Volume 5, Number 2, 1983

Desert Plants

Published by The University of Arizona for the
Boyce Thompson Southwestern Arboretum

Plantago growing at the Arboretum with Bromus rubens. W. B. Thompson saw value in even the lowliest of desert plants. See editorial inside front cover. Photo by Carol D. Crosswhite.

Desert Plants

A quarterly journal devoted to broadening knowledge of plants indigenous or adaptable to arid and sub-arid regions, to studying the growth therof and to encouraging an appreciation of these as valued components of the landscape.

Frank S. Crosswhite, editor

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Published by The University of Arizona
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The Boyce Thompson Southwestern Arboretum at Superior, Arizona, is cooperatively managed by The Arizona State Parks Board, The Boyce Thompson Southwestern Arboretum, Inc., and The University of Arizona.

Editorial

To Instill in Mankind an Appreciation of Plants. In the 1920's W. B. Thompson founded the Arboretum at Superior as a place where plants from arid and sub-arid regions of the world could be brought together, inventoried, their uses catalogued, and research conducted to benefit mankind. Toward this end Thompson stated that the Arboretum would be developed in the form of a museum of living plants, a museum designed "to instill in mankind an appreciation of plants" while (with the same plants) providing scientists the source materials for appropriate research. The collection of desert plants at Superior has grown and prospered during the last 60 years, becoming a virtual "tourist attraction" viewed by a conservatively estimated three million people.

Thompson valued plant life very highly. In his travels around the world he became impressed by the fact that desert lands had a general scarcity of plants and that people living there had a very tenuous existence as a result. He learned however that the inhabitants of desert regions made every use possible of what few plants they had, using them for food, fiber, clothing, shelter and fuel.

He was impressed with how tenaciously desert plants could cling to life under terrible conditions of heat, drought and drying winds which quickly killed other plants. Man needed to better appreciate these qualities for their intrinsic merit as well as for their potential in improving other plants. Thompson noted that plant species were different in each of the world's deserts. A useful plant of one desert region might be an extremely valuable addition to the plant assets of another such region. These plants needed to be brought together where they could be compared and studied.

Thompson viewed plants as assets which all too often were wasted by persons who lived where they were abundant, but were heavily utilized (even to the point of extinction) in places where they were scarce. To Thompson the value of all plants was intrinsic; although this value could be seen easiest under desert conditions where plants were a scarce commodity, the value existed in all plant life. In analyzing the situation he concluded that plants were the primary producers of the world's organic goods. They could produce organic chemicals from two common raw materials: 1) air, and 2) water. They were also capable of changing simple organic substances into more complex ones after absorbing small quantities of nitrogen and various minerals.

The same analytical mind that made millions of dollars for Thompson in the field of natural resources (chiefly mining and oil) told him that plant life represented a great underappreciated and undervalued natural resource which with a little study could be made to yield all sorts of new benefits for mankind. As a gift to humanity and with only a desire to leave this world in a little better condition than when he entered it, Thompson created and endowed two non-profit institutions, each having the general goal of helping man through better appreciating, understanding and developing the hitherto undiscovered or underutilized good qualities which he was firmly convinced waited to be unlocked in plant life.

Both before and after Thompson's death in 1930, the Boyce Thompson Institute for Plant Research in New York has succeeded in making discoveries beyond what could ever have been predicted. It continues today as a brilliant force of dozens of scientists and technicians working in laboratories situated on the campus of Cornell University at Ithaca.

The second institution was the Arboretum in Arizona. Thompson's analytical mind saw a paradox. In deserts where plants were scarce, man seemed to make every use conceivable of them. But where plants were abundant, man poorly appreciated them; without fully utilizing them he was essentially placing himself in an isolation worse than any desert by cutting himself off from the good they could provide. In Arizona Thompson decided to gather together the rugged life forms of desert plants to create an institution one goal of which would be "to instill in mankind an appreciation of plants" which he himself had gained in the world's deserts. Since the 1920's there has been a standing invitation to all persons to view the collection. The Arboretum is open to the public from 8:00 A.M. to 5:30 P.M. every day of the year except Christmas.

The Wild Beans of Southwestern North America

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Beans, all previously considered to be in the genus *Phaseolus*, are an interesting group of southwestern legumes. Ranging from the lower Sonoran desert to the Ponderosa Pine forest, they are excellent subjects for the study of speciation and environmental adaptation. Many have potential for the improvement of cultivated beans, possessing tolerance to heat, frost, drought, flooding, insects (Buhrow, 1981) and diseases (Hubelling, 1957). Unfortunately, the relationships among many of the species have been poorly understood, and because of this, breeders have made very limited use of the characteristics found in this group. This study is an attempt to clarify these relationships, and to describe the environmental adaptation of each species.

An Overview

The Phaseolinae of the Southwest are now considered to form two natural genera, *Phaseolus* and *Macroptilium* (Marechal et al., 1978). The characteristics which distingush these genera are listed in Table 1.

Three *Macroptilium* species occur within southwestern North America. They are: *Macroptilium atropurpureum* (D.C.) Urban (*Phaseolus atropurpureus* D.C.); *Macroptilium gibbosifolium* (Ortega) A. Delgado (*Phaseolus heterophyllus* Willd.); and *Phaseolus supinus* Wiggins and Rollins (*P. supinus* is actually a *Macroptilium*, but the name has not been changed for reasons discussed later in this article). The *Phaseolus* species occurring in this region are *P. angustissimus* A. Gray; *P. acutifolius* A. Gray; *P. filiformis* Bentham; *P. grayanus* Woot. and Standley; *P. metcalfei* Woot. and Standley; *P. parvulus* Greene; *P. ritensis* Jones; and *P. wrightii* A. Gray.

A diagram has been constructed indicating relationships between the species discussed in this article and other domesticated species. Placement of *P. metcalfei* and *P. ritensis* follows Le Marchand et al. (1976). *P. grayanus* is associated with the lunatus branch by seed and fruit characters. The filiformis group of Piper (1926) is placed in the lunatus branch, based on seed and fruit similarities, although this group's status has not yet been satisfactorily resolved. Le Marchand et al. (1976) placed it closer to *P. acutifolius* by pollen characteristics. The sterile hybrid *P. vulgaris* × *P. filiformis* (Marechal and Baudet, 1978) and an unpublished report of *P. acutifolius* × *P. wrightii* with abnormal plantlets (Pratt, 1982) lend support to affinity with *P. vulgaris*. Relationships of *P. coccineus*, *P. vulgaris*, and *P. acutifolius* are based on chemotaxonomic studies by Kloz, Klozova, and Turkova (1966) and interspecific hybridization studies of Honma (1956), Ibrahim and Coyne (1975), and others. Placement of *Macroptilium* spp. follows that of Marechal et al. (1978).

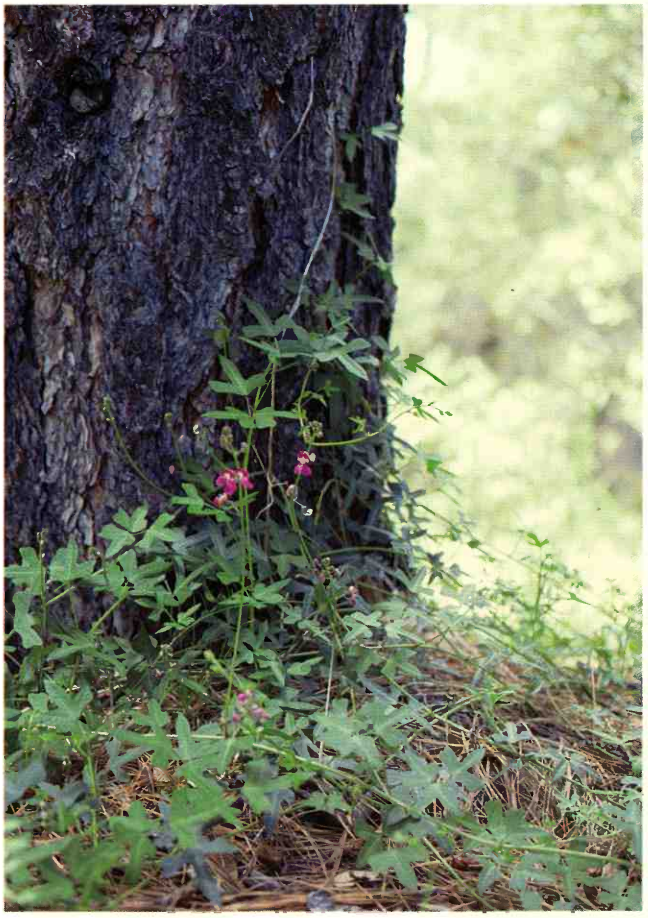
Macroptilium

Macroptilium atropurpureum, found throughout the American tropics, ranges from Peru (Marechal et al, 1978) northward to southern Arizona and Texas. This plant is being domesticated in Australia as a forage crop under the name Siratro. *Macroptilium atropurpureum* is a large plant, with vines up to 6 meters in length produced from seedling plants in one season. The plant is a perennial, returning from drought or winter from stem buds and from the somewhat fleshy root. Germination is barely epigeal, with cordate primary leaves. Found in the Baboquivari and Coyote Mountains in the 1930's and 1940's, *M. atropurpureum* is apparently rather rare at these

Macroptilium gibbosifolium.

Phaseolus ritensis.

Phaseolus angustissimus.



Phaseolus grayanus.

Macroptilium atropurpureum *at the University of Arizona Campbell Avenue Farm.*

localities, or has disappeared, as the author has searched the area for three seasons without success.

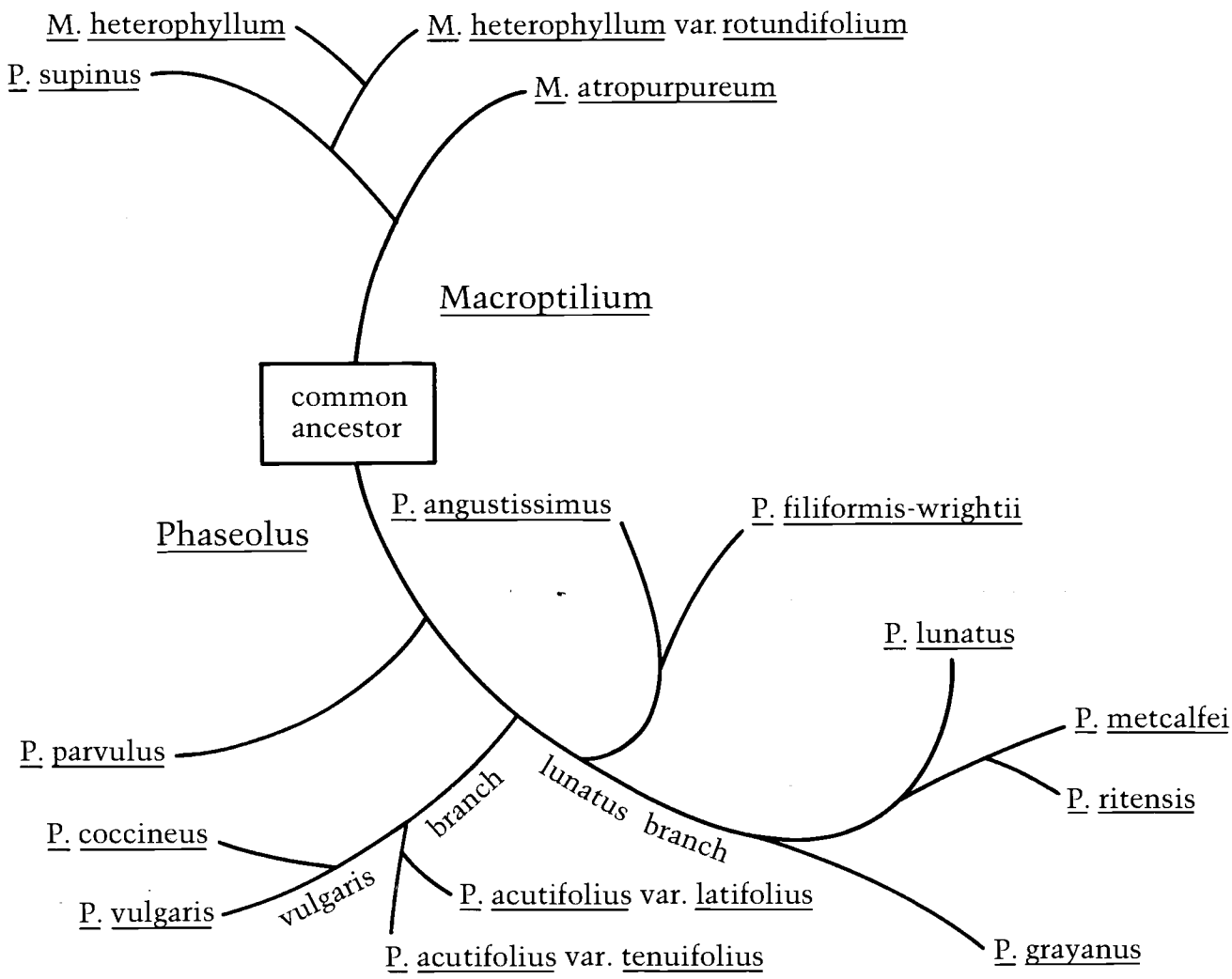
Macroptilium gibbosifolium has the widest distribution of any species in the American Phaseolinae, from Argentina, Paraguay, and Bolivia (Marechal et al., 1978) to central Arizona and New Mexico. A relatively small plant, *M. gibbosifolium* is thin-stemmed and rarely exceeds 2 meters vine length. Plants are perennial from a fusiform or linear lignescent root. Germination is hypogeal, with ovate or cordate primary leaves.

Macroptilium pedatum ? *Phaseolus supinus* is included here based on characters of Marechal et al. (1978). Marechal (1979) considered this taxon to be merely a variant of *M. pedatum* (Rose) Marechal and Baudet. A change in taxonomic status at this time seems inappropriate, pending clarification of the relationship between *M. pedatum* and *P. supinus*. Based upon the type descriptions, these taxa differ primarily in leaflet shape, a very weak character for Phaseolinae. *P. supinus* also is reported to have larger peduncles than *M. pedatum*. Both *M.*

Table 1. Characters distinguishing between *Phaseolus* and *Macroptilium*[1].

