Fire Effects in Southwestern Semidesert Grass-Shrub Communities

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THE use of fire as a tool in the management of southwestern semidesert ranges has been studied intermittently since about 1949 on the Santa Rita Experimental Range south of Tucson, Arizona. However, study of the effects of fire on semidesert plants goes back much further. Thornber (1910), after observing the effects of wildfires a few miles north of the Santa Rita, reported that "such shrubs and trees as creosotebush or greasewood, rayless golden-rod, Mormon tea, bush hackberry or garanbullo (*Celtis pallida*), mesquite, and palo verde were killed" and that these species "may be killed outright at a very small expense by burning over during the annual dry fore-summer, i.e. May to June inclusive."

The general objectives of work on the Santa Rita have been: (1) to determine if and under what conditions fire can be used to control or eliminate undesirable shrubby plants, and (2) to determine the effect of such prescribed burning on the desirable forage grasses.

As might be expected, the effect of burning on semidesert shrubs varies widely, from nearly 100 percent kill for some species, to near-zero kill for others. The effect of burning on grasses varies from drastic reductions in density of some species to increases in

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density of others. These differences depend on the interrelationships among several factors, including: (1) the growth habits of individual species, (2) species patterns of distribution and dispersion, (3) climatic conditions immediately before and after the fire, and (4) fire intensity as a reflection of available herbaceous fuel. In addition, some of these interrelationships will vary with the season of the year in which the fire occurs. The remainder of this paper will illustrate these interrelationships as they apply in the semidesert grass-shrub type of the Southwest, and more particularly in southern Arizona.

The climate of southern Arizona is characterized by two rainy periods: a summer rainy season from July thru September, and a winter rainy season from December thru April, separated by dry periods. Fifty to sixty percent of the annual precipitation typically falls in the summer rainy season. Soils vary widely, from sandy or gravelly loams to clay loams in both the surface and subsoil. Vegetation in the semidesert grass-shrub type consists of a shrubby overstory, dominated by velvet mesquite (most commonly), creosotebush, or a variable mixture of mesquite, paloverde, fourwing saltbush, catclaw acacia, desert hackberry, and cacti, with an understory of perennial grasses and woody half shrubs.

FIRE EFFECTS ON SHRUBS

Velvet Mesquite

Because of the abundance of velvet mesquite (*Prosopis juliflora* var. *velutina*) in the southwestern semidesert, its continuing invasion of grassland areas, and the subsequent reduction in grass production, velvet mesquite probably deserves first consideration. Also, more research has been conducted on the effect of fire on velvet mesquite than on any other of the semidesert shrubs.

The fact that velvet mesquite has long been a problem on southern Arizona ranges has been well documented, both in photographs and by ground surveys. Velvet mesquite has been reported to occur on 9 million acres of range land in southern Arizona. Other varieties of mesquite are found on some 60 million acres in southern New Mexico and west Texas. Approximately half of this total acre-age is estimated to represent mesquite invasions during the past century (Parker and Martin 1952). For example, Figures 1A and 1B show an area on the Santa Rita Experimental Range as it looked in 1903—an open, grass-covered area in the very early stages of mesquite invasion—and the same area as it looked in 1941, with a well-developed stand of velvet mesquite.

Griffiths, in 1910, expressed the opinion that the increase in shrubby vegetation in this area, which was evident to him even at that early date, was probably "primarily the direct result of the prevention of fires." This view was also held by Humphrey (1958). Other investigators have concluded that control of fires was relatively unimportant in the spread of shrubs in this area (Hastings and Turner 1965).

Research on the Santa Rita has shown that velvet mesquite is most susceptible to fire during the late spring and early summer—the hottest and driest part of the year. In one study, 29 percent of mesquite trees were killed on areas burned in June, compared to

FIG. 1A. Open grass-covered area on the Santa Rita Experimental Range in 1903.

