



Descriptive analysis of Montana species of *Amaranthus*  
by Paungpen Sirirugsa

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of  
MASTER OF SCIENCE in Botany  
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Abstract:

The *Amaranthus* species of Montana, *A. albus*, *A. californicus*, *A. graecizans*, *A. hybridus*, *A. powellii* and *A. retroflexus* have been collected and studied. Morphological characteristics of roots, stems, leaves, inflorescences, bracts, flowers (sepals, ovaries, stamens, and pollen), fruits and seeds of all species have been shown by tables and plates.

Herbarium specimens of *A. albus*, *A. californicus*, *A. graecizans*, *A. hybridus*, *A. powellii* and *A. retroflexus* of the U. S. National Herbarium, Smithsonian Institution (Washington, D.C.) and of the herbarium of Montana State University have been studied. The distributions, habitats and dates of collections of the specimens were recorded. The distributions of the six *Amaranthus* species in Montana are shown by maps.

Pollen grains were examined and drawn showing shape and internal morphological characteristics as observed by light microscopy.

Species descriptions and a key, which identifies the species of *Amaranthus* of Montana, are provided.

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OF AMARANTHUS

by

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A thesis submitted to the Graduate Faculty in partial  
fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Botany

Approved:

  
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## ABSTRACT

The *Amaranthus* species of Montana, *A. albus*, *A. californicus*, *A. graecizans*, *A. hybridus*, *A. powellii* and *A. retroflexus* have been collected and studied. Morphological characteristics of roots, stems, leaves, inflorescences, bracts, flowers (sepals, ovaries, stamens, and pollen), fruits and seeds of all species have been shown by tables and plates.

Herbarium specimens of *A. albus*, *A. californicus*, *A. graecizans*, *A. hybridus*, *A. powellii* and *A. retroflexus* of the U. S. National Herbarium, Smithsonian Institution (Washington, D.C.) and of the herbarium of Montana State University have been studied. The distributions, habitats and dates of collections of the specimens were recorded. The distributions of the six *Amaranthus* species in Montana are shown by maps.

Pollen grains were examined and drawn showing shape and internal morphological characteristics as observed by light microscopy.

Species descriptions and a key, which identifies the species of *Amaranthus* of Montana, are provided.

## INTRODUCTION

Amaranthus is a genus of the subfamily Amaranthoideae Schintz ex Engler and Prantl (1960) of the family Amaranthaceae. The family is represented by approximately 50 genera of which four are recorded as being in the Rocky Mountains by Rydberg (1917), but Amaranthus is the only one recorded for Montana (Booth and Wright, 1966).

Within the genus Amaranthus, distinct morphological features on which separation of species can be made are few and the general habit within most species is variably influenced by diverse environments. Sauer (1950) lists important factors that have contributed to confusion in classifying Amaranthus species. First is the wide dispersal of many species which have only subtle differences among them. The problem is compounded because, through the course of botanical history different binomials have been applied in different regions to these widespread species. Second, most of the early species descriptions are minimally brief and the characteristics cited are common to several species or else they emphasize trivial features such as pigmentation. Although the species have been described and named according to rules, a description may apply equally well to different species, or only partially to the original species as now known.

A desire to find recognizable morphological features for use in positive species separation of the many ecological forms prompted the present study of the Montana species of Amaranthus. An interest

has also been developed this genus because it is widely represented in the author's home of Thailand.

The present investigation has been oriented toward the study of field collections from Montana, field observations, and herbarium specimens mostly of Montana plants; although an examination was also made of the worldwide collection in the National Herbarium of the Smithsonian Institution of Washington, D.C.

The objectives of this study were:

1. To study the morphological characteristics of the species of the genus Amaranthus of Montana.
2. To construct an easily usable key to the species of this region.
3. To study the ecological variations in the Montana species of Amaranthus from field observations and from examination of specimens in herbaria of this area and in the National Herbarium in Washington, D.C. with the hope of being able to account for specimen variation that may at times be interpreted as species variation.

## REVIEW OF LITERATURE

Linnaeus (1753) included 11 species of the genus Amaranthus in "Species Plantarum". Three of them, A. graecizans, A. hybridus and A. retroflexus have been found in the northern Rocky Mountains of the United States.

