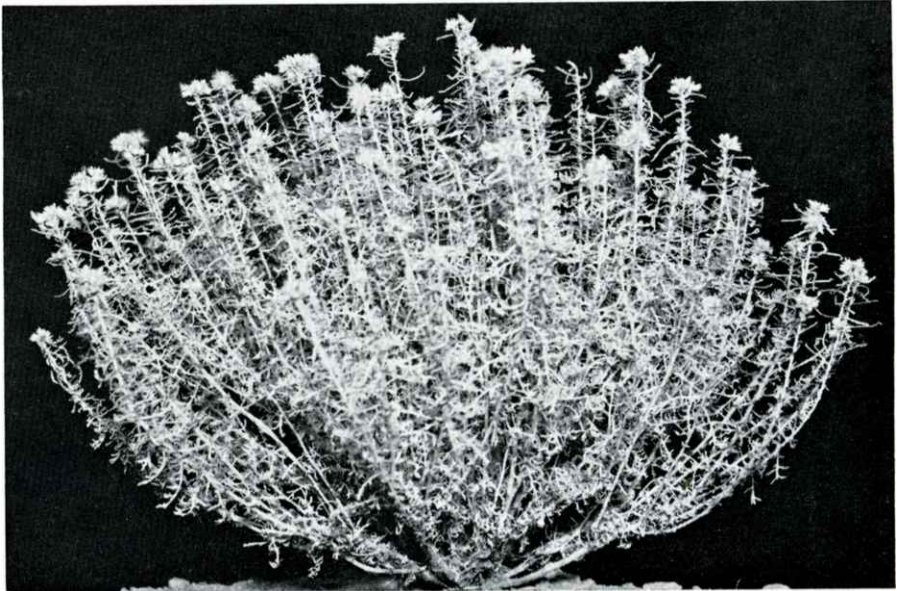


BURROWEED

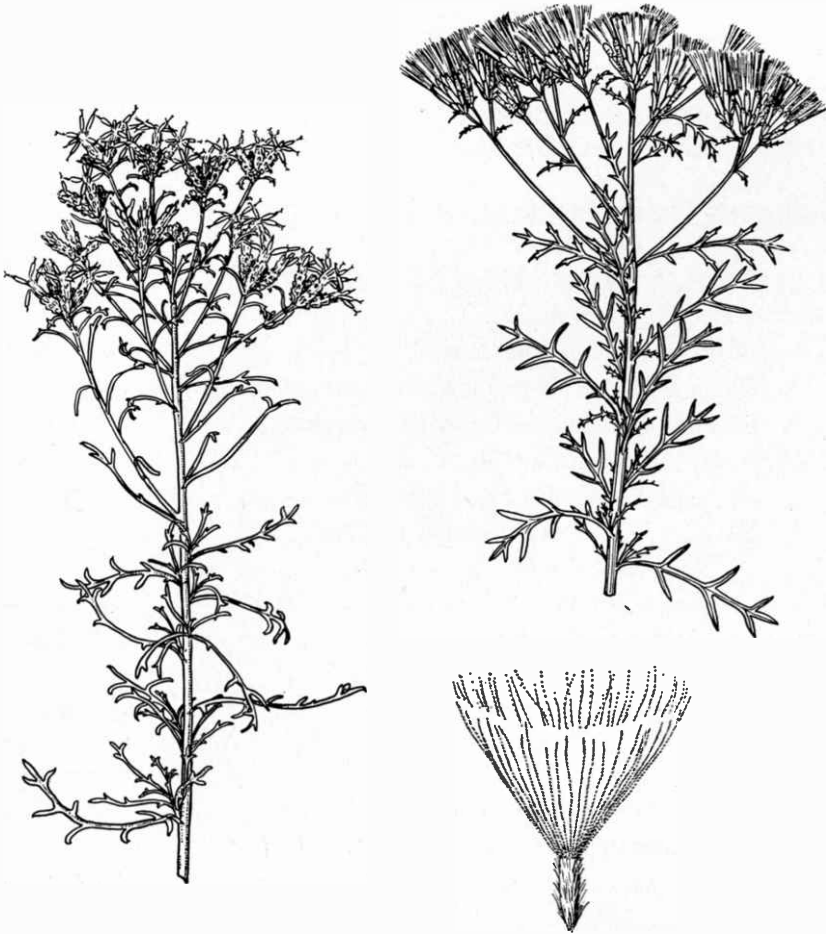


On Southern Arizona Range Lands

AGRICULTURAL EXPERIMENT STATION
THE UNIVERSITY OF ARIZONA, TUCSON
AND
U. S. DEPARTMENT OF AGRICULTURE
COOPERATING

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Burweed (Haplopappus tenuisectus) (X½)

At left, vegetative branch; right, above, flowering branch; below, seed

(Drawing by Lucretia Hamilton, taken from Arizona Agricultural Experiment Station Bulletin 302, "Forage Production on Arizona Ranges—V. Pima, Pinal and Santa Cruz Counties," by R. R. Humphrey)

BURROWEED¹

On Southern Arizona Range Lands

by

Fred H. Tschirley and S. Clark Martin²

The most valuable forage plants on southern Arizona ranges are perennial grasses. High grass production usually is associated with relatively pure grass stands, while low grass production is associated with brushy ranges. Some shrubs are valuable as browse plants, particularly in times of drouth, when their foliage and twigs are much higher in phosphorus and protein than the dry grass. However, many of the shrubs on southern Arizona ranges have little or no forage value. The presence of these woody plants on a range that is capable of supporting perennial grass is usually detrimental. One range weed that has received much attention is the perennial half-shrub burroweed (*Haplopappus tenuisectus* (Greene) Blake). The purpose of this bulletin is to assemble information on burroweed in southern Arizona and to appraise its importance.

Much of the research reported in this bulletin was conducted on the Santa Rita Experimental Range, 30 miles south of Tucson, Arizona. The investigations span almost 50 years and were made by many persons associated with the University of Arizona and the Forest Service and Agricultural Research Service of the U.S. Department of Agriculture.

TAXONOMY

Burroweed (*Haplopappus tenuisectus* (Greene) Blake), which is more often listed as *Aplopappus tenuisectus* (Greene) Blake, is a member of the aster tribe in the family Compositae. Cassini (9), who described the genus, omitted the initial *H*. Many taxonomists have believed that Cassini made an error in omitting the *H* so both forms have been widely used. Hall (17) enlisted the help of a philologist who stated ". . . Turning now to the mean-

¹ Contribution from the Crops Research Division, Agricultural Research Service, and Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, in cooperation with the Arizona Agricultural Experiment Station, Tucson, Arizona.

² Range Conservationists, Crops Research Division, Agricultural Research Service, and Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, respectively, Tucson, Arizona.

ings of the two compound words, we find that *Haplopappus* has a complete and intelligible meaning, namely, single or simple pappus-row; while *Aplopappus* makes mere nonsense . . ." The spelling was settled in 1950 by the adoption of *Haplopappus* as a *nomen conservandum* under the International Code of Botanical Nomenclature.

Burroweed is the accepted common name for the species *H. tenuisectus*. Other common names are rayless goldenrod, goldenweed, and rabbitbrush.

The genus to which burroweed belongs has many synonyms because many of the present species were originally placed in other genera (17). The more common of these older generic names are *Chrysoma*, *Ericameria*, *Isocoma*, *Macronema*, *Pyrocoma*, *Sideranthus*, *Stenotus*, and *Tonestus*. Except for the conserved spelling of *Haplopappus*, the taxonomy of Kearney and Peebles (21) is used in this publication.

LIFE HISTORY

GERMINATION

Burroweed seeds germinate during the cool winter-spring season if rainfall is adequate. Field germination tests during the summer rainy season have never been successful, and seedlings have never been observed on the range during this period. Humphrey (18) reported maximum germination where a cover of annuals or a light stand of perennial grasses resulted in the accumulation of some litter, but germination was reduced where much dead plant material was allowed to accumulate. Humphrey further stated that ". . . there is little or no germination on areas where erosion is so rapid as to prevent the establishment of a grass cover." Dense stands of burroweed seedlings are often found, however, where soil is deposited in miniature alluvial fans.

Voth (38) obtained 23 percent germination at a constant temperature of 41°, 46 percent at 68°, and 42 percent at 77°F. No extended dormant

Table 1. BURROWEED MORTALITY (Adapted from Humphrey, 1937)

Date	Mortality		Rainfall,
	By periods	Cumulative	by periods
	<i>Percent</i>	<i>Percent</i>	<i>Inches</i>
Apr. 4	0.0	0.0	0.00
Apr. 17	14.5	14.5	0.00
Apr. 30	23.2	37.7	0.04
May 16	31.4	69.1	0.00
June 1	14.8	83.9	0.25
June 16	9.5	93.4	0.00
July 3	2.8	96.2	0.52
July 16	0.5	96.7	0.32
Aug. 2	0.7	97.4	1.69
Aug. 16	0.4	97.8	3.53
Sept. 16	0.6	98.4	3.31
Oct. 24	0.3	98.7	0.92
Dec. 4	0.1	98.8	0.89
Jan. 3	0.4	99.2	4.03
May 27	0.0	99.2	5.14

period was necessary for germination. Tests made in the winter with seeds collected the previous October and November germinated without difficulty. Freezing for 6 or 24 hours did not increase germination.

YOUNG-PLANT DEVELOPMENT

Burroweed seedling mortality is high. Mortality was greatest during the dry spring period from April through June (Table 1). By the time the summer rains started in July, 96 percent of the seedlings had died. By late October mortality was 99 percent. Even so, several thousand plants per acre remained alive.

The most important aspect of seedling development is the rapid root growth compared with shoot growth. Plants 6 months old may be only 2 to 3 inches high, but the roots may have penetrated to a depth of 3 feet. The shoots of plants 18 months old averaged 5.5 inches, and roots were four feet long. A 2-year-old plant had a 7-inch shoot and a taproot 7.5 feet long. The rapid elongation of roots permits some plants to survive the critical spring drought.

MATURE PLANTS

The mature burroweed plant is a woody half-shrub, densely branched at the base. (See cover photo). The leaves are resinous and sticky, oblong or spatulate-oblong in outline with narrow, linear lobes extending from each side. The yellow flowers are borne in small, dense heads. The plants are usually one to two feet tall, but exceptionally large ones may exceed that height. During most of the year burroweed is grey-green but it becomes brighter green in September at the latter part of the summer rainy season and in January and February during the winter rains. Burroweed is readily distinguished from related species by the linear lobes on its leaves.

Burroweed reaches reproductive maturity at 18 to 24 months. Flowering begins in September and continues through October. Flowers set seeds that mature two to three weeks after the end of flowering. The seed has a simple pappus, which permits wind dissemination, but it is usually not blown very far since its weight is high in proportion to the amount of pappus. Consequently, seeds accumulate under the parent plant or under nearby shrubs and grasses.

The root system is principally a taproot, which has been traced to a depth of 18 feet. A few lateral roots are present in the upper few feet of soil, but they are much shorter than the taproot.