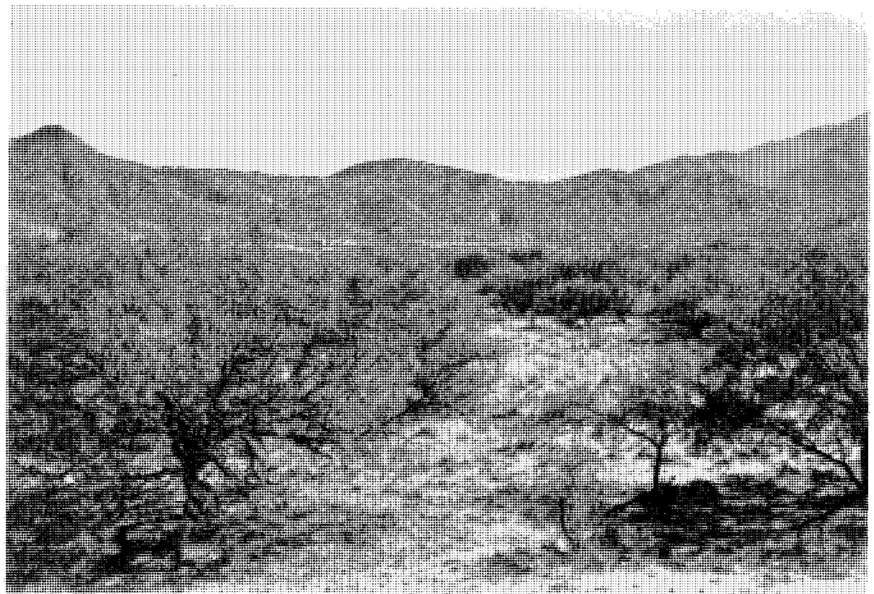


FIG. 1B. Identical area in 1941 shows great increase in mesquite and reduction in grass density.

10 and 4 percent for areas burned in November and February, respectively (Glendening and Paulsen 1955). These areas were broadcast-burned after straw had been added as necessary to provide a total of about 800 lbs of fuel per acre.

Mesquite kill was inversely related to tree size. Sixty percent of trees up to 0.5 inches in basal stem diameter were killed in a June burn. Mortality decreased with each successively larger stem-diameter class, to 11 percent for trees over 5 inches. Increased bark thickness on older and larger mesquite stems is responsible for much of their increased ability to withstand fire.

On a man-caused accidental burn in June 1963, mesquite kills were much lower, even though herbaceous fuel was more abundant. Here mesquite kill averaged 25 percent on an area where ground cover was dominated by Lehmann lovegrass (*Eragrostis lehmanniana*) and only 8 percent on an area dominated by black grama (*Bouteloua eriopoda*) (Cable 1965). The lovegrass provided about twice as

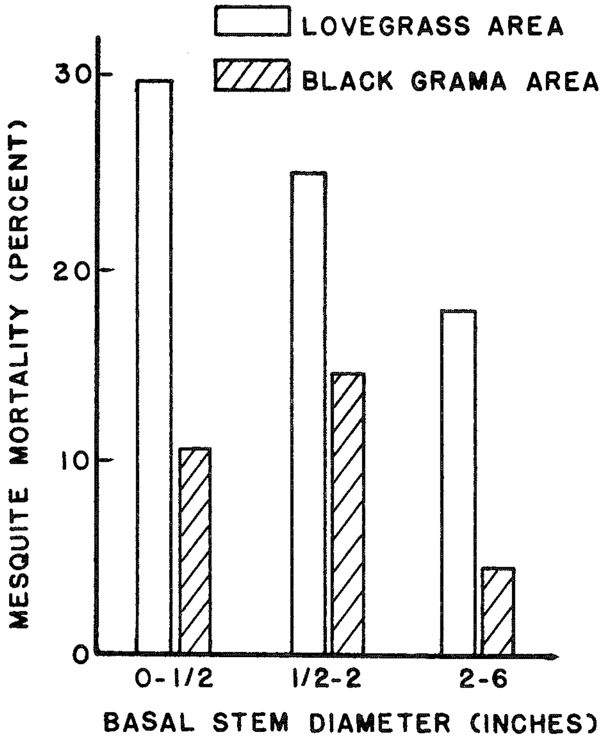


FIG. 2. Mesquite mortality after first growing season following burning, by stem diameter classes.

much fuel as the black grama, resulting in a hotter fire. Mesquite kill was twice as high on the lovegrass area as on the black grama area for plants less than 2 inches in basal stem diameter (27 and 13 percent), and over four times higher for trees over 2 inches stem diameter (18 and 4 percent on the lovegrass and black grama areas respectively) (Fig. 2). Thus, Lehmann lovegrass, because of its ability to produce large volumes of herbage within existing stands of velvet mesquite and other shrubs, might be useful as a fuel source for shrub control in the semidesert.

