SUMMARY OF INVESTIGATIONS DEALING WITH BURROWEED (APLOPAPPUS FRUTICOSUS) AND ITS ECOLOGICAL ASPECTS

by

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SUMMARY OF INVESTIGATIONS DEALING WITH BURROWEED (APLOPAPPUS FRUTICOSUS) AND ITS ECOLOGICAL ASPECTS

INTRODUCTION

Burroweed, Aplopappus fruticosus (Rose and Standley) Blake, is one of the most undesirable plants that has spread over certain areas on ranges in the southwestern part of the United States. Various investigations, dealing with its control and eradication, poisonous properties, commercial uses, and relation to grasses have been made. Together with studies on other undesirable plants, these investigations have been instigated by individual and group enterprises in an effort to increase the carrying capacity of ranges. Many of the studies on the burroweed problem have overlapped, and much of the data has never been summarized or correlated. Confusion of identity has also often resulted because other similar plants have been mistaken for A. fruticosus.

This present study is designed to bring together as a summary all of the material available on the burroweed problem, together with some original investigations. Much of this information is found as isolated references, and a considerable portion appears as unpublished data, and

probably would never be assembled in any other form.

NOMENCLATURE

Nomenclature of the Genus

Aplopappus fruticosus (Rose and Standley) Blake belongs to the Aster tribe of the Compositae, a family of wide distribution, members of which are found in practically all parts of the globe. The nomenclature of the genus has in times past received some discussion, due to disagreements that have existed. According to Hall (1928 p.23), the first description of the genus was made by H. Cassini in 1828 in Dictionnaire des Sciences Naturelles 56:168-169, who spelled it Aplopappus rather than Haplopappus. Then follows his description of a single species A. glutinosus which thus becomes the type for the genus. De Candolle, and perhaps the majority of American botanists, including Gray, follow this spelling. On the other hand, such botanists as Remy, Bentham and Hooker, Hoffman, Ruche, Hall and others have adopted Haplopappus as the corrected spelling, and as Hall (1928 p. 26) says:

> Since the dropping of the initial H gives to the word a meaning entirely different from that obviously intended by Cassini it would seem that Haplopappus should be the preferred spelling by all, except those who follow the original orthography of botanical names regardless of errors.

Hall (p. 25) in spelling the genus with the initial H, is following the International Rules of the Berlin Congress

which includes Haplopappus in the list of nomina conservanda.

Dayton,[1] commenting on the spelling of the genus says:

> Being a little something of a Greek scholar myself I naturally am sympathetic to the viewpoint that Haplopappus is a bit better in accord with the Greek than Aplopappus. However, Haplopappus is not required as I understand it, under the International Code. Aplopappus is the original spelling; it cannot be considered incorrect because "h" does not occur in Greek except as an aspiration; it has been accepted by the great botanical figures of the past (De Candolle, Jussien, Robert Brown, Asa Gray and others), and it is generally admitted that reasonable latitude must be given authors as regards the forms of their botanical names. Moreover, if we change Aplopappus to Haplopappus we shall be obliged, for consistency's sake, to make hundreds and probably thousands of changes in other names, especially in numerous generic names beginning with vowels.

The only other generic name that has been proposed as a substitute, according to Hall (1928 p, 24), is Hoorebekia Cornelissen. He points out, however, (p.25) that the description accompanying Cornelissen's plate, showing habit in some detail, refers to some Chilean species of Grindelia:

> Since Hoorebekia now appears to be a synonym for Grindelia, Haplopappus remains as the proper name for the genus typified by H. glutinosus Cassini.

With respect to section names used for generic names when referring to A. fruticosus, Hall (p. 9) mentions that nearly all of them have at various times been accepted as distinct genera, this being the result of working over

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1. Dayton, W. A.: In a memorandum to Mr. Chapline, dated June 4, 1935. In the files of M. J. Culley, Southwestern Forest and Range Experiment Station, Tucson, Arizona.

limited areas or under conditions when not all of the forms needed to be considered. The generic name Bigelovia Gray, as has sometimes been used with this species as well as with others, he (p. 29) points out, has been the result of an early artificial grouping based on the absence or presence of ray-flowers. Humphrey (1937 p. 2) refers to Bigelovia as being a "synonym in part" and mentions Chrysoma, Ericomeria, Isocoma, Macronema, Pyrrocoma, Sideranthus, Stenotus, and Tonetus as synonyms for the genus Aplopappus. All of these, except the first are section names within the genus, so that such ranking is not surprising.

Mention should here be made of the division of the genus into sections as proposed by Hall (1928). He divides the genus into two unequal groups, one with 10 and the other with 6 sections. The relationship among species of the section Isocoma, to which belongs A. fruticosus, is diagrammed by Hall (p. 222) as given in figure 1.

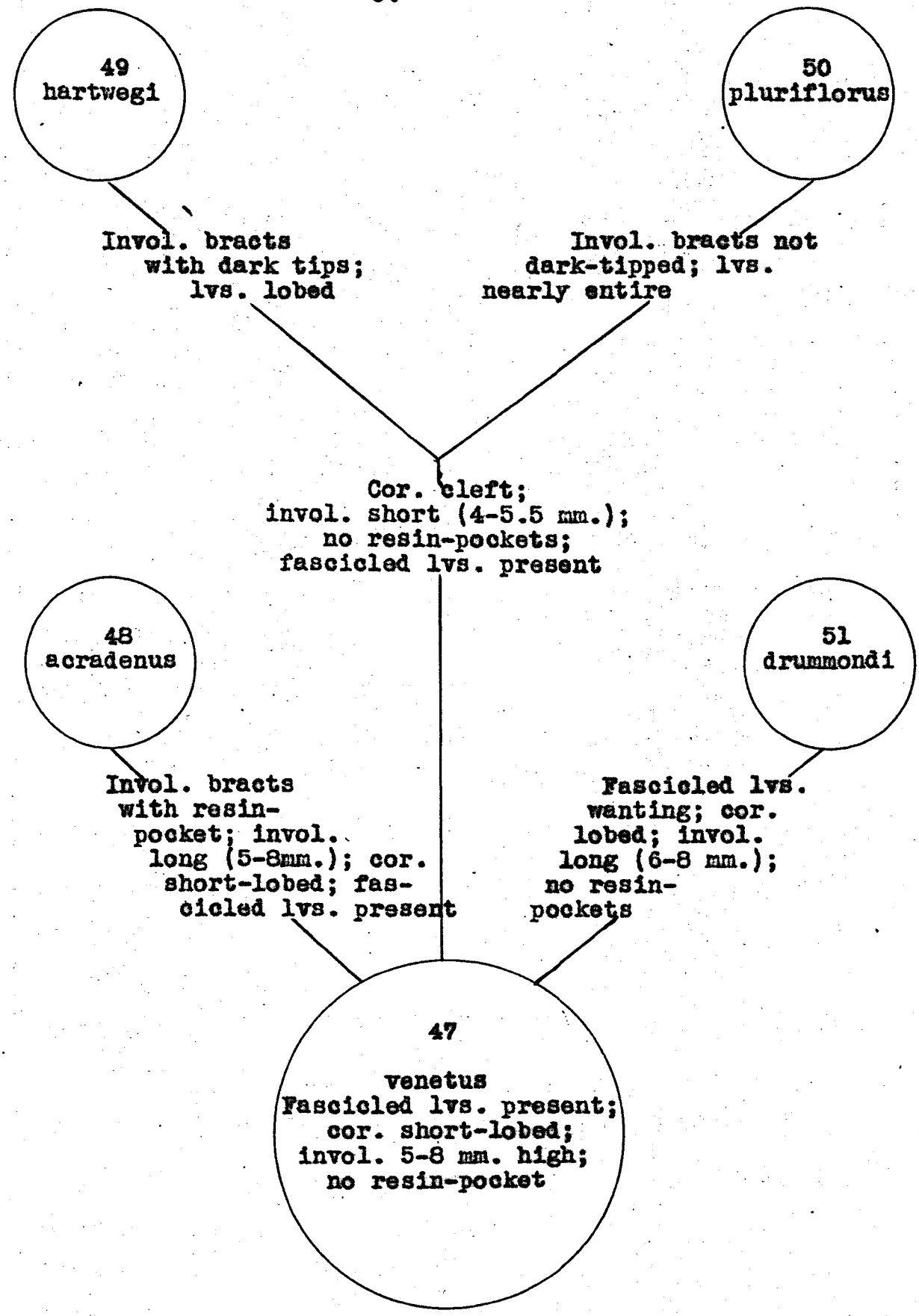

Fig. 1: Phylogenetic chart of Haplopappus section Isocoma (After Hall)

Hall (p. 222) is of the opinion that Aplopappus venetus (H. B. K.) Blake, is the most primitive species of this section, and says;

> Since the typical form of venetus comes from southern Mexico, this fits in with the generally accepted theory that the North American sections had their origin somewhere to the south. . .H. hartwegi and H. pluriflorus are very closely related to each other and both are remarkable in the depth to which the corollas are cleft. These apparently are direct northern derivatives of venetus.

The fact that Aplopappus Hartwegi (Gray) Blake, is derived from A. venetus would account for the opinion of Blake (1926, in Standley's "Trees and Shrubs of Mexico", p. 1492) that A. Hartwegi is similar to A. venetus "and doubtfully distinct from it. . . ."

Nomenclature of the species

Considerable disagreement exists as to the species name of the plant under consideration. Blake (1926 in Standley's "Trees and Shrubs of Mexico", pp. 1492-1493) recognizes two species, A. Hartwegi and A. fruticosus, restricting the former to Mexico. Hall (1928 pp. 235-236), on the other hand, recognized A. Hartwegi, listing A. fruticosus as a synonym. He apparently does this on the ground that Blake's entity fruticosus is based on Isocoma fruticosa Rose and Standley, (Rose and Standley 1912, p. 18 and plate 13) which he considers to be the same as A. Hartwegi except for the fact that the involucreal bracts seem to be obtuse; further, that it is based on Lynosyris coronopifolia Gray, which he considers as

A form of H. hartwegi in which the leaf-lobes are slender, sometimes as much as 10 mm. long. All the gradations in this respect are common in southern Arizona and even the tendency toward elongation of the lobes is not a geographic feature, since some plants from Arizona (Lemmon 3055) have lobes even shorter than in the type of hartwegi from southern Mexico.

The following is a list of minor variations and synonyms as given by Hall (p. 236)

1. Aster coronopifolius O. Kuntze, Rev. 317, 1891 . . .
2. A.hartwegi O. Kuntze, Rev. 318, 1891. . .
3. Bigelovia cornopifolia Gray, Proc. Am. Acad. 8:638, 1873.
4. B. hartwegi Gray in Hemsley, Biol. Centr. Am. Bot. 2:115, 1881 (anomen nudum) and syn. Fl. 12:143,1884.
5. Haplopappus fruticosus Blake, contr. U. S. Nat. Herb 23;1493, 1926. . .
6. Isocoma coronopifolia Greene, Erythea 2:111, 1894. . .
7. I. fruticosa Rose et Standl. , Contr. U. S. Nat. Herb. 16:18, plate 13, 1912. . .
8. I. hartwegi Greene Erythea 2:111, 1894. . .
9. I. tenuisecta Greene, Leaflets 1:169, 1906. . .
10. Linosyris coronopifolia Gray, Pl. Wright 1:96, 1852. . .

In this paper Blake's treatment is followed, but if further study should prove the entity fruticosus to be identical with Hartwegi, then the latter name would have to be retained.

A number of common names have also been used for A. fruticosus. In literature often only these common names are mentioned, so that it is at times difficult to ascertain with accuracy to what species reference is made. From association and deduction, however, often reasonable assurance can be had concerning the plant, and in this paper such a procedure is followed. When, however, any doubt exists reference to that effect will be made.

Humphrey (1937 p. 2) mentions such names as "burroweed," "rabbit brush," "goldenbrush," "goldenweed," and "rayless goldenrod" as being applied to A. fruticosus. This latter name, especially, leads to confusion since it is used promiscuously for a number of species, in particular A. heterophyllus Blake, or A. pluriflorus Gray, which usually goes by the common name "jimmyweed." Cribbs (1938 p. 4) also mentions "broomweed" as inaccurately used for this species. The name "burroweed" is at present most generally accepted as a specific common name for A. fruticosus, although it likewise has been used for other plants. According to Dayton (1931 p. 36), this name has been applied to Allenrolfea occidentalis (Wats.) Kuntze, more commonly known as "pickleweed" or "picklebush," a plant prevalent in the Great Basin; Franseria dumosa Gray, (p. 154); and Baccharis ramulosa (D. C.) Gray, (p. 158).

