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Comparative studies on morphology of selected six species of the genus *Amaranthus* L. from India

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Abstract
Amaranthus is world widely occurred genus, it is cosmopolitan in nature and belongs to family Amaranthaceae. The selected species of Amarnthus from different states of India are viz; *Amaranthus blitum*, *A. blitoides*, *A. deflexus*, *A. dubius*, *A. polygonoides*, and *A. retroflexus*. An indented key is prepared on the basis of morphological characters which helps in the easy identification of the species. The present paper reveals that selected species of *Amaranthus* shows amazing morphological diversity.

Keywords: *Amaranthus blitum*, *A. blitoides*, *A. deflexus*, *A. dubius*, *A. polygonoides*, and *A. retroflexus*, morphological characters

Introduction

Amaranthus is a genus belongs to the family Amaranthaceae. The family is represented by approximately 60 genera. Among the cultivated species, grain amaranths have been grown for more than 8,000 years dating back to before the Pre-Colombian civilization of Central and South America (He and Park 2013) [3, 12]. The genus *Amaranthus* shows both cultivated and wild species. *Amaranthus* is a wide taxonomic group with a large diversity of species, with particular traits such as resistance to biotic and abiotic stresses, high yields, nutritive, nutraceutical and market qualities (Enoch *et al.*, 2014) [2]. Mosyakin and Robertson, 2003 reported that 70 species *of* genus *Amaranthus* consists of inflorescences stretching from red, purple, through green and red to gold. According to Norman (1992) [8] *Amaranthus* is a tremendously short-lived annual plant which develop vigorously, drought resistant and adapt easily to new environments. Majority species shows unisexual Flowers and compressed, black, and shiny seeds. In India, various domesticated forms are grown in Tamil Nadu, Andhra Pradesh, Karnataka and Kerala (Khurana *et al.*, 2013) [4]. Many of the species in this genus are edible and some are cultivated for their leaves (Townsend, 1997). Amaranth seed is borne in a utricle, which is categorized as dehiscent, semi-dehiscent, or indehiscent type (Topwal 2019) [7]. Amaranth shows a wide variety of morphological diversity among and even within certain species. Although the family (Amaranthaceae) is distinctive, the genus has few characteristics that distinguish the species (Oo and Park, 2013) [3, 12]. The morphological characters differed significantly in their frequency of distribution and the amount of variation in the genetic pool (Gerranol *et al.*, 2017) [1]. A desire to find recognizable morphological features for use in positive species separation of the many ecological forms prompted the present study of the Indian species of *Amaranthus*. The present investigation has been oriented toward the study of field collections from India, field observations, and herbarium specimens.

Materials and Methods

Herbarium Study: Herbarium specimen sheets of *Amaranthus blitum*, *A. blitoides*, *A. deflexus*, *A. dubius*, *A. polygonoides*, and *A. retroflexus* of the BSI were studied to obtain information about habitats, morphological variation, phenology and distribution.

Field Collection Specimens: of *Amaranthus blitum*, *A. blitoides*, *A. deflexus*, *A. dubius*, *A. polygonoides*, and *A. retroflexus* were collected in India during 2017 to 2020. The collected specimens were identified with the help of The Flora of The Presidency of Bombay (Cooke, 1967) [10] and Flora of Kolhapur (Sardesai and Yadav, 2003), Flora of Maharashtra State (Singh and Karthikeyan, 2000) [9]. These specimens were used for analysis of morphological characters. The location, habitat, and the collection date of each specimen were recorded.

Morphological Character Study: Roots, stems, leaves, inflorescences, flowers, and seeds of each species were examined, measured, drawn and photographed, as described below:

Roots: The color and system of roots were determined by gross inspection. The depth of the roots was measured with a metric ruler.

Stems. The colors, textures and branching patterns of the stems were determined by gross inspection. The statures of the stems were measured with a metric ruler.

Leaves. The colors, textures and the shapes of the leaves of each species were determined by gross inspection. The sizes of the leaves were measured with a metric ruler.

Inflorescences and flowers. The inflorescences of the species were examined and the flowers of each species were examined with dissecting microscope. The number of bracts, tepals, ovaries and stigmas of the pistillate flowers and stamens of the staminate flowers were counted.