Phaseolus	*Macroptilium*
Uncinate hairs present	Uncinate hairs absent
Pedicels longer than the calyx	Pedicel length less than or equal to that of the calyx
Floral bracts persistent to anthesis	Floral brackets caducous
Knots of the rachis not swollen	Rachis of inflorescence somewhat knotty at the insertion of the pedicels
Style closely coiled 1.5-2 turns	Keel and style closely curved at the tip
Standard with a small marginal indentation and a diffuse central thickening	

1. Translated after Marechal et al. (1978).



Evolutionary relationships of wild southwestern and cultivated Phaseolinae.

pedatum and *P. supinus* possess above-ground and subterranean flowers and fruits. Flowers were reported by Rose (1903) as purple for *M. pedatum*, and flowers of *P. supinus* are orange. Flowers of both *M. gibbosifolium* and *P. supinus* dry to a purple color, and it could be that Rose reported the color from dried materials, since the type specimen was collected by Pringle. Plants of *P. supinus* typically grow with grasses and due to the fine stems and creeping habit, are nearly invisible in habitat unless in bloom. Vine length may reach 1 meter, but half that length is more usual. Plants are perennial from a fusiform root. Germination is hypogeal, with ovate-lanceolate primary leaves. The plants are apparently rare, known only from 3 localities: Sycamore Canyon, Atascosa Mountains, Arizona; between Mazatan and Colorado, Sonora; and Los Ruiz, Nayarit (Delgado, 1979). The type locality of *M. pedatum* is Iguala, Guerrero, Mexico.

Phaseolus

Phaseolus acutifolius, the only southwestern member of Phaseolinae which has been domesticated, is also known as the tepary bean. Four forms are known: domesticated variety *latifolius*, wild variety *latifolius*, the nominate variety *acutifolius*, and variety *tenuifolius*. Variety *latifolius* can be distinguished from variety *tenuifolius* as having ovate or ovate-lanceolate, rather than linear, lanceolate, or lance-ovate leaves; primary leaves deltoid or deltoid-saggitate, rather than deltoid-lanceolate or lance-ovate; heavier stems and larger seeds. Domesticated variety *latifolius* has lost most of its twining ability, has larger seeds of a more uniform color, and is less hard seeded than wild variety *latifolius* (Nabhan, 1978). Wild variety *latifolius* is basically an understory plant of canyon bottoms and floodplains, habitats where runoff from adjacent uplands accumulates, creating a more mesic environment than the surrounding area. In good years, this allows the plants to become quite large, climbing into the canopy up to 4 meters (Freeman, 1918). Variety *tenuifolius* is generally found in canyon bottoms and on rocky slopes, rarely exceeding 2 m vine length. There is also an elevational separation of these varieties. The nominate variety is found near El Paso, Texas, but plants with leaf shape similar to the type specimen have been found at Sycamore Canyon,

Phaseolus supinus *removed to show plant form, Sycamore Canyon, Atascosa Mountains, Arizona, 1160 m (3800 ft.).*

Atascosa Mountains (Nabhan, 1978), and in the Coyote Mountains, Arizona.

Variety *acutifolius* is essentially an unusually broad-leaf var. *tenuifolius*, having similar growth form and seed size. Considerable leaf variation exists within var. *tenuifolius*, from very narrow leaves to leaves similar to the nominate type. The following synonymy is proposed:

Phaseolus acutifolius Gray 1852. var. *acutifolius* =
Phaseolus acutifolius var. *tenuifolius* Gray 1853.

Germination of *P. acutifolius* is epigeal and the plants are annual.

P. angustissimus ranges farthest north of the southwestern Phaseolinae, reaching northern Arizona. The plants are perennial, with vines to 2 m long, and are often found in association with Ponderosa Pine. Plants are also found at lower elevations in riparian habitats. Leaflet shape varies from linear to orbicular and from entire to lobed. Germination is hypogeal, with cordate based, ovate-lanceolate primary leaves.

Sometimes misidentified as *P. acutifolius* var. *tenuifolius*, *P. angustissimus* may be distinguished by its perennial habit, waxy leaves, 2-4 seeded pods, rather than the 4-10 seeded for *P. acutifolius*, rugose seeds, heavier, more glabrous stems, and magenta or pink, rather than light lavender flowers.

Confusion exists regarding *P. filiformis* and *P. wrightii*. In Gray's (1852) original description of *P. wrightii*, he states that it may be a variety of *P. filiformis*. His later description of Wright 952 (1853) adds confusion to the literature which persists today. The later specimen was *P. grayanus*, a perennial. This error was cited by Wooton and Standley (1913). Specimens from the type locality of *P. wrightii* (El Paso, Texas) fall within the normal range of variability seen throughout the range of *P. filiformis*. Kearny and Peebles (1960) and Shreve and Wiggins (1964) all state that there seems little justification for maintenance of *P. wrightii* as a species. The following synonymy is proposed:

Phaseolus filiformis Benth. 1844. =
P. wrightii A. Gray 1852.

Phaseolus filiformis is the only species of *Phaseolus* adapted to extremely arid conditions. Its range includes some of the most xeric environments in North America. Perhaps the most interesting of all the southwestern Phaseolinae, *P. filiformis* is able to withstand drought, extreme heat, and frost. These adaptations permit *P. filiformis* to grow essentially independent of the temperatures which normally occur in its habitats, allowing utilization of any available moisture. Plants have been observed flowering and fruiting both in the summer (46° C) and in mid-winter (-6.7° C). This desert bean is an annual, although some plants will grow in the winter, go semi-dormant, and regrow in the summer before dying. People of the Pinacate region of northwest Sonora and southwest Arizona are

continued on page 82

Australian Acacias Used For Landscaping in Arizona

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Acacia aneura.

There is an increasing interest in drought resistant plants among nurserymen and consumers. New plant introductions are being grown by some wholesale nurseries and made available to the public. Among these new introductions are plants from Australia, of which the *Acacia* species are popular. In addition to being drought-resistant, many are colorful and probably do not contribute to allergy problems. They produce a cloud of sticky pollen that is transmitted by insects attracted to their colorful flowers.

The Acacia blooms are a tightly packed cluster of many individual flowers giving an attractive puffball appearance, sometimes extending into a short spike. The majority of Australian Acacias have modified midribs, termed phyllodes, which function as leaves. Aside from the phyllode and flower similarities, the Acacias are a very diverse group of plants. They range in use from groundcovers and small or large shrubs to small and medium-sized trees.

The following descriptive list is of Australian Acacias that grow in Arizona. Some are readily available. Others can be bought in small quantitites but may become more common when more is known about them.

Acacia acuminata
RASPBERRY JAM WATTLE

This is a small tree that grows to thirty feet in height, with a spreading crown and pendulous branches. It is noted for its raspberry fragrance. This wattle prefers a warm, moist, sandy soil. Golden yellow flowers on one inch long spikes appear in February. The phyllodes are narrow and three to ten inches long.

Acacia aneura
MULGA

Mulga is a shrub or small tree that can grow to 20 feet in height with ascending branches and spreading crown. It grows on a wide range of soils. Yellow flowers on half-inch long spikes appear in March and April. The phyllodes are an inch and a half to three inches long and an eighth inch wide.

Acacia armata
HEDGE WATTLE, KANGAROO THORN

This shrub grows to ten feet tall and makes a good, quick hedge or barrier. The branches are sharply spined. Deep yellow flowers make a showy display from February to April. The phyllodes are under one inch long.

Acacia colletioides
WAIT-A-WHILE

This acacia is a compact, rounded shrub that spreads wider than its six to nine foot height. It requires a well-drained soil. Golden yellow flowers appear in spring and make a very showy display. The phyllodes

Acacia ligulata.

are very stiff, half an inch to one inch long, and needlelike.

Acacia craspedocarpa

Acacia craspedocarpa is a slow-growing shrub or small tree that grows from six to twelve feet tall. The phyllodes are oval or rounded and half an inch across.

Acacia ligulata

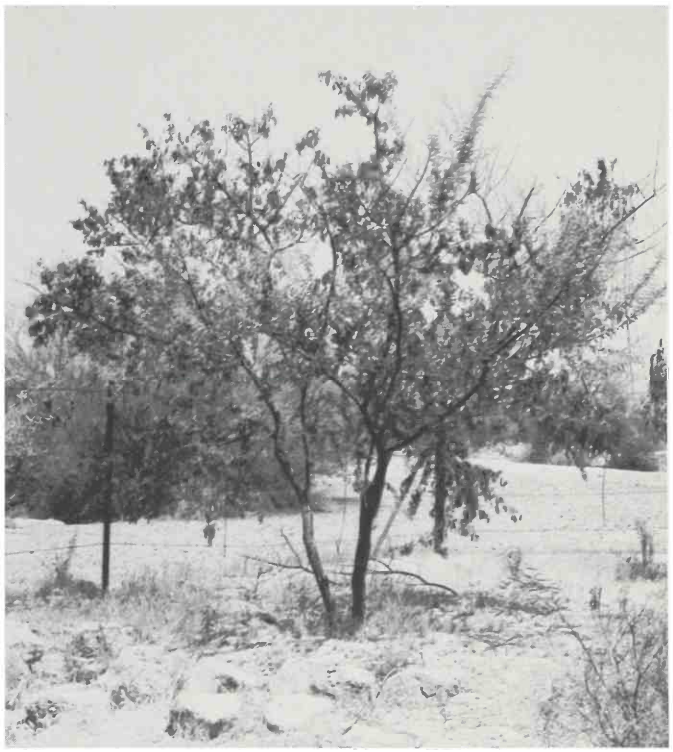
SMALL COOBA

This plant is a hardy, compact shrub that spreads to a width greater than its six to nine foot height. It grows well on a wide range of soils but is best in sandy types. It tolerates saline and alkaline soils. Bright yellow or orange-yellow flowers appear in winter to early spring. The phyllodes are two to three and a half inches long and a quarter inch wide.

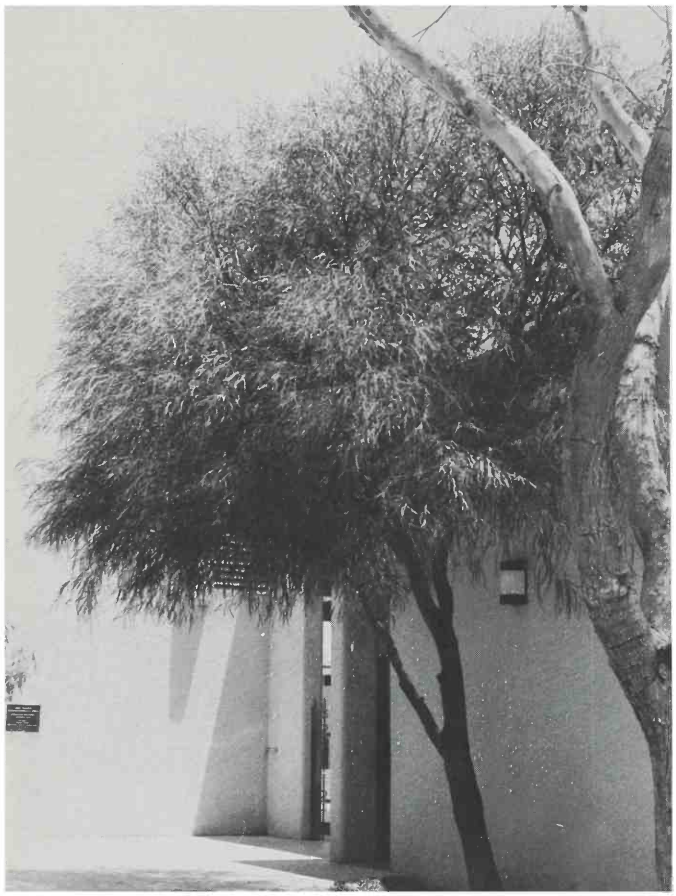
Acacia montana

MALLEE WATTLE

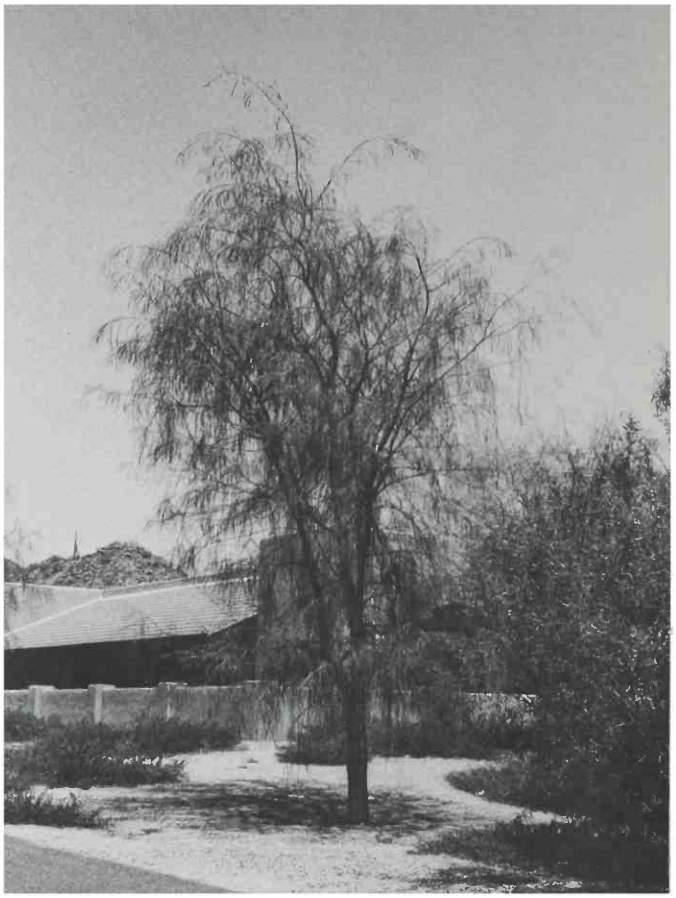
Mallee Wattle is a dense, low shrub that grows from six to nine feet tall. It can be used for large-scale ground-covers. Flowers are solitary or in pairs and appear in late winter. Phyllodes are narrow and an inch to an inch and a half long.