DESCRIPTION OF BURROWEED

A complete botanical description of burroweed is given by Hall (1928 pp. 235-236). Less inclusive descriptions are also given by Blake (1926 in Standley's "Trees and Shrubs of Mexico" p. 1492), Rose and Standley (1912 p. 18; see also plate 13), and Gray (1884 p. 143). A general description of the plant is given by McGinnies[1] who says:

> Burroweed or rayless goldenrod is a small, shrub-like plant, one to two feet tall, with a woody base and rather small gray-green leaves. The characteristic yellow flower heads appear in late summer or early fall and the dry, bleached heads remain on the plants most of the winter.

This description, however, is very general and no botanical name is used. Buehrer (1928) in his chemical analysis of the plant says that

> Burroweed. . . can readily be recognized by the characterisito clumpy shape of bush, the stems of which radiate out and upward from a common root, attaining in damp seasons an average height of 1 to 2 feet. The stems are partially covered with very small alternate leaves which have a surface resembling that of a glistening skin drawn taut, and which, when pressed between the fingers, are sticky, resinous, and give off a very characteristic odor. The flowers are bright yellow.

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1. McGinnies, W. G.: In a letter to Ariz. Cattle Grower's Association, Phoenix, Ariz. , dated March 28, 1929. In the files of the Range Ecology Dept., U. of A. , Tucson, Ariz.

Thornber and Brown (1920 p. 458), describing burroweed (B. coronopifolia), speak of it as follows:

> It belongs to the goldenrod group of the sunflower family and is a woody shrub one to three feet tall. The leaves are skeleton-like, and pinnately parted nearly to the mid-rib. The flowers are golden yellow, and borne mostly in terminal clusters in the summer and fall. The whole plant is strongly resinous, with a pronnounced bitter odor. . .

Darrow (1935 p. 71) refers to burroweed as ". . . an erect shrub, 30 - 60 cm. high, with numerous woody branches arising from near the base." Humphrey (1937 p. 2) says:

> Burroweeds are low shrubs, densly branched from near the base. . . The leaves are about an inch in length, oblong or spatulate-oblong in shape, and lobed or pinnately parted. The numerous yellow flowers are borne in small, dense almost sessile heads. Mature plants on the open range are usually about a foot in height, although in better-watered habitats, as along irrigation ditches or roadsides they sometimes reach a height of 3 or 4 feet.

Cribbs (1938 pp. 4-5) describes burroweed as

> A perennial shrub with numerous erect leafy stems growing from a thick, coarse, woody base. The plant is commonly about 16 inches high but under favorable conditions may reach a height of four feet. The narrow straplike leaves, about an inch long and less than 1/16 inch wide, have small projections along the margins. Burroweed leaves are grayish green and when crushed produce a strong pungent odor. The yellow many-flowered heads, about ¼ inch across, are borne on the tips of the stems and bloom from early summer to late fall.

He (p. 5) also speaks of the plant as "whitish to grayish green in color," and having seeds with "long coarse hairs."

From these descriptions it will be seen that the size of the plant varies considerably, depending on soil and moisture conditions. These descriptions, although including flowers

and flower heads, fail to mention the absence of ray flowers, a characterisitc which the plant has in common with the other species of the section Isocoma. Discussing ray flowers in the genus Aplopappus, Hall (1928 p. 19) says: "Isocoma is the only North American section in which the ray-flowers are constantly suppressed in all the species."

ORIGIN AND DISTRIBUTION

The problem of origin and distribution has in times past received considerable attention, and possibly the final word has not yet been said, partly due to our dynaric universe with its many interactive ecological factors. Hall (1928) however, offers some interesting explanations on this point, based in part on relationships within the genus, and in part on generic characteristics in general.

Center of Distribution

According to Hall (1928 p. 28), this genus is "one of the most highly developed genera of the homochromous Astereae, . . . and that there was formerly a connection with some aster-like members of the Heterochromeae." Thus we find that those sections which occasionally have purple ligules[1] belong to the lower members of the genus. As to the original center of distribution of the genus, Hall(p.27) is of the opinion that

1. For example, the section Blepharodon of the North American group, and Euhaplopappns of the south. (see Hall 1928, p. 29)

it was "in Mexico or some similarly warm temperate district and that from this center migrations carried the genus both toward the north and to the west coast of South America." Thus, he points out (p. 28) that, in past geologic times, the genus was separated into two groups, or sub-genera, so that today the tropics form an impassible barrier between them. That the genus is fairly old is further substantiated by the fact that it is at present quite distinct.

There also seems to be evidence supporting a Mexican origin of the section Isocoma as well as Hazardia (Hall p. 40), and that there has been a general migration northward "changing and adapting their characters in the process." It may be possible that this explanation accounts (in part at least) for the differences of opinion held by botanists concerning the entities, Hartwegi and fruticosus, of the particular species under consideration in this paper. At least it has already been pointed out in the discussion on nomenclature that occasionally leaf characteristics of A. fruticosus as found in Arizona are strikingly similar to some of A. Hartwegi of southern Mexico.

Present limits

Geographically, burroweed (A.fruticosus) is at present confined to the southwestern part of the United States and northern Mexico. Hall(p.236), discussing A. Hartwegi, refers to it as found in "Southern Texas and Arizona to

southern Mexico". Hartweg's plant, referred to as the type came from Lagos, Jalisco in Mexico. A number of specimens, including minor variations, are listed by Hall (p. 236). These are located in herbaria of the United States and Europe, collected from various parts of its range: e. g., the lower Rio Grande and Eagle Pass in Texas; Tucson, mesas near Tucson, Santa Catalina Mountains, and Dixie Canyon, Mule Mountains in Arizona; and McDougal Pass, Pinacate Mountains in Sonora. Discussing A. Hartwegi, Hall (p.237) refers to it as ". . .one of the common half shrubs of desert plains in southwestern United States and northern Mexico, where it belongs exclusively to the Lower Sonoran Zone. Here it sometimes is dominant or subdominant, especially in the open desert scrub of the Larrea-Flourensia association. . ." According to Clements (1920 p. 300) Isocoma coronopifolia and its varieties are prevalent in northern Mexico and Arizona "from the lowermost Prosopis valleys upward into the Bouteloua-Aristida grassland". Darrow(1935 p. 71) says that

> Burro-weed ranges from western Texas to southern Arizona and southward into Sonora, Mexico. It is sometimes dominant or sub-dominant, especially in the open desert shrub association characterized by creosote bush. On the Santa Rita Experimental Range burro-weed is commonly found in the Bouteloua-Aristida association on the mesas at an elevation of from 3000 to 4000 feet.

Further information concerning its altitudinal range is indicated by Humphrey (1937 p. 3) who speaks of A. fruticosus as "typically desert or semidesert plants and are not known

to occur above the lower limits of the oak-juniper type of vegetation." He mentions the occurrence of another species, Aplopappus laricifolius Gray, above 4,300 feet, although in less abundance than A. fruticosus below. Upson, Cribbs, and Stanley (1937 p. 21) remark that "Except at the upper extreme (over 5000 feet), altitude is apparently not an important factor in determining its distribution."

Humphrey (1937 p. 3) says that burroweed is ". . . common on desert or semidesert areas throughout much of southwestern United States and northern Mexico." Blake (1926 in Standley's "Trees and Shrubs of Mexico" p. 1493) is a little more definite and gives its range as Sonora, Texas, and Arizona. Likewise Dayton (1931 p. 157) refers to burroweed as ranging from western Texas to southern Arizona and Sonora.

Cribbs (1938 pp. 4-5) speaks of burroweed as occuring

> . . . most commonly on dry outwash plains as well as on the lower foothills of mountains and along streams and washes from wouthwestern Texas to and including Arizona, and in northern Sonora, Mexico. Although found in New Mexico, it is not common.

With respect to its distribution in New Mexico, Johnson and Archer (1922 p. 24) state that "Rayless goldenrod (Isocoma spp.) occurs quite generally over the southern half of the state of New Mexico in the lower and medium latitudes," but one cannot be sure what species are referred to. W. G. McGinnies[1] referes to

1. Unpublished report, without date: Burro Weed a Menace to Arizona Ranges. In the files of Rnage Ecology Dept. , U. of A.

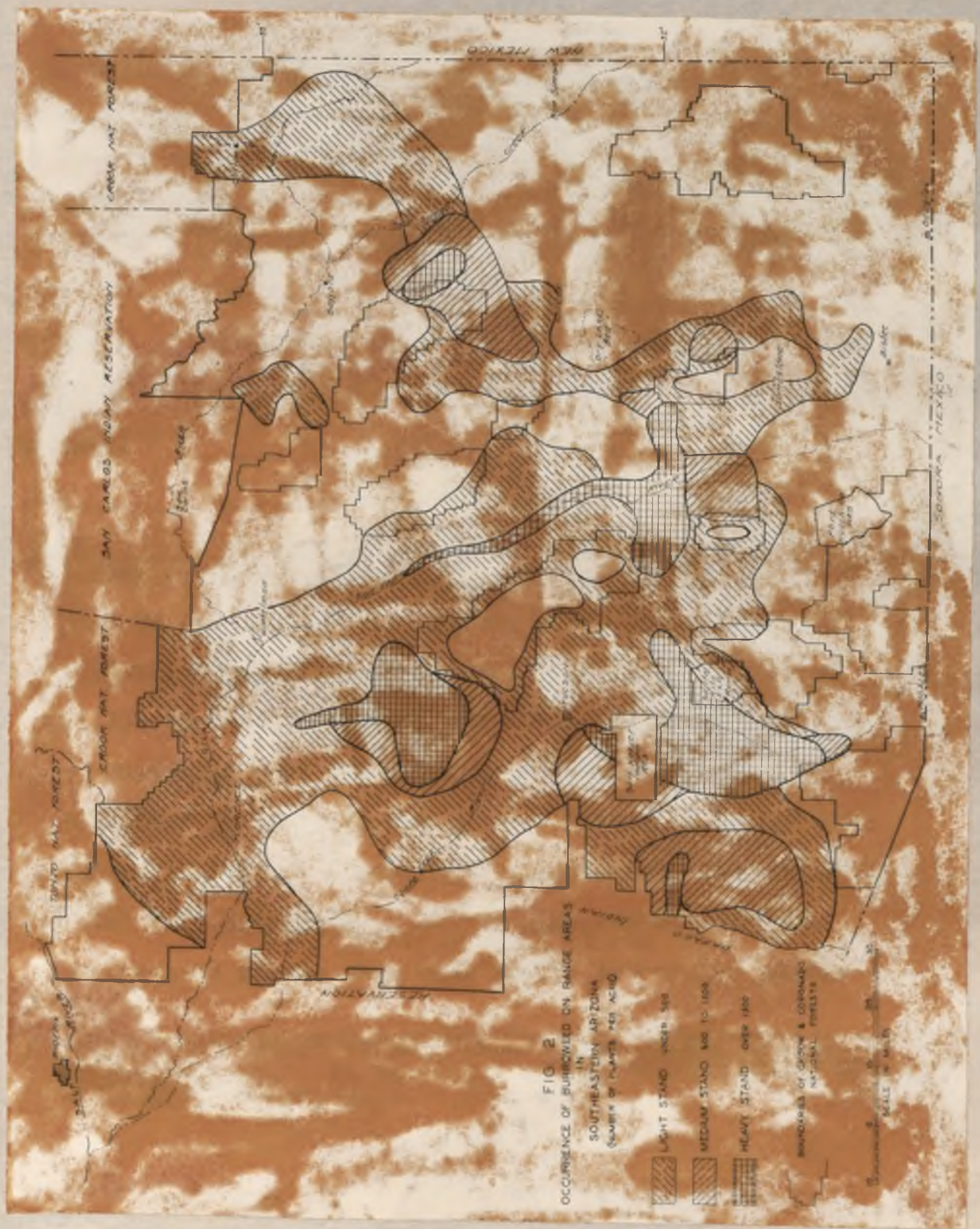
a rather wide range:

> Burroweed, or rayless goldenrod as it is sometimes called, is found from southern Colorado to the Texas Phanhandle and south to Chihuahua and Sonora. In Arizona the largest area infested with this weed lies mostly in Pima and Pinal Counties. It is found in more or less abundance in practically every county of the state.

