cells (Plate 2).

4- *Amaranthus retroflexus*: Rounded in the cross sections, solid, epidermis has one layered of rounded cells. Outer cortical zone consists of 4-6 layers of homogenous collenchyma cells ended with patches meristematic tissues.. No restricted obvious vascular medulla is present; numerous collateral vascular bundles are scattered, some of them inward the meristematic tissues. Sandy crystals are recorded in cortex and pith. Stomata in this type is anisocytic type which surrounded by sinuate subsidiary cells.

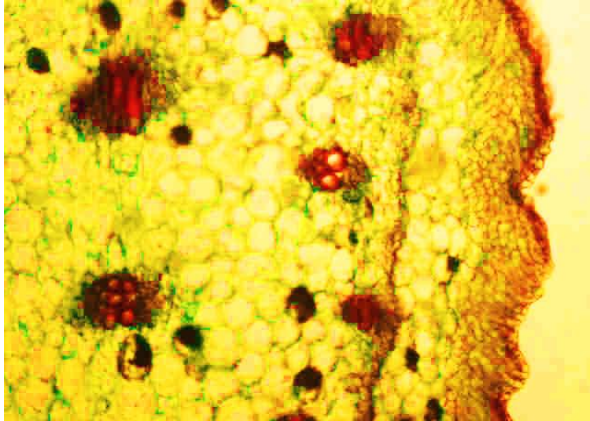
5- *Amaranthus spinosus*: Terete in the outline, epidermis with 1-2 layered of papillose elongated cells. The outer cortical zone consists of 8-10 layers of lacunar collenchyma cells. Cambial ring is formed in the inner layers of the cortex and continued surrounded the numerous vascular bundles. Some bundles move inwards to the pith zone. Sandy crystals are noticed in cortex and pith.

6- *Amaranthusviridis*: Ovate to circular in outline, solid, epidermis one layered of rounded or parallel cells, replaced by

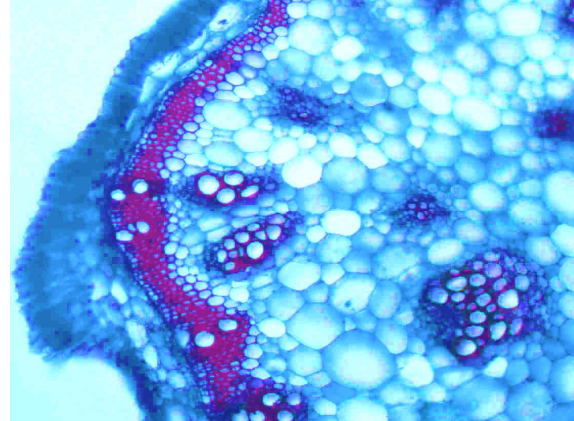
cortical zone which consist of 3-5 layers of collenchymatous cells followed by inner zone of 2-4 layers of parenchyma cells. Medullary bundles are scattered and numerous, each bundle sheathed with sclerified parenchyma cells. Formations of meristematic tissue ring are similar to those of *A. spinosus*. Pith represents the vast central area consisting of hexagonal parenchyma cells. Medullary bundles form single ring sheathed with clarified parenchyma cells. Common sandy crystals are noticed in the cortex and the pith. Stomata in this type are anisocytic type surrounded by four undulated subsidiary cells (Plate 2).

DISCUSSION

Most of the investigated species showed distinct anatomical characters which can be used as a confirmatory taxonomic character. In this work comparative anatomy is the tool that is used throw light on investigated species of genus *Amaranthus*. Anisocytic types of stomata were the most common and frequent, occurring in species of *A. caudatus*, *A. hybridus*, *A. retroflexus*, *A. spinosus* and *A. viridis*.