Studies by several taxonomists of the northern Rocky Mountain species of Amaranthus began in the last century. Coulter (1885) described 5 species from the Rocky Mountain region between New Mexico and the Canadian border, although he used the spelling "Amarantus" instead of "Amaranthus". Two of the species listed by Coulter were A. albus and A. retroflexus, both of which are of interest in this study.

Uline and Bray (1894) described 32 species in North America. Five of them, A. californicus, A. graecizans, A. hybridus, A. powellii and A. retroflexus are included in this study. The species were identified by number of sepals and stamens. A. powellii is in the group with 5 sepals and 3 stamens. A. hybridus and A. retroflexus are in the group with 5 sepals and 5 stamens. A. graecizans is in the group with 3 sepals and 3 stamens. A. californicus is in the group with sepals fewer than 3 and 3 stamens.

Howell (1903) listed 5 species in northwest America, of which A. californicus, A. graecizans and A. hybridus are in the northern Rocky Mountains of the United States and are discussed in this study.

Howell tried to distinguish among the species by the numbers of sepals and bracts.

Rydberg (1917) described and provided a key to 11 species of Amaranthus found in the North American Rocky Mountains and adjacent plains. Five of the species listed by Rydberg are included in this study.

Stanley (1917) described and provided a key to 42 species of Amaranthus in North America. Five of the species listed by Stanley, A. californicus, A. graecizans, A. hybridus, A. powellii and A. retroflexus are included in this study.

Ashton (1933) cited A. retroflexus as being in the Rocky Mountain National Park of Colorado growing along roadsides and on other disturbed ground and referred to it as "rough pigweed".

Stevens (1950) listed, with a key, 4 species that occur in North Dakota; these species are A. albus, A. graecizans, A. hybridus and A. retroflexus.

Davis (1952) described 6 species of Amaranthus in Idaho and presented a key to these species. Only one of the Idaho species is not included in the area of this study.

Harrington (1954) named 8 species, but three of these are of questionable occurrence in Colorado. The remaining 5 are present in the study area of this thesis.

Tucker and Sauer (1958) described aberrant characteristics of sepals, bracts, fruits and inflorescences of 5 species of Amaranthus that occur in California. Three of these species, A. hybridus, A. powellii and A. retroflexus are included in this study.

Hitchcock et al. (1964) listed 5 species of Amaranthus as being in the Pacific Northwest, all of which are present in the Rocky Mountain area and are included in this study.

Booth and Wright (1966) listed 6 Montana species and provided a key to these species. All of these, A. albus, A. californicus, A. graecizans, A. hybridus, A. powellii and A. retroflexus are of importance in this study.

Sauer (1967) characterized A. retroflexus as a native riverbank pioneer of the central and eastern United States and adjacent regions of southeastern Canada and northeastern Mexico. A. powellii is a pioneer of canyons, desert washes, and other open habitats ranging through the western Cordilleras of North and South America. It appeared as an uncommon adventive in eastern North America about 1900. Since 1940 it has been regarded as a widespread and troublesome weed there. A. hybridus is evidently a native riverbank pioneer of mild and moist regions from eastern North America through Mexico and Central America to northernmost South America. Its earliest and most successful historically documented emigration was to the Mediterranean

region where it arrived by the 18th century. A. hybridus was also recorded by Hanelt (1968) as a cultivated crop of American origin. It is among the oldest cultivated plants of American agriculture.

There are only indirect evidences of the prehistoric range of Amaranthus as a recognizable taxon. Sauer (1950) recorded that evidence of the use of Amaranthus as crop plants occurs very faintly among the Indians of the southwestern United States, is more distinct in northwestern Mexico and in a central Mexican stronghold of the crop, but is indistinct in southern Mexico. A small isolated center of use is found in Guatemala and a large one in the Andes including Peru, Bolivia and northwestern Argentina. On the western side of the Pacific, indistinct evidence of crop use occurs in Manchuria and interior China. There once was a major center in the Himalayas and indistinct use in Afghanistan and Persia. There was a small outpost in southern India and Ceylon. There are vague traces of the use of Amaranthus as a crop in Africa.