No botanical name is used in this paper and therefore one cannot be absolutely sure whether he is speaking of A fruticosus only, or a number of species.

Early references to the distribution and abundance of A. fruticosus in Arizona are found only incidentally, and it is noteworthy to ovserve that none are found prior to the 20th century. Griffiths (1904), Thornber (1907), Griffiths (1910), Thornber (1910) and Wooton (1916) speak of an increasing abundance of burroweed in the state.

Upson, Cribbs, and Stanley (1937) have prepared a report on shrubs, based on a survey covering the southeastern part of the state. Figure, 2, and table 1, as given by Upson, Cribbs, and Stanley, show the prevalence and distribution of burroweed in this area.



(After Upson, Cribbs, and Stanley)

TABLE 1: Distribution and abundance of burroweeds (After Upson, Cribbs, and Stanley)

Abundance	Number of plants per acre	Area		Composition		
				Burro-weed	Perennial Grasses	Other Plants
	Number	Acres	Pct.	Pct.	Percent	Pct.
Heavy	Over 1,500	703,000	5.9	59.2	9.2	31.3
Medium	500-1,500	761,000	6.4	32.0	24.4	43.6
Light	Under 500	4,030,000	33.4	3.4	36.4	60.2
Subtotal		5,494,000	45.7	*14.5	*31.3	*54.2
None		6,540,000	54.3	0.	48.5	51.5
Total		12,034,000				

*Weighted Averages

It will be seen from these figures that on this surveyed area of slightly over 12,000,000 acres, burroweed is found on 5,494,000 acres, or 45.7% of the area. This survey, however, evidently does not include the entire distribution of burroweed in Arizona, for W. G. McGinnies[1] mentions that "at least 10 million acres in Arizona are now more or less infested with this weed. . ." He also states that "on badly infested ranges more than 25,000 individual plants

1. Unpublished Report without date: Burro Weed a Menace to Arizona Ranges. In the files of the Range Ecology Dept., University of Arizona.

per acre have been found by actual count. The average infested range may show as many as 500 mature plants and perhaps 5,000 seedling plants per acre."

The occurrence and density of A. fruticosus on the Santa Rita Experimental Range, south of Tucson, is shown in figure 3 as given by Humphrey (1936). It is of interest to notice that according to Humphrey (1936 p.2) burroweed occurs abundantly on 84 out of the 94 square miles included within the Range boundaries.

Some information regarding soil conditions on areas occupied by A. fruticosus is also available. For example, Hall (1928 p. 237) refers to burroweed as "moderately alkali tolerant." This species also seems to tolerate or even thrive on depleted soils. Humphrey (1937 p.3) mentions that

> Inasmuch as they appear to thrive about as well on the fine alluvial soils of river valleys as on the coarser soils of outwash slopes, soil aeration or texture seem to affect their distribution little or not at all.

ECONOMIC IMPORTANCE OF BURROWEED

Poisonous properties

Burroweed is often considered to be a poisonous plant, although evidences to support such contentions are for the most part indirect. For example, Thornber (1919 p. 428) includes rayless goldenrod or burroweed (B. coronopifolia Gray, and B. Hartwegi Gray?) in a list of plants that are

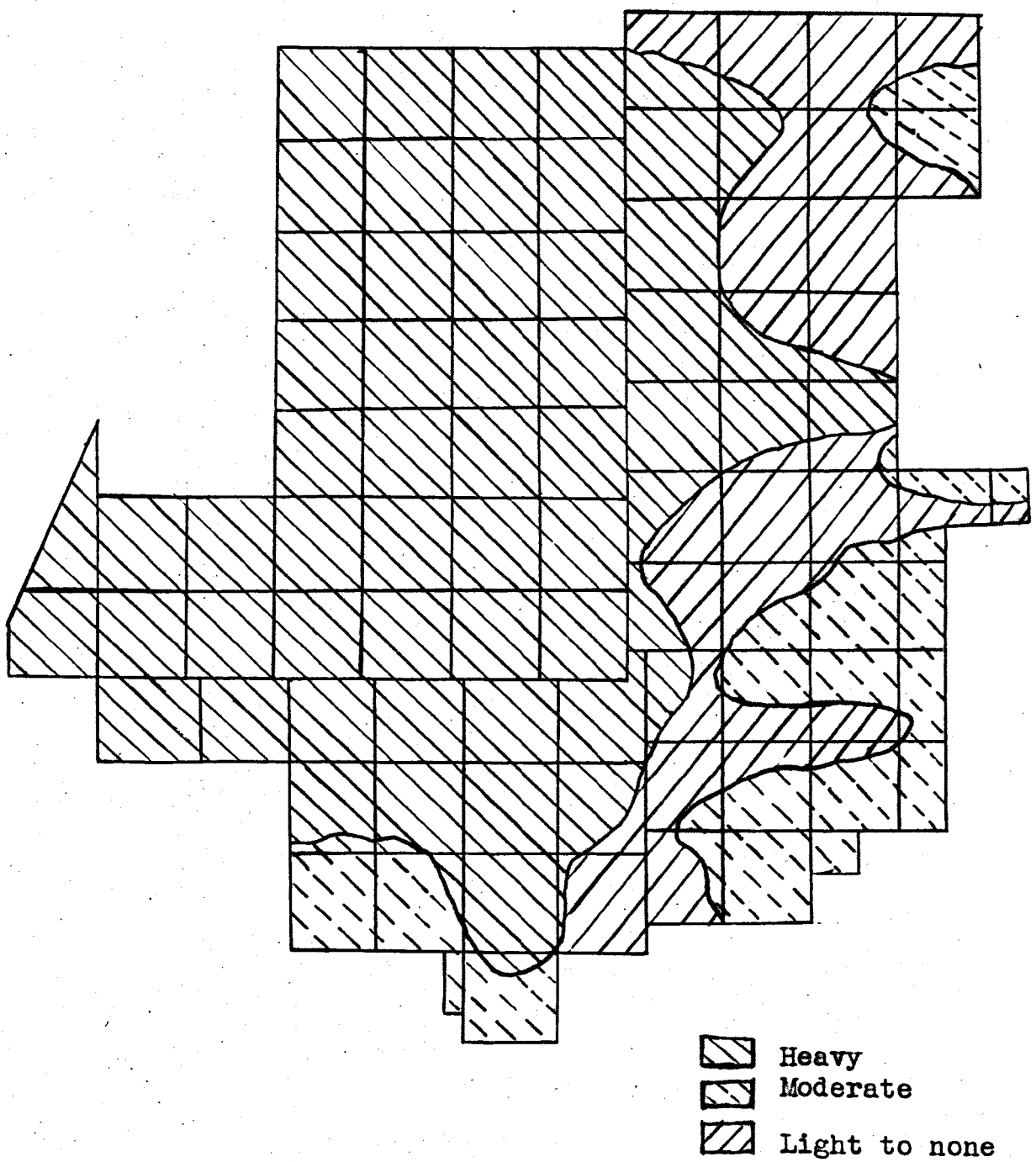


Fig 3: Distribution of burroweed on the Santa Rita Experimental Range February 1935 (After Humphrey)

believed to be poisonous at certain seasons of the year. Williams (1920) reports a number of stock losses, with symptoms of the poisoning, in southern Arizona between the years 1904 - 1920, supposedly due to rayless goldenrod or burroweed. Thornber and Brown (1920 pp. 457-458), in an article based in part at least on Williams' work, substantiate stock losses due to burroweed, B. coronopifolia, and describe the symptoms thus:

> The first indication of this disease in animals is lack of thrift. They become gaunt, listless, separate from the herd, and lie down. The horses appear fagged as if overridden and exhausted. The disease seemed to exist in two forms. In the acute form the animals have some fever and die within a day or so, while in the slower form they linger three to five days, losing flesh and becoming weaker. A few hours before dying they tremble violently, often fall down with the legs spread out, drop the head and neck, and froth at the mouth. Some animals break down over the loins and fall down with their hind legs sprawled out. The disease attacks both sexes and all sizes, ages, and conditions of animals, and very few of the affected ones recover.

In view of the fact that the botanical name which appears as a synonym for A. fruticosus, with a rather detailed description of the plant is given here, one is reasonably certain about the identity of the plant. It is worthwhile to notice that according to the reports as given by Williams (1920) and Thornber and Brown (1920 pp. 457-458), these losses occurred invariably under extreme conditions of overgrazing or during the winter when little other feed was available. Thornber and Brown (1920 p. 458) remark that ". . . stock rarely eat it except when driven by stress of

hunger. Sheep and goats, however, eat the blossoms and seed heads and appear to relish them."

To study the poisonous effects of burroweed, two experiments were carried out by the Botany and Animal Husbandry Departments of the University of Arizona in 1920. In the first case, as reported by Williams (1920) a strong horse in medium condition, together with a sheep were put in a lot containing large quantities of burroweed plants in various stages of growth, but from which all other weeds were removed. No other feed was given these animals, although they had access to water at all times.

The horse died on the twelfth day of the experiment, losing 34 pounds in weight during that time. While the experiment was in progress the horse was seldom actually seen eating burroweed; however, the feces was hard and showed considerable amounts of dry, hard stems of the plant. Reference is made to the fact that the horse ate less of the plant than the sheep, but no estimated amounts are indicated. As the experiment continued, the horse showed signs of lack of sufficient food, and, shortly before death, staggering was also noticed. On the morning he was found dead it was observed that the ground at his feet had been plowed up by his feet passing back and forth. A post mortem examination indicated that digestive disorders were present, and a large secretion of serum and urine was noticed. Although the horse's death may have been due to burroweed poisoning,

a note found with this report throws doubt on such conclusions.[1]

In the second case as reported by Thornber and Brown (1920 pp. 458-459), a mare was fed on a meal obtained by grinding the leaves, woody stems, and herbaceous growth of burroweed, together with a mere subsistence ration of alfalfa, bran, and barley, for a period of over a month. Although the mare had consumed about 150 pounds of burroweed during that time, she showed no signs of poisoning. The authors (p.459) indicate that the alfalfa, bran, and barley may have helped to offset the effects of any poison present.

Johnson and Archer (1922 p. 71) report rayless goldenrod (Isocoma spp.) as being poisonous, based on experiments carried out at Roswell, New Mexico, in the spring of 1920. Marsh and Roe (1921) likewise report rayless goldenrod, A. heterophyllus, as poisonous, also based on experiments conducted at Roswell, New Mexico, in 1920. Marsh, Roe, and Clawson (1926) refer to these same experiments, continued at the Salina, Utah experiment station from 1920-23, also based on A. heterophyllus. In these latter two cases at least, a different species than A. fruticosus has been under consideration as substantiated by their description. In view of the fact that Johnson and Archer's reference is based on these same experiments, one would be reasonably certain that they, likewise, refer to another plant.

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1. This note, signed J. R. R. and dated March 17, 1920, the date of the horse's death reads as follows: "The old horse is down, starved to death. He has never eaten any of the goldenrod."

McGinnies,[1] in a letter refers to the poisonous properties of burroweed as follows:

> The plant is poisonous to all classes of livestock, causing trembles which in many cases ends in death. The trembling or even violent shaking of the body after exercise is the most noticeable symptom. The animal is usually dull and inactive and sometimes unable to rise after falling. There is no medicinal cure known at the present time. Prevention seems to be the best cure or else the removal of the animals to good pasture after the symptoms are noticed. Losses occur mostly in winter and it is considered to be safe to graze burroweed ranges in summer.

He describes the plant thus:

> Burroweed or rayless goldenrod is a small shrub-like plant one or two feet tall with a woody base and rather small gray-green leaves. It is very common in the valleys of the Gila and Santa Cruz, and a few scattering plants may be found nearly everywhere in Arizona at lower elevations. The characteristic yellow flower heads appear late in summer or early fall, and the dry, bleached heads remain on the plants most of the winter.

The author fails to use any botanical name, and since his description of the plant is very general, its identity is not apparent.

Dayton (1931, p. 156) mentions the poisonous properties of A. heterophyllus, adding the possibility of human poisoning through the consumption of milk from poisoned animals. Marsh (1929, pp. 68-69) also mentions A. heterophyllus as poisonous, and refers to A. fruticosus as producing the same effects.