DISTRIBUTION

Burroweed is confined to the southwestern United States and Mexico. It is found mainly in Arizona south of the Gila River. Benson and Darrow (4) stated that burroweed was found in Arizona south of the Gila River, in extreme western New Mexico, in Texas along the Rio Grande and in the Big Bend Region; and also in the Mexican States of Sonora and Chihuahua. Norris (26) and collections of the senior author confirmed the New Mexico distribution. Gentry (13) did not find burroweed in Durango, Mexico, but collected it west of Fresnillo, Zacatecas. Gentry's work suggests that the major distribution of burroweed is in Mexico.

In southern Arizona burroweed is most commonly found on the alluvial plains of the desert and in the semidesert grassland. From 2,700 to 3,800 feet elevation, burroweed is often the dominant understory beneath velvet mesquite (*Prosopis juliflora* (Swartz) DC. var. *velutina* (Woot.) Sarg.),

where it is found growing with cholla and prickly pear cacti (*Opuntia* spp. Tourn.). The principal associated grasses are the gramas (*Bouteloua* spp. Lag.) and three-awns (*Aristida* spp. L.). Burroweed is less commonly associated with creosote bush (*Larrea tridentata* (D.C.) Coville) and four-wing saltbush (*Atriplex canescens* (Pursh.) Nutt.).

FACTORS LIMITING DISTRIBUTION

The limited geographic distribution of burroweed suggests that its ultimate spread is restricted by rigid limiting factors. The best documented information on factors affecting distribution and abundance of burroweed is that obtained from the Santa Rita Experimental Range 30 miles southeast of Tucson on a bajada with a high elevation of 4,300 feet at the southeast corner and a low elevation of 2,900 feet at the northwest corner. Surveys of the area in 1934 and 1954 (Mehrhoff, 24) plotted the distribution

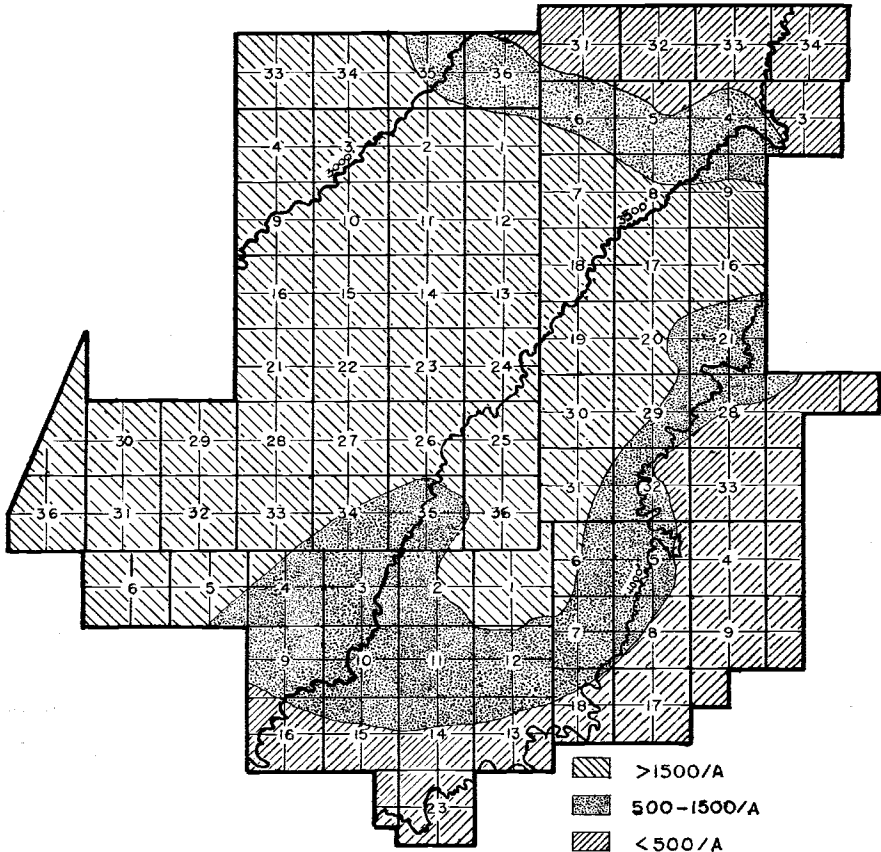


Figure 1—Distribution and abundance of burroweed on the Santa Rita Experimental Range in 1954 (Mehrhoff, 1955)

of burroweed and other vegetation. The 1954 distribution and abundance of burroweed on the experimental range are shown in Figure 1.

Since burroweed germinates during the cooler months, winter temperatures may play an important role in its distribution. Generally speaking, increasing elevation in southern Arizona is accompanied by decreasing temperatures and increasing precipitation. The effects of these influences are apparent in the number of burroweed plants per acre at different elevations on the Santa Rita Experimental Range.

Usually the densest infestation (more than 1,500 plants per acre) occurs below 3,800 feet. The intermediate infestation, ranging from 500 to 1,500 plants per acre, is found at 3,800 to 4,000 feet. The light infestation of less than 500 plants per acre was found at 4,000 to 5,000 feet. Very little burroweed is found above 5,000 feet in Arizona, but it is found near 6,000 feet in New Mexico. The altitudinal limit may mark the minimum temperature barrier for burroweed germination. Voth (38), for example, obtained only 23 percent germination at a constant temperature of 41°F, which suggests that the germination of burroweed is greatly reduced where daily minimum temperatures approach freezing in the winter. Such is usually the case at elevations of about 5,000 feet in southern Arizona. The lower elevational limit of burroweed distribution (about 2,000 feet) may simply coincide with the line beyond which burroweed will not grow because of lack of moisture.

Burroweed is found in areas receiving 9 to 20 inches of annual precipitation. It does not thrive in extremely arid locations where lack of moisture may limit either summer growth or germination during the winter. One possible explanation for the abundance of burroweed in southern Arizona and its limited distribution in New Mexico is the difference in winter moisture and temperature. Rainfall at the Santa Rita Experimental Range headquarters from November through February averages 5.76 inches. At Deming, New Mexico, average rainfall for the same period is only 1.95 inches. The rainfall difference, coupled with the temperature difference (January mean: experimental range headquarters 47.1°, Deming 41.6°F) may account for the more general distribution in southern Arizona than in New Mexico.

The effects of soil on burroweed have received only limited study. Unpublished data³ indicate that burroweed does best on neutral or slightly acid soils that are free of calcium deposits at least in the surface 6 to 12 inches. Heavy burroweed stands rarely occur on highly calcareous soils. The effects of soil on burroweed distribution are most striking on the northeast part of the Santa Rita Experimental Range where soil differences cut across precipitation and elevation lines (Fig. 1). At the extreme northeast corner a light infestation is found on soils of the Laveen and Pinal series which are characterized by highly calcareous surface soils. The adjacent intermediate infestation is found on soils of the Anthony series, which have calcareous subsoils. The heaviest infestation is on soils of the Comoro series, which are recent alluvial deposits characterized by being leached of lime and other salts.

³ Buehrer, T. F., J. E. Fletcher, C. B. Brown, and K. W. Parker.

POISONOUS PROPERTIES AND CHEMICAL COMPOSITION

The poisonous properties of burroweed are well substantiated despite confusion with jimmyweed (*Haplopappus heterophyllus* (A. Gray) Blake). In the early literature both plants were called "rayless goldenrod." According to Thornber (34, 35) burroweed was not definitely known to be poisonous, but it was the suspected cause of occasional livestock losses. A year later Thornber (36) reported that a rancher near Tucson lost 65 horses and 30 cows from burroweed poisoning. Many other cases have been reported since then (Voth (38) and Pistor⁴).

The affliction caused by burroweed poisoning has been called trembles, acidosis, and milk sickness. The name "trembles" is derived from the violent trembling of poisoned animals. Acidosis, coined by Couch (10), refers to the odor of acetone evident in the urine, breath, and blood of poisoned animals. Milk sickness refers to similar symptoms in humans, that become evident after drinking the milk of a poisoned animal.

Identical symptoms have been observed from poisoning by burroweed, jimmyweed, and richweed (*Eupatorium rugosum* Houtt.) The poisonous property was isolated first from richweed (11) and identified later in jimmyweed. It has the formula $C_{16}H_{22}O_3$ and is called tremetol.

The symptoms of burroweed poisoning start with a severe trembling followed by the animal falling—often with legs outstretched—and then being unable to rise. Several hours after trembling starts, sick animals begin to excrete large amounts of acetone. If burroweed poisoning is suspected, the animals should be fed hay, but should not be moved.⁴

All parts of the plant are poisonous, but the dried flowers are eaten most frequently. Since tremetol is cumulative, the animal does not have to eat large quantities at one time to develop symptoms of poisoning. A few bites a day, taken with grass, will build up to toxic proportions in time.

Buehrer et al. (7) give a chemical analysis of burroweed. Table 2 shows the percentage of various constituents in the leaves, stems, and roots. Resins and saponifiable oils are present in large amounts, but they have never been extracted for commercial use.

Table 2. CHEMICAL CONTENT (DRY WEIGHT BASIS) OF LEAVES, STEMS, AND ROOTS OF BURROWEED. (Buehrer et al., 1939)

Constituent	Chemical Composition			
	Leaves	Stems	Roots	Whole Plant
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Resins	24.90	4.77	1.25	7.92
Essential Oils	—	—	—	1.24
Rubber	2.48	1.88	0.10	1.56
Total nitrogen	1.72	1.00	0.87	—
Total protein (calc.)	10.75	6.25	5.44	6.94
Pentosans	7.98	14.56	15.51	13.48
Reducing sugars	1.05	0.44	1.25	0.52
Saponifiable oils (as olein)	—	3.80	1.86	6.86
Starch	5.62	3.88	2.04	3.23
Crude fiber	6.76	42.30	52.50	37.74
Ash	13.06	7.44	5.95	8.19

⁴ Pistor, Wm. J. Personal communication.

RELATIONSHIP TO THE GRAZING INDUSTRY

Burroweed is a potential problem wherever it occurs on rangeland. Usually it is eaten by livestock only when there is an extreme scarcity of other forage. However, it may be a problem even when sufficient grass is available, especially when livestock are moved from a pasture free of burroweed to one having a dense infestation.⁴

Nichol (25) rates burroweed as having zero palatability for mule deer, but evaluations have not been made for other game animals.

The invasion of rangelands by burroweed has concerned many people. Consequently, the response of burroweed to grazing and to various methods of control, as well as its relation to grass production, has been studied intensively.

No data are available on the value of burroweed for erosion control or its effect on water yield from a watershed. McGinnies and Arnold (23) reported that the water requirement of burroweed is about three times as great as that of the average perennial grasses. For erosion control, the long taproot characteristic of burroweed does not have the soil-holding capability of the fibrous root systems found in grasses. The high water requirement and poor soil-holding capability indicate that it is not a desirable plant on watersheds.

INVASION OF GRASSLAND

Burroweed almost certainly occupies a larger area today than it did 60 years ago; however, reliable data on the spread of burroweed over the years are fragmentary. In 1901 Griffiths (14) wrote that drought and heavy stocking had destroyed the ranges and that mesquite was increasing, but he did not mention burroweed. Soon after, in 1905 (15), he wrote regarding the abundance of burroweed in the Santa Cruz and Altar valleys. Other early reports (16, 32, 33, 39) also expressed concern about the spread of burroweed.