The type of sprouting after a fire is influenced by differences in fire intensity. Mesquite does not sprout from roots. Dormant buds are present not only on the crown branches, however, but also in a zone at the base of the trunk. This zone usually lies just below

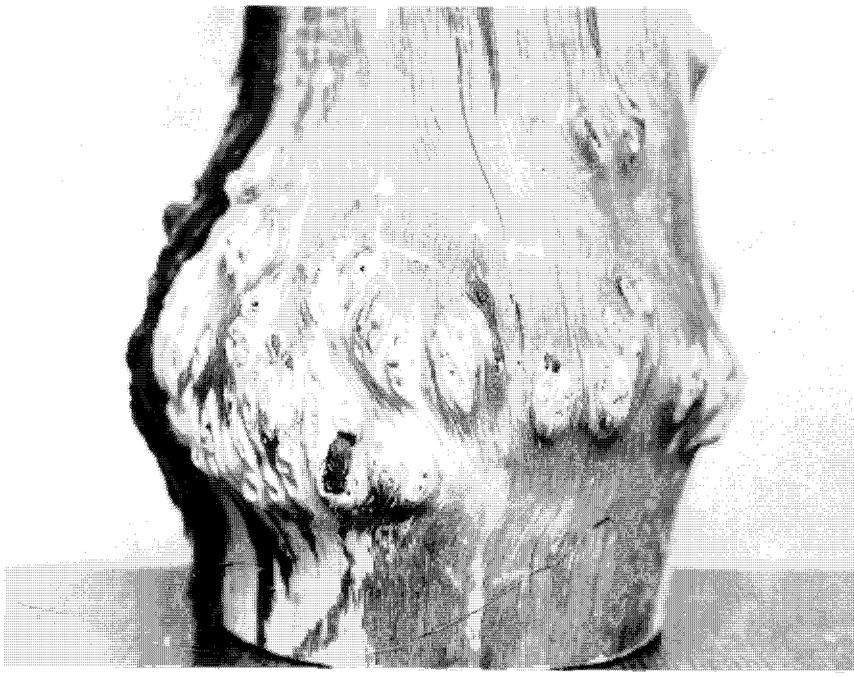


FIG. 3. Bud zone on stem of velvet mesquite. This stem is 4 inches in diameter at ground level, at the top edge of the photo.

ground level, and is well insulated from the fire's heat (Fig. 3). Because buds on the uppermost branches tend to sprout first, crown sprouting will predominate if the crown is only damaged, and not killed as in a fire of lower intensity. If the crown branches are completely killed, sprouting will originate from the basal buds only. Frequently, both types of sprouting will occur. In this study, basal sprouting predominated on trees less than 2 inches diameter, because the crown buds on these small trees were severely damaged; crown sprouting predominated on the larger trees.

Even very small mesquite trees are able to survive burning and produce basal sprouts. One study showed that burning killed only two-thirds of mesquite plants 4–6 inches tall and less than 1 year old. One plant out of three was only top-killed and sprouted from the base (Cable 1961).

We can conclude from these studies that: (1) velvet mesquite is relatively resistant to fire, (2) the basis of this resistance is its marked ability to sprout from basal stem buds, or from crown buds if the fire is not too severe, (3) mature stands probably cannot be killed by fire because herbage production is inadequate to carry a fire and because mature trees are hard to kill, and (4) fire probably can be used to maintain a relatively mesquite-free aspect in relatively young invasion stands or where large "fire-immune" trees have first been killed by some other method. Periodic burning in such areas would top-kill the small trees, keep the basal sprouts close to the ground, and prevent the trees from reaching seed-bearing size. Such a practice could enhance range forage production because velvet mesquite competes seriously with perennial grasses for soil moisture.