Acacia victoriae.



Acacia saligna.



Acacia stenophylla.

Acacia pendula
GOLDEN WATTLE

This large shrub or small tree grows from twelve to twenty-five feet tall. Outer branchlets become pendulous with age. Golden Wattle is frost tender when young. Deep yellow, fragrant flowers appear in spring. The phyllodes are three to six inches long and slightly curved.

Acacia redolens

Acacia redolens is a fast-growing groundcover or low shrub that can become up to four feet tall and eight to twelve feet wide. It prefers a well-drained soil. Small yellow flowers appear in spring. The dull bluish-green phyllodes are three inches long and half an inch wide.

Acacia retinoides
WIRILDA

This species is a small compact tree that becomes from ten to twenty feet tall. It withstands flooding and is good either singly or mass planted. The flowers are not showy, but appear sporadically all year. The phyllodes are three to five inches long and a quarter inch wide.

Acacia rigens
NEEDLE BUSH WATTLE

This compact, rounded shrub grows from eight to ten feet tall. It does well with dry conditions and a well-drained soil. Bright yellow flowers appear in winter and continue until spring. The phyllodes are sharp, needle-like, and from one to five inches long.

Acacia salicina
WILLOW WATTLE, COOBA

Willow Wattle is a small- to medium-sized tree that becomes from ten to forty feet tall with pendulous branches. The creamy yellow flowers appear in winter. The phyllodes are two to five inches long and a quarter inch to a half inch wide.

Acacia saligna
GOLDEN WREATH WATTLE

This small tree grows from ten to twenty-five feet tall with a bushy, spreading crown. It does well in almost any soil, from light to heavy. Golden yellow to almost orange flowers appear in spring. The six to ten inch long phyllodes are conspicuous on angular stems.

Acacia sowdenii
WESTERN MYALL

Western Myall is a long-lived, frost- and drought-resistant small tree that grows from twelve to eighteen feet tall with drooping branches. It prefers a dry, well-drained soil. Yellow flowers appear irregularly, but are prolific when conditions are right. Silvery, needlelike phyllodes are three to four inches long.

Acacia redolens.

Acacia spectabilis
MUDGEE WATTLE

This species is a shrub or small tree that grows to ten or fifteen feet tall. It is one of the most attractive wattles and is suited to garden or residential plantings. The yellow flowers are in racemes four to seven inches long. The bipinnate leaves are one to four inches long and wide.

Acacia stenophylla
SHOE-STRING ACACIA, RIVER COOBA

Shoe-string Acacia is a small tree that grows from ten to thirty feet tall with pendulous branchlets and phyllodes. It is attractive either singly or in groups. Cream colored flowers appear mainly in winter or sometimes in early summer. There is a bushier form that is more dense and makes a good screening or windbreak.

Acacia trineura
THREE-VEIN WATTLE

This wattle is a dense, rounded shrub that grows to eight feet tall. Dark yellow flowers in short racemes appear in late winter. The phyllodes are two to three inches long, a quarter inch wide, and have three prominent veins.

Acacia victoriae
BRAMBLE WATTLE

This species grows into a much-branched twelve to fifteen foot shrub that makes a good hedge if mass planted. It performs best in warm, dry conditions. Pale yellow flowers in two to three inch racemes generally appear in spring. The phyllodes are an inch to an inch and a quarter long and an eighth to a quarter inch wide.

The Australian Acacias are generally colorful and quite variable. One can be found to fit almost any situation. Their use covers the whole range of landscape categories, except for the category of extremely large trees. The species listed are generally available through local nurseries that specialize in drought-resistant plants. As the demand for these *Acacia* species grows, so will the supply, until they are likely to become common plants carried by almost all nurseries in the desert southwest.

Biogeographical Distribution of Salt Marsh Halophytes on the Coasts of the Sonoran Desert

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Abstract:

Twenty-four species of intertidal halophytes were recorded from 15 coastal salt marshes of the Sonoran desert. The Pacific salt marshes were found to be the most diverse, with 14.4 species per marsh, while the western Gulf of California had 8.9, and the eastern Gulf, 13.7. A low species diversity was found in the northwestern Gulf due to the absence of mid- and high-zoned halophytes. High-zoned species were geographically patchier on all coasts.

The species formed three elevational groups within the intertidal zone: LOW: *Spartina foliosa* Trin, *Distichlis palmeri* (Vasey), *Rhizophora mangle* L., *Laguncularia racemosa* (L.), *Avicennia gerimans* (L.), *Salicornia bigelovii* Torr., *S. europaea* L., and *Batis maritima* L.; MID: *Salicornia virginica* L., *Suaeda californica* S. Wats., *Jaumea carnosa* (Less.), *Sesuvium verrucosum* Raf., *Limonium californicum* (Boiss.) and *Cressa truxillensis* H.B.K.; HIGH: *Salicornia subterminalis* Parish, *Allenrolfea occidentalis* (S. Wats.), *Frankenia grandifolia* Cham. and Schlect, *F. palmeri* S. Wats., *Monanthochloe littoralis* Engelm., *Distichlis spicata* (L.), *Suaeda fruticosa* (L.), *Atriplex barclayana* (Benth.), *A. canescens* (Pursh) and *Sporobolus virginicus* (L.). Thirty additional species were recorded in the supralittoral zone.

Introduction

The Sonoran desert has over 3400 km of coastline. This includes the outer Baja peninsular coast (1250 km), the inner Baja peninsular coast (1300 km) and the Sonora mainland coast (900 km) (Figure 1). While the total salt marsh acreage is unknown, the Sonoran desert coast is frequently indented by salt marshes. These salt marshes are typically hypersaline "negative estuaries" since they receive little or no fresh water influx (Thompson et al., 1979). Negative estuaries are characterized by high salinities at their heads due to evaporation. (Water Resources Study Team, 1979). The extremes of salinity and temperature in the Gulf Coast of the Sonora desert salt marshes are comparable to those found in the Red Sea. The Pacific coast salt marshes however, tend to have similar salinities from head to mouth due to the moderated climate produced by the cool waters of the California current.

The salt marsh flora of Baja California has been described from Ensenada south to Puerto Chale (24°30'N) (Dawson 1962; Phleger and Ewing, 1962; Macdonald, 1967 and 1969; Neuenschwander, 1972; Thorsted, 1972; Macdonald and Barbour, 1974). The occurrences of some Gulf of California salt marsh plants has been mentioned (Kniffen, 1932; Nicols, 1965; Felger, 1966; Foster, 1975; Felger and Lowe, 1976); but no detailed study has been made to date. This report compares distributions of salt marsh halophytes from 14 negative estuaries along the Pacific and Gulf coasts, and one positive river estuary near Mulege, Baja California, where the Rio Santa Rosalia enters the Gulf of California.

Survey Method

Fifteen salt marshes (Figure 1) were surveyed for halophytes during August of 1979. These primary data were supplemented by earlier visits to six additional sites on the Sonoran coast during the previous 4 years. We consider a halophyte as any phanerogam capable of growing in sea water (34 to 40 ppt), i.e., within the intertidal zone. The sea grasses, *Zostera marina* L., *Phyllospadix torreyi* Wats. and *Ruppia maritima* L., which occur in subtidal zones of Sonoran desert coasts were not surveyed. Percent of coverage by the halophytes was estimated from the area covered by the foliage of a species projected on the ground (Smith, 1966) and then converted to the following coverage classes derived from Braun-Blanquet (1951). Plants were considered: a) RARE, if less than 1%; b) UNCOMMON, 1-5%; c) COMMON, 6-25%; and d) ABUNDANT 26-100%. Vertical ranges of the intertidal distributions were based on natural halophyte zones: low, mid, high and supralittoral (see Macdonald and Barbour 1974). We found, however, that the mid to high vegetation change was not always apparent. Taxomomic designations follow Shreve and Wiggins (1964), Munz (1974) and Wiggins (1980).

Results

No overall correlation between number of species per marsh and latitude was evident along any coastline, even though species composition varied with latitude. Species diversity was significantly lower in the western gulf (8.9 per marsh) than in the Pacific (14.4 per marsh) or the Sonoran coast (13.7 per marsh) (Table 1). The marshes of San Felipe (30°10'N) and Bahia San Luis Gonzaga (29°45'N) had only six species, each, and are largely responsible for the lowered diversity.

In total, 24 species were recorded from the intertidal zone: 15 of which were found on all coastlines. Twenty-one species

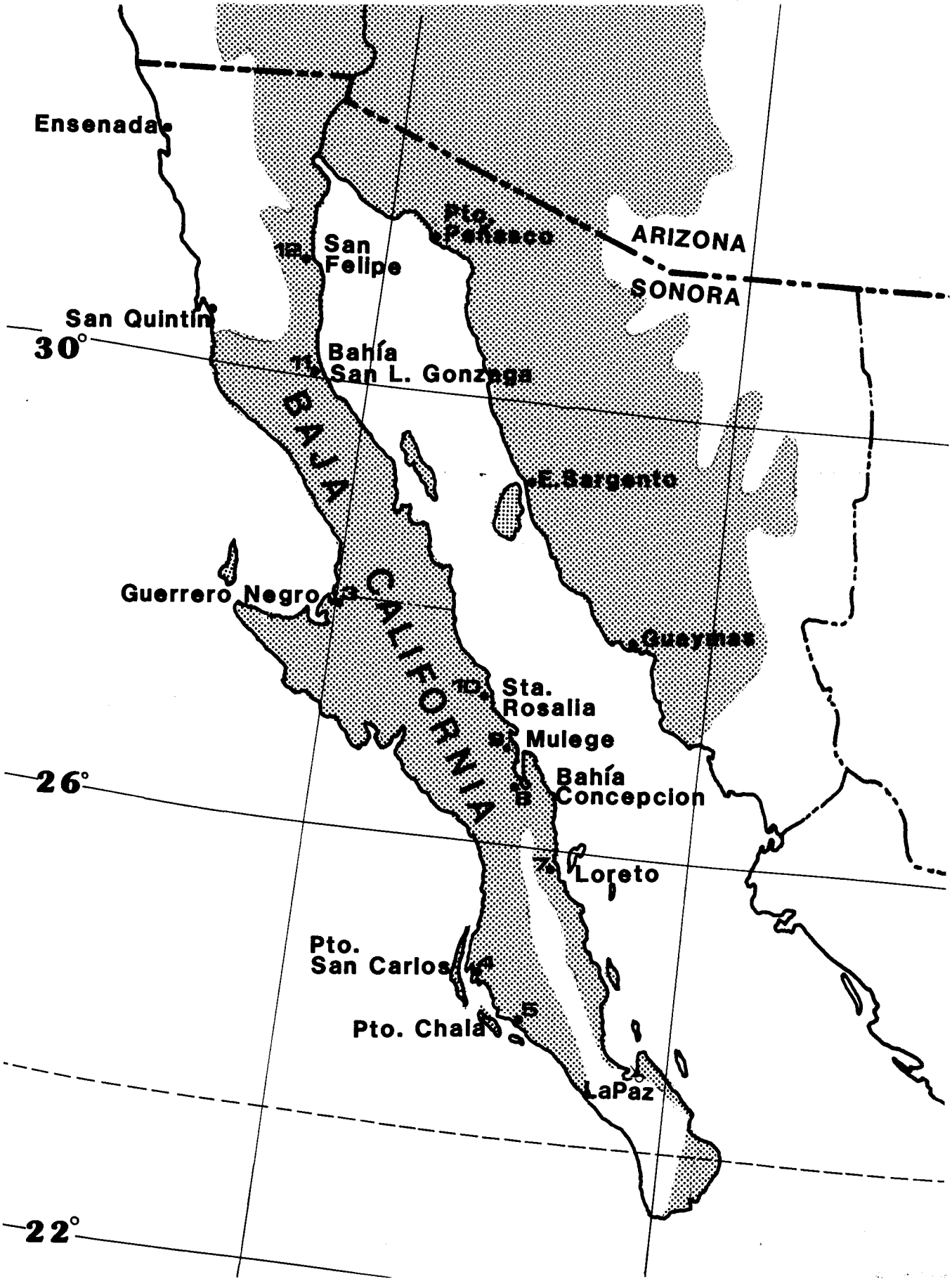


Figure 1. *Map showing limits of the coastal Sonoran Desert and the salt marsh study sites.*

were found on the Pacific coast of Baja California, 18 on the gulf coast of Baja California, and 19 on the gulf coast of Sonora (Figure 2). Four species were found only on the Pacific coast of Baja California, whereas 3 species were found only in the Gulf of California.

Species composition of each marsh was examined as a function of vegetation zones. The halophyte zones were distinguished as low, middle and high intertidal zones (Figure 3), and a supralittoral zone (Table 2) in accord with Macdonald and Barbour's zones (1974).

Spartina foliosa was the dominant plant in the low zone of salt marshes on the Pacific coast as far south as Guerrero Negro (28°N). Three degrees further south, in marshes surrounding Bahia Magdalena (25°N), mangrove species were the dominants in the low zone. *S. folisa* was still present and occurred as far south as Puerto Chale (24°30'N) but does not penetrate into the mangroves' significantly attenuated sunlight. The northern gulf endemic *Distichlis palmeri*, was a dominant in the low zone. But, unlike *S. folisa*, its range did not extend south ot the mangroves. Also in the low zone, the annual succulents were found: *Salicornia bigelovii* on the Pacific coast and *S. europaea* on the gulf coasts. Although they were rarely dominant, they were found in almost all of the marshes. *Batis maritima* was found in all the marshes except San Felipe and Bahia San Luis Gonzaga, often as a subdominant.

In the middle zone, the perennial succulent, *Salicornia virginica* was typically the dominant species. The widely distributed *Sesuvium verrucosum* and *Cressa truxillensis* were found along all three coastlines and *Cressa* became a subdominant in the depauparate salt marshes of the northwestern gulf. The well distributed *Suaeda californica* did not occur below San Felipe on the gulf coast of Baja California. *Jaumea carnosa* and *Limonium californicum* were restricted to the northern Pacific coast of Baja California.