The rapid increase of burroweed in the late 20's caused great concern among ranchers, range administrators, and range ecologists (22). As a result, 12 million acres in southeastern Arizona were surveyed (37). Burroweed was found on 5.5 million acres of the area surveyed. Light, medium, and heavy infestations were classified on the basis of numbers of plants (Table 3, Fig. 2).

The literature contains many references to burroweed on the Santa Rita Experimental Range. A photograph taken in 1903 at an elevation of about 3,250 feet shows a moderate stand of burroweed. Griffiths (15, 16) stated that much of the northwestern part of the experimental range was badly infested with burroweed, that invasion undoubtedly had begun before the range was fenced in 1903, but that it had increased and thickened perceptibly during the 6-year period ending in 1909. Thornber (33) said that "rayless goldenrod" was generally abundant below 3,500 feet. The publications of Griffiths and Thornber do not mention burroweed at elevations above about 3,500 feet, and burroweed is not conspicuous in photographs taken about 1920 at elevations above 3,500 feet (Fig. 3). Many of the same locations show dense stands of burroweed 15 years later. Since 1935, burroweed numbers have declined in many of these same areas. Studies by Humphrey and Mehrhoff (19) indicate that burroweed was present to some extent over the entire range in 1934, and that comparatively little change in the abundance or distribution of burroweed occurred on the Santa Rita from 1934 to 1954.

These documented changes in burroweed numbers raise at least three questions: (1) What factor or factors kept the intermediate elevations free of burroweed prior to 1920? (2) Why did burroweed spread so rapidly from 1920 to 1935? (3) Why have the density and vigor of burroweed stands declined since the mid-thirties? Available records do not adequately answer any of these questions.

Table 3.—ABUNDANCE OF BURROWEED IN SOUTHEASTERN ARIZONA IN 1936
(Upson et al., 1937)

Stand Classification	Area Infested	
	Acres	Percent
Heavy (1500+)	703,000	5.9
Medium (500-1500)	761,000	6.4
Light (0-500)	4,030,000	33.4
Total	5,494,000	45.7

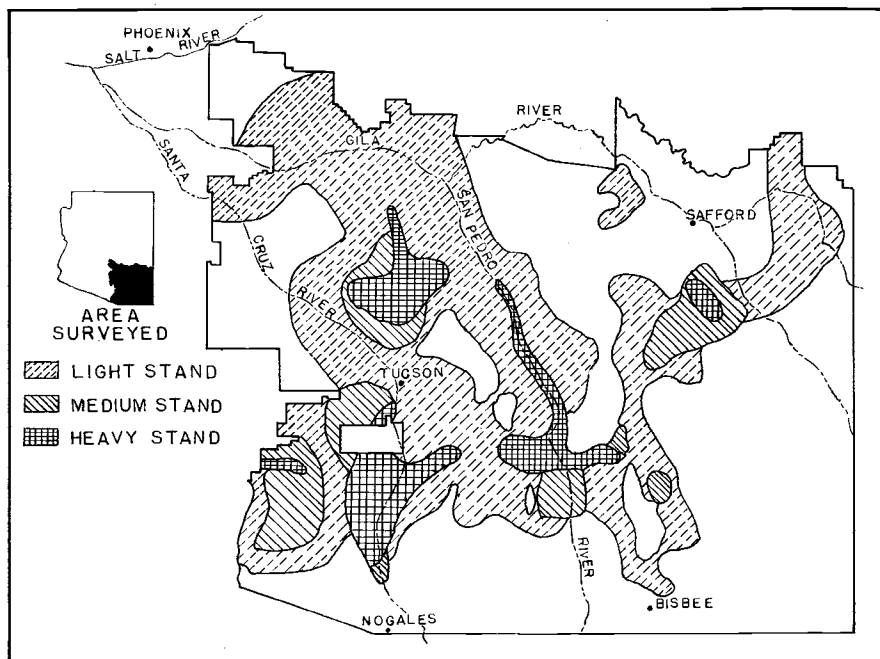


Figure 2—Degree of burroweed infestation in southeastern Arizona in 1936.
(Upson et al., 1937)

Cessation of range fires and continuous heavy grazing are common explanations for the spread of burroweed. At the time the range was fenced in 1903, the transition between the relatively brush-free grass range and the brushy range was at an elevation of about 3,500 feet (15). The absence of brush above this line was attributed to recurrent fires by Griffiths (15), who felt that the range below 3,500 feet normally produced too little herbage to carry a fire. Results presented below and on pages 26 and 27 in this report show that burroweed is relatively scarce in well-grassed enclosures and that summer fires will kill burroweed. However, the record does not show how often fires swept over the Santa Rita Experimental Range prior to 1903. Actual grazing use is not known, but the experimental range is believed to have been heavily stocked during the years before fencing.

Changes in the amount and distribution of rainfall may also be partly responsible for changes in burroweed numbers. Climatic records for southern Arizona show that above-average winter precipitation in 1904 and 1925 was followed by extremely high spring rainfall. Both years were preceded and followed by summers of average precipitation. The high winter-spring rainfall of 1904 and 1925 appears to have been especially favorable for the germination and establishment of burroweed. Heavy stands of burroweed may have become established in these periods and caused much of the concern expressed by writers in the early 1900's and in the 1930's.

Continuous heavy grazing, absence of fire, and high winter-spring precipitation appear to favor the establishment of burroweed, while light to moderate grazing, periodic burning, and low cool-season precipitation have the opposite effect.

The question of whether a good stand of perennial grasses will prevent or slow down the invasion of burroweed has been raised often. A study conducted on the Santa Rita Experimental Range offers at least a partial answer to the question. Native perennial grasses were transplanted immediately adjacent to mature burroweed plants. The five native species were (1) bush muhly (*Muhlenbergia porteri* Scribn.), (2) Arizona cottontop (*Trichachne californica* (Benth.) Chase), (3) tanglehead (*Heteropogon contortus* (L.) Beauv. ex Roem. & Schult.), (4) alkali sacaton (*Sporobolus airoides* (Torr.), and (5) perennial three-awn species. Plants were set out in two areas, one of which was protected from cattle grazing and the other from both cattle and rabbits.

Survival of perennial grasses in this study showed that Arizona cottontop was the easiest to establish in the presence of burroweed and that bush muhly was most difficult (Table 4). Whether the variation in survival among species is the result of differences in burroweed tolerance or simply of differences in the abilities of the different species to survive transplanting is not answered by this study. However, mortality rates for Arizona cottontop and alkali sacaton from October 1935 to August 1939 suggest that the former species is better able to live with burroweed. Combining the data for both degrees of protection shows that alkali sacaton lost almost two-thirds of its initial stand during this period, whereas the decline in Arizona cottontop was only 23 percent. Protection from livestock and rabbits had no apparent effect on the survival of transplanted grasses.

Competition between the surviving grass transplants and adjacent burroweed plants was also observed during the study (Table 5). When first observed, in 1937, the percentage mortality of burroweed plants with adjacent living grass clumps (15.7 percent) and burroweed plants without this immediate competition (14.1 percent) was not significantly dif-

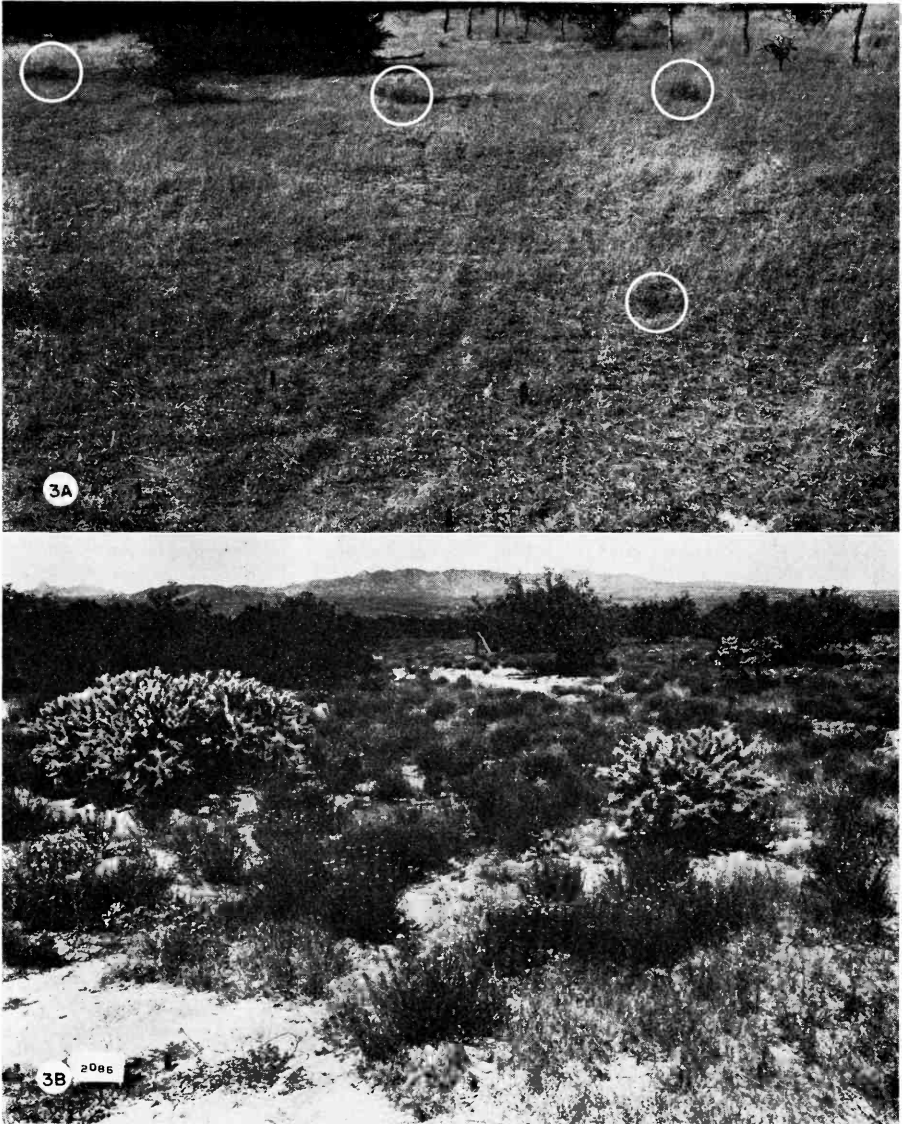
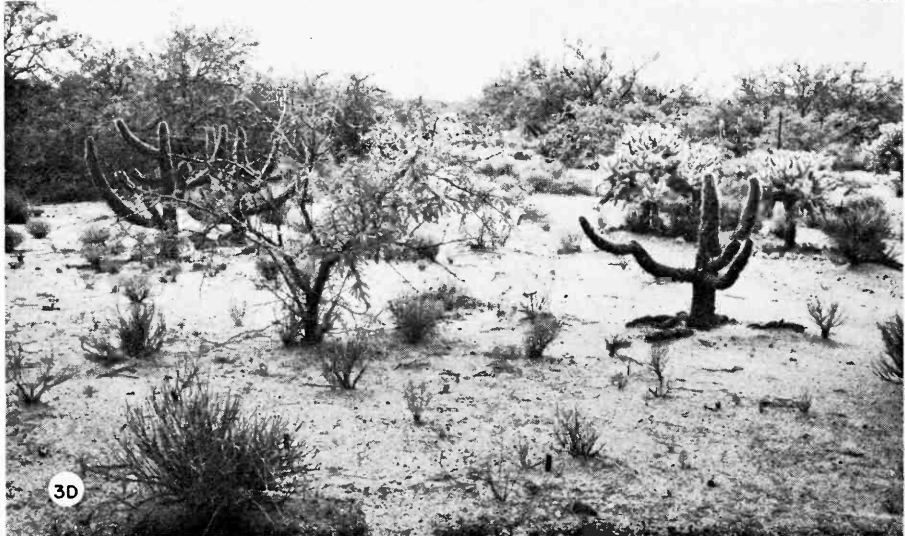
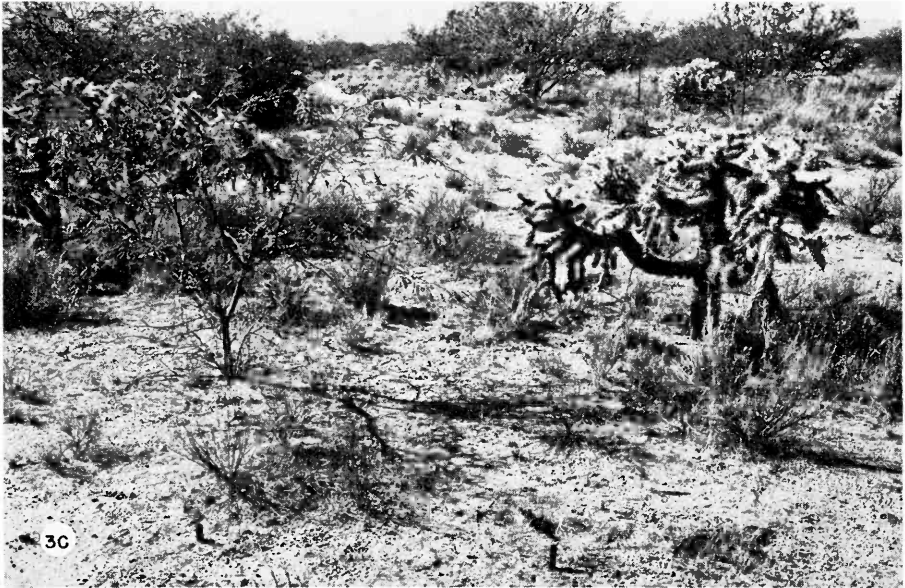