Wodehouse (1935) studied pollen and recorded that all species of Amaranthus are wind pollinated, and that several are troublesome hay fever weeds. A. retroflexus flowers from August to October, does not shed much pollen but occasionally becomes a factor in hay fever, particularly in Arizona, Oklahoma, California and Oregon. A. hybridus flowers at the same time as A. retroflexus. It probably is an

important cause of hay fever. A. graecizans sheds much less pollen than most other members of the genus and is not important in hay fever.

Erdtman (1952) documented that pollen grains of amaranthoid type testify to the close relationship between Amaranthaceae and Chenopodiaceae, supporting the opinion that Amaranthaceae and Chenopodiaceae, because of many natural affinities, actually may be considered to comprise a single family.

Seeds of the genus Amaranthus were studied by Martin and Barkley (1961). They described the gross structure of the seeds of this genus as: circular-lenticular, with edge narrowed into a thin rim; notched on margin; usually shiny black or dark reddish brown; mostly 1-1.5 mm. in diameter. Also they reported that the embryo is curved around a firm and starchy endosperm.

Wiese and Davis (1967) reported that the emergence of A. retroflexus from soil in a growth chamber was best with an 8-hr. night temperature of 65° F and a 16-hr. day temperature of 80° F, at a 1/2 in. depth of planting, and using a coarse-textured soil rather than on a fine-textured soil. Under dry soil conditions, emergence was reduced by soil crusting.

Experiments of Palmblad (1969) indicated that A. retroflexus often has germination polymorphism (discontinuous germination).

Darlington (1922), Kivilaan and Bandursky (1973) reported from Dr. W. J. Beal's seed viability experiment that A. retroflexus seeds

remain viable for 40 years, but they probably do not remain viable after 50 years.

Goering (1967) reported that the starch in seeds of A. retroflexus is composed of 2 distinct entities: a small amount of very small spherical granules and a large amount of massive starch chunks. These starch chunks were found to have unusual "pasting" characteristics. The Brabender viscosity curve for this starch does not show a cooking maximum; it is different from any other known natural starch. The low solubility and expansion of chunk pigweed starch suggest it has very strong, uniform and extensive forces holding the mass together.

Bamberger and Mayer (1960) reported that kinetin induces formation of red pigments in seedling of A. retroflexus in the dark. The pigment is not an anthocyanin, and its formation is not affected by inhibitors of anthocyanin formation.

The results of Marshall et al.'s experiments (1967) indicated that leaves of A. retroflexus contained 12 to 30% oxalate, expressed as oxalic acid (on a dry weight basis). On the basis of its high oxalate content, they concluded that this species should be classed as potentially toxic to animals. The nitrate content of the A. retroflexus plants analyzed was highly variable. The plant has been shown to be a causative agent of perirenal edema of swine (Marshall et al., 1967). That pigs fed with A. retroflexus developed clinical signs of

perirenal edema was also reported by Osweiler et al. (1969). Certain biochemical values and electrolyte levels of blood were changed in pigs fed A. retroflexus, i.e., large and consistent increases in serum potassium and smaller increases in serum magnesium levels, and marked increase in blood urea nitrogen value.

Grant (1959) reported the chromosome numbers of 30 species of Amaranthus. Five of them, A. albus, A. graecizans, A. hybridus, A. powellii, and A. retroflexus are included in the area of this study. A. albus, A. graecizans and A. hybridus have  $2n = 32$ . A. powellii and A. retroflexus have  $2n = 34$ . A cytological study of A. cruentus x powellii x retroflexus showed that this hybrid has a somatic chromosome number of 32. Another hybrid between A. cruentus ( $2n = 34$ ) and A. hybridus ( $2n = 32$ ) has a somatic chromosome number of 34. The investigated species of Amaranthus may be organized into two groups upon the basis of haploid chromosome numbers, i.e., one group in which  $n = 16$  and another in which  $n = 17$ .

## MATERIALS AND METHODS

### Herbarium Study

Herbarium specimen sheets of Amaranthus albus, A. californicus, A. graecizans, A. hybridus, A. powellii, and A. retroflexus of the world collection of the U. S. National Herbarium (Smithsonian Institution, Washington, D.C.) and of the Herbarium of Montana State University were studied to obtain information about habitats, morphological variation, phenology and distribution.

### Field Collection

Specimens of A. albus, A. californicus, A. graecizans, A. hybridus, A. powellii, and A. retroflexus were collected in Montana during July and September of 1972. 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.