In the high zone the distributions were patchier than the low and middle zone. The short, bristly grass, *Monanthochloe littoralis*, for example, formed extensive mats in some salt marshes, but was absent from others. To the south it was more conspicuously absent. Also to the south on the Sonoran coast another high-zoned grass *Sporobolus virginicus*, ranged south from the mangrove-populated Estero Sargento (29°20'N). *Suaeda fruticosa* was present along the tide line at various locations on all three coastlines. The typically supralittoral halophytes, *Atriplex barclayana, A. canescens* and *Distichlis spicata*, appeared in the high zone of some estuaries.

The desert shrub, *Frankenia palmeri*, and the closely related alkali heath, *F. grandifolia*, were found along all three coastlines, although not below 28°N latitude. These two species appeared the most dissimilar along the Pacific coast and the most similar in the northern Gulf of California. The width-length ratio of *F. grandifolia* leaves differed significantly between specimens from the Pacific and gulf coasts (Table 3). Specimens from Guerrero Negro appeared to be transitional, in that leaf length was less than specimens from Ensenada or San Quintin, but greater than specimens from Puerto Penasco (Table 3). Leaf dimensions of *F. palmeri* were similar among specimens from all locations (data not shown). At San Felipe, where *F. grandifolia* was absent, *F. palmeri* seemed to move into the niche of *F. grandifolia*.

Allenrolfea occidentalis grew to two meters in height

Table 1. Number of intertidal halophyte species per marsh in Sonoran desert coastal salt marshes. Pacific Baja = Pacific coast of Baja California; Gulf Baja = Gulf of California coast of Baja California; Gulf Sonora = Gulf of California coast of Sonora.

Pacific Baja	
Ensenada (31°45'N)	13
San Quintin (30°30'N)	13
Guerrero Negro (28°N)	15
Pto. San Carlos (25°N)	15
Pto. Chale (24°30'N)	16
Average species/marsh	14.4
Gulf Baja	
San Felipe (31°10'N)	6
Bahia Luis Gonzaga (29°45'N)	6
Sta. Rosalia (27°N)	10
Mulege (27°N)	12
Bahia concepcion (20°35'N)	8
Loreto (26°N)	6
La Paz (24°10'N)	14
Average species/marsh	8.9
Gulf Sonora	
Pto. Penasco (31°15'N)	16
Estero Sargento (29°30'N)	13
Guaymas (28°N)	12
Average species/marsh	13.7

*Significantly different from means for Pacific Baja and Gulf Sonora at 95% confidence interval by Duncan's multiple-range test (Steel and Torrie 1960:107-109).

Table 2. Sonoran desert halophytes from the supralittoral and adjacent desert saline habitats. Locations indicate areas (Figure 1) from which plants were recorded.

Species	**Locations**
Abronia maritima	2,4,6,7
Amaranthus cf. palmeri	6
Ambrosia dumosa	3,4,5,11,15
Atriplex barclayana	4,11
Atriplex canescens	13
Atriplex lentiformis	13
Atriplex semibaccata	2
Atriplex watsonii	1,2
Baccharis sp.	7,15
Carpobrotus aequilaterus	1,15
Carpobrotus edulis	1,15
Cuscuta salina	2
Dudleya spp.	2
Gasoul crystallinum	1,2,3,5,15
Gasoul nodiflorum	1,2,3,4
Heliotropium curassavicum	1,3,4,7,9,10
Hordeum vulgare	4
Juncus cf. acutus	9
Lycium sp. #1	1,2,4
Lycium sp. #2	2,6,7,9,10
Maytenus phyllanthoides	4,6,7,8,10
Opuntia fulgida	7
Opuntia bigelovii	15
Parapholis incurvata	1
Phoenix dactylifera	7,10
Plantago sp.	9
Prosopis julifora	7,8,10
Simmondsia chinensis	15
Tamarix pentandra	2,3
Triglochin maritima	3

(Bahia San Luis Gonzaga) and was a dominant bush along the tide line in many of the marshes. The smaller *Salicornia subterminalis* occupied a similar habitat along the northern Pacific and gulf coasts of Baja California and along the Sonoran coast. In the Gulf of California, however, it was exclusively intertidal.

The supralittoral species were even patchier than the high-zoned species (Table 2). Many species were recorded from only one salt marsh, and the average representation was only 2.3 marshes per species. The most widely distributed supralittoral species was *Heliotropium curassavicum* L. (present in 6 marshes), followed by *Ambrosia dumosa* (A. Gray), *Lycium* sp. #2, and *Maytenus phyllanthoides* Benth. (present in 5 marshes each).

Discussion

The results support the conclusion that the three coasts of the Sonoran desert are of the same salt marsh phytogeographic region, in that 15 of 24 species are found on all three coasts. *Salicornia bigelovii* may be only a variant of *S. europaea* (Shreve and Wiggins, 1964; Munz, 1974). In this case, the number of shared species is 16, and the Pacific coast would have only 3 unique species. Two of these, *Jaumea carnosa* and *Limonium californicum*, are californian species that just enter the northern region of the Pacific coast of the Sonoran desert. The Pacific coast salt marshes have significantly more species per salt marsh than those of the gulf.

Despite the gulf's rigorous physical extremes and the seemingly severe selection pressure only a single species, the salt grass *D. palmeri*, is endemic. *D. palmeri* may be derived from *D. stricta* populations in the vicinity of the mouth of the Colorado River. The reproductive structures clearly indicate affinities with *D. stricta* (Shreve and Wiggins, 1964). In the Colorado River Delta area, the Cocopa indians cultivated and harvested the grain of *D. palmeri*. This human influence may have assisted in its differentiation.

Some of the species found in the estuaries represent inland desert and alkali flat halophytes, such as *Allenrolfea occidentalis, Atriplex barclayana* and *A. canescens*. These high-zoned species tolerate extreme salinities and temperatures. The low and middle zone species rarely occur inland, although the lower zoned species may extend north into the temperate Pacific coast salt marshes as far as San Francisco Bay (Macdonald and Barbour, 1974).

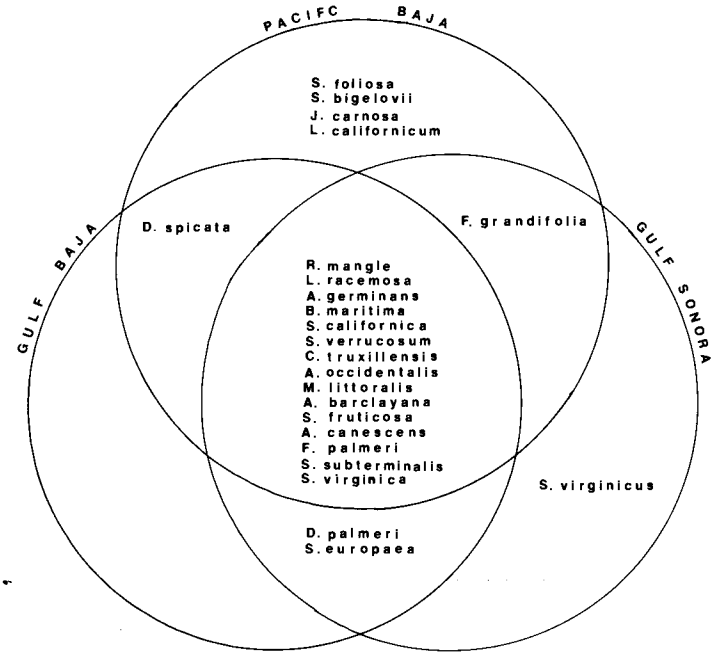


Figure 2. *Venn diagram showing species distributions and overlaps with respect to the three Gulf of California coastlines.*

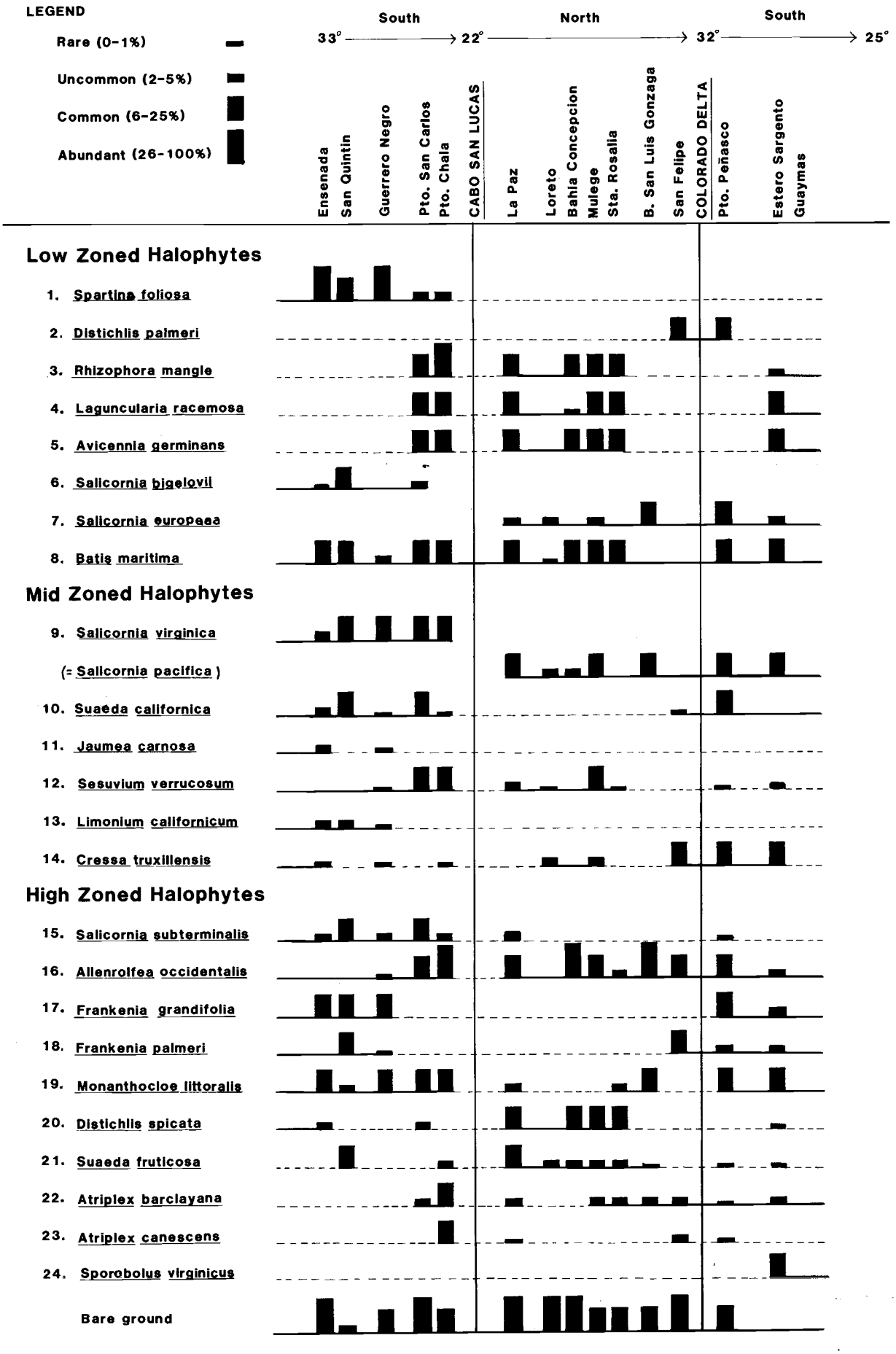
The dominant tropical species were the three species of mangroves. Temperature undoubtedly controls the northern limits of the mangroves along all three coastlines. Moser (unpublished) has described the freezing damage to mangroves in Estero Sargento, Sonora. This estuary is near the northern mangrove limit along the mainland gulf coast (29°N latitude). This is considerably north of the mangrove limits on the colder Pacific coast of Baja California (26°N). The mangrove limit on the gulf coast of Baja California (27°N) is between the other two limits. This mangrove distribution closely follows the mean sea surface of the coldest month, January. Robinson's (1973) 70°F (15.6°C) January isotherms coincide with the limits of the mangroves on all three Sonoran desert coastlines.

The southern limits of four species, *Frankenia grandifolia, F. palmeri, Jaumea carnosa*, and *Limonium californicum*, occur at approximately 28°N. The first two species are disjunctly distributed between the Pacific and gulf coasts. The latter two were only found on the Pacific coast. The factor(s) limiting these southern distributions may be related to temperature, such as cold stratification of seeds or predator survival.

A few exotic species are beginning to move into the relatively undisturbed Sonoran desert salt marshes. Macdonald and Barbour (1974) have noted that in Bahia San Quintin, "Fifteen species were encountered on the marsh, all but one of which (*Mesembryanthemum nodiflorum* L. [= *Gasoul nodiflorum* L.] were indigenous—a marked contrast to the many introduced species of the more disturbed American (U.S.A.) marshes..." The present study adds another species to the introduced list: the South African *G. crystallinum* (L.) in

Table 3. Length, width, and ratio of width to length of leaves of *Frankenia grandifolia* collected at four sites along the Pacific coast of Baja California and the eastern coast of the Gulf of California. Fully expanded basal leaves from secondary branches of herbarium specimens were measured with a caliper. Ten leaves were measured per datum point. Within a column, values followed by the same letter are not significantly different at the 95% confidence interval by Duncan's multiple-range test (Steel and Torrie 1960:107-109).