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1. McGinnies, W. G. : In a letter dated March 28, 1929 to Arizona Cattle Growers' Association at Phoenix.

He says (p. 69):

> Another rayless golden rod, A. fruticosus, found in southern Arizona, produces the same harmful effect as A. heterophyllus.

That same year Marsh (1929 A p.8) in another article confirms the poisonous properties of burroweed:

> Recently it has been shown that another species of rayless goldenrod A. fruticosus (Rose and Standley) Blake, growing in some abundance in Arizona has poisonous properties idenctical with those of A. heterophyllus.

In the 45th Annual Report of the University of Arizona Agricultural Experiment Station (1934 p. 45) rayless goldenrod or burroweed, including both A. Hartwegi and A. pluriflorus, is listed as a poison plant. Darrow (1935 p. 71) also recognizes the poisonous properties of burroweed.

Humphrey (1936 p. 1), Judd (1937 p. 333), and Cribbs (1938 p. 4) make passing remarks about A. fruticosus causing death losses of livestock. Upson, Cribbs, and Stanley (1937 p. 22) voice their opinion as follows:

> There is also considerable opinion among stockmen that burroweed, if eaten by cattle at certain times of the year, or under certain other conditions, cuases death. Instances of cattle losses have been reported which point definitely to burroweed as the cause. On the other hand, chemical analysis by the Arizona Agricultural Experiment Station of the foliage and branches of the plant have not revealed the presence of toxic elements or compounds.

Recently Pistor[1] confirmed the reports of A. fruticosus as being poisonous, citing in particular that on Roble's Ranch 24 miles west of Tucson, Arizona, 32 animals were poisoned from this plant.

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1. Pistor, W. J.: Associate Professor of Veterinary Medicine. These data are obtained through a personal interview.

He[1] also reports that some animals have been affected on Rigg's Ranch near Cochise, Arizona.

The toxic constituents of burroweed have received some attention. Marsh and Roe (1926 p. 21) consider the poisonous properties of A. heterophyllus to be due to a cumulative poison. They state that "there is some elimination, but it is not sufficient to prevent poisoning even when the plant is fed in very small quantities." Couch (1926) also referring to this species, speaks of such poisoning as acidosis, since acetone is excreted in the urine of animals suffering from this poison, and later (1930 pp. 649-658) showed that the toxic property of A. heterophyllus is due to tremetol, $C_{16}H_{22}O_3$ first isolated from richweed, Eupatorium urticaefolium Reichard. He says (p. 658):

> Tremetol $C_{16}H_{22}O_3$ is the toxic constituent of rayless goldenrod. This compound was first isolated from richweed, and is a substance in richweed that causes trembles in animals and milk-sickness in man.
>
> Dried rayless goldenrod appears to lose its toxicity slowly. The process is much less rapid than in the case of richweed.
>
> Animals poisoned on rayless goldenrod develop a ketosis, excrete acetone, become hyperglucemic, and in all respects resemble those poisoned on richweed.

Buehrer (1928) found that A. fruticosus contains alkaloids and also pyridine, and suggests that the toxicity of the plant to animals may be due largely to the pyridine in it.

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1. Pistor, W. J.: Associate Professor of Veterinary Medicine. These data are obtained through a personal interview.

His tests for inorganic toxic constituents such as copper, zinc, boron, and arsenic proved to be negative.

Commercial potentialities

The foregoing chemical analyses deal directly with the toxic constituents found in these plants. We find, however, that Buehrer's analysis was instigated in an effort to find some commercial uses for A. fruticosus. Since this plant is so abundant in the Southwest, it was thought that if burroweed could be utilized commercially, it might be kept from spreading into good grasslands. It is of interest to notice that Gildemeister and Hoffmann (1922 p. 183) found that Bigelovia veneta Gray, (Aplopappus discoidens D. C.), a species not distantly related to A. fruticosus, upon distillation yields a volatile oil traded as "Damiana leaf oil."

Buehrer used burroweed plants gathered a few miles north of Tucson from non-irrigated sandy soil, separated them into leaves, stems, and roots, and ground these portions into a powder which readily passed through a 100 mesh screen. Then, by a process of successive extractions with different solvents the important constituents were separated and chemically analyzed. The results of these extractions as given by Buehrer (1928) are shown in table 2.

Buehrer was successful in liberating essential oils from the mass of resins and fibers by steam distillation from a 5% NaOH solution. Analysis showed 1.24% essential oils content, and they distilled over "in clear yellowish droplets."

Buehrer purified this oil by an additional distillation, washed repeatedly with acid solutions and water, separating it in dropping funnels. This oil was then dried with stick calcium chloride, distilled in vacuo from the calcium chloride, and then several fractions used for identification. He found its chemical composition to be "$C_{10}H_{18}$ which differs from turpentine by two hydrogen atoms." Buehrer says further:

> The bromine number was determined on the oil and it was found to be high, namely 1723 or 1. 723 gms. Br. pr. mol. wt. of oil. This indicates also that it is a characteristic essential oil of high degree of unsaturation.

Table 2: Successive extractions of 25 gm. portions of burroweed stems, leaves, and roots. (All percentages on dry basis) (After Buehrer)

Solvent	Percent extracted from		
	Leaves	Stems	Roots
Benzene	30.30	4.87	3.16
85% alc.	16.40	6.40	3.48
Water	8.90	9.32	7.60
Dilute H_2SO_4	13.60	4.72	7.40
Dilute NaOH	12.04	24.95	19.98
Residue (Crude fiber & ash)	19.82	49.74	58.45
Totals	101.06	100. 00	100.07

The rubber content of burroweed was also determined by Buehrer. His method consisted of extraction first with acetone to remove the resins, fats, essential oils, and coloring matter, then with benzol in which the rubber is soluble. Buehrer tested the separate parts of the plant with the following results:

Leaves..... 2.48%
Stems..... 1.88%
Roots-..... 0.10%
Entire plant..1.56%

These results are similar to those of Hall and Long (1921) who found from .1% to 3% rubber in desert plants of this type. It is of interest to notice, however, that Hall and Long (p. 46) found negative results in two species of this genus, A. parryi Gray, and A. spinulosus (Pursh) D. C., both of which were collected in Colorado, the former at Pike's Peak, and the latter at Colorado Springs. In the genus Aplopappus, Buehrer (1928) points out, the rubber when present is found in small globules in the cells throughout the tissue, rather than in a special structure called a latex system. He also mentions that the rubber content will depend on the season of the year and the soil on which the plant grows.

Another important constituent found by Buehrer to be present in burroweed is resin. He says (p. 11): "The resins are readily extracted with the ordinary solvents, and when the solvents are evaporated off, they leave a smooth, tough surface, similar in character and waterproof like the best varnishes." Buehrer found these resins to vary from 24.9% in leaves and 4.77% in stems to 1.25% in roots; or, the entire plant containing 7.92%. Other constituents were also tested for, and table 3 is a summary of the chemical analysis of burroweed as given by Buehrer. In his conclusions Buehrer lists the following possible uses of the products of burroweed:

1. The plant extracts--of alkaloidal nature
   - Pharmaceuticals
   - Anaesthetics
2. Resins
   - Varnishes, electrical insulation, waterproofing
   - Filler in writing paper
   - Phonograph records
3. Essential oils
   - Cosmetics
   - Antiseptics
   - Perfumery
   - Pharmaceuticals or medicinals
   - Insecticides
4. Rubber
5. Crude fiber
   - Wrapping paper
   - Briquetting for fuel
   - Fiber for twines or cords, because of toughness.

Table 3: Summary of analytical data on the chemical analysis of burroweed (dry basis). (after Buehrer)

Constituent	Leaves	Stems	Roots	Entire Plant
Rubber	2.48	1.88	0.10	1.56
Total nitrogen	1.72	1.00	0.87	----
Total Protein	10.75	6.25	5.44	6.94
Pentosans	7.98	14.56	15.51	13.48
Essential oils	----	----	----	1.24
Reducing sugars (as glucose)	1.05	0.44	0.29	0.52
Alkaloids (calculated as cinchonine)			----	0.78
Total Plant oils saponifiable (as olein)	16.51	3.80	1.86	6.86
Resins	24.90	4.77	1.25	7.92
Starch	5.62	3.88	2.04	3.23
Pyridine (oxalate)	----	----	----	4.53
Crude fiber	6.76	42.30	52.50	37.74
Ash	13.06	7.44	5.95	8.19
Undetermined (by Diff.)				7.00
				100.00

ECOLOGY OF BURROWEED

Growth habits

The ecologic factors influencing the life history of burroweed have not been completely studied, although some information is available. The age of burroweed, its root system, seed production, and mortality rates bear a direct relationship to the plants' successful struggle for existence.

Age.--The life span of this plant is not definitely known although Humphrey (1937 p. 8) calls attention to the fact that

> It might seem that, inasmuch as the plants have hard, woody stems, their age could be determined by counting the annual rings. However, although the rings are present, they do not seem to be "annual" in all instances and are in addition often indefinite and sometimes impossible to distinguish; consequently, it is felt that they are an unreliable criterion of age. On the other hand, the general appearance of the weeds and the amount of soil retained by them under conditions of accelerated erosion, indicate that they often live for many years, possibly from 15 to 20.

The causes responsible for the mortality of mature burroweed plants Humphrey (p. 8) attributes largely to fire, drought, and physical injuries due to trampling or other influences. Wooton (1916 p. 17) infers that competition given burroweed by grasses is a possible cause, and Griffiths (1910 p. 18) speaks of "maximum density" as possibly causing the death of individual plants.

Seed production.--Humphrey (1937 p. 8) points out that burroweed plants are usually 18 to 24 months old before their

initial flowering season, and that flowering in general is conditioned by drought as well as moisture supply:

> In spite of the fact that moisture conditions are usually good during the spring months, and that vegetative growth is active at this time, flowering does not occur until after the early summer drought has been broken by the summer rains. It was observed in the summer of 1934 that the weeds were flowering rather generally by August 1, while the following year they did not reach the same stage of flowering until about 5 weeks later. Yet the summer rains in 1934 were definitely subnormal, while those of 1935 were considerably above average and began a week earlier than in 1934. It has been suggested that this apparent anomaly is normal and to be expected inasmuch as drought conditions are often required to initiate flower formation, although the embryonic flowers complete their development only as a result of subsequent rainfall.

Field observations have also shown that in some cases at least, branches of the current year's growth do not bear flowers. In such instances the terminal bud continues growth the next season.

Flowering, as Humphrey (1937 p. 8) shows, "begins late in summer rainy period and continues until well into the fall. As seed maturation occurs from two to three weeks after the flowers open, it is evident that they are being produced during most of the flowering season". Large quantities of seeds are thus produced and, being wind disseminated, they are carried for considerable distances, although Humphrey (1937 p. 9) says that the seeds are rather heavy for the amount of pappus, and thus are not carried far, but rather have a tendency to accumulate around burroweed plants and other vegetation.

Seed germination

Germination in the field.--A great majority of the burroweed seeds evidently never germinate, or die shortly after germination. McGinnies[1] remarks that "certain years seem to be more favorable than others for the growth of new plants, but conditions which favor or hinder its growth have not been thoroughly worked out." Humphrey (1937 p. 3) states that "seed germination occurs during the cool rainy winter or early spring months during a period of low temperatures and rather abundant soil moisture." He says further (p. 4):

> Since germination tests made during the summer rainy season have not been successful, and since very young seedlings have never been observed on the range during this period it would seem that conditions for germination are favorable only during the winter.
>
> It has been noted that maximum germination generally occurs on soils where a fairly heavy cover of annuals or a light stand of perennial grasses results in the accumulation of a fair amount of litter. On the other hand, germination is poor on areas under protection from livestock where much dead material from ungrazed grasses is allowed to accumulate. There is little or no germination on areas where erosion is so rapid as to prevent the establishment of a grass cover.

Germination tests.--It would seem from the foregoing discussion that low temperatures are essential for germination.

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1. McGinnis, W. G. : In a letter dated March 29, 1929 to Arizona Cattle Growers' Association at Phoenix.