Seeds. Mature seeds were collected separately for each species during study. They were examined under a dissecting microscope and then drawn.

Herbarium Study: The genus *Amaranthus* grows throughout the India and other countries in the world. *Amaranthus blitum, A. blitoides, A. deflexus, A. dubius, A. polygonoides,* and *A. retroflexus* have been collected from different states of India. The habitats of *Amaranthus* plants are usually waste places or cultivated fields.

Field Collection

Six species of *Amaranthus* have been found in India: *Amaranthus blitum, A. blitoides, A. deflexus, A. dubius, A. polygonoides,* and *A. retroflexus* .They are found along roadsides, waste areas, and on cultivated lands.

Table 1: Studied *Amaranthus* Species

Species	Locality	Floristic region
A. deflexus L.	19° 15' 28.0440" N and 76° 46' 25.4748" E	Parabhani
	31° 38' 2.3280" N and 74° 52' 20.1396" E.	Amritsar
	28° 38' 41.2800" N and 77° 13' 0.1956" E.	Delhi
	30° 44' 29.3352" N and 76° 46' 5.0376" E.	Chandighar
A. blitum	16°59'2.44" N and 74°07'26.94" E	Shirala
	17°16'48.00" N and 74°12'0.00" E	Karad
	16° 52' 19.3692" N and 74° 2' 29.1408" E.	Bambavde
	11° 24' 36.0000" N and 76° 41' 59.9892" E.	Ooty
A. blitoides	16°51'15.77" N and 74°33'51.01" E	Nathavade
	16° 52' 3.4824" N and 74° 34' 13.4004" E.	Sangli
	28° 38' 41.2800" N and 77° 13' 0.1956" E.	Delhi
	27° 10' 36.0120" N and 78° 0' 29.0592" E.	Agra
A. dubius,	29° 58' 10.2468" N and 76° 52' 41.8116" E.	Kurukshetra
	26° 55' 19.4520" N and 75° 46' 43.9860" E.	Jaipur
	12° 18' 42.5772" N and 76° 39' 10.7460" E.	Mysore
	30° 54' 16.1496" N and 77° 5' 48.2388" E.	Solan
A. polygonoides	17° 39' 35.7120" N and 75° 54' 22.9932" E.	Solapur
	16° 52' 3.4824" N and 74° 34' 13.4004" E.	Sangli
A. retroflexus	19° 54' 3.7944" N and 75° 21' 8.9208" E.	Aurangabad
	16° 52' 3.4824" N and 74° 34' 13.4004" E.	Sangli
	19° 4' 33.9240" N and 72° 52' 38.7336" E.	Mumbai
	19° 15' 28.0440" N and 76° 46' 25.4748" E	Parabhani
	31°36'17.81"N and 74°34'20.37"E	Wagha Border

Morphological Character Study

The morphological characteristics of roots, stems, leaves of each species are compared in Table 1and inflorescences, bracts, flowers, fruits, and seeds of each species are compared in Table 2. Each species is described based on morphological characteristics. A key has been constructed for separating the six species *of Amaranthus*.

Table 2: Comparison of Vegetative Characteristics of *Amaranthus* Species

Sr. No.	Taxon Character	*A. blitum*	*A.blitoides*	*A. deflexus,*	*A. dubius,*	*A. polygonoides*	*A. retroflexus*
1	Geographic Origin	Shirala Karad Bambavde Ooty	Delhi Nathavade Sangli, Agra	Parabhani Amritsar Delhi Chandighar	Natoli Kurukshetra Jaipur Mysore Solan	Solapur Sangli	Aurangabad Sangli Mumbai Parabhani Wagha Border
2	Longevity	Annual	Annual	perennial or Annual	Annual	Annual	Annual
3	Root System Type	Tap root	Tap root	Tap root	Tap root	Tap root	Tap root
	Size	4-14cm	2-9cm	2-10cm	5-16 cm	2-8cm	8-26cm
4	Stem						
5	Colour	Green	Greenish Red	Brownish Green	Green	Reddish green with white streaks	Light green
6	Surface	glabrous	smooth glaucous	pubescent	glabrous	Smooth pubescent	Covered with white hairs
7	branching	branched	branched	branched	branched	branched	branched
8	Habit	Prostrate	Prostrate	prostrate	Erect	Prostrate	Erect
9	Stature	10-90 cm	10-60cm	20-60cm	100cm	35-50cm	250-300cm
10	Leaves						
11	Shape	Obovate	obovate	lanceolate	ovate	lanceolate	Ovate
12	Colour	green	green	green	green	Pale green	green
13	Blade length	3.5-9cm	3-4cm	1-3 cm	3-16cm	1.5-3.5cm	4-15 cm
14	Blade width	1.5-6.2cm	1.5-2cm	0.5-1.5 cm	2-8cm	0.5-2cm	3-9cm
15	Leaf Margin	entire	entire	entire	entire	Entire	
16	Length of Petiole	1-4cm	1-3.5cm	1.5-3cm	2-7cm	0.5-2cm	9-12cm