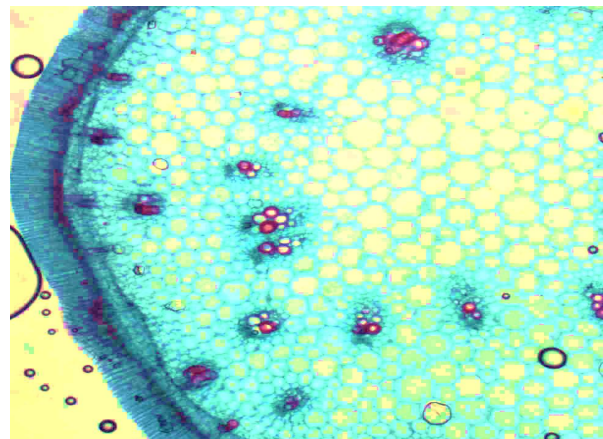
1- *A. caudatus*



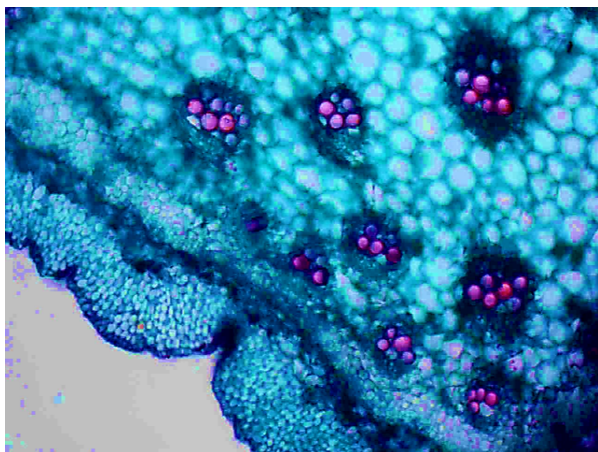
2- *A. graecizans*



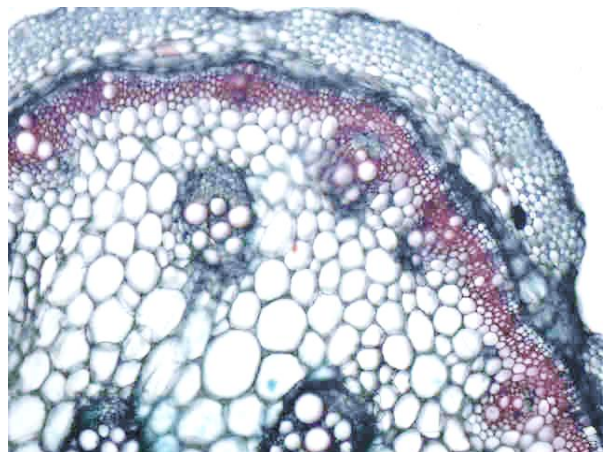
3- *A. hybridus*



4- *A. retroflexus*



5- *A. spinosus*



6- *A. viridis*

Plate 2. Stem transfer sections of the studied species

Anomocytic type of stomata is found only in *A. graecizans*. Such results are differed with results of Abdulrahman and Oladele, 2010. The stomatal index of all the examined species of *Amaranthus* show a wide range of variation. Different stomatal behavior and stomatal index on upper and lower surfaces is presented in Table 2. Stomatal index is found to be high in *A. viridus* (33.33%) to (44.82%) and lowest in *A. graecizans* (13.79%) to (26.78%) respectively, while the stomatal index in *A. hybridus* (15.47 to 22.77%), *A. retroflexus* (15.58% to 26.86%) and in *A. spinosus* (16.17% to 29.41%), respectively. Transverse sections of mature leaves show similar structural patterns. Outline of the stem in cross section is generally terete. All the epidermal cells are papilose except *A. hybridus*. The cortex is generally distinguished into two zones: outer zone of collenchymas patches especially in ribs or parenchyma patches alternating with collenchymas. Inner zone consists of parenchyma which can be mixed chlorenchyma. Primary vascular bundles are collateral in the investigated species. In the studied species, bundles are conjoint and scattered in medulla. They arranged in ring. All stem of the investigated taxa are solid. Sandy crystals are common in all the parenchyma of the studied species. In old stem most of the epidermal cells are replaced in older internode by tangentially elongated cells. Secondary growth starts with the initiation of a meristematic zone. In the outer cortex, there are a growth ring consisting of secondary xylem move inwards and secondary phloem outwards, conjunctive tissues consists of outer parenchyma and inner sclerified parenchyma. Sandy crystals are common in all the parenchyma of the studied species except *Amaranthus caudatus* has a druses crystal; such results differed with results of Salama, 1988 which had a comparative taxonomical studied on family Amaranthaceae in Egypt. The following key show the possibility of using both of the morphological and anatomical characters for identification purposes on the general level:

1. a. Leaves with 2 small hard axial spines..... *A. spinosus*
- b. Leaves without axial spines.....2
2. a. Inflorescence in axillary cymose cluster.....*A. graecizans*
- b. Inflorescence in spikes.....3
3. a. Ornamental herb up to 2 m height..... *A. hybridus*
- b. Weeds of cultivation, less than 2 m height4
4. a. green plant with red inflorescences, has a druses crystals....*A. caudatus*
- 4.b. Green plants with non-red inflorescences; several vascular bundles...5
- 5.a. Leave up to ≤8-10 cm long,.....*A. viridis*
- 5.b. Leaves up to ≥ 10-12 cm long.....*A. retroflexus*

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