Cacti

Several species of cacti are common on the Santa Rita, particularly jumping cholla (*Opuntia fulgida*), cane cholla (*O. spinosior*), and pricklypear (primarily *O. engelmannii*). The degree of control that can be obtained by burning depends largely on fuel concentrations under and near individual plants. In one study, 32 percent of the pricklypear, 45 percent of the cane cholla, and 63 percent of the jumping cholla plants were killed by a prescribed burn, but a second prescribed burn on the same area 3 years later produced no significant changes in cactus densities (Cable 1967). The major difference between the two burns was that the long-time accumulation of dry cactus joints, dry grass, and other litter around the bases of the plants was consumed by the first burn, creating local hot spots around most plants and killing the more susceptible ones. The 3-year interval between the two burns was too short for any appreciable accumulation of litter under the remaining live plants (those least susceptible to the first burn). Because of little litter, the second burn was cooler and killed few plants. Comparatively, less fuel accumulates around the bases of pricklypear than cholla plants, and pricklypear, thus, is usually damaged less by a hot fire than are the two chollas. In a cooler fire, there is some indication that the chollas, but not pricklypear, may increase in numbers from the sprouting of fallen, but otherwise undamaged, joints.

Burroweed

Burroweed (*Aplopappus tenuisectus*), an unpalatable half-shrub, common in the semidesert, is easily killed by burning. Several studies on the Santa Rita have shown that from 90 to 98 percent of burroweed plants can be killed by burning in June. Its high susceptibility to fire is due mainly to two factors: (1) it does not sprout from the roots or root collar, and (2) it burns with a high intensity because of the resinousness of the foliage and the fine-stemmed character of the crown branches.

Adequate control of burroweed by burning, however, requires periodic reburning because burroweed reinvades. Reinvasion can be fast or slow. Humphrey (1949) reported little reinvasion of burroweed on one area but complete reinvasion of another 15 years after fires in 1933, but offered no explanation for the difference. Vigorous stands of perennial grasses apparently retard the establishment of burroweed to some extent (Humphrey 1937; Tschirley and Martin 1961). The rate of invasion by burroweed also is strongly influenced by the abundance of winter precipitation, on which it depends for germination and establishment. If viable seed is available, two or three consecutive wetter-than-average winters or one extremely favorable one will produce large numbers of burroweed seedlings. If the usual May-June drought is not too severe, many of these seedlings will survive until the summer rains begin, thereby initiating a new stand of burroweed. For example, a stand of 4443 burroweeds per acre was almost eliminated by burning in June 1952 (Fig. 4a, 4b). Six years later the area was dominated by native perennial grasses, but 14 years after burning there were more than twice as many burroweeds (10,433/acre) as before the burn (Fig. 4c, 4d).

Creosotebush

It has been estimated that creosotebush (*Larrea tridentata*) covers between 35 and 46 million acres in the Southwest. On much of this area rainfall is too low or too erratic to support good stands of perennial grass. Some areas do receive enough rainfall, however, but now produce little grass herbage because of thickening of the stands since the turn of the century. To evaluate the possibility that creosotebush could be controlled by prescribed burning, White

(1968) studied the influence of season of burning and age of plant on creosotebush mortality following burning (natural ground fuel was supplemented by adding straw under the plants). Of seven dates on which individual creosotebush plants were burned, maximum mortality (100 percent) and minimum sprouting (0 percent) were obtained from burning in early June, the hottest and driest part of the year. June was the time of minimum available carbonhydrates in the roots (5.94 percent), maximum temperature in the top 2 inches of soil (102.4°F), minimum soil moisture content (2.2 percent, averaged for the 0–12 inches layer), and highest fire intensity. Mortality was lowest (8 percent) from burning in mid-August, the wettest part of the year. White concluded that "season of burning influenced mortality most through effects on fire intensity and duration."

Of the three age groups studied (young, mature, old), mortality was highest, and sprout production was lowest, in young plants; mortality was lowest and sprout production highest in old plants. Duration of fire was also significantly longer and soil temperatures were higher under young plants than under mature or old plants, because of more fuel under young plants.