The leaves were cleared for study of venation. Leaves were first immersed in a beaker of hot water, and then chlorophyll was removed by placing the leaves in hot 70% alcohol. Then the leaves were placed in petri dishes containing approximately a 2.5% aqueous NaOH solution for a week until all parts appeared translucent. The clearing solution was poured off and the leaves were rinsed several times in tap water. A strong aqueous solution of chloral hydrate (250 gm chloral hydrate in 100 ml water) was added to the petri dishes. After a few days, the materials became nearly transparent. They were very cautiously washed in several changes of distilled water. The materials were passed through the following dehydration series:

- a. 50% alcohol for 5 min.
- b. 70% alcohol for 5 min.
- c. 95% alcohol for 5 min.
- d. 100% alcohol for 5 min.
- e. 100% alcohol for 10 min.

- f. 100% alcohol for 10 min.
- g. 1:1 absolute alcohol and xylene for 10 min.
- h. 1:1 absolute alcohol and xylene for 10 min.

The cleared leaves were mounted on microscope slides with clove oil and were studied unstained under the dissection microscope at 25X. The number of paired major veins in the leaves were counted and patterns of venation were drawn.

Inflorescences and flowers. The inflorescences of the species were examined and measured in the metric system.

The flowers of each species were examined with optical aid of a dissection microscope. The number of bracts, sepals, ovaries and stigmas of the pistillate flowers and stamens of the staminate flowers were counted. The pistillate flowers, staminate flowers, bracts, sepals, ovaries and stamens were measured in the metric system and were drawn. The floral diagram of the pistillate flowers and the staminate flowers were constructed for each species.

Pollen grains. Raw pollen grains of each species were mounted in water, examined under the compound microscope, measured with a calibrated ocular-micrometer and drawn.

Seeds. Mature seeds were collected separately for each species during July and September of 1972. They were examined by gross

inspection and measured with a metric ruler under a dissection microscope and then drawn.

#### Seed Germination

After all seeds were stored for nine months, fifty seeds each of A. albus, A. californicus, A. graecizans, A. hybridus, A. powellii and A. retroflexus were placed on square towel papers and moistened with distilled water in square boxes (13 x 13 cm). The boxes were placed in the refrigerator at the temperature about 40° F for five days. Then the boxes were moved to the seed germinater alternating conditions of 8 hours light (at 59° F) and 16 hours dark (at 77° F).

## RESULTS

### Herbarium Study

The genus Amaranthus grows throughout the United States and many countries in the world. A. albus, A. californicus, A. graecizans, A. hybridus, A. powellii, and A. retroflexus have been collected from 22, 7, 28, 17, 6, and 36 states of the United States, respectively. The distribution of collections in Montana is shown by maps (see Fig. 1). The maps are based upon both the accessioned herbarium collections studied and the personal observation and collection of the author.

The habitats of Amaranthus plants are usually waste places or cultivated fields. As they have been found, A. albus, A. graecizans, A. hybridus, A. powellii, and A. retroflexus grow at altitudes of about 732-2227 meters (2400-7300 feet), 348-1830 meters (1440-6000 feet), 336-2715 meters (1100-8900 feet), 1235-1983 meters (4050-6500 feet) and 290-1830 meters (950-6000 feet), respectively.

The herbarium specimens of these species collected in the United States were dated between July and November (A. albus), July and September (A. californicus and A. powellii), July and October (A. graecizans and A. hybridus), May and November (A. retroflexus).

### Field Collection

Six species of Amaranthus have been found in Montana: A. albus, A. californicus, A. graecizans, A. hybridus, A. powellii, and