Geographical Region	Collection Site	Length (Millimeters)	Width (Millimeters)	Ratio Width : Length
Temperate Pacific Coast	Ensenada	13.1 a	6.7 a	1 : 1.98 a
	San Quintin	14.1 a	6.5 a	1 : 2.24 a
Desert Pacific Coast	Guerrero Negro	6.7 b	3.1 b	1 : 2.18 a
Desert Gulf Coast	Puerto Penasco	7.1 b	1.2 c	1 : 6.21 b


LEGEND
Rare (0-1%)
Uncommon (2-5%)
Common (6-25%)
Abundant (26-100%)
South
33°
22°
North
32°
South
25°
Ensenada
San Quintin
Guerrero Negro
Pto. San Carlos
Pto. Chala
CABO SAN LUCAS
La Paz
Loreto
Bahia Concepcion
Mulege
Sta. Rosalia
B. San Luis Gonzaga
San Felipe
COLORADO DELTA
Pto. Peñasco
Estero Sargento
Guaymas
Low Zoned Halophytes
1. Spartina foliosa
2. Distichlis palmeri
3. Rhizophora mangle
4. Laguncularia racemosa
5. Avicennia germinans
6. Salicornia bigelovii
7. Salicornia europaea
8. Batis maritima
Mid Zoned Halophytes
9. Salicornia virginica
(= Salicornia pacifica)
10. Suaeda californica
11. Jaumea carnosa
12. Sesuvium verrucosum
13. Limonium californicum
14. Cressa truxillensis
High Zoned Halophytes
15. Salicornia subterminalis
16. Allenrolfea occidentalis
17. Frankenia grandifolia
18. Frankenia palmeri
19. Monanthocloe littoralis
20. Distichlis spicata
21. Suaeda fruticosa
22. Atriplex barclayana
23. Atriplex canescens
24. Sporobolus virginicus
Bare ground

the supralittoral of Bahia San Quintin. In 1978, this species also appeared at Station Beach, Puerto Penasco, Sonora, on the eastern coast of the northern Gulf of California. *G. crystallinum* has not been observed in Sonoran salt marshes.

The high proportion of indigenous species in the Sonora desert salt marshes as compared to the United States Pacific coast marshes may be due to the lesser influence of man (Macdonald and Barbour 1974). But it should not be overlooked that these desert marshes represent a harsh environment which may protect the native species against encroachment by exotic species.

In conclusion, the Sonoran desert salt marsh halophyte flora is a unique phytogeographical region undisturbed by invading species and man. Although the region has only one endemic species (possibly derived by man) there appears to be an excellent opportunity to study natural speciation processes in an undisturbed halophyte flora. The desert forms still have intact ranges, even with respect to the patchy upper zoned halophyte species. Future studies may reveal how the disjunct distributions arose and what mechanism(s) may be limiting the southern distributions. Our observations that the mangroves' northern limits (26°, 27°, and 29°N latitude) corresponding to the 70°F (15.6°C) isotherm supports the conclusion that the mangroves are temperature limited. The desert coastal estuaries north of the mangrove limit have extreme physical conditions, but have been the least studied. Hopefully, this note on desert halophytes will both stimulate and assist future studies in this interesting area.

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Figure 3. *Distribution and estimated abundances of Sonoran Desert salt marsh halophytes and bare ground. Intertidal species are grouped according to their vertical distribution within the halophyte zone. Solid lines indicate inferred distributions.*

continued
from page 71

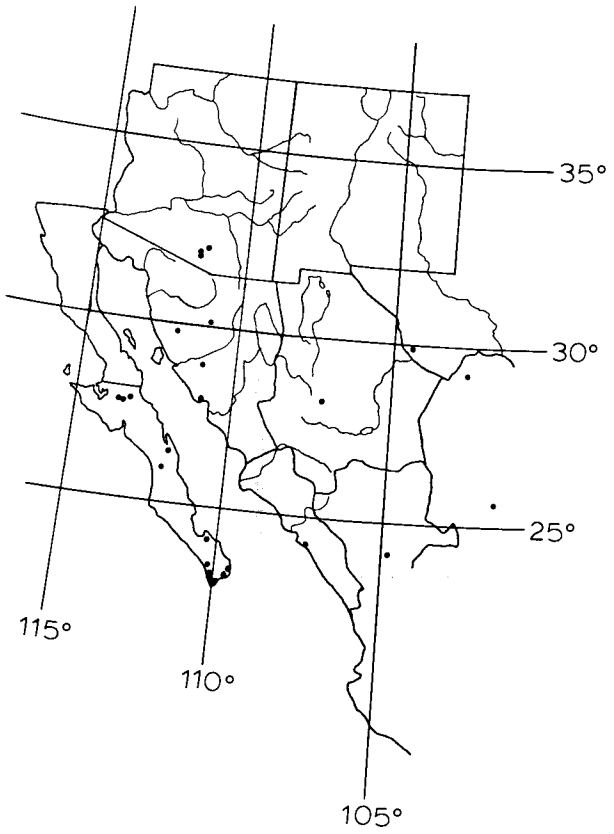
reported to eat both immature pods and mature seeds of *P. filiformis* (Nabhan, 1982). Germination is epigeal, and primary leaves are cordate. Mature plants have vines up to 1 m length.

As previously mentioned, *P. grayanus* has been confused with *P. filiformis (P. wrightii)*. This is due to the similarity of leaf shape of certain *P. filiformis* and *P. grayanus* plants. The similarity ends at that point. *P. grayanus* is a plant of oak woodlands and pine forests, a perennial from a lignescent thickened root, a much larger plant with fruits and seeds very different from *P. filiformis*.

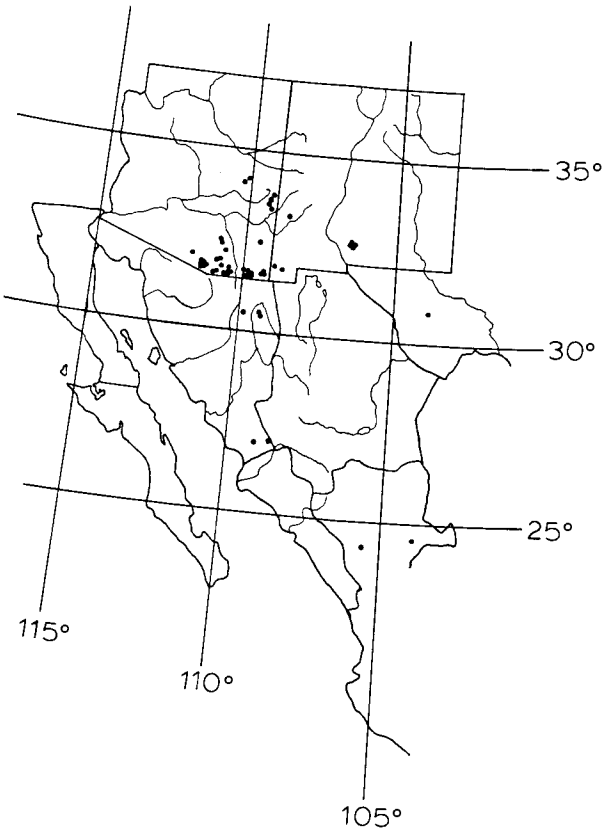
Phaseolus metcalfei and *P. ritensis* are two sibling species of a group which includes at least four members (Piper, 1926). Although difficult to distinguish in flower, fruited specimens are easily separated (Nabhan et al., 1980). Useful characters are listed in Table 2.

Both species are found in oak savannas, oak woodland, and chapparal, but *P. metcalfei* has a broader range, including Chihuahuan grasslands. Germination of both species is hypogeal. Both species are perennial from rather large, lignescent roots. Vines reach lengths of up to 5 m. They have been sporadically used as forage crops, sometimes under the name *P. retusus*, and are the only wild southwestern *Phaseolinae* whose products (medicinal roots) are currently marketed (Nabhan et al., 1980).

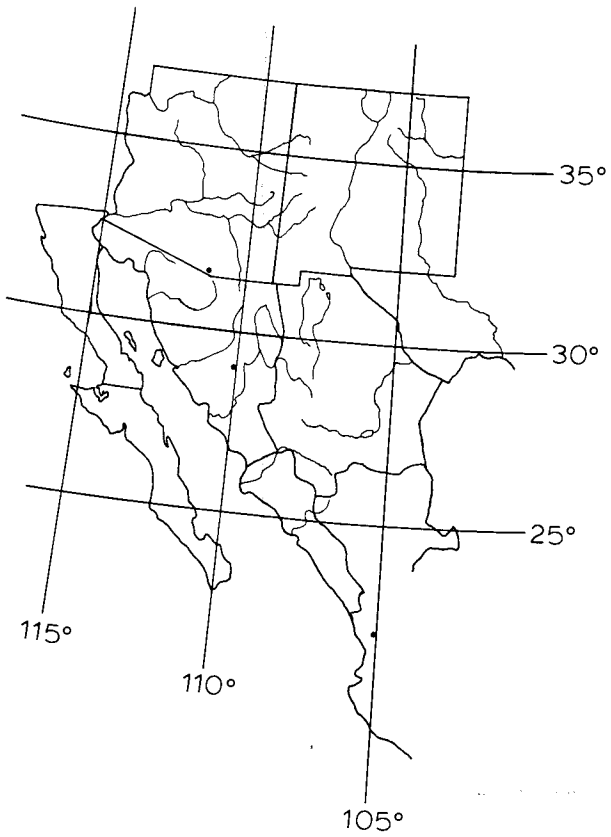
Phaseolus parvulus, a species of pine forests, is the smallest



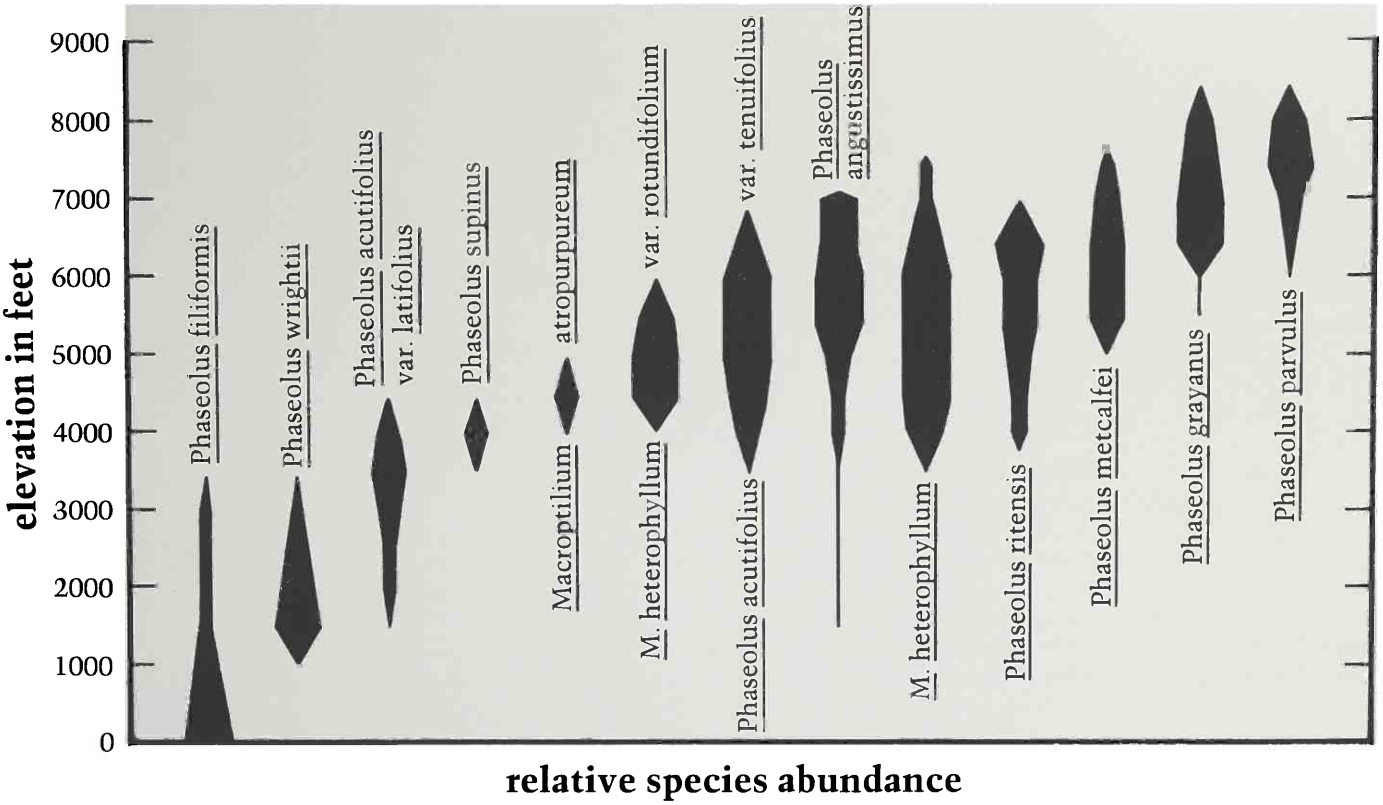
Macroptilium atropurpureum.



Macroptilium gibbosifolium.

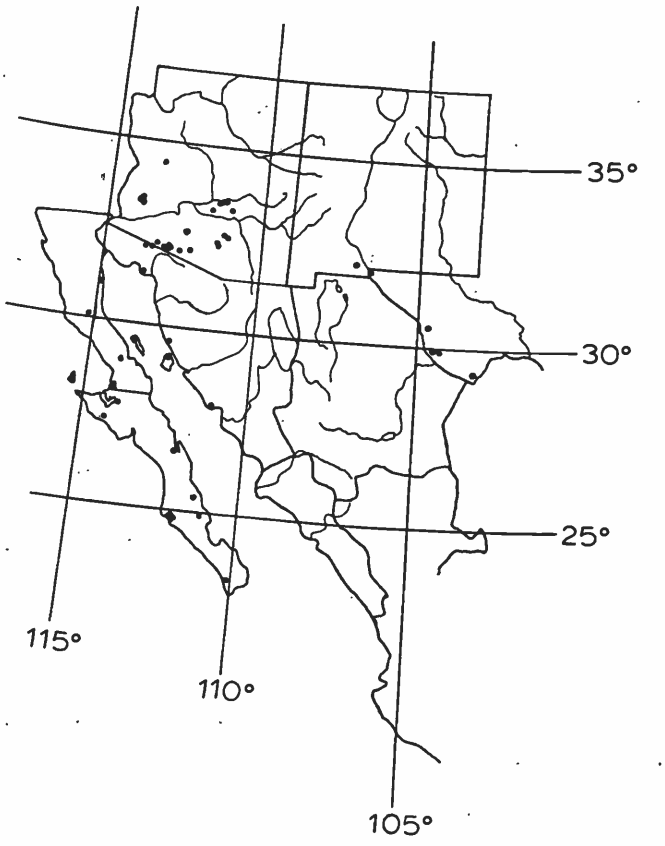


Phaseolus supinus.