E. L. Little (1937)[1], testing some seeds for the Southwestern Forest and Range Experimental Station, included A. fruticosus seeds gathered on the Santa Rita Experimental Range in 1934 and 1936. This test was made at Parker Creek Branch Station during the month of June, 1937. Germination chambers, set at approximately 80° F were used and the achenes put on moist blotters in petri dishes. Daily examinations were made for the first 10 days and thereafter at five day intervals. Seedlings, when about ½ inch long, were removed periodically. Table 4 gives his results.

Table 4: Germination of A. fruticosus seeds. (June 2, to July 2, 1937.) (Modified from Little.)

Year collected	No. of seeds used	Germination in number of seeds by periods					Germination (%)	Remarks at end of test
		1-6	7-12	13-18	19-24	25-30		
1934	100	15	3	2	1	0	21	No hard achenes left.
1936	0	0	0	0	0	0	0	No hard achenes left.

This table shows that whereas Little obtained a 21% germination of the 1934 seeds, no germination occurred with the 1936 seeds.

To determine more accurately the viability of burroweed seeds, the writer made a germination test at the University of Arizona during the winter of 1937-1938. The achenes used for the test were hand picked from seeds collected on the Santa Rita Experimental Range during the fall of 1937 as follows: Seeds in lot A were collected near Desert Grassland Station in October; lot B was collected at Gravelly Ridge in November; lots C, D, E, and F were collected near Desert

1. The data of this test are in the files of the Southwestern Forest and Experimental Range, Tucson, Arizona.

Grassland Station in November with the latter three treated before the test as follows: lot D was frozen for four hours before the test and then dried for 16 hours at 21°C; lots E and F were frozen for 6 and 24 hours respectively. No effort was made to get only "plump" seeds, but rather a lot that was representative of the collection, and free from chaff. The seeds were placed between moist filter papers in petri dishes, but these were not sterilized. As a result molds began to appear after 10 days in those lots kept at the two higher temperatures. The seeds were kept moist throughout the test.

Drying ovens, placed in a refrigerator, were used for the two higher temperatures. This arrangement was used to insure a constant temperature. Those at 15° C were placed in the head house of the nursery, those at 10° C in a compartment of the refrigerator where the drying ovens were located, while those at 5° C were placed in a refrigerator with special cooling devices. The temperature of the lot kept at 15°C varied 6°C, but in all other cases this variation was not more than 3°C throughout the test. The petri dishes were examined daily, and seedlings with cotyledons showing were removed. Many of those kept at 5° C seemingly did not have enough energy to "push out" their cotyledons, and thus were removed when the roots were well exposed, although the cotyledons were not entirely out.

At the end of the experiment the achenes which were left were examined to determine whether or not embryos were present. The results of this test are given in table 5.

Table 5: Germination test of A. fruticosus seeds (based on 100 seeds per lot)

Temp. °C.	Lot	Germination in days				Germination (%)	Germination by °C (%)	Embryos in remaining seeds		
		1-6	7-12	13-18	19-30			Pres.	Doubt.	Abs.
5	A	4	29	4	-	37		28	7	28
	B	-	24	8	4	36		31	5	28
	C	-	3	3	-	6	22.67	49	10	35
41	D	4	24	1	2	30		22	13	35
	E	-	7	5	1	13		38	9	40
	F	-	6	8	-	14		33	9	44
10	A	42	5	-	-	47		9	12	32
	B	55	1	-	-	56		5	3	36
	C	37	5	-	-	42		10	7	42
	D	32	3	-	-	35	41.00	4	9	52
50	E	24	5	4	-	33		9	11	47
	F	30	3	-	-	33		4	5	58
15	A	57	3	2	-	62		7	4	27
	B	59	-	-	-	59		5	5	31
	C	50	4	-	-	54	46.17	9	7	30
	D	38	1	1	-	40		9	9	42
59	E	25	1	2	-	28		11	3	58
	F	34	-	-	-	34		7	8	51
20	A	42	2	-	-	44		7	8	41
	B	65	-	-	-	65		1	11	23
	C	55	3	-	-	58	46.17	4	11	27
	D	30	2	-	-	32		10	18	40
18	E	44	1	-	-	45		13	12	30
	F	33	-	-	-	33		14	22	31
25	A	31	5	2	-	38		8	9	45
	B	60	-	-	-	60		3	10	27
	C	37	1	1	-	39		6	10	45
	D	30	1	-	-	31	42.33	2	8	59
77	E	48	1	-	-	49		11	5	35
	F	37	-	-	-	37		4	15	44

As a check, a lot of 100 seeds, similar to those used for the test, was examined to determine the number of seeds with embryos, with the following results:
Seeds with embryos present, 62; doubtful 8; absent 30.

It will be seen from table 5 that with the exception of those seeds kept at 5° C, germination was practically completed by the end of the 6th day. At 5° C, germination was delayed for several days and the total percentage of germination was approximately half that obtained at higher temperatures. The total germination of this entire lot of 3000 seeds was 39.97%. Under field conditions this percentage would undoubtedly be lower, since a continuous moisture supply is usually not available. No indication of a long dormant period necessary prior to germination is apparent from this test, since the seeds were of the current year's crop. The question of variation in the viability of seeds from year to year, however, is not answered yet, although Little's test may indicate such a possibility. The upper limit where temperature significantly retards germination has not been reached in this test, for there is relatively little difference in germination at 10°. 15°, 20°, and 25° C.

Seedling mortality

The mortality of burroweed seedlings in the field is exceptionally high, possibly being affected to a large ex-

-tent by climatic conditions at this critical period. Thus Humphrey (1937 p. 4) has shown by actual count that the greatest seedling mortality occurs during the dry spring months, preceding the summer rains. Table 6, as given by Humphrey (p. 4) shows this fact. The counts were made at intervals and based on the average of 10 one-meter quadrats. The number of seedlings found on April 4, 1934 was 309.8, whereas by January 30, 1935 it had decreased to 2.4

Table 6: Burroweed seedling mortality as related to precipitation. (After Humphrey)

Date	No. of seedlings	Rainfall, inches*
April 4, 1934	309.8	
April 17	265.0	0.00
April 30	192.9	0.04
May 16	95.9	0.00
June 1	49.9	0.25
June 16	20.6	0.00
July 3	11.9	0.52
July 16	10.1	0.32
August 2	8.1	1.69
August 16	6.9	3.53
September 16	5.0	3.31
October 24	3.9	0.92
December 4	3.7	0.89
January 30, 1935	2.4	4.03
May 27	2.4	5.14

*Rainfall since the previous date noted.

There was a slow decrease of seedlings during the month of April, then a rapid decrease as the dry period advanced with a decreased death rate during the summer rains. Some of the remaining seedlings succumbed during the dry fall months. Thus, as Humphrey points out (p.4), "Comparatively few seedlings survive from one year to the next". This high mortality rate Humphrey attributes in part to the close

competition which exists between the burroweed seedlings and grasses with respect to moisture supply, for during this time "burroweed roots and grass roots occupy approximately the same soil zones." Gibbs (1937, pp. 15-18) reemphasizes this opinion.

In comparing the number of burroweed seedlings which occurred on protected areas having a good stand of grass with conditions on grazed ranges, Humphrey (1937 p. 5) found that whereas the grass density was 20% on the protected areas with only 5.3 seedlings per square meter, the grass density was only 9% on the grazed range with 23.2 seedlings per square meter. These figures are the means, based on 9 study areas, the average of from 5 to 35 counts recorded for each area. These data, Humphrey (p. 6) points out, show a relatively higher seedling count on open ranges and suggest "that the relatively few seedlings present on protected plots may be the result, directly or indirectly, of heavier stand of grass there than on the grazed ranges."

In another paper Humphrey (1936 p. 6) discusses the relation of burroweed seedlings to mature plants, and shows

> . . . that under grazing there was an average of 3.4 seedlings beneath the bushes as compared with 0.2 on the adjacent areas, while under protection from grazing there was an average of 1.2 seedlings beneath the bushes and 0.2 on the areas between.

Humphrey (1937 p. 6) shows further the relation between the number of burroweed seedlings and altitude on the Santa Rita Experimental Range in table 7. He summarizes

the significance of the study as follows:

> It will be noted that the greatest number of seedlings occurred between altitudes of 3,400 and 3,500 feet. This portion of the range is for the most part an area where annual grasses and mesquites (Prosopis velutina) are abundant and perennial grasses occur rather sparsely. This poor perennial grass cover and the fair amount of litter from annuals and mesquite leaves seem to provide rather ideal conditions for seedling establishment. The smaller number of seedlings above and below these elevations may be due, above, to greater competition from the better grass cover, and below, to so slight an accumulation of litter as largely to prevent seedling establishment.

Table 7: Relation between number of burroweed seedlings and altitude. (After Humphrey)

Altitude in feet	seedlings*
3900-4000	3
3800-3900	4
3700-3800	14
3600-3700	7
3500-3600	26
3400-3500	51
3300-3400	22
3290-3300	11
3100-3200	2
3000-3100	0.28
2900-3000	0.35

*Counts made June 11, 1935

Root System

Comparatively little work has been done on the study of the root system of A. fruticosus. Judd (1937 p. 334) mentions that the plant has a tap root which may extend 7 feet or more in depth. Humphrey (1937 pp. 6-8), in studying the root systems of seedlings, found that root growth is rapid and in most cases vertical, rather than horizontal. He cites cases of seedlings 6 months old with tap roots 32 inches in length, 18 months old plants with

tops only 5½ inches in height whose roots extended 48½ inches downward, and two year old plants with 7 inch tops and tap roots 7 feet 6 inches long. Discussing the root system of mature burroweed plants he says:

> Root systems of mature burroweeds. . . are well adapted for obtaining moisture in regions of low rainfall. Seven plants were excavated on the Santa Rita Range each of which had a long taproot from which a few lateral roots branched off near the soil surface. The length of these branch roots was not determined. The taproots, however, extended vertically for from 5 to 18 feet. Except for the branches near the soil surface there were almost no other side roots. From observations made on these and other excavated individuals it seems probable that most mature burroweeds growing on upland soils with a deep water table develop taproots 12 or more feet in length.

Cribbs (1937 p. 16), in discussing the relation of burroweed seedlings with perennial grasses also points out the fact that at least during the first 3 months of their life, burroweed seedling roots occupy the same soil zone as grasses, and extend vertically to a depth of 18 to 30 inches.

Root studies were also made on the Santa Rita Experimental Range by the writer while serving as field assistant in the Range Ecology Department[1] of the University of Arizona during the summer of 1937. The root systems of 4 mature burroweed plants, growing in rocky soil, were traced out.

These studies show that burroweed plants have a very extensive root system. Although most of the lateral roots branch from the tap root in the first 2 feet of soil these laterals sometimes extend out 5 feet from the main root and then have a tendency to grow downward. Not only are there often present as many as 10 good-sized laterals, but

1. The data of this work are in the files of the Range Ecology Department, University of Arizona

with their sublaterals, and also numerous short laterals arising from the tap root they form a very adequate system, extending over considerable areas around the plant. Below the 3 foot level, the lateral roots are less numerous and at least in this rocky soil twine around the main root and grow downward with it, although at intervals some spread out, terminating as small rootlets possibly 12 inches away. This tendency to twine around the main root may be due largely to the rocky soil, following the line of least resistance. The greatest depth reached by roots of the plants excavated in this rocky soil was 11 feet 2 inches, although it seems probable that some may grow down even farther.

Factors influencing the spread of burroweed

The settlement of the Southwest, which is basically range country, naturally resulted in the establishment of the cattle industry. Stocking these ranges has upset the original ecological status, and has brought into play interactive factors of great importance. Due to a limited supply of moisture, combined with heavy grazing, the productivity of extensive areas has been reduced considerably, and in many cases the grasses have given way to undesirable weeds. These weeds are often native species of such areas, forming an integral part of the vegetation; as long as the grasses, their natural plant dominants, are given a fair chance, these undesirable species are largely held in check. Speaking of the relation between weeds and grasses Wooton (1915 p. 23) says:

> In the main, these native plants which have become commonest and apparently most important range weeds are not very aggressive and would not occupy the large areas they do but for the effective assistance in their struggle for existence which they receive from animals. Yet so important has this factor of animal interference with the adjustment of plants in different associations become that large areas are often occupied by almost pure stands of plants that would normally form but an insignificant part of the vegetable covering.