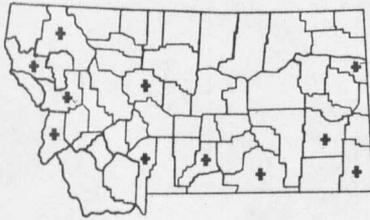
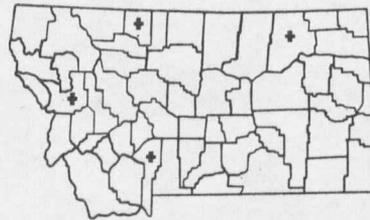
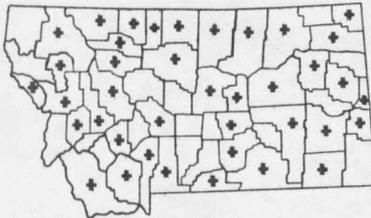
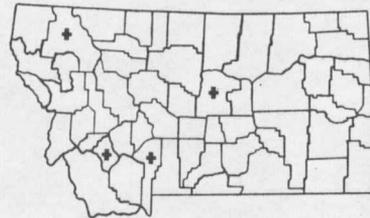
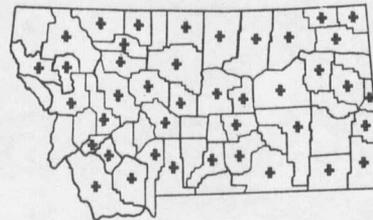
A. albusA. californicusA. graecizansA. hybridusA. powelliiA. retroflexus

Fig. 1. Distribution maps of six taxa of Amaranthus occurring in Montana. A "+" symbol within a county indicates a recorded collection from that county.

A. retroflexus. They are found along roadsides, waste areas, and on cultivated lands.

#### Morphological Character Study

The morphological characteristics of roots, stems, leaves, inflorescences, bracts, flowers, fruits, and seeds of each species are compared in Table 1 and plates (Figs. 2 to 7). Each species is described based on morphological characteristics (see pages 27 to 44). A key has been constructed for separating the six species of Amaranthus of Montana (pages 55 and 56).

Pollen grains. The results of the measurement of the pollen grain of the six species of Amaranthus were that the pollen grains of A. albus and A. powellii range from 0.015-0.020 mm in diameter; of A. californicus, A. graecizans and A. powellii range from 0.018 to 0.022 mm in diameter; of A. retroflexus range from 0.025-0.030 mm in diameter. The average of the sizes of the pollen grains of each species have been illustrated in Table 1.

#### Seed Germination

After the seeds were placed in the seed germinator for a week, the numbers of seedlings of each species were counted. The percentages of seed germination were shown in Table 2.

Table I. Comparison of Characteristics of Montana Species of Amaranthus.

Character	Taxon	
	<u>A. albus</u>	<u>A. californicus</u>
<u>Geographic Origin</u>	Tropical America (Munz and Keck, 1959)	California, Nevada and northwestern North America (Munz and Keck, 1959)
<u>Longevity</u>	Annual	Annual
<u>Root System</u>		
Type	Excurrent	Excurrent
Size	About 4-12 cm deep	About 4-8 cm deep
Color	White	White
<u>Stem</u>		
Form	Rigid, branching freely, pyramidal shape	Branching from the base to form mats over the ground
Stature	Erect, to 6 dm tall	Prostrate, forming mats about 1-4 dm wide
Surface	Glabrous	Glabrous
Color	White	White
<u>Leaf</u>		
Outline	Spatulate to obovate	Spatulate
Apex	Mucronate	Mucronate
Margin	Undulate	Entire to undulate
Base	Decurrent	Decurrent
Size	Blade 0.5-2.5 cm long, 0.3-1.2 cm wide, about twice length of petiole	Blades 0.3-2 cm long, 0.1-0.7 cm wide, about 4 times as long as the petiole
Veins	Mostly 4 pairs	Mostly 2 or 3 pairs
Veinlets	Not prominent	Not prominent

Table I continued

Character	Taxon	
	<u>A. albus</u>	<u>A. californicus</u>
Surface	Glabrous	Glabrous
Color	Pale green	Upper surface green, lower surface and petiole purple
<u>Inflorescences</u>		
Type	Small axillary clusters	Small axillary clusters
<u>Bracts</u>		
Number	1	1
Shape	Lanceolate, acicular	Subulate, acicular
Size	About 2-2.5 mm long, twice as long as the sepals	About 2 mm long, almost twice as long as the sepals
Color	White, translucent, midnerve green	White, translucent, midnerve green
<u>Pistillate</u>		
<u>Flower</u>		
Sepals:		
Number	3, unequal	3, very unequal, 2 of them reduced as scales
Shape	Lanceolate, acute	Linear-lanceolate, acicular
Size	1-1.5 mm long	The largest one about 1 mm long
Color	White, translucent, midnerve green	White, translucent, midnerve green
Ovary	1 carpel, about 2 mm long, 1-1.3 mm wide, stigmas 3	1 carpel, about 2 mm long, about 0.8-1 mm wide stigmas 3