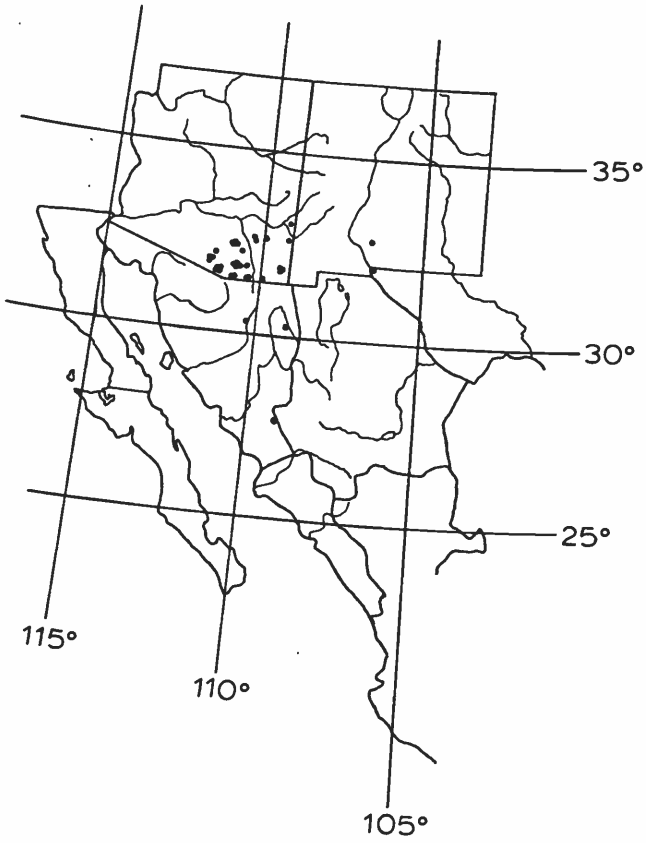


Elevational distributions of Southwestern Phaseolinae.

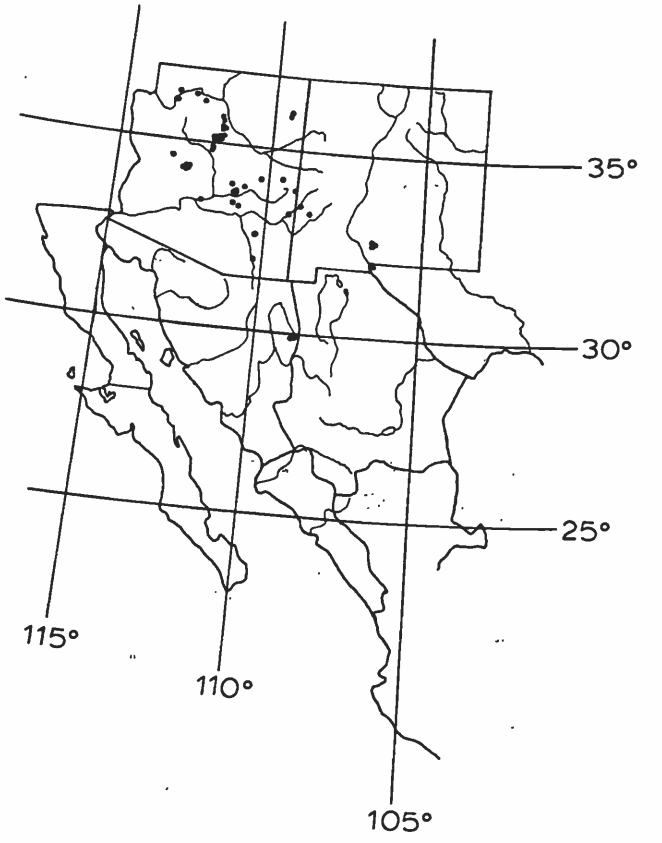
Phaseolus filiformis *at the University of Arizona Campbell Avenue Farm.*



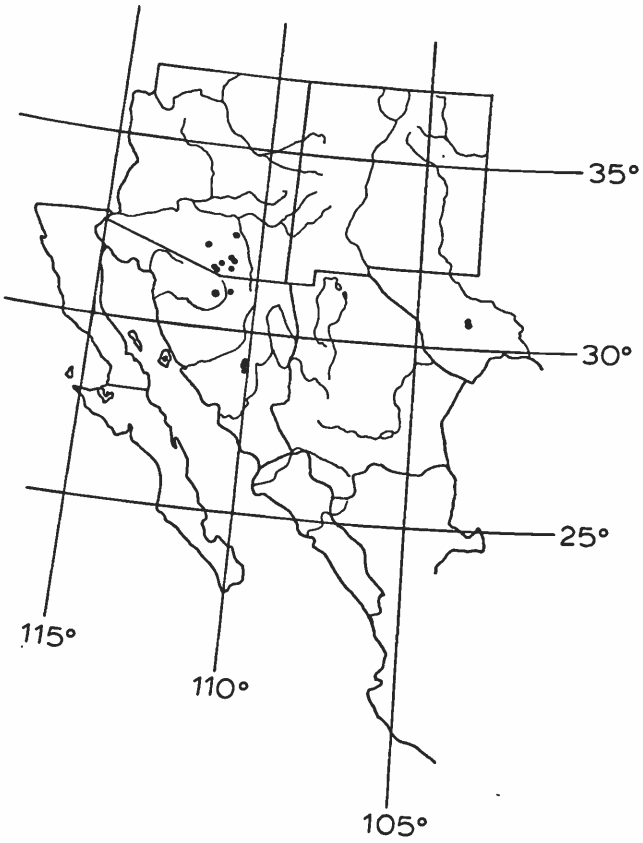
Phaseolus filiformis.



Phaseolus acutifolius var. *acutifolius.*



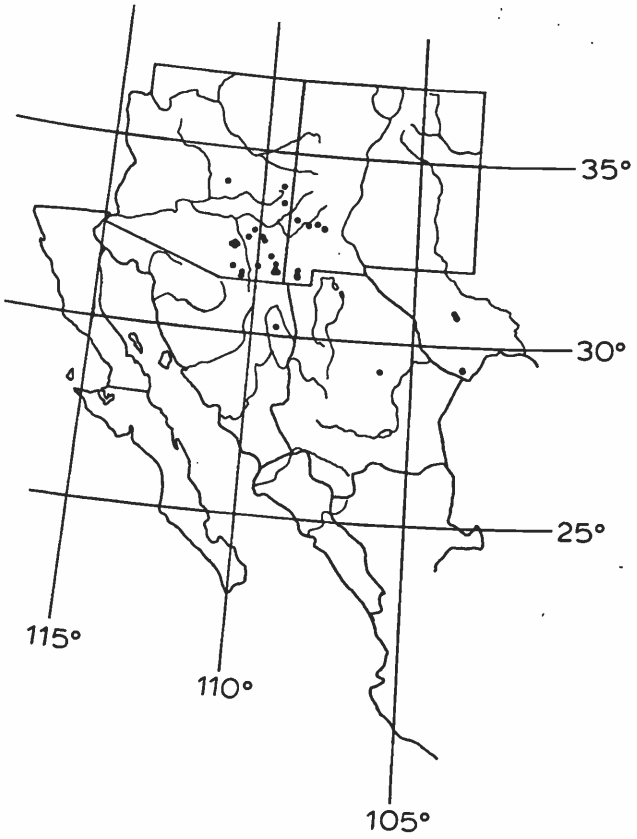
Phaseolus angustissimus.



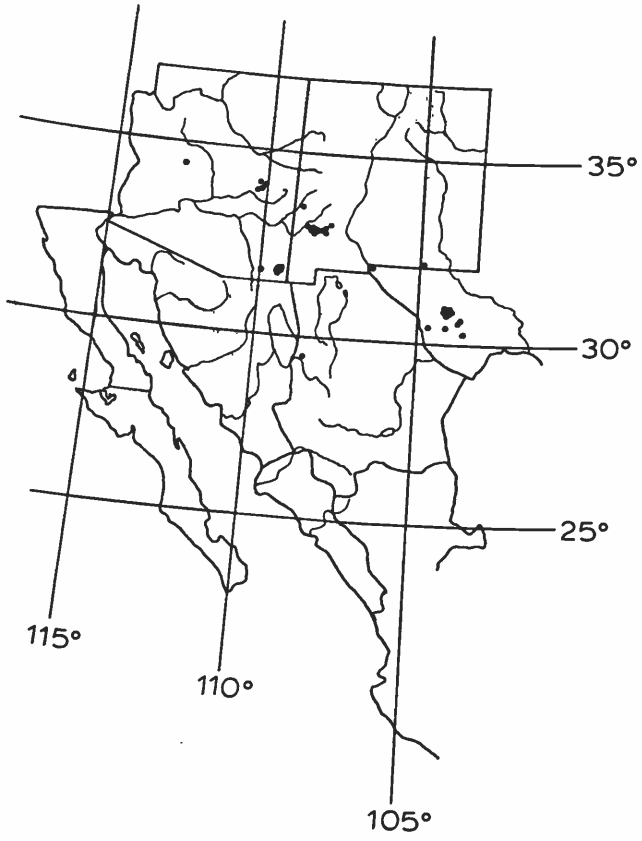
Phaseolus acutifolius var. *latifolius.*

Phaseolus acutifolius *var.* acutifolius *at the University of Arizona Campbell Avenue Farm.*

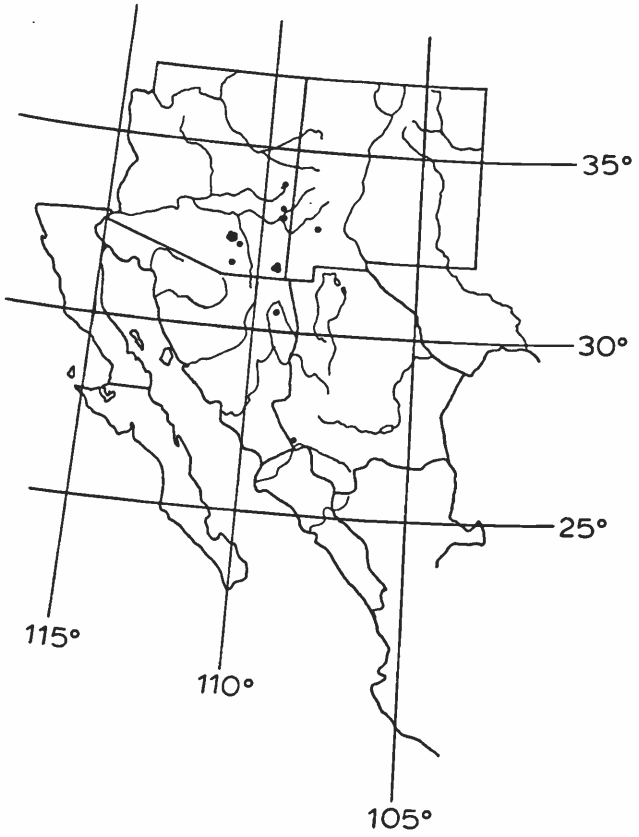
Phaseolus acutifolius *var.* latifolius *growing on volcanic talus, Sycamore Canyon, Atascosa Mountains, Arizona, 1160 m (3800 ft.).*



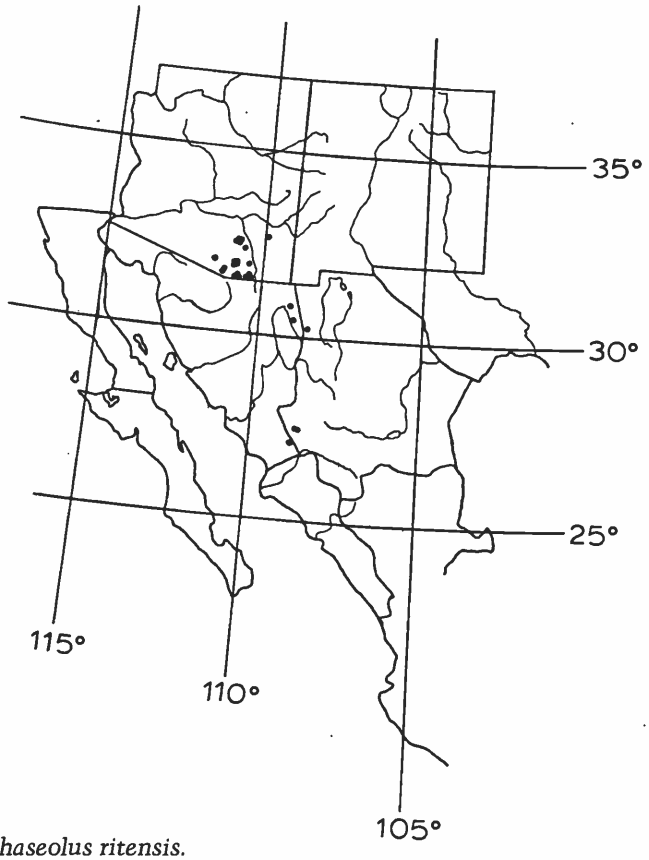
Phaseolus grayanus.



Phaseolus metcalfei.



Phaseolus parvulus.



Phaseolus ritensis.

Phaseolus metcalfei *growing from a roadcut along the Tombstone-Pierce road, Dragoon Mountains, Arizona, 1830m (6000 ft.).*

plant of the group, rarely reaching sizes greater than 40 cm. Growing from a small, round tuber, the plants usually emerge in late July or early August and have gone dormant by October.

Domesticated *Phaseolus* species are major contributors to the world food supply. Valuable characters unknown within domesticated species are found in the wild Phaseolinae of the Southwest. Unfortunately, many populations are in danger of extinction or have already been lost. Protection of threatened populations and species is imperative if the full potential for utilization of this group is to be achieved. This would not be protection in the conventional sense, since the group is most successful as disturbance indicators or colonizer species. Overgrazing and fire suppression are probably the most harmful factors for the group's survival. Successful populations are found on landslides, roadcuts, unstable soils, and recently-burned areas. Preservation of this group of wild plants merits the attention of those concerned with the continuation of a stable, long-term food supply.