Griffiths (1901 pp. 10-14), in discussing range conditions of Arizona during the opening years of the 20th century, includes some letters from "old-timers", the result of a questionnaire, which indicate clearly the depletion of ranges as a result of over-stocking. This over-stocking was encouraged by the land tenure system in operation at the time. Naturally, such principles led to shortage of feed during years of drought. Continued grazing, when natural influences already limited the growth of grasses, damaged the ranges still more. Often ranchers lost stock because of feed shortage, but rather than let newcomers compete with them, they grazed the land to its utmost capacity during the better years and took the losses which inevitably followed during lean years. Wooton (1915 p. 28) refers to such an attitude as expressed by an experienced cattleman:

> I can better afford to take the $2,500 loss of stock which I know I will have when the dry years come than to take my stock off my ranges and try to save the grass which I know I will need in those dry years. I hold my range now only by having my stock on it. If I take my stock off, someone else will take my range, and I can afford to lose the stock better than lose the range.

Such conditions then, are in part responsible for the spread of burroweed and as Clements (1920 p. 300) points out, this plant is an indicator of overgrazing.

As has already been noted in the discussion on the distribution of burroweed, its spread on the ranges has taken place rather recently. Griffiths (1910 p. 18), in speaking of the encroachment of burroweed (Isocoma coronopifolia) on the enclosure (what is now the Santa Rita Experimental Range south of Tucson, Arizona), says that

> Here this plant has spread upwards from the river bottom and now occupies the rocky ridges and mesas between the grassy section and the more level desert lands below. It has thickened and increased perceptibly during the last five years. The rainfall in the region where it is most abundant was very light in 1908, and it consequently made but little growth. No one can tell what the future of this plant may be; it is quite probable that the grasses, unmolested, would hold their own against its encroachment, but with the grassy vegetation weakened by grazing it may increase to such an extent as to crowd out nearly all of the valuable plants... .

He then mentions the fact that this spread had begun years before the area was brought under protection from grazing, but that already in 1909 it had possibly reached its maximum density because many of the plants were dying off, even though the season was exceptionally favorable.

Upson, Cribbs, and Stanley (1937 p. 45) are of the opinion that burroweed comes in after and not before the grasses have been weakened or killed, and as a result of the unpalatability of this weed, it is given a better chance than the grasses.

> The rapid spread of burroweed. . . into the present and original grassland type is apparently due to loss of soil and soil fertility, to the thinning out or killing of pre-existing vegetation and to the subsequent changes in growth conditions and vegetation relationships that thus take place. The weight of available information is not to the effect that these shrubs are actively killing out more desirable forage plants.

Cribbs (1937) has shown that in some cases at least, erosion appears to be even more important in the spread of burroweed than grazing for "sheet erosion is invariably associated with increased numbers of burroweed where the plant has access to the area." The writer for the Southwestern Forest and Range Experiment Station (1938 p. 14) reiterates these conclusions by calling attention to the fact that,on protected plots where soil erosion was absent and the soil in good condition, burroweed plants were less numerous than on the adjoining grazed areas; however, on protected plots where sheet erosion was evident and the soil depleted, possibly from the effects of free-range days, this weed was more numerous than on adjoining grazed areas.

W. G. McGinnies[1], likewise, is of the opinion that grazing may have favored the spread of burroweed by killing out the more palatable plants, but mentions that protection of the ranges from fire in recent times may also be responsible for this rapid increase, and in a letter[2] includes low temperature as a limiting factor. Humphrey

1. Unpublished report without date: Burro Weed a Menace to Arizona Ranges. In the files of the Range Ecology Department, University of Arizona.

2. McGinnies,W.G.: In a letter to Hub. Russell, dated August, 22, 1932

(1937 p. 2) puts an even greater emphasis on fire as an important factor in its spread, for as he puts it:

> Although it is possible that this spread was due to a deteriorated condition of the ranges prior to protection, various studies indicate that prevention of fires probably played a greater part in this spread than heavy grazing.

He, however, also indicates (p. 9) that protection arrests the growth of burroweed since "Recent studies have shown that on areas where protection from grazing resulted in a good stand of grass there were fewer mature burroweeds than on areas not so protected." He accounts for this condition as being brought about by the fact that relatively few burroweed seedlings become established on areas where good grass cover is present.

Wooton (1916 pp. 15-16) mentions an experiment where all plants on an area were killed out, and the return of vegetation observed. Plant collections were made before eradication by plowing was done, and collections were also made on check plots. One of these areas was heavily infested with burroweed, and even after plowing some of these plants remained. For the first two years at least, no burroweed seedlings were found on the plowed area, although seeding plants were abundant in the vicinity, and a few were also present on the plowed area itself. Wooton expresses the opinion that grasses will take possession of this plowed area sooner than of the over-grazed areas, since the soil's ability to retain water is increased and plenty of seed for

revegetation will be available.

Recently Shreve and Hinckley (1937 pp. 472-473) have reported an increase of burroweed in their vegetational study conducted on areas at the Desert Laboratory located near Tucson, Arizona. This area has been protected from grazing since 1907. In 1928 eight contiguous areas of 10 meters square were established on " a slightly rolling surface with a light loam soil . . . The location was selected because it differs greatly from all of the others in the texture and structure of its soils and in the openness and poverty of its vegetation." Speaking of the increase of vegetation in these areas, the authors say:

> A large part of the increase found in 1936 is due to the appearance of 197 young individuals of A. hartwegi. Of this number 152 are grouped under the light shade of a Prosopis tree which covers 40 square meters. The remaining 45 plants are more or less evenly distributed over the other parts of area B. This species of Aplopappus is extremely abundant in the Tucson region and is known to have multiplied greatly in the last 25 years, presumably as an indirect effect of overgrazing. It is not common on the Laboratory grounds and there will be considerable interest in learning from future study of this area whether it multiplies under natural conditions.

BURROWEED CONTROL

Possibilities of range improvement

The need for burroweed control has long been felt, and various methods have been tried. Before taking up this phase of the problem, attention should be called to the possibilities of improvement of forage cover on southwestern ranges. The general distribution of burroweed and its prevalence in the

Southwest has been discussed earlier. In this connection Upson, Cribbs, and Stanley (1937) divide the area covered in their survey into 9 types as given in table 8. They then arranged the 8 types (exclusive of the woodland-timber type) into the following order of relative importance (Upson, Cribbs, and Stanley, 1937 p. 9, condensed report):

Present Forage value	Possibilities of Improvement in Forage Value
1. Grassland	1. Grassland
2. Mesquite	2. Burroweed
3. Saltbush	3. Snakeweed
4. Snakeweed	4. Mesquite
5. Cactus	5. Cactus
6. Burroweed	6. Saltbush
7. Blackbrush	7. Blackbrush
8. Creosotebush	8. Creosotebush

As the authors point out (pp. 16-17), those areas with heavy stands of burroweed do not offer much chance for improvement, but to some extent within the areas of medium stands, and especially where light stands occur, the soils are still in relatively good condition, and there is sufficient quantity of grasses left to warrant adequate control measures.

Natural control

The problem of burroweed control has centered chiefly around natural and artificial methods. To a large extent the program of natural control deals with restricted grazing. In other words, the idea has been proposed that if grasses are given a fair chance, they will arrest the invasion of burroweed, and possibly eventually "crowd out" these intruders.

TABLE 8: Area, density, and composition of the principal plant cover on ranges in southeaster Arizona (After Upson, Cribbs, and Stanley)

Principal plant cover type	Area		Ave. density total vegetation	Principal species making up the plant cover of each type shown in column 1								
				Creosote-bush	Blackbrush	Cactus	Saltbush	Burroweed	Snakeweed	Mesquite	Perennial grasses	Other plants
	Acres	Pct.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Creosote-bush	3,002,000	24.9	.30	66	0	3	0	0	5	5	0	21
Blackbrush	509,000	4.2	.35	19	29	0	0	3	5	15	4	25
Cactus	1,116,000	9.3	.36	1	0	37	0	3	0	3	5	51
Saltbush	306,000	2.5	.33	2	0	0	97	0	0	1	0	0
Burroweed	1,110,000	92	.34	0	0	9	0	52	4	20	5	10
Snakeweed	454,000	3.8	.32	0	2	0	0	10	32	18	11	27
Mesquite	850,000	7.1	.35	0	0	0	0	10	7	59	9	15
Grassland	3,809,000	31.7	.35	0	0	0	0	2	3	9	76	10
Woodland-timber	878,000	7.3		See note								
Total	12,034,000 acres											

Note: In the last nine columns 0 percent means the plant in question was absent or made up less than 1/2 of 1 percent of the vegetation.

The woodland-timber type occurs mostly within the Coronado and Crook National Forest These areas, having already been covered by Forest Service range surveys, were not covered in the shrub survey. While details as to composition are not given in the above table, the plant cover contains mostly grasses and other plants and only scattering shrubs.

Burroweed-grass relationship.-- In connection with this problem then, the relationship of burroweed to perennial grasses is af great importance. Wooton (1916 p. 17), in speaking of this relation compares parts of the enclosure (now the Santa Rita Experimental Range) as described by Griffiths (1904) and as it existed in 1914. Wooton mentions that whereas in 1903 the area showed a scattering growth of burroweed (Isocoma Hartwegii), in 1914 it was covered thickly with mature plants of this species, but large numbers were dying, "probably as the result of the encroachment of the grasses which are gradually taking possession of the area." He says further:

> The rayless goldenrod is of no value as a forage plant and it is customary to think and speak of it as a range weed and a nuisance. But it certainly protects the soil from erosion, retards run-off, and furnishes the conditions favorable to germination of the grass seeds. The grasses will probably eventually crowd it out.

Humphrey (1936 pp. 3-5), in studying the relation of burroweed to perennial grasses, gathered data, based on a series of 400 or more pairs of typical quadrats. Table 9 gives the result of his study. Discussing these findings, Humphrey (p. 5) says:

> . . . on both grazed and ungrazed areas there was a lower total density of short grasses beneath the burroweeds than on the areas between. A study of the grasses composing the short grass total shows that on the grazed series, black grama, Rothrock gama, and Santa Rita three-awn all had a lower density directly beneath the weeds than on the adjacent weedless areas. With the exception of black grama the same tendency (was) obtained on the protected plots.

Table 9: Effect of burroweeds on grass density under grazed and ungrazed conditions. (After Humphrey)

Grass		Density			
		Grazed		Ungrazed	
Type	Kind	Beneath Burroweeds	Area Between Burroweed	Beneath Burroweeds	Area Between Burroweeds
		Cm^2	Cm^2	Cm^2	Cm^2
Short	Black grama	43.6	59.8	66.7	52.8
	Rothrock grama	65.7	122.3	38.9	78.3
	Santa Rita three-awn	43.1	56.3	49.2	126.4
	Total	152.4	238.4	154.8	257.5
Tall	Bush muhly	3.1	0.0	0.0	0.0
	Cotton grass	17.4	2.0	6.7	2.3
	Poverty three-awn	37.1	6.8	90.2	20.0
	Tanglehead	8.2	.8	1.0	0.0
	Total	65.8	9.6	97.9	22.3

> All tall grasses--bush muhly, cotton grass, poverty three-awn and tanglehead--both when grazed and when protected, had a higher density beneath than between the bushes.

From these results Humphrey concludes that possibly some other factor than the protection from grazing furnished by the weed operates in bringing about this increased grass growth of the tall grasses.

Cribbs (1937), in discussing the relation of burroweed seedlings to grasses, points out that few or no seedlings survived on enclosures that had moderate to good stands of perennial grasses, but seedlings were abundant on the grazed range and on enclosures where there was little grass. He also shows that the roots of burroweed seedlongs occupy a soil zone similar to that of Rothrock grama and the three-awn grasses, and thus on areas with greater grass density, burroweed seedling mortality would be greater.

Restricted grazing.--Cribbs (1937) has reported one of the most inclusive studies on protection from grazing as a method of burroweed control. This study was made on the Santa Rita Experimental Range, and he summarizes the results as given in Table 10 of this paper.

In this table Cribbs has divided the 90 enclosures with check plots, established adjoining these areas, into 5 groups as follows:

> In group A the enclosure fences have been continuously cattle proof since the establishment of the enclosure. Almost all are protected only against grazing by cattle and only a very small number against rodents. All

Table 10: Amount of burroweed under various conditions of grazing and erosion. (After Cribbs)

Groups*	Grazed Areas		Ungrazed Areas	
	Total acres of sample	Average number of individual plants per acre	Total acres of sample	Average number of individual plants per acre
A	7.65	1559	15.39	314
B	1.73	2797	1.04	2609
C	2.81	3010	1.82	4003
D	3.40	61	1.49	17
E	7.32	1281	5.69	762

*See text for explanation of groups.

are located in areas where burroweed occurs in moderate to heavy stands. In some of these enclosures there is a mild degree of sheet erosion but in no case is it excessive. . . .