Figure 3.—Changes in burweed numbers from 1922 to 1958. A, 1922, only a few small burweed plants (circled) present; B, 1935, dense



burrowweed stand; C, 1947, and D, 1958, Burrowweed numbers declining.

Table 4.—SURVIVAL OF PERENNIAL GRASSES TRANSPLANTED ADJACENT TO BURROWEED PLANTS

Degree of protection	Species	Planted July 1935	Survival October 1935	Survival August 1939
		<i>Number</i>	<i>Percent</i>	<i>Percent</i>
Year-long protection from livestock and rabbits	Bush muhly	189	0.5	0.5
	Perennial three-awns	248	10.9	8.9
	Arizona cottontop	188	69.1	50.0
	Tanglehead	195	5.6	3.1
	Alkali sacaton	196	15.8	6.1
Total		1,016	19.7	13.3
Year-long protection from livestock	Bush muhly	342	2.0	0.3
	Perennial three-awns	348	7.2	6.6
	Arizona cottontop	509	50.5	42.2
	Tanglehead	317	9.1	3.5
	Alkali sacaton	436	20.4	6.9
Total		1,952	20.8	14.3
Total both areas		2,968	20.4	14.0

Table 5.—MORTALITY OF BURROWEED PLANTS ADJACENT TO GRASS TRANSPLANTS

Degree of protection	Species	Observed October 18, 1937		Observed August 3, 1939	
		Burroweed Plants	Dead	Burroweed Plants	Dead
		<i>Number</i>	<i>Percent</i>	<i>Number</i>	<i>Percent</i>
Year-long protection from livestock and rabbits	Bush muhly	1	0.0	1	100.0
	Perennial three-awns	23	0.0	22	63.6
	Arizona cottontop	106	9.4	94	36.2
	Tanglehead	5	0.0	6	50.0
	Alkali sacaton	16	18.8	12	41.7
Total		151	8.6	135	42.2
Year-long protection from livestock	Bush muhly	7	0.0	1	100.0
	Perennial three-awns	25	40.0	23	73.9
	Arizona cottontop	221	19.0	215	46.0
	Tanglehead	15	13.3	11	54.5
	Alkali sacaton	70	14.3	30	63.3
Total		338	18.9	280	50.7
Total all species in both areas		489	15.7	415	47.9
Check: no grass		149	14.1	180	34.4

ferent. However, two years later competition from the grasses had become more evident, causing 47.9 percent death loss of burroweed as compared with 34.4 percent mortality when there was no competition from grass transplants. These differences are significant at the one percent level as tested by Chi square. These data add some support to the general observations on the effects of grass on burroweed. Many old exclosures having good stands of such grasses as black grama, bush muhly, and Arizona cottontop have only a few burroweed plants. However, burroweed is long-lived and well adapted to its present range. Consequently, any change from burroweed to grass through competition alone is likely to be slow.

RESPONSES TO GRAZING AND CONTROL

The effect of grazing on the competitive relationships between burroweed and native grasses has been studied intensively. In this study replicate blocks designated as Area 130 and Area 131 were established at elevations of 3,800 feet and 3,500 feet, respectively. Both areas slope gently downward from southeast to northwest, and are similar with respect to vegetation and climate. Soils at Area 130 are classified as Whitehouse coarse sandy loam and those at 131 as Sonoita sandy loam. The areas were desert grassland invaded by mesquite and burroweed. The vegetation consisted of a sparse mesquite overstory, a relatively uniform cover of burroweed, and a sparse stand of perennial grasses. Annual rainfall averaged 13.12 inches at Area 130 and 12.42 inches at Area 131 over a 17-year period. However, in 5 years of the 17 more rain fell at Area 131 than at Area 130.

The basal intercepts of perennial grasses at the beginning of the study, as measured by the line interception method (8), were 1.43 and 0.34 percent respectively, for Areas 130 and 131. Respective crown intercepts of burroweed were 5.58 and 7.07 percent.

The experimental design for the study was a split plot having four grazing systems in major plots and eight burroweed control treatments in minor plots. Grazing systems included total protection from livestock and rabbits, exclusion of cattle year-long, seasonal exclusion of cattle, July 1 to November 1, and no exclusion. The sizes of major plots varied from 2.5 to 10 acres. Minor plots were 0.1 acre, 33 x 132 feet, bordered on all sides by an 8.5-foot isolation strip. Each minor plot was subdivided into eight 16.5- x 33-foot strata for sampling convenience as shown in Figure 4. Two 33-foot transects were located at random in each of the eight strata each time a measurement was made.

Burroweed control treatments applied to the eight minor plots were: (1) none, check, (2) seeding with rothrock grama (*Bouteloua rothrockii* Vasey), (3) burning, (4) burning followed by seeding with rothrock grama, (5) grubbing, (6) grubbing followed by seeding with rothrock grama, (7) spraying with a 15 percent aqueous solution of sodium chlorate, and (8) spraying as in (7) followed by seeding with rothrock grama.

Treatments were made in 1938. The first post-treatment measurements were made in 1939, and subsequent measurements in 1941, 1947, and 1949.

Changes in Burroweed Crown Intercept

Burroweed crown intercept changed as plots were reinvaded after the control treatments (Table 6). Post-treatment intercepts were lower in 1939 and 1941 than the pre-treatment intercept in 1938, but recovery was virtually complete by 1947. Reinvansion was most rapid from 1939 to 1941.

This may be explained in part by better-than-average rainfall beginning with the summer of 1940 and continuing through the winter and spring of 1940-41.

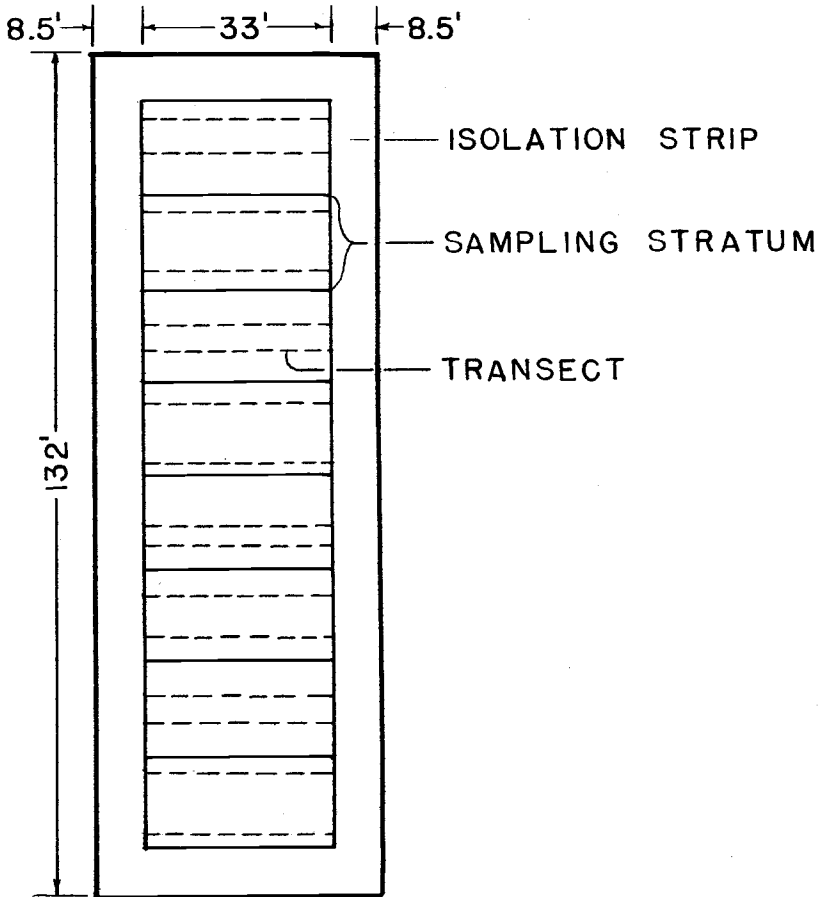


Figure 4.—Minor plot showing sampling details.

Burroweed intercept decreased progressively with increased levels of protection but the differences were not significant. Increases from 1941 to 1949 were negligible except for the area open to year-long grazing.