Table 2. Characteristics that Distinguish *P. metcalfei* and *P. ritensis.*

	P. metcalfei	*P. ritensis*
Seed Weight	.2 - .3 g	.04 - .06 g
Pod Width	9-18 mm	6-10 mm
Pod	Constricted Between Seeds	Nearly Smooth
Peduncle Length	Not over 30 cm	Up to 1 m
Leaf Color	Blue green	Dark green
Primary leaf	Deltoid, petiolate	Lance-ovate, lanceolate subsessile
Node 3 leaf	Trifoliate	Unifoliate

Phaseolus parvulvus, *in mixed* Pinus ponderosa, Robina neomexicana *forest, Oracle Ridge, Santa Catalina Mountains, Arizona, 2400 m (7900 ft.). Seedlings are visible in the right foreground.*

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Greenhouse Establishment of Alfalfa in Three Soil Materials Associated with Arizona Coal Mining[1]

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Abstract

The effects of three soil materials, three mulching treatments, and two moisture treatments on the growth and forage production of 'Vernal' alfalfa (*Medicago sativa* L.) for use in coal mine waste reclamation were studied in a 3-year experiment in the greenhouse at Tucson, Arizona. The three soil materials were: (1) Gila loam, (2) Unmined soil, and (3) Coal mine soil. The three mulching treatments were: (1) No mulch, (2) Barley (*Hordeum vulgare* L.) straw, and (3) Russian thistle (*Salsola kali* L.). The two soil moisture treatments were: (1) Optimum (60 cm total) and (2) Stressed (30 cm total).

Significant differences were observed in number of stems per pot, plant height, and forage yield between soil materials, mulching treatments, and soil moisture treatments. The greatest number of stems per pot, the tallest plants, and the highest forage yield were produced in the Gila loam, barley straw mulch, and optimum soil moisture treatment. Use of a soil mulch (incorporated organic matter mulch) produced better plant growth and more forage than when soils were not mulched. Barley straw was a more effective mulching material than was Russian thistle. Within soil materials and within mulching treatments forage yields were significantly higher with optimum soil moisture than they were when moisture was limited.

Additional Index Words: Mine Spoils, Revegetation, Stabilization, Disturbed Land, Environmental Pollution.

Introduction

As the demand for energy increases each year, an alternative source of energy is needed to relieve the dependency on oil. Coal takes a strong lead as this alternative source of energy due to its availability and relative abundance. However, as more pressure is placed on the coal industry to supply this commodity, increased pressure is also placed on the strip mines to minimize the deleterious effects of the mine wastes produced. Reclamation of these wastes, especially in semiarid regions where rainfall averages less than 25 cm per year, is needed to stabilize the waste material against wind and water erosion and to return the mined land to a productivity level equal to or greater than the original productivity level prior to mining.

Literature Review

The practice of applying mulch as a reclamation amendment has been utilized for many years. The application of mulch has many purposes: to help conserve moisture, to reduce surface temperature, and to control erosion (Barth, 1977). In addition, a mulch serves to build organic matter in the soil, to improve the soil structure, and increase resistance to surface crusting (Luellen, 1977). Hardwood bark mulch has been very effective in curtailing erosion (Franz, 1975). Sarles and Emanuel (1977) compared hardwood bark mulch with straw mulch and found the bark to be intermediate between straw and unmulched soil in the production of vegetative cover. Jones et al. (1975) found that by planting a fast growing species, such as wheat (*Triticum aestivum* L. em Thell.) or barley (*Hordeum vulgare* L.), disturbed land can be quickly stabilized with a ground cover while providing an "in-place" mulch for seeding permanent grasses and legumes.

While the feasibility of using Russian thistle as an "in-place" mulch may be studied, its desirability as a permanent

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reclamation ground cover would be questionable. In a semi-arid region such as northeastern Arizona, other plant species such as grasses and legumes, either native or introduced, would be more desirable. Power et al. (1978) reported that viable seed of native grasses is not readily available and when used may require over 3 years to become established on a disturbed site. They also reported that introduced species are easier to establish and often more tolerant of adverse conditions during establishment and initial growth; however, they may require more preparation to become established. Holechek (1981) has shown good initial establishment of alfalfa (*Medicago sativa* L.) as an introduced legume in mine spoils on the Northern Great Plains. Alfalfa has also produced high yields in sand tailings (Mislevy et al., 1981) and pyritic uranium tailings (Murray and Moffett, 1977). In addition to providing a high yielding vegetative cover, alfalfa has been shown to contribute to the nitrogen economy of disturbed soil when used on china clay wastes (Marrs et al., 1980).

The objectives of this research were to compare the growth and yield for Vernal alfalfa grown in three soil materials, with three mulching treatments, and with two soil moisture treatments in the greenhouse.

Materials and Methods

Research was conducted in the greenhouse at Tucson, Arizona from 1979 through 1981 to compare the effects of three soil materials, three mulching treatments, and two soil moisture levels on the growth and yield of 'Vernal' alfalfa.

The following soil materials were evaluated for their effect on the growth and yield of 'Vernal' alfalfa.

1. Gila loam soil without mulch (control).
2. Gila loam soil mulched with barley straw (control).
3. Gila loam soil mulched with Russian thistle (control).
4. Unmined soil without mulch.
5. Unmined soil mulched with barley straw.
6. Unmined soil mulched with Russian thistle.
7. Coal mine soil without mulch.
8. Coal mine soil mulched with barley straw.
9. Coal mine soil mulched with Russian thistle.

The Gila loam soil material used as a control was previously prepared by combining Gila loam soil with peat moss to improve its organic content in a ratio of 1:1 and pasteurizing by heating to 72°C. Gila loam soil is a member of the sandy-loam, mixed (calcareous), thermic Typic Torrifluvents. It is an excellent agricultural soil and is frequently used as a "check-soil" in greenhouse experiments.

The unmined soil was obtained from the surface of areas adjacent to but not included in the strip mining operations at Black Mesa Coal Mine near Kayenta, Arizona. This soil (Fruitland soil series), which belongs to the soil family of coarse-loamy, mixed (calcareous), mesic Typic Torriorthents, had experienced overgrazing and supported a sparse vegetative cover of native grasses, saltbush, and sagebrush on less than 25 cm of annual precipitation.

The coal mine soil was also obtained from the Black Mesa Coal Mine near Kayenta, Arizona. This soil was collected from freshly contoured strip mine overburden and consisted of particles ranging in size from silt to crushed sedimentary rock fragments 15 cm in diameter. At the time of collection, this overburden supported no vegetation.

Dried Russian thistle was gathered from representative surface mined areas at the Black Mesa Coal Mine. The Russian thistle and barley straw were reduced in size by a hammer mill with a 6 mm screen for use as an incorporated organic mulch material.

The mulched soil materials were prepared by adding one part of mulch to two parts of soil on a volume basis. The soil materials were placed in 20-cm clay pots. Vernal alfalfa was planted in each pot and thinned to four plants per pot after establishment. A watering schedule was maintained after establishment and for the duration of the experiment that insured that those pots that received optimum moisture (a total of 60 cm at the end of the experiment) were never stressed for soil moisture. The quantity of water applied and the frequency of application was such that the soil was not allowed to completely dry between waterings and the plants never showed signs of moisture stress.

Those pots that received insufficient soil moisture (a total of 30 cm at the end of the experiment) were maintained with only 50% of the optimum moisture levels. This lesser quantity of water applied did allow the soil to dry between waterings and the plants did show signs of moisture stress between applications.

The experimental design was a split-split-plot with soil materials as main plots, mulching treatments as sub-plots, and soil moisture treatments as sub-sub-plots with four replications. The plot size was one pot. At periodic intervals during the 3-year experiment, the forage in the pots was harvested and data were recorded. All data were analyzed using the standard analysis of variance and means were compared using the Student-Newman-Keuls' Test as described by Steel and Torrie (1960).

Results and Discussion

Analyses of the three soil materials used are given in Table 1. The pH of coal mine soil was lower than the pH of unmined soil or Gila loam soil. Plants that grow well in a less alkaline environment may be better adapted to this specific coal mine soil than plants that grow best under alkaline conditions. The ESP in all three soils was virtually non-existant, indicating that sodium should not present any problems. The total soluble salts in coal mine soil was much higher than in Gila loam or unmined soil. Salt sensitive plant species may be injured when grown in coal mine soil at the level of salt indicated. The nitrogen content (nitrate nitrogen) of coal mine soil was much higher than the nitrogen content of Gila loam and unmined soil. Lower nitrogen fertilizer applications would be needed for plants growing in coal mine soil than would be necessary for plants produced on unmined soil. The total amount of phosphorus in coal mine soil was lower than the phosphorus content of the other two soils. All three soils contained similar amounts of potassium which is sufficient for the growth of most plants. The organic matter of coal mine soil was higher than that of unmined soil, although lower than Gila loam. This higher figure may be the result of residual coal in the overburden from which the coal mine soil was derived.

Stems per pot, plant height, green forage yield, and dry forage yield for Vernal alfalfa grown in the greenhouse in three soil materials, with three mulching treatments, and with two soil moisture treatments are reported in Table 2.

Table 1: Average pH, $EC_e \times 10^3$, ESP, total soluble salts, nitrogen (N), phosphorous (P), potassium (K), sodium (Na), and organic matter (OM) in three soil materials in the greenhouse at Tucson, Arizona, in 1978.

Soil Material	pH	$EC_e \times 10^3$	ESP	Total Soluble Salts	N	P	K	Na	OM
				(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(%)
Gila loam	7.5	1.1	0	735	30	2.8	47	11	3.2
Unmined soil	7.4	0.9	0	658	16	2.5	11	8	1.2
Coal mine soil	7.1	8.0	0.6	5607	151	1.3	17	178	2.6

Comments:

1. K and Na were obtained by water soluble extraction and N and P were obtained by CO_2 extraction; pH was obtained by the paste method.

Table 2. Average number of stems per plot, plant height, green forage yield, and dry forage yield for Vernal Alfalfa grown in three soil materials, with three mulching treatments, and with optimum and stressed soil moisture treatments in the greenhouse at Tucson, Arizona, in 1978 through 1980 (3-year average).

Soil material	Mulching treatment	Soil moisture treatment	Stems per plot at harvest	Plant height	Green forage yield	Dry forage yield (12% moisture)
			(no.)	(cm)	(g)	(g)
Gila loam	Not mulched	Optimum	42 a+	45 a	42 a	11 a
		Stressed	27 b	36 b	21 b	6 b
	Barley straw	Optimum	55 a	51 a	64 a	16 a
		Stressed	40 b	39 b	49 b	13 b
	Russian thistle	Optimum	47 a	48 a	45 a	11 a
		Stressed	30 b	36 b	23 b	7 b
Unmined soil	Not mulched	Optimum	37 a	44 a	28 a	7 a
		Stressed	19 b	32 b	15 b	4 b
	Barley straw	Optimum	47 a	48 a	39 a	10 a
		Stressed	26 b	34 b	18 b	5 b
	Russian thistle	Optimum	39 a	46 a	32 a	8 a
		Stressed	24 b	33 b	16 b	4 b
Coal mine soil	Not mulched	Optimum	13 a	37 a	10 a	4 a
		Stressed	6 b	29 b	8 b	2 b
	Barley straw	Optimum	33 a	40 a	32 a	8 a
		Stressed	14 b	32 b	14 b	4 b
	Russian thistle	Optimum	24 a	40 a	19 a	5 a
		Stressed	12 b	32 b	10 b	3 b
Significance of differences:						
Between soil materials			*	*	**	**
Between mulching treatments			*	*	**	**
Between soil moisture treatments			*	*	**	**

* = Significant at the 5% level.

** = Significant at the 1% level.

\+ = Means followed by the same letter, within soil materials, within mulching treatments, and between soil moisture treatments are not different at the 5% level of significance using the Student-Newman-Keuls' test.

In the reclamation of mine wastes, the number of stems produced per plant is important. A high number of stems is desirable for providing a more complete ground cover and producing more forage per unit area. A significant difference was observed in the number of stems per pot between soil materials, between mulching treatments, and between soil moisture treatments (Table 2). Gila loam and barley straw mulch produced the highest number of stems per pot. Within soil materials and within mulching treatments, the average number of stems per pot were higher in the optimum soil moisture treatment than in the stressed soil moisture treatment. Taller plants are desired in coal mine reclamation because they provide better soil protection and higher forage yields than do shorter plants. The plant heights observed in the experiment were greater with Gila loam and barley straw mulch than they were with the other treatments (Table 2). Within soil materials and within mulching treatments, the average plant height was greater with optimum soil moisture than it was when plants were stressed for moisture.

Significant differences were also observed for forage yields among the soil materials tested and among the mulching treatments used (Table 2). Gila loam produced the highest forage yield followed by unmined soil and coal mine soil, in decreasing order. Among the mulching treatments, barley straw produced the highest forage yield and no mulch produced the lowest yield. Within the soil materials and within

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A Report on Special Events at the Boyce Thompson Southwestern Arboretum

Carol D. Crosswhite

Boyce Thompson Southwestern Arboretum

To promote in-depth learning experiences centered around desert plants, the Arboretum annually stages a number of special events. They are scheduled primarily in the cooler months to coincide with peak visitation periods and with most comfortable outdoor temperatures. A variety of topics are treated, changing from year to year. Generally special events last through the day, and guests are presented with a smorgasbord of learning experiences from which to choose. Often certain topics are repeated several times during the day, allowing visitors to devise individual schedules based upon their interests and needs. There is no charge made to attend special events other than the normal admission fee for entering the Arboretum itself ($1.00 for adults, children under 17 free when accompanied by adults).

As examples of the types and range of material covered, Arboretum special events for the Fall of 1982 through the Spring of 1983 are summarized below. Events each year are different although a few are repeated annually because of popularity. *Desert Plants* subscribers receive advance notice of scheduled events. Flyers are either stuffed in the envelope with the journal or mailed separately to subscribers. Friends of the Arboretum are notified through the FOTA Newsletter not only of the special events open to the general public, but of the extra special events which are planned just for them. Thanks and deep appreciation go to the many people who have given freely of their time and knowledge to help with our programs.