Increasing the amount of fuel (500, 1000, 2000 lb/acre) also increased the mortality and reduced subsequent sprouting. Since 100 percent kills can be expected from burning at the proper season, creosotebush can be considered to have low resistance to burning. However, mature stands of creosotebush rarely contain enough herbaceous fuel to carry a fire (Fig. 5). Control of creosotebush by burning probably is feasible during the early stages of its invasion of grasslands.

This points up one of the problems involved in any program of prescribed burning in the Southwest: in most years there is not enough herbaceous fuel to carry a fire. Production of grass herbage may be only a few pounds per acre in 1 year and several hundred pounds the next. This extreme variation, however, is not entirely a disadvantage, because ranges that are stocked on the basis of an average or poorer year will always have a surplus of forage in the good years. In exceptional years, part of the range can then be left ungrazed and will support a prescribed burn. Thus with ap-

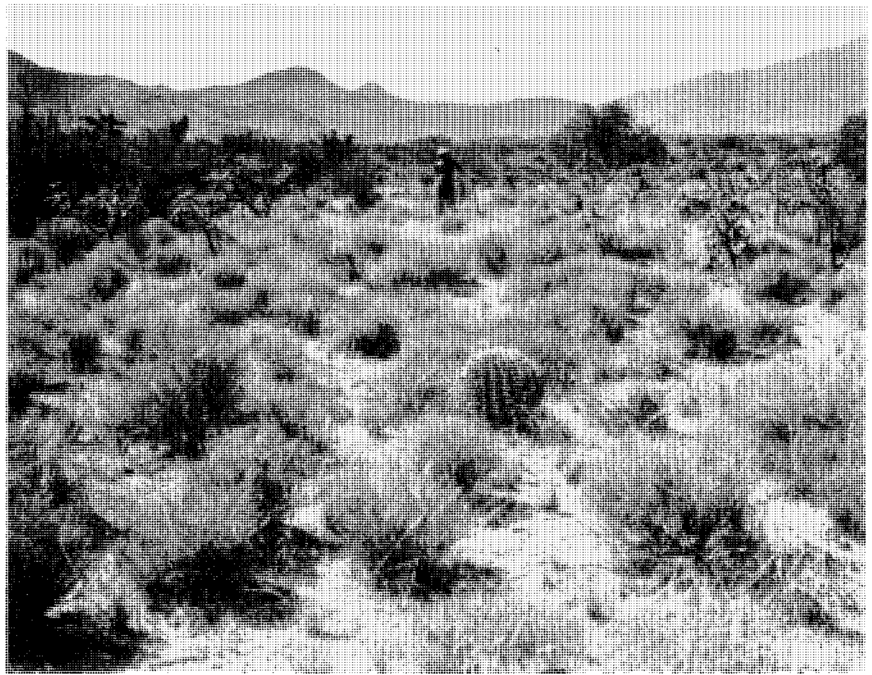
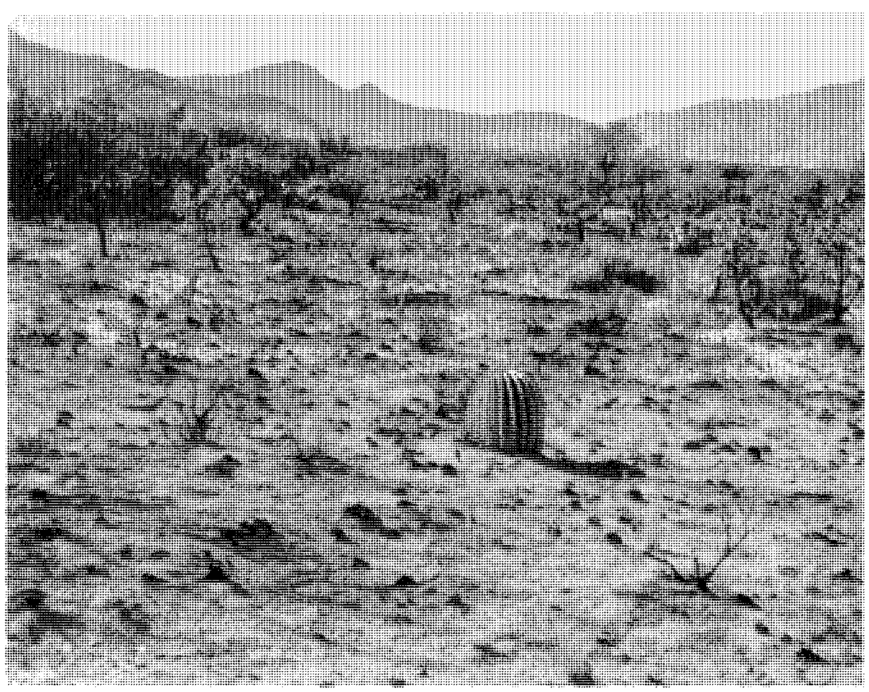