Burning and grubbing were equally effective from the standpoint of initial control and subsequent reinvasion (Table 6). Burroweed intercept was reduced 100 percent by burning and almost as much by grubbing. Only a token reinvasion had occurred by 1941, but by 1947 burroweed intercept on burned and grubbed plots was 52 and 68 percent, respectively, of the check treatment and 38 and 48 percent of the 1938 intercept.

Spraying with sodium chlorate reduced the burroweed intercept in the first year, but recovery and re-establishment were very rapid. About 50 percent of the burroweed plants were killed with sodium chlorate and the space occupied by them was soon invaded by seedlings. Seeding with rothrock grama had no influence on the effectiveness of any control method.

Changes in Perennial Grass Basal Intercept

An inverse relationship between the basal intercept of perennial grasses and the level of use is apparent (Fig. 5). However, the differences among means for grazing treatments are not significant at the five percent level and only comparisons between yearlong grazing by both cattle and rabbits and other grazing treatments were significant at the 10 percent level of probability.

Generally speaking, the highest grass intercepts occurred under total protection from grazing on plots burned or grubbed. Seeding increased the grass intercept significantly only on the grubbed plots under exclusion of cattle.

Table 6.—GROUND COVER OF BURROWEED AS MEASURED BY CROWN INTERCEPT BEFORE (1938) AND AFTER INDICATED TREATMENTS

Treatments	1938	1939	1941	1947	1949	Mean ⁵
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
None (check)	6.45	2.91	8.57	5.19	6.15	5.70 _{ab}
Seeding ⁶	5.97	2.73	8.98	7.35	6.34	6.35 _a
Burning	7.08	0	.02	2.70	2.72	1.36
Burning and seeding	7.21	0	.02	3.36	4.18	1.89
Grubbing	7.24	.05	.57	3.51	4.13	2.07
Grubbing and seeding	5.47	.02	.15	3.24	3.59	1.75
Sodium chlorate ⁷	5.95	.87	5.04	7.84	7.55	5.32 _{bc}
Sodium chlorate and seeding	5.97	.75	5.26	6.28	7.23	4.88 _c
Mean ⁵	6.42 _a	.92	3.57	4.93 _a	5.24 _a	—

⁵ Any two means with no subscript or with one or more subscript letters in common are not significantly different. Any two means not having subscript letters in common are significantly different at the 5 percent level.

⁶ Rothrock grama

⁷ 15 percent aqueous solution

From the standpoint of determining the effect of burroweed on grass intercept, the results of this study were inconclusive. No correlation could be established between crown intercept of burroweed and basal intercept of perennial grasses, although overall averages show the heaviest final grass intercept on areas where the burroweed control treatment was most effective. The interaction between grazing systems and burroweed treatments as they affected final grass intercept may be of most importance. Burning gave marked increases in grass intercept only on plots protected from both

cattle and rabbits and grubbing increased grass intercept markedly only on plots protected from cattle or protected from both cattle and rabbits. Neither control method increased grass production under yearlong grazing or under protection from cattle during the summer. The logical conclusion is that no real benefits may be expected from burweed control unless it is followed by protection from grazing.

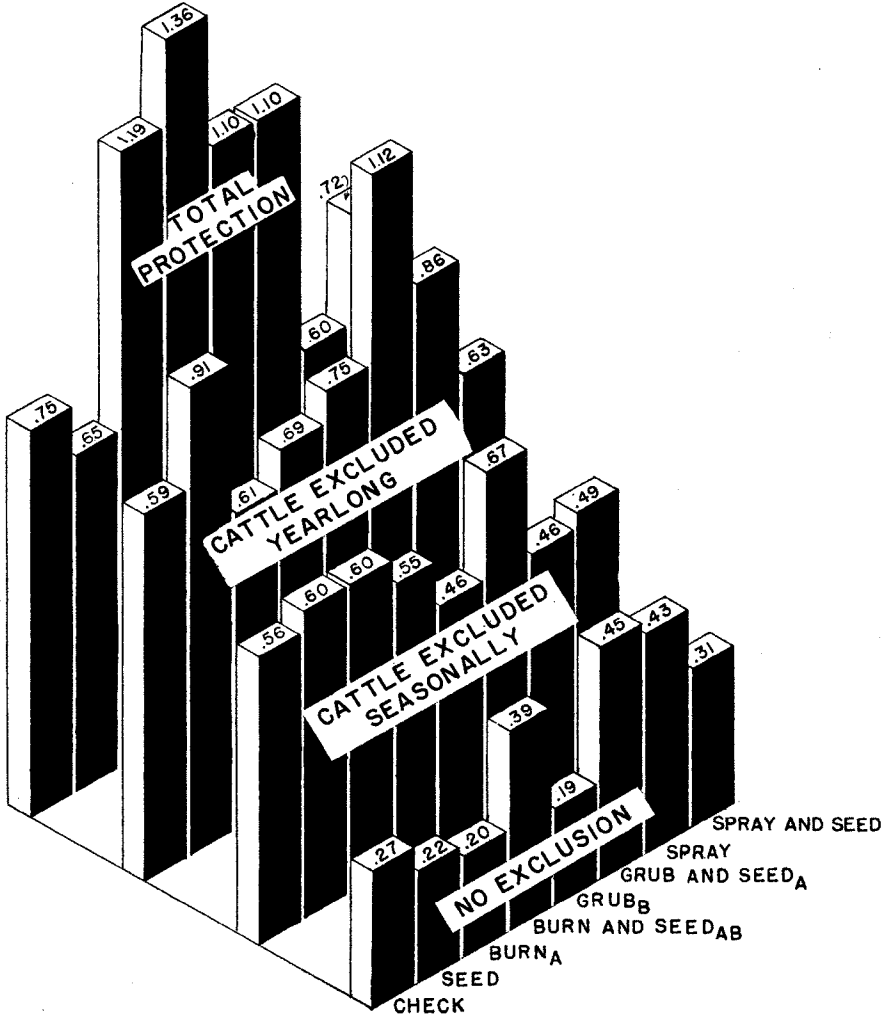


Figure 5.—Effects of grazing systems and burweed control treatments on basal intercept of perennial grasses. Subscript letters indicate significance. Refer to footnote No. 5.

EFFECTS ON FORAGE PRODUCTION

Another study in which the effects of burroweed control were studied involved controlling: (1) burroweed, (2) mesquite, (3) burroweed and mesquite, and (4) neither (check). The four treatments were applied in 1940 on 1-acre plots in a 4 x 4 Latin square. The plots were sampled each year from 1941 through 1949 and in 1951 to determine the herbage yield of annual and perennial grasses. The unfenced study area was about one mile from stock water in a pasture grazed yearlong by cattle. Early results of this study were reported by Parker and Martin (29).

Herbage Yields of Annual Grasses

The principal annual grasses in southern Arizona are needle grama (*Bouteloua aristidoides* (H.B.K.) Griseb.) and six-weeks three-awn (*Aristida adscensionis* L.). Both species complete their life cycle within several weeks after the summer rains start. They are shallow-rooted and receive most of their moisture from the surface four to six inches of soil. These annuals are not dependable forage, but they are important in providing litter, which reduces the erosion hazard and can potentially improve soil-fertility and soil-moisture relationships.

The herbage production of annual grasses is highly dependent on rainfall as shown in Table 7. Production on all plots was low in drought years, but high in years with favorable rainfall on plots that had both mesquite and burroweed controlled. Burroweed did not compete as much with annual grasses as did mesquite. Compared to the check plot the mean annual grass production for the 10 years of measurement was three times as great where only burroweed was controlled, seven times where only mesquite was controlled, and 12 times where both burroweed and mesquite were controlled.

Table 7.—TOTAL HERBAGE YIELD (DRY WEIGHT) PER ACRE
OF ANNUAL GRASSES IN RELATION TO CONTROL
OF MESQUITE AND BURROWEED

Year	Rainfall	No shrub control	Burroweed control	Mesquite control	Mesquite and burroweed control
	<i>Inches</i>	<i>Lb./A</i>	<i>Lb./A</i>	<i>Lb./A</i>	<i>Lb./A</i>
1941	9.08	10	35	109	189
1942	5.76	T	T	7	10
1943	8.08	17	62	199	279
1944	6.97	T	2	23	72
1945	8.66	6	34	90	145
1946	10.80	124	329	322	650
1947	4.86	1	5	8	15
1948	6.50	7	20	53	59
1949	9.04	11	97	371	695
1951	6.95	1	2	89	107
Mean		17.7	58.6	127.1	222.1

Table 8.—HERBAGE YIELD (DRY WEIGHT) OF SEVERAL PERENNIAL GRASSES UNDER FOUR CONDITIONS OF SHRUB REMOVAL

Species and Treatment	1941	1942	1943	1944	1945	1946	1947	1948	1949	1951	Mean
	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A	Lb./A
Rothrock grama											
No shrub control	70.9	7.2	11.2	49.4	21.2	67.8	17.0	20.8	0.3	21.1	28.7
Burroweed control	141.0	5.0	27.3	29.0	14.4	24.8	8.8	7.4	0.8	1.0	26.0
Mesquite control	150.1	41.9	143.7	337.4	132.4	277.6	62.3	98.9	19.8	192.0	145.6
Burroweed, mesquite control	175.0	26.8	116.3	194.4	90.1	117.4	48.6	38.1	11.0	90.8	90.8
Black grama											
No shrub control	19.0	10.6	17.4	26.9	48.0	23.1	11.8	14.5	7.2	17.0	19.6
Burroweed control	88.9	7.6	10.7	13.6	12.9	15.0	1.0	0.8	1.4	10.0	15.2
Mesquite control	43.5	16.7	32.1	48.0	20.2	51.8	19.8	31.4	22.0	29.1	31.5
Burroweed, mesquite control	8.9	2.4	7.1	22.1	6.6	11.8	6.8	5.3	0.8	0.8	7.3
Arizona cottontop											
No shrub control	3.5	17.7	7.3	68.1	126.0	139.2	52.1	63.9	23.7	19.8	52.1
Burroweed control	38.8	3.3	7.4	13.0	100.4	84.5	25.8	21.7	13.2	13.8	32.2
Mesquite control	6.2	8.3	7.4	62.8	119.0	134.5	52.5	83.3	10.0	76.7	56.1
Burroweed, mesquite control	82.2	14.2	24.9	40.3	134.0	95.8	69.5	54.5	44.1	54.6	61.4
Three-awns											
No shrub control	15.4	17.3	8.1	54.4	33.6	67.8	6.5	6.9	3.9	12.3	22.6
Burroweed control	80.8	19.0	20.5	25.3	52.0	46.0	13.0	11.6	2.2	7.3	27.8
Mesquite control	45.7	11.1	17.5	71.8	32.6	98.5	32.7	50.8	39.2	97.8	49.8
Burroweed, mesquite control	82.6	9.3	16.6	46.5	29.3	44.1	11.3	13.9	12.9	41.0	30.8
Other											
No shrub control	3.1	1.1	1.0	5.1	4.2	2.1	0.6	1.8	0.0	0.1	1.9
Burroweed control	0.4	0.1	0.1	0.1	0.2	10.7	1.4	0.5	0.0	0.0	1.4
Mesquite control	26.4	0.9	0.2	7.9	21.8	0.6	4.8	8.7	0.0	0.0	7.1
Burroweed, mesquite control	39.2	5.2	6.0	21.8	27.0	57.9	20.7	11.2	5.5	0.1	19.5
Total											
No shrub control	111.9	53.9	45.0	203.9	233.0	300.0	88.0	107.9	35.1	70.3	124.9
Burroweed control	349.9	35.0	66.0	81.0	179.9	181.0	50.0	42.0	17.6	22.1	102.6
Mesquite control	271.9	78.9	200.9	527.9	326.0	563.0	172.1	273.1	91.0	366.5	290.1
Burroweed, mesquite control	387.9	57.9	170.9	325.1	287.0	327.0	156.9	123.0	74.3	187.3	209.7

Herbage Yields of Perennial Grasses

The perennial grasses were segregated by species to determine possible species differences in response to control of burroweed, mesquite, and both. Rothrock grama, black grama (*B. eriopoda* (Torr.) Torr.), and Arizona cottontop were studied individually (Table 8). Perennial three-awns were grouped together as were other perennial grasses that occurred infrequently.