Group B includes a small number of enclosures which have at one time or another since their establishment been subjected to a limited amount of grazing. For the most part they are rather old enclosures, the fences around which have fallen into disrepair and have since been replaced. No accurate data are available as to the amount of grazing that occurred before replacement of the fences, but it probably did not exceed an average of one to two year's use. . . .

Group C includes all enclosures which are subject to heavy sheet erosion. During the period of unregulated grazing prior to the establishment of the Santa Rita Experimental Range in 1903 the damage to the grass cover was so great that erosion started over an extensive area. Over some of this area subsequent protection and regulation of grazing has been ineffective in stopping this erosion. The soils are in poor condition and either are not improving or are improving at such a slow rate that 33 years protection against grazing has made no appreciable difference. The plots in this group are often influenced by flowing water originating both in and outside the enclosure. Not infrequently wind erosion is an important factor. Without doubt the assembled forces of erosion are of far greater importance than the grazing use on the open portions of the range or the influences of the enclosure fences. For this reason these enclosures are placed in a separate group. . . .

> Group D includes enclosures that are located in the foothills of the Santa Rita Mountains near the edge of the burroweed advance. In such locations grass densities are usually higher than the average for the entire range and the amount of burroweed is relatively less.

In group E Cribbs placed all enclosures that were less than 5 years old.

Cribbs points out that in group A there are approximately 5 times as many burroweed plants on the grazed check areas as on the ungrazed enclosures; that group B shows only a slight difference in favor of the ungrazed areas; in group C the burroweed averages one third more inside the enclosures than on the grazed range; in group D the ratio is similar to group A, although the numbers are considerably less; and that group E shows somewhat less burroweed plants within the enclosure than on the grazed range, although the difference is not as great as in groups A and D. This he explains by inferring that short-time protection is not adequate. In general then, this study shows that on protected plots where soil erosion was absent and the soil in good condition, burroweed plants were less numerous than on the adjoining grazed areas, but on plots where sheet erosion was evident and the soil depleted, the reverse is true.

Table 11 is taken from Cribbs' (1937) report and represents the arrangement of groups A and E of table 10 into 4 groups according to the lengths of time the enclosures have existed. In summarizing the significance of these results Cribbs (1937 p. 15) says:

Table 11: Continued protection as a factor in burroweed control. (After Cribbs)

Age of Plots In years	Grazed Areas: Area in Acres	Grazed Areas: Ave. number of individual burroweeds per acre	Ungrazed Areas: Area in Acres	Ungrazed Areas: Ave. number of individual burroweeds per acre
½-4	3.74	2335	3.36	1246
5-9	2.62	1346	2.87	253
10-14	1.93	2204	7.23	174
15-33	5.15	2030	5.29	492

It is noteworthy that the ratio of numbers of burroweed within enclosures to the number of grazed range shows the maximum difference in the group of enclosures that range from 10 to 14 years of age, and that after this time there is an increase in the amount of burroweed within the enclosures.

These conclusions are reiterated by the writer for the Southwestern Forest and Range Experiment Station (1938) in an article based on this report.

Sampson and Malmsten (1926) have shown that on mountain range areas, continued heavy grazing reduces the size of roots and tops of prennial grasses, thus weakening their growth and ability to obtain soil water. Cribbs (1937 p. 17) points out that burroweed plants, which are generally not eaten by stock, have a decided advantage over grasses in this respect, and more of these weeds will therefore survive on heavily grazed areas than where the grasses are protected.

There is another phase of this problem that needs attention, and that is the burroweed-range relationship that

exists on areas not typically occupied by perennial grasses. Cribbs (1937 pp. 19-20) mentions that extensive areas in the Southwest, where burroweed is abundant, support but a light stand of prennial grasses. The larger part of these areas are composed of annual grasses and annual weeds during short periods of the year. Cribbs says that

> There is no indication that the density of these annuals shows the inverse relation to the stand of burroweed as is shown by the perennial grasses.

Another factor of importance in this burroweed-grass relationship is the relative amount of water used by these plants. Arnold (1938) has presented data from experiments conducted by the Range Ecology and Botany Departments of the University of Arizona on the Santa Rita Experimental Range which show the water requirements of native grasses and shrubs. These studies show that burroweed ranks relatively high among shrubs, requiring 1984 grams of water to produce one gram of dry weight. In native grasses this amount is considerably less, ranging from 366 grams in slender grama to 710 grams in Johnson grass. Darrow (1935 p. 76) shows that burroweed reaches its maximum transpiration rate around noon, with a decided decrease as night approaches although some water is lost constantly, even at night. He further shows (p. 77) that air temperature and solar radiation have the highest correlation coefficients of the factors influencing transpiration.

Natural enemies.--Various attempts have been made in the past to discover some natural enemies of burroweed which might be utilized in an effort to control or even eradicate this weed. Although a few organisms have been found to infest the plants, it is doubtful whether they are of much significance, especially since they seem to be an integral part of the biotic structure of this region. Since this is the case it is questionable whether such enemies will at any time become sufficiently large in numbers to produce spectacular results. The best that can be hoped for is that they may do their small part to help.

Humphrey (1937 p. 8) reports that

> Burroweeds are parasitized by the grubs of two species of round-headed borers, Crassidium intermedins and C. longipenis, which live on the heartwood of the lower stems and roots. About 80 per cent of the mature plants have been found thus parasitized, and except for the fact that they may be somewhat more easily broken off than unaffected plants they are apparently unharmed by the grubs. The hollow stems and roots left by the borers are usually occupied by ants and termites which, in their turn seem to do the plants little if any damage.

Humphrey (p. 8) also lists two species of grasshoppers, Taeniapoda eques and Hesperotittix viridis viridis, feeding on burroweed leaves during the summer, but seemingly with no harmful effects to the plants. The writer, while serving as field assistant in the Range Ecology Department of the University of Arizona during the summer of 1937, discovered another natureal enemy of burroweed. This is the larva of a moth, Thiodia stramineana Wlsm., of the family Olethreutidae,

and has thus far not been reported as infesting burroweed.[1] This larva feeds on the branch tips of burroweed plants. Counts, based on 50 list quadrats were made to determine the degree of infestation. Such counts were made at Gravelly Ridge and Desert Grassland Stations on the Santa Rita Experimental Range. 29.73% of the plants or 5.71% of the flower tips of the plants at Desert Grassland and 40.59% of the plants or 4.5% of the flower tips of the plants at Gravelly Ridge were found to be infested.

The ecological relationship of these larvae to burroweed has not been thoroughly worked out, and not much can be said concerning its life history. It was observed in 1937 that by June 14 larva were already present in the branches as evidenced by the blackened tips, and were still present October 10, 1937. The reaction of the plant to the invasion of these larvae is varied; in some cases the tip forms a coil and then continues to grow upwards, while in other instances the flower tip dies, but new flowering branches develop below the tip. In either case the larvae seem to do little if any damage to the flowering capacity of the plant.

Artificial Control

A large part of the program in connection with the control and eradication of burroweed has been based upon artificial methods. The methods which have been tried are (1) grubbing

1. These larvae were "reared" by Dr. L.P. Wehrle of the Entomology Dept., University of Arizona, who then sent the adult specimens to the Bureau of Plant Entomology U.S.D.A. where they were identified by Carl Heinrich.

and cutting, (2) spraying, and (3) broadcast and torch burning.

Grubbing and cutting.--Thornber (1907 p. 228; 1910 p. 289) refers to grubbing and cutting methods on experimental plots, estimating the percentage of kill to be approximately 50% when cut two inches above the ground and 100% successful when cut below the ground surface. He mentions, however, that this method of eradication is more expensive and less satisfactory than burning. Marsh, Roe and Clawson (1926 p.23) also report digging as a means of control and record that only a few plants had reappeared in pastures cleared seven years before. They believe digging to be practicable in fenced pastures. Although their reference is to another species, A. heterophyllus, the plants are very similar in growth habits to those of A.fruticosus.

Humphrey (1937 p. 9), on the other hand, thinks grubbing to be impracticable on ranges where burroweed occurs, because of the low value of the ranges. In another paper Humphrey (1936 pp. 12-14) discusses this problem in greater length, showing that

> although more burroweed seedlings germinated on ungrubbed areas, the rate of growth, general vigor, and number of seedlings that survived to maturity were all greater on areas from which the mature weeds had been grubbed. In view of this rapid reoccupation of grubbed areas by the weeds, their eradication by grubbing does not seem practicable.

The data upon which Humphrey bases his conclusions were obtained by counting seedlings on a series of meter-square quadrats at 50 pace intervals a year after grubbing was done.

This grubbing was done "on two transects, each about seven miles long and 100 feet wide, one on each side of the Florida-Continental road. The transects were established approximately at right angles to the contour lines and each extended from an altitude of 3,200 feet to 4000 feet." Table 12 shows the result of these counts as given by Humphrey (1936 p. 13.)

Table 12: Survival of burroweed seedlings on grubbed[1] and ungrubbed ranges. (After Humphrey)

Elevation	Grubbed		Ungrubbed	
	Seedlings present June 11	Seedlings present Aug. 5	Seedlings present June 11	Seedlings present Aug. 5
3200-3300	15	9	11	4
3300-3400	17	12	22	6
3400-3500	44	26	51	16
3500-3600	38	27	26	9
3600-3700	19	15	7	6
3700-3800	20	10	14	6
3800-3900	8	1	4	1
3900-4000	1	1	3	1
Average	20.2	12.6	17.2	6.1

1. Mature burroweeds grubbed winter of 1934

Judd (1937 p. 334) says that "Grubbing is to be recommended only where a relatively few plants are found on an area. These should be cut 2 or 3 inches below the surface of the soil." Upson, Cribbs, and Stanley (1937 pp. 42-43) doubt the advisability of grubbing, and furthermore state that such methods tend to increase reproduction. Later,

Cribbs (1938 p. 5), in commenting on the work reported by Humphrey (see table 12), says that the year following this grubbing

> . . . more young live burroweed seedlings appeared on the grubbed strips than outside these strips where no grubbing was done. This seems to show that the loosening of the earth in grubbing favored the establishment of burroweed seedlings. And from this, one may conclude that burroweed eradication by grubbing--at least when done during the fall and winter seasons--does not seem to be practicable.

The weight of evidence thus appears to be that grubbing cannot be recommended as a method of eradication, except in cases of isolated plants.

Spraying.--In view of the fact that sprays of various kinds have been utilized to combat obnoxious weeds in garden, field, and along roadsides, a number of attempts have been made to use similar methods to eradicate burroweed. Sulfuric acid seems to be the material used most extensively, although such chemicals as sodium arsenate have also been suggested.

McGinnies (1928) reports the effectiveness of H_2SO_4 spray on burroweed as follows:

Strength	Result
10%	Defoliation
5%	Defoliation
3%	Defoliation
2%	Partial defoliation
1%	Partial defoliation

He adds, however, that some of the plants defoliated with such treatment may produce sufficient leaves to survive.

Later, in a letter[1] McGinnies comments on the use of chemical weed eradication as follows:

> Sulfuric acid appears to be the most satisfactory because of its cheapness and also because weak solutions will kill burroweed. . ., and at the same time do little or no injury to grasses. The disadvantage of this method is that it takes a great deal of water which is usually scarce and under range conditions power sprays would have to be used.

Brown and Street (1928 p. 307) experimented with sulfuric acid sprays to control obnoxious weeds and list burroweed among the plants so treated. Table 13 is taken from that part of their report which deals with burroweed.

Table 13: Sulfuric acid spray for burroweed. (Modified from Brown and Streets)

Weed	Stage of Growth	Date	% Acid	Temp. F	Approx. % of killings	Remarks
Rayless-goldenrod or Burroweed:	Large and small	May 28	1	99	15	Small leaves & tender tips killed
	6-24" tall, green not flowering	May 28	2	99	90	Most of the leaves and tender tips killed
		May 28	3½	99	100	All leaves and tips killed
		May 25	5	92.6	100	Cortex probably killed
		May 25	10	92	100	Cortex killed to ground
		May 19	5	92	100	Cortex probably killed
		May 19	10	92	100	Cortex killed

From this table it will be seen that they obtained a very high percentage of kill (90%-100%) with all except the 1%

1. McGinnies, W. G.: In a letter to Hub. Russell, dated Aug. 22,1932. In the files of the Range Ecology Dept., U. of A.

strength. Their recommended strength for most cases is 5%.