FIG. 4A. An area on the Santa Rita in June, 1952, with a stand of 4443 burrow: weeds/acre.

FIG. 4B. Sames as 4A, July 1952, 8 daysafter burning; fire killed 94 percent of the burroweeds on this area.



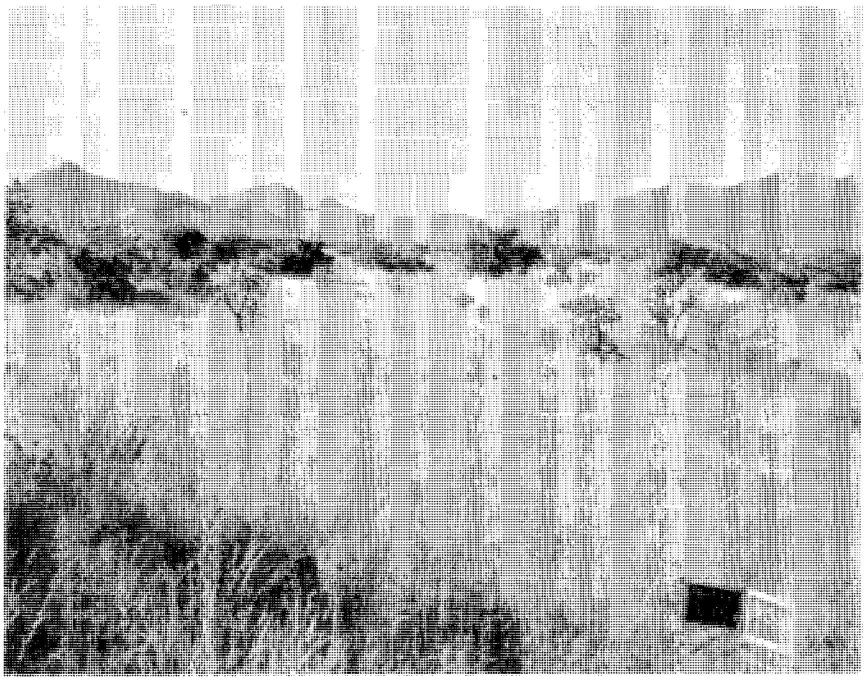
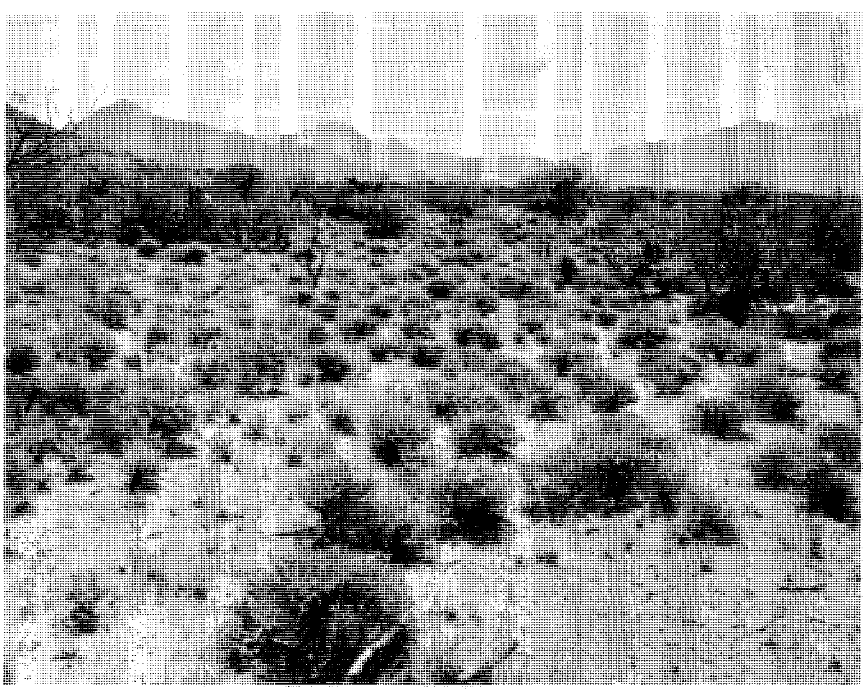