Rothrock grama.—Rothrock grama is a short-lived perennial with an average life span of about two years. It is very responsive to rainfall fluctuations and to the removal of competing vegetation. Herbage production on the check plot was markedly reduced by the drought in 1942. Production increased in several years of the study, but showed a net decrease over the period of record on the plots where neither burroweed nor mesquite was removed.

The response on plots where only burroweed was controlled closely paralleled the check plot. Herbage production dropped precipitously in 1942 and never regained the 1941 level of production. The 10-year mean is slightly, but not significantly, lower than that of the check plot.

Rothrock grama reacted in an entirely different manner on plots where mesquite was controlled. Herbage production was reduced as a result of drought, but not so markedly as on plots where mesquite was not controlled. Recovery after drought was greater and mean herbage production exceeded that of the check area by four times.

Herbage production on plots where both burroweed and mesquite were controlled was intermediate between that on plots where burroweed only was controlled and that on plots where mesquite only was controlled. This apparent paradox may be explained in part by the fact that the perennial grasses were almost always grazed more closely on plots where both burroweed and mesquite were controlled than on plots where only the mesquite was controlled. There was greater production of annual grasses which used some of the available moisture and nutrients. Also perennial grasses frequently grow up within the crowns of burroweed plants. When this happens, the grasses are protected from grazing, but are still recorded in vegetation measurements. Since burroweed protects grasses from grazing, higher production is to be expected where only mesquite is controlled than where both burroweed and mesquite are controlled.

Black grama.—In 1941 the yield of black grama was greatest on the burroweed control plots, second on the mesquite control plots, and lowest where both mesquite and burroweed were killed. Ten years later the yield of black grama was highest on the mesquite control plots, second on the checks, and lowest on the burroweed control plots. This striking decline in herbage production where burroweed was controlled was accompanied by a much less pronounced decline where both mesquite and burroweed were killed. Black grama remained constant during the study period on the check plots and dropped only about one-fourth in herbage production under mesquite control. As in the case of rothrock grama, removal of burroweed subjected black grama to some detrimental influence, probably that of heavy grazing.

Arizona cottontop.—Arizona cottontop was the only species that gave the highest herbage production where both burroweed and mesquite were controlled. This production was not appreciably higher than that resulting from mesquite control alone, however. Controlling only the burroweed resulted in the lowest production, approximately 38 percent below that on the check area.

Three-awns.—The highest production of perennial three-awns resulted from mesquite control. The check area and the other two treatments were not significantly different.

All perennial grasses.—The highest total perennial grass herbage production occurred where only the mesquite was controlled, followed by the areas where both mesquite and burroweed were controlled. The check area where no shrubs were controlled was third, while the areas where only burroweed was controlled produced the least perennial grass herbage.

Total herbage production, annuals and perennials combined, averaged slightly higher on the burroweed-free plots than on the check area, and higher on the plots cleared of both burroweed and mesquite than on plots cleared of mesquite alone. Thus, the decline in perennial grasses, which was associated with burroweed control, was made up in quantity at least by increased production of annuals. The question arises then whether the decline in perennial grass intercept and yield is due to the burroweed control directly or to some associated influence. Destruction of perennial grasses in the process of grubbing burroweed apparently had little effect on grass production because the yields in 1941, only one year after grubbing, were highest on the grubbed plots. Since it does not seem logical to assume that burroweed and perennial grasses do not compete, an associated factor such as grazing pressure is suspected.

As discussed earlier, burning and grubbing resulted in grass intercept increases only under protection from grazing. In this study heavier grazing was consistently recorded on plots where the burroweed had been removed. Furthermore, most of the perennial grasses on a heavily grazed grass-shrub range are found within the protection offered by burroweed and other shrubs. So it is suspected that grazing by cattle and rabbits had more to do with the decrease in perennial grasses on burroweed-free plots than did the removal of the burroweed. If this is true, then burroweed control as a range improvement practice cannot be recommended unless the area receives adequate protection from grazing. Otherwise, removing the burroweed from a heavily grazed range so that the few remaining perennial grasses are no longer protected by burroweed crowns is almost sure to do more harm than good.

CONTROL

Efforts to control burroweed have included many tests of mechanical and chemical methods, burning, biological control possibilities, and chemical analysis of the plant itself to determine when it might be most susceptible. All this work was predicated on the assumption that burroweed control would be economically justified on the basis of increased forage production or decreased livestock losses. Two reports in 1938 (1, 12) summarized methods of burroweed control. Since then much additional effort has been expended on burroweed control methods.

RELATION OF CARBOHYDRATE STORAGE TO CONTROL

Maximum susceptibility to control in many plants occurs when stored food reserves are at or near the annual minimum. Stevenson (31) found that the total carbohydrate reserves in the roots and woody part of the burroweed stems decreased markedly during the flowering season as a result of starch depletion. Sucrose increased in all plant fractions through the period of flower-bud formation, but decreased rapidly thereafter. Reducing sugars remained virtually constant throughout the flowering period.

In a study conducted by the Botany Department of the University of Arizona from October 21, 1943, to September 21, 1944, samples of burroweed were collected and analyzed for reducing sugars, sucrose, starch, and total carbohydrates (Fig. 6). Sampling dates coincided with the dates of burning, grubbing and mowing for which results are presented in Figures 8 to 10. Samples were collected at random from a uniform stand of burroweed on the Santa Rita Experimental Range at monthly intervals from October 21, 1943, to September 21, 1944. Duplicate samples were taken, each sample containing 20 plants. Plants were brought into the laboratory and separated into the following fractions:

1. Root: 2 to 12 inches of the tap root and the associated laterals.
2. Root crown: Approximately 2 inches above and 2 inches below the ground line.
3. Old shoots: Woody stems of previous years' growth down to the root crown.
4. New shoots: Current growth from October 1943 to April 1944 for 1943 shoots, and from April to September for 1944 shoots.

After separation, the root and root crown fractions were washed and shredded. The old shoots were separated from the new shoots without washing. The plant material was dried in a quick-drying oven for 30 minutes and then placed in a forced-draft oven. The samples were ground in a 200-mesh Wiley mill and stored in air-tight containers for subsequent analysis.

Total carbohydrates throughout the year were highest in new shoots followed in order by old shoots, roots, and crown (Fig. 6). Seasonal change in total carbohydrates was greatest in the roots. Total carbohydrate content of the roots was highest in fall and winter and relatively low during late spring and summer, reaching an extreme low in late August.

Marked differences were found in the composition of the total carbohydrate among the different plant fractions. The new shoots, for example, were high in reducing sugars and in starch, but relatively low in sucrose throughout the year. The old shoots had about equal amounts of reducing sugar, sucrose, and starch. The same was true of the burroweed crowns. The roots differed from other parts of the plant in having a high sucrose content during the winter and approximately equal amounts of sucrose, reducing sugars, and starch from February through August. The total carbohydrate content of the roots was highest during the cool winter, when control measures were least effective.

BIOLOGICAL CONTROL

Burroweed has some natural enemies. Humphrey (18) listed two species of grasshopper (*Taenapoda eques* (Burm.) and *Hesperotettix viridis viridis* (Thomas)) that feed on burroweed leaves in the summer, but apparently they do not seriously harm the plants. Voth (38) reported that the larvae of the moth *Thiodia stramineana* Wlsh. feed on flowers of burro-

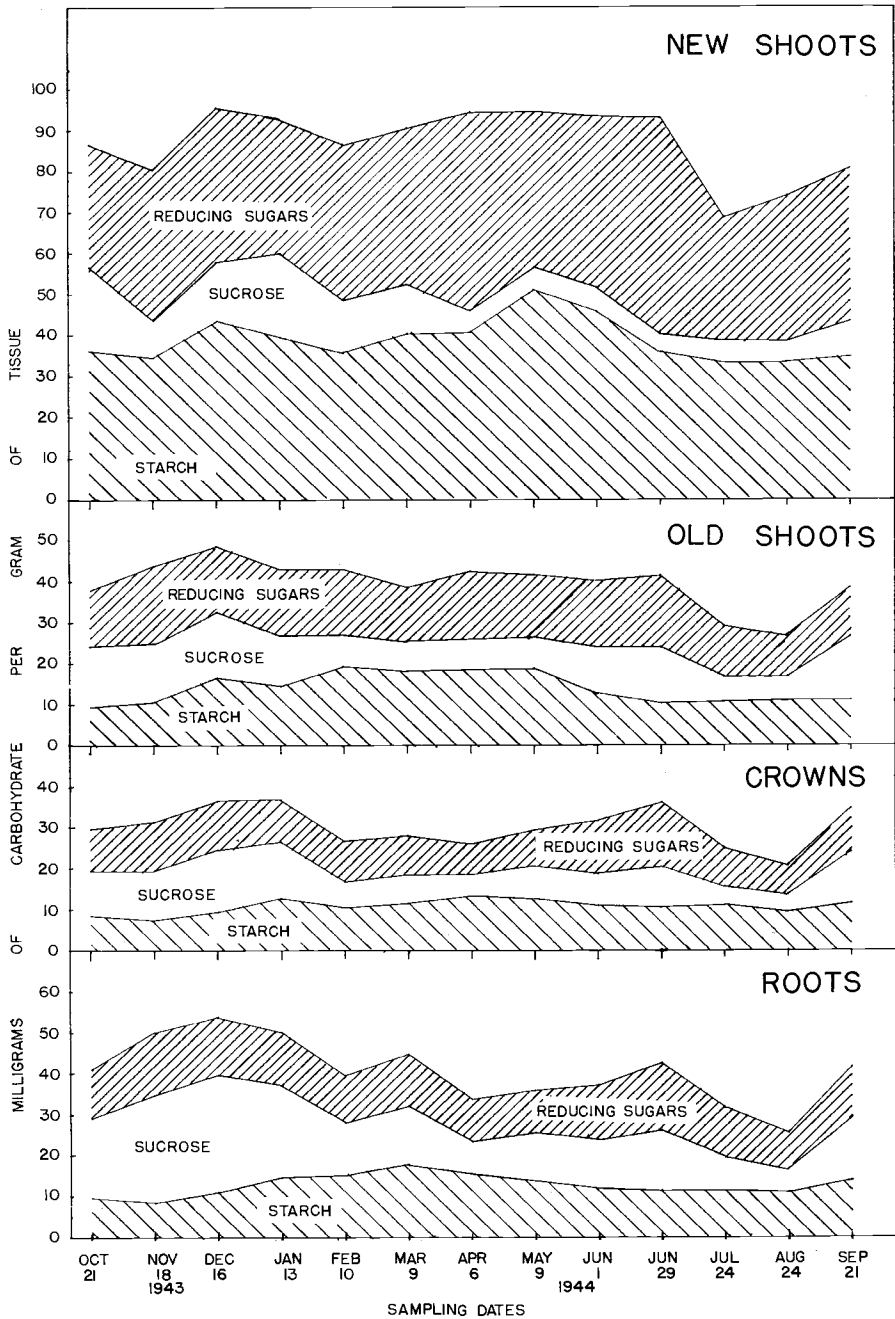


Figure 6.—Carbohydrate content of burweed plants.

weed. Voth determined that 30 to 50 percent of all burroweed plants were infested. Although the ecologic relationships of this moth have not been worked out, Voth concluded that it did little or no damage to burroweed.