Fall Landscaping Festival. This was held on Saturday, November 18, 1982 from 9:00 a.m. to 4:00 p.m. This event celebrated the fall planting season, ideal for establishment of perennial landscaping. The focus was on drought-tolerant plants, with presentations geared to their selection, kinds, care and use. Guest experts and Arboretum staff gave 45-minute talks, demonstrations and slide presentations. During morning hours, some of the topics were 1) Planting and Care of Trees and Shrubs, 2) the Basics of Landscaping with Desert Plants, 3) Native Drought-tolerant Plants to Use in Home Landscaping, 4) Propagation Techniques for Desert Plants, 5) Common Pests of Landscaping Plants and How to Control Them, 6) How the Environment Affects our Plantings. After lunch, participants could choose between a slide presentation or a garden walk of some kind. For instance, at 1:00 p.m. "A horticulturist's tour through Australia and New Zealand" was shown in the lecture room. Some guests were conducted on an Arboretum walk to view specimen plants of drought-tolerant trees and shrubs. Others were given a tour of the Arboretum experimental ground-cover plots.

Vegetable and Fruit Workshop for Desert Families. This was held Saturday, January 22, 1983 from 10:00 a.m. to 4:00 p.m. A sluggish economy has encouraged more and more families to take up home gardening. Because special cultural practices, planting schedules, and plant varieties must be used in the Desert Southwest, a workshop was arranged to help gardeners moving to Arizona from other areas as well as to aid first-time gardeners or those wishing to improve their skills. Dr. Paul Bessey of the University of Arizona Department of Plant Sciences was asked to serve as chairman of the event. The experts he assembled spoke hourly from 10:00 a.m. to 2:00 p.m. on such topics as 1) Vegetable Gardening Through Frost and Sun, 2) Garden Fruits and Nuts, 3) Fertilizing and Watering, 4) Citrus at Home, and 5) Container and Small Space Gardening. Participants could also choose to view slide presentations on 6) Varieties of Fruits and Vegetables for the Desert, 7) Birds and Beasts in the Garden, and 8) What is a Desert? Red onion sets and seeds of virus resistant Columbia tomato, a variety recommended for Arizona, were given free to people attending the event.

Arbor Day Weekend. The formal activities took place on Saturday, February 12, 1983 from 10:00 a.m. to 4:00 p.m. The Arboretum honored trees in general and promoted "tree appreciation" on this day. The following presentations were repeated at 10:00 a.m., 11:00 a.m., and 1:00 p.m.: 1) How to Plant a Tree, 2) Importance of Trees, 3) The State Tree Seedling Program for Private Landowners, 4) Budding and Grafting, and 5) What Tree Rings Can Tell Us. A special tree-planting ceremony was held at 2:00 p.m., with honored guests Joseph Thompson Jr. and William Thompson ("Wallace" of "The Wallace and Ladmo Show" on Phoenix TV) representing the founder's family. Dolan Ellis, Arizona's official State Balladeer,

Mary Dieterich demonstrates tapestry weaving at the Arboretum's workshop on dyeing and weaving last May. Natural plant dyes from desert plants produce beautiful soft colors. Photo by Carol D. Crosswhite.

concluded the ceremony with a selection of his own songs. Free tree seedlings were given to children who attended the event, along with care instructions written especially for the youngsters to use. During the course of the day, over 1,500 seedlings were given away.

Arid Land Plant Show (ALPS). This event was held Saturday, April 2, 1983 from 8:00 a.m. to 5:30 p.m. The Arboretum is charged with teaching about drought-tolerant plants, providing information about them, and encouraging their use. To help accomplish these, a multi-faceted event was designed and coordinated, involving many cooperating individuals and institutions. The main attraction was a series of displays on arid land plants, staged in an area adjacent to the arboretum picnic area. Exhibits were colorful, informative, and manned by experts in the subject matter, so that visitors had a chance to ask questions as well as to learn on their own. The following partial list of display titles gives an idea of the types of subjects that were treated: Food Plants of the Desert; Cacti and Succulents for Landscaping; Ground Covers for Arid Regions; Plant Adaptations to the Desert; Halophytes—Salt Tolerant Plants; Propagation of Plants by Tissue Culture; Plants of the Arizona Chaparral; Arboretum Wildflowers; Drip Irrigation; Meet the Sonoran Desert; Xerophytic Plants for House, Porch, and Patio; Seed-grown Cacti; and others.

Other learning opportunities were also available. A series of slide presentations occurred hourly in the Arboretum lecture room, and there were several screenings of the new motion picture dealing with the Arboretum. Well-known botanical illustrator Lucretia Hamilton displayed and demonstrated some of her works at a booth in the Visitor Center patio area. Nearby was the Authors' Autograph Table where visitors could ask various authors of botanical works to sign copies of the books they had written. In addition, guided tours of the Arboretum were offered at 9:30 and 10:00 a.m. and at 2:00 and 2:30 p.m.

Dye Plant Day. This was scheduled for Saturday, May 14, 1983 from 10:00 a.m. to 3:00 p.m. On this day, two very knowledgeable experts gave us fascinating insights into the use of plants as dyestuffs. The day began with Mary Dieterich talking about basic principles of dyeing with plant materials. As she talked she illustrated with her own samples and work. Next Susan Clark gave a demonstration of dyeing wool with a representative plant dye. After lunch Mrs. Dieterich talked about her own specialty, tapestry weaving, as well as weaving in general, and demonstrated her craft as she worked on a tapestry piece in progress. The day was concluded by an Arboretum walk led by Susan Clark to show plants from which dyes can be obtained.

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the mulching treatments, plants grown with optimum soil moisture conditions produced higher yields than did plants stressed for soil moisture.

Experiments in the greenhouse indicate that for optimum revegetation of disturbed land in a semiarid environment, the soil material should be mulched with an organic soil mulch and the plant cover should not be stressed for soil moisture during establishment.

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Reviews

Although the purpose of reviewing books in *Desert Plants* is not to sell them, in response to requests by readers who have found it difficult to obtain titles elsewhere, the Arboretum will, as a courtesy, make them available by mail at the prices set by the publishers, with the request that $1.00 per book be added for postage and handling. Orders may be sent to Boyce Thompson Southwestern Arboretum, P.O. Box AB, Superior, Arizona 85273.

Exotica. Series 4.
Alfred Byrd Graf. Roehrs Company. East Rutherford, New Jersey. 1982. 2,560 pp. (2 vols.), $175.00.

Users of the various editions of this pictorial cyclopedia of exotic plants doubted that the book could get much larger when in 1963 "Series 3" proved to be a volume four inches thick at the spine and weighing 13 pounds. But the publishers nevertheless seem ever intent on continuing to expand this reference work. The new "Series 4," released in 1982, represents essentially the eleventh edition and weighs over 17 pounds. The problem of fitting it all into one book was solved by binding it in two volumes.

Exotica 4 contains 16,600 illustrations compared to 11,300 in Series 3 and 7,600 in Series 2. There were only 4,000 in the original version which appeared in 1957. Aside from the additions, there have been numerous corrections over the years.

Regardless of which edition a person refers to, many of the exotic plants depicted come from arid or sub-arid regions. Cacti and succulents are well represented. Over the last 25 years *Exotica* has been perhaps the most commonly consulted work for identifying tropical and subtropical plants cultivated in temperate countries. Users generally open the book to the proper plant family and then page through until a photo is located which resembles the plant in question. This pragmatic technique is quite different from (and much easier than) the theoretic approach to plant identification taught in college plant taxonomy classes; it has undoubtedly evoked shudders from countless scholastics. Nevertheless, *Exotica* has clearly established itself as the reference of choice among plant professionals and hobbyists alike for quickly finding the name of perhaps 80% of the plants commonly grown in greenhouses or as house plants. It can also be used as a "wish book" for finding names of plants which might be desired for greenhouse collections or "indoor landscaping." In the Sonoran Desert, where the winters are mild, it is possible to grow many outside.

Agaves of Continental North America.
Howard Scott Gentry. University of Arizona Press. Tucson, Arizona. 1982. 670 pp. $49.50.

This is Dr. Gentry's *magnum opus* on the Century Plants and their wild relatives. It is the result of a lifetime of exploration in rugged terrain (largely in Mexico) and careful study in herbarium, laboratory, library and garden. Certainly no other person knows nearly as much about the genus *Agave* as Gentry. The author very ably shares his knowledge with the reader. We owe Gentry an enormous debt of gratitude for sorting through the hundreds of proposed taxa to eventually characterize 136 acceptable species for continental North America. Gentry's mature judgement is all the more appreciated because the bewildering array of morphologic types in the genus has made taxonomic decisions difficult. Although the classification is obviously arbitrary in many places, we feel better about accepting it knowing that the subjective decisions were made by a person who knew the plants so well.

Although the book is clearly the last word in taxonomy of the genus, it also admirably treats various ethnobotanic aspects of Agave. Several species provided food, fiber and drink for prehistoric and modern people. Indeed, hardly a species exists which has not been used by man for one purpose or another.

The complex Nahuatl society of central Mexico made ceremonial use of an alcoholic drink made from the large "maguey" Agaves. Such a fermented product is still drunk in Mexico under the name "pulque." The art of distilling fermented Agave (to concentrate the alcohol and remove unwanted tastes) dates from the Spanish occupation only. Nevertheless, this has produced the "tequila" made in Jalisco as well as the "mescal bacanora" of Sonora and "mescal con su propria gusano" bottled in Oaxaca. The latter product includes a larva of the *Agave* weevil in the bottom of each bottle as proof of being a genuine Agave drink!

Pit-baking of *Agave* "cabezas" (hearts of the plant with the leaves cut off) provided food for prehistoric and modern Indians in northern Mexico and the Southwestern United States. The cooked cabezas were sweet and tasty. Usually a larger quantity was processed than was eaten right away. The excess cooked cabezas were cut into chunks which were flattened out and air-dried. The resulting "mescal cakes" were stored for later use or were traded to Indians who lived far away from a good source of Agaves.

Indians, both prehistorically and recently, have woven sandals, mats, blankets, bags, nets, baskets, clothing and other articles from *Agave* fibers. Although most any *Agave* could be used for fiber to some extent, two types were long ago selected for special cultivation in quantity. *Agave fourcroydes* has produced huge annual tonnages of "henequen" fiber while *Agave sisalana* has yielded even larger tonnages of "sisal."

Agave species have precursor chemicals capable of yielding either cortisone or synthetic hormones suitable for birth-control pills. Precursor chemicals are extracted from *Agave* leaves as byproducts of sisal and henequen fiber operations. Dr. Gentry's work with *Agave* was stimulated by the desires of the U. S. Department of Agriculture to assay as many wild species of *Agave* as possible to determine if they might be better sources of corticosteroid precursors than the cultivated fiber types. Dr. Gentry's *Agave* explorations resulted in the success of this program and some of the chemical findings are summarized in the present book. Several wild species with high concentrations of corticosteroid precursors await exploitation.

Indian Paintbrush (Castilleja chromosa) *growing near the Boyce Thompson Southwestern Arboretum. Photo by Carol D. Crosswhite.*

Selenium and Castilleja. *Castilleja* is a genus of perennial herbs of the Scrophulariaceae. Native to North America, the species are numerous in rugged terrain of the western United States and Mexico, making extremely rapid growth in early spring under adverse conditions. They seldom are noticed except in summer when they become spectacular wildflowers with the name "Indian Paintbrush," as if they had been dipped in bright paint. *Castilleja* is very unusual in several major respects, each of which might be inter-related. First, the tops of the plants display prominent red or yellow (occasionally purplish) pigment in well-defined bands as if resulting from a chromatography experiment in a chemistry class. The pigments themselves differ markedly from the common anthocyanins which are byproducts of normal plant metabolism. Even the manner of deposition of the pigments is anomalous, being concentrated more in the leaves surrounding the flowers than in the flowers themselves. Second, the plants are obligately hemiparasitic, forming attachments to the roots of other plants. Unlike many parasites, however, *Castilleja* retains chlorophyll. Since parasites live on the sugars of their hosts, the possibility exists that *Castilleja*, freed from the need to produce sugar, could be using its chlorophyll to produce something other than normal photosynthate, perhaps involving a chemical compound which facilitates "robbing" or taking over the host's resources. This speculation has never been studied. Third, the plants grow on selenium soils and concentrate this element in their bodies! How is the selenium being used?

Selenium is an unusual red powder somewhat resembling sulfur but with quite unique properties. It has a vitreous form which is black and a crystalline form which is metallic gray. Its neighbors in the periodic table are sulfur, chlorine, bromine, iodine, tellurium, antimony, arsenic and phosphorus, elements which are far from being inert, having strong characteristics, activities and reactivities. Selenium is an extremely complex substance with multiple valences, isotopes, physical forms and activities relating to light and electricity.

When eaten by animals, *Castilleja* can be so high in selenium as to cause poisoning. Interestingly, selenium has recently been implicated as a factor in human nutrition, its deficiency resulting in physiological problems. Another recent discovery that could possibly prove to be a breakthrough is that selenium appears to have strong anti-cancer activity.

Although the role of selenium in plants and animals is still very poorly understood, the reactions of the element in the chemistry laboratory have led to numerous applications today in photocopy machines, solar cells and exposure meters. Selenium is also used in making rectifiers and semiconductors for the electronics industry. Apparently without selenium many of our modern electronic gadgets simply would not function. Physiologists have clearly shown that plants and animals, and particularly humans, are remarkable machines. Although we know how some of this living machinery functions with regard to photosynthesis, respiration, circulation of the blood, and basic cell metabolism, we still have much to learn concerning regulation and feedback, suppression of discordant growth (cancer), how genes are turned on and off, functioning of the brain, and the relation of sight to experience, memory and perception, to name a few intriguing areas. Is selenium involved? This question is like asking a stone-age cave-dweller to explain the circuitry of a modern electronic gadget. At our present state of knowledge we know practically nothing about the role of selenium in living machinery. With this issue of *Desert Plants* we suggest that the role of selenium may be exaggerated in *Castilleja* to the point where (cf. salivary chromosome banding in *Drosophila*) a phenomenon may be observed which would be difficult to detect in normal living systems.