FIG. 4C. Same as 4A, September 1958, showing the area dominated by native perennial grasses.

FIG. 4D. Same as 4A, September 1966, 14 years after burning, showing complete reinvasion by burroweed, 10,443 burroweeds/acre.



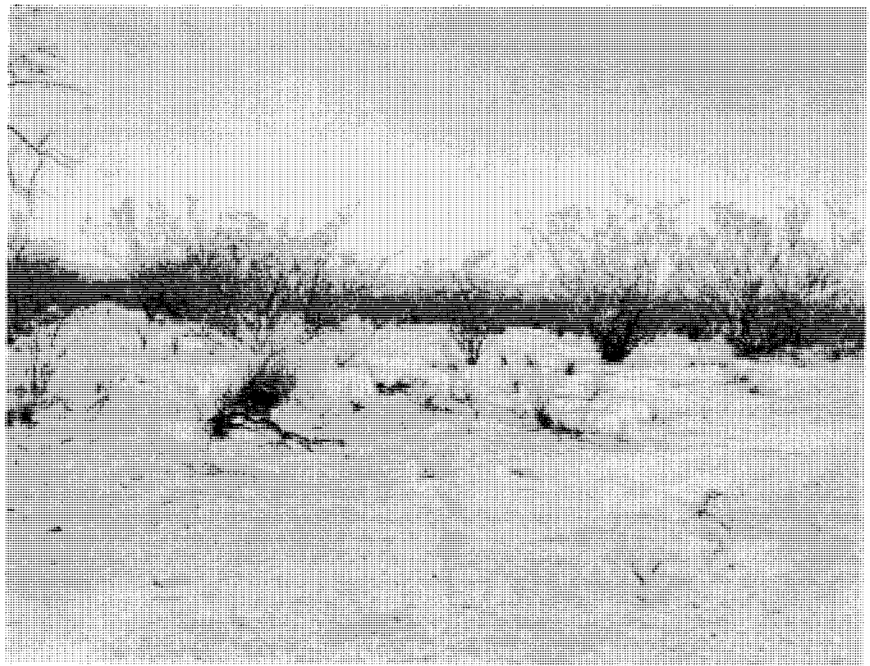


FIG. 5. Creosotebush stand on the Santa Rita, with extremely low density of herbaceous plants.

propriate grazing management, occasional prescribed burns may be feasible even on relatively dry semidesert ranges.

OTHER SHRUBS

Larchleaf goldenweed (*Aplopappus laricifolius*) was reported as "sensitive to wildfire" and showed little recovery after two growing seasons (White 1965) even though judged to be only moderately damaged by fire. False-mesquite (*Calliandra eriophylla*) and velvet-pod mimosa (*Mimosa dysocarpa*), on the other hand, had recovered by the second growing season following the fire, even though judged to have been severely damaged by the fire. Larchleaf goldenweed is a close relative of burroweed, and like burroweed, does not sprout. False-mesquite and velvet-pod mimosa both produced abundant basal sprouts.

FIRE EFFECTS ON GRASSES

Native Annual Grasses

Because annual grasses start from seed each year, burning has little direct effect on herbage production the following growing season; seeds on the ground, from which the next crop will be produced, apparently are not damaged by the usual fire. Indirect effects can be appreciable, however, largely because of changes in soil moisture brought about by elimination or reduction in the density of competing perennial species.