Table I continued

Character	Taxon	
	<u>A. albus</u>	<u>A. californicus</u>
<u>Staminate</u>		
<u>Flower</u>		
Sepals:		
Number	3, equal	3, equal
Shape	Lanceolate, acute	Linear-lanceolate, acicular
Size	1-1.5 mm long	About 1 mm long
Color	White, translucent, midnerve green	White, translucent, midnerve green
Anthers:		
	Versatile	Versatile
Number	3	3
Pollen	Spherical, about 0.017 mm in diameter	Spherical, about 0.020 mm in diameter
<u>Fruit</u>	1 seeded, circumscissile utricle	1 seeded, circumscissile utricle
<u>Seed</u>		
Color	Smooth, shiny, dark brown	Smooth, shiny, dark brown
Shape	Discoid	Discoid
Size	About 1 mm in diameter	About 0.8-1 mm in diameter

Table I continued

Character	Taxon	
	<u>A. graecizans</u>	<u>A. hybridus</u>
<u>Geographic Origin</u>	Eastern North America (Linn, 1753)	Eastern North America, Central America, and northern South America (Sauer, 1967)
<u>Longevity</u>	Annual	Annual
<u>Root System</u>		
Type	Excurent	Excurent
Size	About 3-15 cm deep	About 10-15 cm deep
Color	White	White
<u>Stem</u>		
Form	Branching from the base, spreading over the ground	Branching freely, erect, straight, rigid
Stature	Prostrate, mats to 10 dm wide	Erect to 9 dm tall
Surface	Glabrous	Glabrous
Color	Pale green, tinged with red	Pale green, tinged with red
<u>Leaf</u>		
Outline	Spatulate to obovate	Mostly rhombate
Apex	Retuse to mucronate	Acute to mucronate
Margin	Entire to undulate	Undulate
Base	Decurrent	Oblique
Size	Blade 0.5-4 cm long, 0.5-1.8 cm wide, about 4 times as long as the petiole	Blade 1.5-8 cm long, 0.7-3.5 cm wide, less than twice as long as the petiole
Veins	Mostly 5 pairs	Mostly 8 pairs

Table I continued

Character	Taxon	
	<u>A. graecizans</u>	<u>A. hybridus</u>
Veinlets	Not prominent	Visible but not prominent
Surface	Glabrous	Glabrous
Color	Pale green	Dark green
<u>Inflorescence</u>		
Type	Small axillary clusters	Terminal or axillary cylindrical spikelike panicle
<u>Bract</u>		
Number	1	1
Shape	Lanceolate, acicular	Lanceolate, tapering to spine tip
Size	About 1.5-2.5 mm long, about half as long as sepal	About 4-5 mm long, about twice or more as long as sepal
Color	White, translucent, midnerve green	White, translucent, midnerve green
<u>Pistillate Flower</u>		
Sepals:		
Number	5, unequal	5, about equal
Shape	Lanceolate, spine tip	Lanceolate, acute
Size	About 2.5-3.5 mm long	About 2 mm long
Color	White, translucent, midnerve green	White, translucent, midnerve green
Ovary	1 carpel, about 3 mm long, about 1.5-2 mm wide, stigmas 3	1 carpel, about 2 mm long and 0.8-1 mm wide, stigmas 3

Table I continued

Character	Taxon	
	<u>A. graecizans</u>	<u>A. hybridus</u>
<u>Staminate</u>		
<u>Flower</u>		
Sepals:		
Number	5, unequal	4-5 equal
Shape	Lanceolate, spine tip	Lanceolate, acute
Size	About 2.5-3.5 mm long	About 2 mm long
Color	White, translucent, midnerve green	White, translucent, midnerve green
Anther:		
Number	3 or 4	3 or 4
Pollen	Spherical, about 0.020 mm in diameter	Spherical, about 0.020 mm in diameter
<u>Fruit</u>	1 seeded, circumscissile utricle	1 seeded, circumscissile utricle
<u>Seed</u>		
Color	Smooth, shiny, black	Smooth, shiny, black
Shape	Discoid	Discoid
Size	About 1.7 mm long	About 1.3 mm long

























































