Parker and Martin (28) reported that the principal parasites of burroweed are two species of beetle belonging to the genus *Crossidius* Lec. Larvae live within the roots and lower stems of the plants. Studies indicated that 40 percent of burroweed plants examined contained living larvae, 55 percent showed signs of having been infested, and 5 percent were free of damage. Although these larvae may be a controlling factor in localized areas, they apparently do not kill burroweed over extensive areas within its geographic range.

SPRAYING

Parker (27), in summarizing burroweed control measures, concluded that chlorate sprays, borate or chlorate mixtures, and diesel oil, in that order were the most effective chemical control methods. Brown and Streets (6) reported good kills by spraying burroweed with two percent sulphuric acid. Personnel of the Arizona Agricultural Experiment Station (2) found that aqueous sprays of 0.1 and 0.2 percent 2,4-D (2,4-dichlorophenoxyacetic acid) gave kills of 94 percent when used in small-plot tests with hand spray equipment. Lower kills were obtained when the sprays were used with power-driven ground equipment in extensive tests (3). In 1952, Brown (5) reported that good control could be obtained by spraying in April with a low-volatile ester of 2,4-D. One pound of the active ingredient in a 1:4 diesel oil:water emulsion applied at the rate of five gallons per acre was recommended.

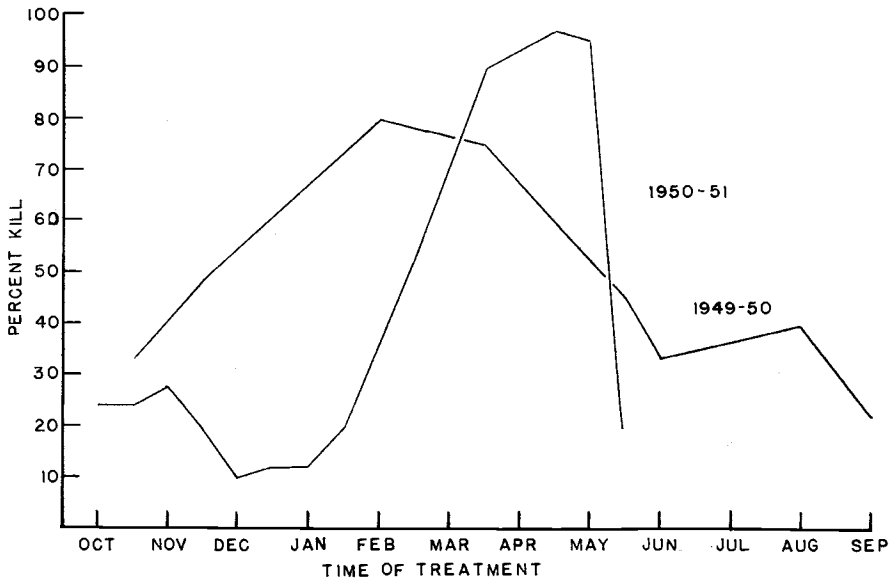


Figure 7.—Seasonal response of burroweed to spraying with 2,4-D. (Brown 1952).

Comparable results were not obtained in all years. Burroweed kills were poor if spraying was not done at the proper stage of plant development. Best results were obtained by spraying when the leaves were succulent; spraying should not be done after the leaves have become hard and waxy. In general, spraying from March 1 to May 1 is most effective, but the plants should be observed closely before treatment because vegetative development varies widely from year to year and place to place. Figure 7 shows the results from two years of treatment at one location in southern Arizona. In an extension of this work the same treatment was applied during one week at four widely scattered locations and gave extremely variable results, 10 to 80 percent kill.

A table of materials, rates, and dates of application that have been used on burroweed is given in the appendix.

BURNING

Early attempts to control burroweed were reported by Thornber (32, 33). He obtained good results by burning in June. Wooton got similar results in 1916. Judd (20) reported no difference in burroweed kill after burning on grazed and ungrazed areas. Parker (27) reported that burning was most effective in the spring and summer and relatively ineffective

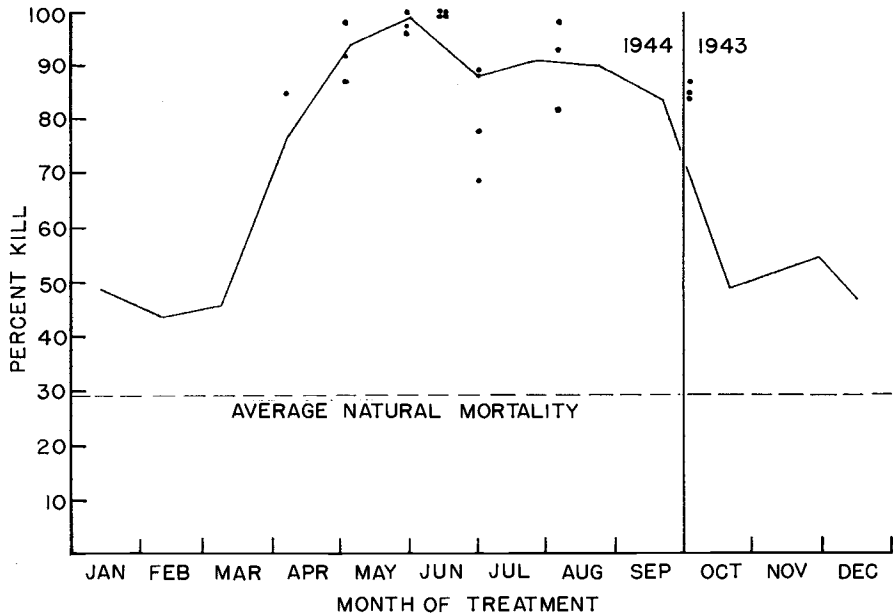


Figure 8.—Percentage kill of burroweed after burning at 4-week intervals from October 21, 1943, to September 21, 1944. Each point marked by a dot represents a burn on the date indicated but at a different location and usually in a different year.

during the remainder of the year. Reynolds and Bohning (30) reported an 88-percent burroweed kill resulting from a June burn. The results of one study in which burning was done at all seasons of the year show burning to be reasonably effective from mid-April to mid-September, but most effective about June 1 (Fig. 8). The accumulated information shows clearly that summer burning is an effective burroweed control method but that burning during the cooler months, from October through March, gives unsatisfactory results. Good clean burns in May or June, where there is sufficient accumulated fuel to carry fire and before grass growth starts, may be expected to kill about 90 percent of the burroweed.

GRUBBING

Like burning, grubbing has been reported as a possible burroweed control method for almost 50 years. Tests show that grubbing is the most consistently effective method (Fig. 9). It is effective over a longer season than any other method tested. Mature seeds are present on the plant in late fall and early winter. Grubbing at this time may scatter and cover a large number of seeds just before the period of germination. The net results may, therefore, be an increase rather than a decrease in the number of burroweed plants. Also, it is so expensive and time consuming that it is impractical for use on low-value rangelands, except possibly for the control of small colonies of burroweed during the early stages of invasion.

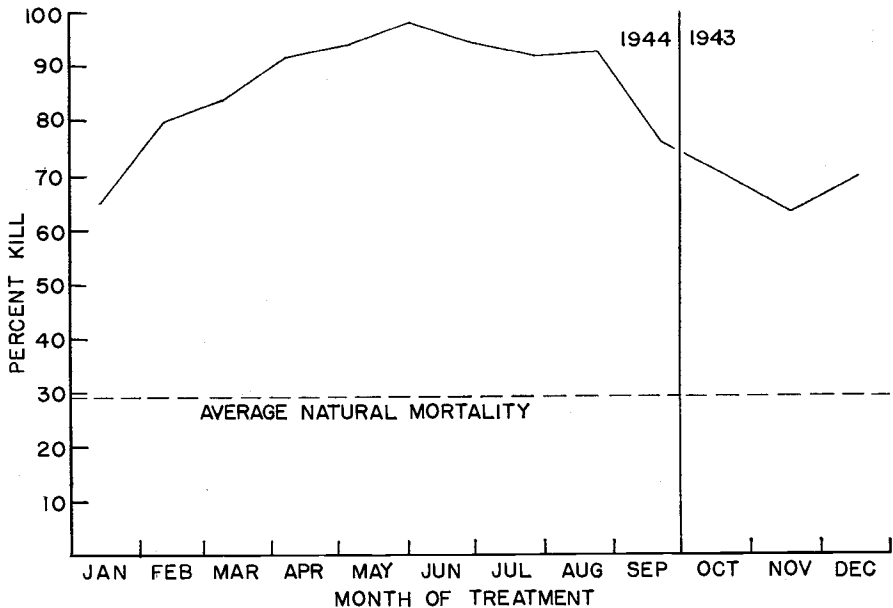


Figure 9.—Percentage kill of burroweed after grubbing at 4-week intervals from October 21, 1943, to September 21, 1944. Final counts were made November 11, 1945.

MOWING

The results of hand clipping to simulate mowing at different times of the year are indicated in Figure 10. Care was taken to clip all branches. Clipping gave good results in June and July. However, other tests, represented by dots in the figure, fail to show consistently good results even during the summer. Failure to obtain good kills by clipping may be the result of leaving several of the lower branches on most burroweed plants. Mowing does not appear to be a practical control method because much of Arizona's burroweed-infested range is too rough or too brushy for machine mowing.