Humphrey (1936 p. 12 and 1937 p. 9) refers to acid spray as not practicable on low-value ranges where burroweed occurs. Likewise, Upson, Cribbs, and Stanley (1937 p. 26 condensed report) and later Cribbs (1938 p. 5) substantiate this view by referring to the fact that after 2 years there was only a slight decrease of mature plants, and the expense involved was too great when compared with results.

Fire.--Reference has already been made to fire as a limiting factor in the distribution of burroweed and this method of eradication has received considerable attention in the past. Burning as a method of control was already in use in the early years of the 20th century. Thus Thornber (1907 p. 228) refers to such an experiment conducted on June 28, 1906 on what was then the "small range reserve tract", and speaking of the effect of burning on burroweed in particular he says:

> All the plants in the area burned over, even those only partly charred, were killed outright including such other shrubs as the catclaw, creosote bush, Brigham's tea, mesquite, and Zizyphus. This may prove an easy means of destroying well-defined patches of such worthless range weeds as the above, when growing in the open.

The same author (1910 pp. 288-289) mentions the fact that burroweed can be killed at a very small expense by broadcast burning during the dry fore-summer period (e. g. May to June), although torch burning for the more scattered bushes is suggested. In this same bulletin (1910 pp. 288-289) as well as in another article (1905 p. 18) Thornber refers to

a fire which lasted two days and spread over an area of approximately 12 square miles. With respect to the effect of this fire on the vegetation, Thornber (1910 pp. 288-289) says:

> Two years after the large fire. . .the area in question was covered with a remarkably good growth of the summer grasses and Mexican poppy, and practically free from large plants of the rayless goldenrod.

The name "rayless goldenrod" as here used, refers to A. fruticosus

Such fires are generally considered as having occurred at intervals in early days.[1] It should be borne in mind, however, tha, in general, the ranges had much better grass cover during these early times, and fires which occurred, either accidentally or were started willfully, had relatively greater ease of spreading.

Griffiths (1910 p. 18) also mentions the possibilities of burning as a method of burroweed control, emphasizing that the dry summer months be used for this purpose. McGinnies (1928) reports that on a large area which was burned, this treatment of 85% successful as far as eradication of burroweed was concerned, but adds that some valuable browse species were also killed. He further states that burning the plants at the base with a torch was 75% successful, while burning the leaves and stems resulted in 95% of the plants being killed. The same author,[2] referring to burroweed

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1. See for example Thornber (1905 p. 18; 1910 pp. 288-289; 1911 p. 474); Wooton (1916 p. 18); Griffiths(1901 p. 12)
2. McGinnies, in a letter to Hub. Russell, dated Aug. 22, 1932. In the files of the Range Ecology Dept., U. of A.

and broomweed says:

> It was found that these weeds could be killed by broadcast burning, but only during the dry season and when there was an abundance of dry grass. The cost of such burning runs from 25 cents to $3.00 per acre, depending on conditions.

Reference in this letter is also made to an estimated cost of $1.00 to $5.00 per acre when using torch burners, although this cost is based on burning broomweed.

Judd (1937 p. 333-334) refers to the effects of burning on burroweed and grasses. In his experiments two 100 x 50 meter lots were established, one of which was fenced to exclude cattle. One-half of each of these two lots was burned, it being necessary first to spray the plants with crude oil to facilitate burning. The burroweed plants were counted before burning, and again one year later to determine percentage of survival. In the cattle excluded area 400 or 5.35% of the 7,477 plants present before burning survived, while on the grazed area 723 or 7.13% of the 10,139 plants survived. Judd also found that the height growth of grasses was only slightly greater on the unburned lot of the protected area when compared with the burned lot of the same area, while the increase in number of stems was slightly greater in the latter.

Humphrey (1937p. 9) also mentions the possibilities of eradicating burroweed by broadcast burning on those areas covered by perennial grasses when not overgrazed. His views are more fully set forth in another report (Humphrey 1936).

In this paper Humphrey (pp. 15-20) shows rather definitely the advantages of burning areas as a control measure, based on two different study lots as shown in tables 14 and 15.

In commenting on the significance of these results, Humphrey states that such methods of control are effective and economical (p. 15 and p. 20). He points out, as table 14 shows, that Rothrock grama, the principle grass of the region, was more abundant on the burned than on the unburned portion, although "there was a tendency for the total number of Rothrock grama plants on the burned range to decrease as the season advanced." He attributes this decrease to heavier grazing by stock and jackrabbits. Humphrey (p. 17) also shows that two years later the annual grasses were approximately twice as heavy on the burned as on the unburned areas. His observations in 1935 also brought out the fact "that all burroweed and approximately 50% of the Cholas (Opuntia, spp.), mesquites (Prosopis, velutina), and bisnagas (Echinocactus wislizeni) were killed by the fire." He further says that

> The small number of burroweed seedlings on the burned area two years after the fire is of particular importance since it indicates that revegetation to burroweeds may be slow, even on small areas surrounded by a large number of mature seed-producing plants.

Humphrey shows further (pp. 17-18) that the removal of burroweed by burning definitely decreases soil loss from water erosion. This decrease in erosion he explains thus:

> On the unburned range the soils directly beneath the crown spread of the plants are, to a considerable extent protected from water erosion. As a result of this protection little soil is lost from beneath the plants although erosion may continue unhampered on the

TABLE 14: A comparison of vegetation on burned and unburned range.[1] (After Humphrey)

Species	Number of individuals per sq. meter[2]							
	Counts made March 7		Counts made April 4		Counts made May 31		Counts made June 4	
	Unburned	Burnd	Unburned	Burned	Unburned	Burned	Unburned	Burned
Rothrock grama	16.00	27.00	5.40	22.30	6.25	14.67	6.18	13.74
Three-awn grasses	.18	.16	T	T	.32	.15	.59	.03
Total grasses	16.18	27.16	5.40	22.30	6.57	14.82	6.77	13.77
Burroweed seedlings	10.00	2.30	3.00	1.40	4.04	1.00	15.06	.51
Chollas	.15	.02	T	T	.18	.07	.21	.06
Total shrubs	10.15	2.32	3.00	1.40	4.22	1.07	15.27	.57

1. Beach ranch area: burned June 1933
2. Counts made in 1935

TABLE: 15 A comparison of vegetation on burned and unburned range.[1] (After Humphrey)

	Number of individuals per sq. meter[2]	
	Burned	Unburned
Black grama	.00	.31
Bush muhly	.00	.09
Cotton grass	.00	.02
Feather Grass	.00	.04
Rothrock grama	.20	.02
Tanglehead	.05	.09
Three-awn grasses	1.59	.90
Total grasses	1.84	1.47
Burroweed (mature)	.01	.71
Burroweed (ssedling)	.25	5.16
Chollas	.01	.02
Snakeweed	.13	.66
Total shrubs	.40	6.55
Baccharis wrightii	.05	.00
Euphorbia	.63	.03
Total weeds	.68	.03

1. Sierrita area: burned April or May, 1933
2. Counts made July 5 and 6, 1935

> unprotected areas between. As burroweed crowns intercept little water, most of the precipitation falling on the plants reaches the ground and, flowing from the mounds beneath the weeds is concentrated in the lower, eroded areas. The resultant accelerated erosion is often sufficiently heavy to largely prevent establishment of grasses except in the immediate vicinity of the bushes.
>
> It has been noted that following removal of burroweeds, the formerly protected, relatively uneroded soil was washed into the gullies until the entire surface became essentially plane. As a result, excess water during rains was more evenly distributed over the soil surface and erosion was markedly reduced. In addition, the better grass stand that develops after fire soon plays a definite part in further reducing soil loss.

He cautions, however, that the vegetational and erosional observations need further corroboration.

Upson, Cribbs, and Stanley (1937 p. 26 condensed report) mention blowtorch burning as resulting in a high percentage of kill of burroweed with but little injury to grass, but being very limited in use because of the expense connected with this method. They express their viewpoint on broadcast burning as follows:

> Some preliminary work has been done upon the removal of burroweed by broadcast burning and so far fairly good results have been obtained from the standpoint of the removal and prevention of reproduction of the plants. Nothing is yet known concerning the effect of the burning on the range grasses or upon the fertility of the soil, its rate of water absorption, or surface run-off. These are factors just as important as the removal of shrubs themselves and further experimentation should consider them fully before any such method can be recommended.

Cribbs (1938 p. 5) in a later article points out that broadcast burning is probably the least expensive of artificial methods of control, but to be effective should be done in spring and probably at 5-year intervals to destroy the larger plants.

He cautions against this intermittent burning, however, as possibly not being the best procedure. Another point brought out by Cribbs is the fact that the fresh growth of grass which follows burning attracts jackrabbits and also results in a concentration of livestock on such areas. Thus, by too close grazing and trampling, considerable loss of grass results.

SUMMARY

1. A. fruticosus is commonly called burroweed and belongs to the Aster tribe of Compositae. Much confusion has occurred concerning the identity of this plant and of related species.

2. The genus Aplopappus had its origin in Mexico or some similarly warm temperate district. Migrations to the north and to the west coast of South America have occurred in past geologic times, so that today the two sub-genera are separated by the tropics.

3. The North American members of the genus Aplopappus may be divided into two unequal groups, one with ten and the other with six sections. A. fruticosus belongs to the section Isocoma.

4. Isocoma is the only North American section in which the ray-flowers are constantly suppressed in all species.

5. A. fruticosus ranges from southern Texas and Arizona to Sonora in northern Mexico. In southern Arizona it is very

abundant over extensive areas, found typically in the desert shrub association characterized by the creosote bush. On the Santa Rita Experimental Range it occurs quite generally in the Bouteloua-Aristida association at an elevation between 3000 and 4000 feet.

6. Burroweed is slightly alkali tolerant, and grows well on depleted soils. Since it also thrives on alluvial soils, soil aeration or texture does not seem to affect its distribution.

7. Burroweed is generally considered as a poisonous plant, and evidences are available to support this contention, although stock losses from the plant are rarely heavy. Its poisonous properties are similar to those of A. heterophyllus, and have been reported to be due to alkaloids, pyridine, or similar constituents.

8 A. frutiocosus offers some commercial possibilities, containing essential oils, rubber, and resins as well as other constituents that might be utilized.

9. The flowering season of A. frutiocosus begins in late summer and lasts well into fall. Individual flowers mature seeds in about two to three weeks.

10 Germination usually occurs during the cool, rainy winter or early spring months. Germination tests seem to indicate that moisture is probably a greater limiting factor than temperature, although germination apparently does not occur during the summer rainy season.

Such tests do not indicate a long dormant period necessary prior to germination.

11 Seedling mortality is very high, and is conditioned largely by competition and lack of moisture combined with high temperatures.

12 Burroweed roots often reach a depth of twelve feet or more;a number of lateral roots branch from the main tap root in the first two or three feet of soil, and together with numerous sublateral roots form a very extensive root system. The roots of burroweed seedlings and grasses occupy a similar soil zone.

13 Burroweed requires more than twice the amount of water used by grasses to produce a given amount of dry matter.

14 Burroweed is most abundant on overgrazed ranges. It is seldom grazed by livestock, thus giving it a decided advantage over grasses in the competition for existence.

15 Natural and artificial methods of control have been attempted with only a slight degree of success.

16 Eradication does not seem advisable when such procedure increases the chances for erosion .

17 A few insect enemies have been found to infest burroweed, with little apparent damage to the plants.

18 Studies have shown that protection from grazing offers some possibilities of control on areas where there is a minimum amount of erosion. Protection from grazing

over a period of ten to fourteen years seems to produce the maximum benefit.

19. Grubbing and cutting, although practicable with individual plants, do not offer satisfactory methods of control.

20. Spraying likewise is not practicable because the expense is too high when compared with results.

21. Control by burning offers some possibilities, but often desirable species are also killed. The effect on soil fertility and rate of water absorption or surface-runoff has not been completely determined.

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