Table 3: Comparison of Floral Characteristics of Amaranthus Species

Sr.No.	Taxon Character	*A. blitum*	*A.blitoides*	*A. deflexus,*	*A. dubius,*	*A. polygonoides*	*A. retroflexus*
1	InflorescenceType	axillary clusters/cyme	axillary clusters	terminal	terminal and axillary spikes	condensed axillary cyme	Terminal dense cluster of flowers
2	Bracts	shorter than tepals	larger than the tepals	as long as tepals	shorter than tepals	ovate	spiny green bracts.
3	Staminate Flower	Radial	Radial	Radial	Radial	Radial	Radial
4	Tepals	3	3	2-3	5	5	5
5	Stamens	3	3	2-3	5	2	5
6	filaments		short	short		short	
7	Pistilate Flower	Radial	Radial	Radial	Radial	Radial	Radial
8	Tepals	3	3	2-3	5	5	5
9	Style and Stigma	2-3	3	3	3	3	3
10	Fruit	compressed utricle	compressed utricle	Ovoid, smooth	Ovoid Urceolate	Compressed Urticle	Membranous Urticle
11	Seed Colour	Black to reddish brown	dark brown or black,	dark brown to black	Reddish brown to black	Blackish red,	black or red brown in colour
12	Shape and Texture.	subglobose or broadly lenticular slightly rugose, shiny	Lenticular smooth and Shiny	Elliptic to obovate, Shiny	Globose or lenticular, smooth and shiny.	seeds ovoid Lenticular glossy smooth.	Oval, flattened, notched at the narrow end, shiny.

Results and Discussion

The frequency distribution of 16 qualitative morphological (Vegetative) traits for the Amaranthus species is shown in Table 1. And 12 qualitative morphological (Floral) traits for the Amaranthus species is shown in Table 2. The morphological characters of *Amaranthus blitum, A. blitoides, A. deflexus, A. dubius, A. polygonoides,* and *A. retroflexus* were studied in detail. Key based on the general distinguishable morphological characters was prepared. The general morphological characters have been summarised in Table 1 and Table 2. The key to the species in the country were described in the paper and written as follows:

1. Tepals 2-3; Stamens 2-3
2. Bracts longer than tepals.
3. Flowers in axillary and terminal clusters; fruit indehiscent…… *A. deflexus*
3. Flowers in axillary clusters only; fruits usually indehiscent.
2. Bracts shorter than tepals.
4. Flowers in axillary and terminal spikes.
4. Flowers in condensed axillary cyme.
5. Fruits compressed urticle; indehiscent……..…. *A.blitum*
5. Fruits compressed urticle; dehiscent…… *A. blitoides*
1. Tepals 5; Stamens 5.
6. Bracts with spiny tip; as long as tepals or longer than tepals…… *A. retroflexus*.
6. Bracts without spiny tips; shorter than tepals
7. Flowers in terminal and axillary spikes…… …… *A. dubius*
7. Flowers in condensed axillary spikes….. *A. polygonoides*

Conclusion

The different morphological characters of the 6 species of Amaranthus under study helps in the easy identification of Amaranthus species. Twenty eight characters were considered at 2 growth stages: (16) vegetative and (12) reproductive. The species shows primitive to complicated characters in the order *Amaranthus blitum, A. blitoides, A. deflexus, A. dubius, A. polygonoides,* and *A. retroflexus* suggesting an evolutionary relationship between them.

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