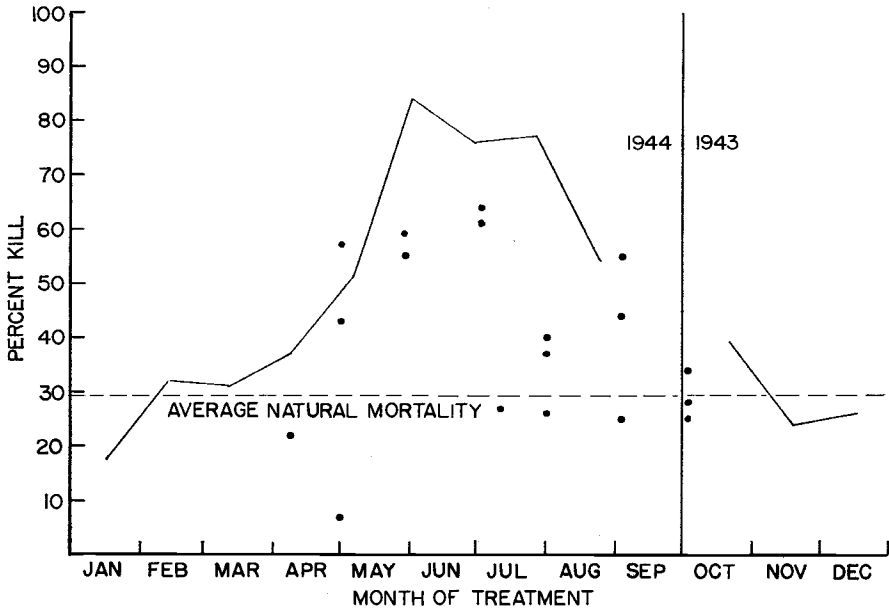


Figure 10.—Percentage kill of burroweed after mowing at 4-week intervals from October 21, 1943, to September 21, 1944. Final counts were made November 11, 1945. Each point marked by a dot represents clipping on the date indicated but at another location and usually in another year.

SUMMARY AND CONCLUSIONS

Burroweed, which has been considered a potential problem on southern Arizona rangelands for many years, has been the subject of much research. Investigations have included studies of (1) life history and growth habits, (2) geographic distribution, (3) poisonous properties, (4) invasion and its causes, (5) relation to grazing, (6) competition with forage plants, and (7) methods of control. The more important conclusions derived from these studies follow:

1. Burroweed is a perennial woody halfshrub, densely branched at the base, having small dense heads of yellow flowers. Burroweed seeds germinate in the cool winter-spring rainy seasons, but seedlings suffer high mortality in the April to June dry period. Plants that survive quickly develop deep, extensive root systems and flower at 18 to 24 months.

2. Burroweed is found in southern Arizona, southwestern New Mexico, the Big Bend Region of Texas, and south as far as Zacatecas, in Mexico.

In southern Arizona the range of burroweed is between 2,000 and 5,000 foot elevation. It is most abundant at about 3,500 foot elevation on non-calcareous soils. Low winter temperatures apparently restrict germination and seedling establishment above 5,000 feet; low precipitation restricts germination and seedling establishment below 2,000 feet.

3. Burroweed is poisonous to cattle and horses. The toxic agent, tremetol, is cumulative and causes trembling, falling, and finally a strong odor of acetone is evident in the breath, blood, and urine of affected animals.

Burroweed poisoning usually occurs only in times of extreme forage shortage, but not all cases are due to hunger. If animals that are not familiar with burroweed are turned onto an infested range, poisoning may occur. An adequate supply of good forage appears to be the best insurance against burroweed poisoning.

4. On the Santa Rita Experimental Range, where most burroweed studies have been made, burroweed made its most rapid spread from 1900 to about 1930. Photographic evidence indicates that most of the invasion above 3,500 feet occurred between 1920 and 1935. Since then the rate of spread has been relatively slow and many of the older stands have decreased in density.

5. Cleared areas open to yearlong grazing are reinvaded more rapidly than are areas protected from grazing.

6. Increases in basal intercept of perennial grasses followed the control of burroweed on plots that were protected from grazing. On range open to yearlong grazing, burroweed control did not increase intercept or herbage production of perennial grasses. However, burroweed-free plots were invariably grazed more closely than the burroweed-infested plots.

7. Of the many chemicals that have been tested for burroweed control, the ester of 2,4-D applied in the spring before leaves harden has given the best results. However, even the best chemical methods have given erratic results.

Burning in June when there is ample herbage to carry a fire is very effective in controlling burroweed. The benefits to be expected from burning depend largely on the grazing practices before and after the fire.

Hand grubbing is an effective but expensive control method and is often followed by a large crop of burroweed seedlings. Grubbing may be useful for controlling small patches in the early stages of invasion. Close mowing in June or July may be fairly effective, but the method is not applicable to many areas because of rocks, rough ground, or large shrubs.

APPENDIX

Table of Herbicides That Have Been Tested on Burroweed

Herbicide and Formulation	Month Treated	Year	Concentration	Carrier	Volume	Tests	Kill
			<i>Lb./A</i>		<i>gpa</i>	<i>No.</i>	<i>Percent</i>
2,4-D, acid	Apr	1945	0.8	Water	100	1	47
"	May	1945	"	"	"	2	44
"	Jul	1946	"	"	"	4	53
"	Jul	1946	1.6	"	"	1	87
"	Aug	1945	0.8	"	"	1	53
"	Aug	1948	0.9	"	35	2	25
"	Aug	1951	1.0	"	20	1	40
"	Sept	1945	0.8	"	100	1	33
"	Oct.	1945	0.8	"	"	1	18
2,4-D, ammonium salt	Feb	1947	0.8	Water	100	1	51
"	Feb	1947	1.6	"	"	1	83
"	Feb	1947	2.4	"	"	1	71
"	Apr	1950	1.0	"	20	1	25
"	Jul	1946	0.8	"	100	1	68
"	Aug	1950	1.0	"	20	3	10
"	Oct	1950	1.0	"	20	1	20
"	Dec	1950	1.0	"	20	1	10
2,4-D, sodium salt	Jul	1947	0.8	Water	20	1	20
2,4-D, amine	Aug	1951	1.0	Water	20	1	20
2,4-D, ester	Feb	1947	0.8	Water	100	1	60
"	Feb	1947	1.6	"	100	1	82
"	Mar	1952	1.0	1:4 ^s	5	2	23
"	Mar	1952	1.0	1:4	10	2	30
"	Apr	1950	1.0	1:4	20	1	70
"	Apr	1953	1.5	1:4	12.5	1	35
"	Apr	1953	1.5	Diesel oil	12.5	1	75
"	Apr	1953	1.5	"	25	2	57
"	Apr	1953	1.5	1:4	25	2	57
"	May	1950	1.0	1:4	10	1	30
"	May	1950	1.0	Diesel oil	10	1	27
"	May	1950	1.0	1:4	20	1	20
"	Aug	1948	0.14	Kerosene	35	3	22
"	Aug	1948	0.14	Diesel oil	35	3	30
"	Aug	1951	0.50	Diesel oil	20	1	25
"	Aug	1948	0.70	Kerosene	35	3	45
"	Aug	1948	0.70	Diesel oil	35	3	27
"	Aug	1951	0.75	Diesel oil	15	1	30
"	Aug	1948	0.90	Kerosene	35	1	50
"	Aug	1948	0.90	Diesel oil	35	1	65
"	Aug	1948	0.90	Water	35	1	45

Table of Herbicides That Have Been Tested on Burweed

Herbicide and Formulation	Month Treated	Concentration	Carrier	Volume	Tests		Kill
					<i>Lb./A</i>	<i>gpa</i>	
2,4-D, ester	Aug	1950	1.00	1:4	20	2	53
"	Aug	1951	1.00	Diesel oil	20	1	50
"	Aug	1951	1.25	Diesel oil	20	1	95
"	Aug	1951	1.50	Diesel oil	30	1	90
"	Aug	1948	1.50	Diesel oil	35	3	42
"	Aug	1948	1.50	Kerosene	35	3	55
"	Aug	1951	2.00	Diesel oil	15	1	60
"	Aug	1951	2.00	Diesel oil	20	1	75
"	Aug	1951	2.00	Diesel oil	25	1	65
"	Aug	1951	2.00	Diesel oil	30	1	60
"	Aug	1951	2.00	Diesel oil	40	1	80
"	Aug	1951	4.00	Diesel oil	20	1	85
"	Aug	1951	8.00	Diesel oil	20	1	90
"	Oct	1950	1.00	1:4	20	1	25
"	Dec	1950	1.00	1:4	20	1	25
2,4,5-T, acid	Aug	1952	1.00	Water	20	2	10
2,4,5-T, amine	Aug	1952	1.00	Water	20	1	30
"	Aug	1952	1.00	1:3	20	1	30
"	Aug	1952	1.00	Diesel oil	20	1	50
2,4,5-T, ester	May	1950	1.00	1:4	10	1	23
"	May	1950	1.00	Diesel oil	10	1	63
Sulfamic acid	Feb	1947	50	Water	100	1	75
"	Apr	1953	25	"	25	1	70
"	Jul	1946	50	"	100	1	61
Ammonium sulfamate	Feb	1947	25	Water	100	1	73
"	Feb	1947	50	"	"	1	73
"	Feb	1947	100	"	"	1	93
"	Apr	1950	10	"	20	1	44
"	May	1950	10	"	20	1	25
"	Jul	1946	50	"	100	1	97
"	Aug	1950	10	"	20	2	13
"	Oct	1950	10	"	20	1	25
"	Dec	1950	10	"	20	1	20
Trichloroacetic acid	Apr	1953	25	Water	25	1	90
"	Aug	1951	4	"	20	1	55
Ethylene dibromide	Apr	1953	10%	1:4	25	1	100
Pentachlorophenol	Aug	1948	1%	Diesel oil	35	1	25
"	Aug	1948	5%	"	35	1	58
Dinitro-o-sec-butylphenol	Aug	1948	.55%	Kerosene	35	1	20
"	Aug	1948	"	Diesel oil	35	1	85

Table of Herbicides That Have Been Tested on Burroweed

Herbicide and Formulation	Month Treated	Concentration	Carrier	Volume	Tests	Kill
Diesel oil	Jun	1945		100	1	23
"	Aug	1948		35	1	20
"	Aug	1951		20	1	75
Kerosene	Aug	1948		35	1	25

Herbicide and Formulation	Concentration Percent	Treatment Month			
		Feb.	May	Aug.	Nov.
Sulphuric acid ¹⁰	2.5	0.0	47.6	0.0	0.0
"	5.0	0.0	61.6	12.5	0.0
"	7.5	5.1	72.9	0.9	0.0
"	10.0	10.6	83.0	1.1	1.2
Atlacide ¹⁰	5.0	15.6	78.0	28.9	12.2
"	10.0	16.6	81.6	41.6	34.6
"	15.0	60.4	94.6	56.3	73.4
"	20.0	72.1	95.4	66.6	65.2
"	25.0	71.6	99.2	67.4	85.9
Sodium chlorate ¹⁰	5.0	28.6	63.2	33.4	38.1
"	10.0	44.8	88.0	54.6	69.1
"	15.0	79.8	90.4	56.8	85.1
"	20.0	88.0	79.5	71.4	92.2
"	25.0	91.2	96.1	84.4	95.6

⁸ Ratio of diesel oil to water.

⁹ 2,4,5-trichlorophenoxyacetic acid.

¹⁰ Taken from Parker, Kenneth W. 1939. The Control of Burroweed. Southwestern For. and Range Expt. Sta., Res. Note No. 72.

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