The most abundant summer-growing annual grasses on the Santa Rita are needle grama (*Bouteloua aristidoides*) and sixweeks three-awn (*Aristida adscensionis*). Herbage production of these species is highly correlated with summer rainfall, but is also highly correlated (negatively) with the abundance of competing perennial grasses and shrubs. Production of annual grasses shows little change in drier years following a burn, but in years of average or above-average summer rainfall following a burn, production has been higher on burned than on unburned areas. Annual grass production was about twice as high on burned as on adjacent unburned areas in the wet years 1954 and 1958, but little or no higher in the dry years of 1955 and 1956 (Cable 1967). Perennial grasses and shrubs have a competitive advantage over annual grasses in the semidesert because their roots are more extensive and are in place and ready to begin using moisture when the summer rains first start, while the annual grasses must germinate and grow their root systems each year.

Native Perennial Grasses

Determining the influence of fire on the desirable perennial grasses is the second major objective of burning studies on the Santa Rita. One study area was burned in June 1952, and half of the burned area was reburned in 1955 (Cable 1967). The effects of the two fires were different, and the effects differed among the several species of perennial grasses.

The differences were apparently due to (1) differences in the amounts of rain received in the summers immediately following the burns, and (2) lack of burroweed at the time of the second burn and the local "hot spots" created by burning burroweeds. Summer rainfall following the first burn was 26 percent below the long-time mean, and perennial grass basal cover decreased 36 percent, as measured at the end of the summer. Basal cover increased the following year, nearly reaching that of the unburned check. In contrast, rainfall following the second burn was slightly above the long-time mean, and the grasses had essentially recovered fully by the end of the summer.

While the data show no permanent loss of total basal cover from two burnings, there were changes in species composition. These changes apparently were due largely to differences in distribution patterns of the grasses. For example, tall threeawns (primarily *Aristida hamulosa* and *A. ternipes*) usually grew within the crowns of burroweed plants. Such plants were subjected to more heat than were plants in the open, because of the extra fuel provided by the fine-stemmed, resinous burroweeds. Also, the tall threeawn plants contain many large, dried sheaths and culms which burn readily. As a consequence, basal cover of the tall threeawns decreased about 70 percent following the first burn.

In contrast, Santa Rita threeawn (*A. glabrata*), a lower growing, more palatable species, tends to be more evenly dispersed in the openings, away from the burroweeds. Also, its culms remain green and its sheaths are small. As a result, comparatively few of these plants were subjected to the extra heat of the burning burroweeds, and basal cover of Santa Rita threeawn increased the summer following the burn.

The other major perennial grass species, Rothrock grama (*B. rothrockii*), Arizona cottontop (*Trichachne californica*), and tanglehead (*Heteropogon contortus*) were intermediate in their degree of dispersion and association with burroweed, and in their reactions to burning.

Damage to a stand of black grama was studied following an accidental June fire on the Santa Rita in 1963. This fire burned the top growth to within ⅛ to ¾ inch from the root crown. Some black grama plants started to sprout about 3 weeks after the fire, but only 10 percent of the original plants finally sprouted. No seedlings were found (Cable 1965).

After a wildfire in desert grassland vegetation near Sasabe, about 75 miles south and west of Tucson, essentially all species of perennial grass present decreased the first growing season after the fire, but were essentially completely recovered by the end of the second season (White 1965). These results were similar to those obtained on the Santa Rita, except that on the Sasabe area there were smaller changes in composition. Plains lovegrass (*Eragrostis intermedia*), however, increased markedly during the second growing season. Dominant grass species on the Sasabe area were hairy grama (*Bouteloua hirsuta*), plains lovegrass, and side-oats grama (*B. curtipendula*). Subdominant grasses were bullgrass (*Muhlenbergia emersleyi*), spidergrass (a tall threeawn, *Aristida ternipes*), and wolftail (*Lycurus phleoides*).

Lehmann Lovegrass

Lehmann lovegrass (*Eragrostis lehmanniana*), an introduced grass from South Africa, has been used extensively for reseeding in the semidesert Southwest. It has several desirable characteristics, including drought resistance, ability to tolerate heavy grazing, ease of establishment, and aggressiveness in competing with other vegetation for soil moisture. It also produces more green herbage during the winter and early spring than the native perennial grasses do. Its major drawbacks are: (1) it is relatively unpalatable during the summer growing season, and (2) it is so aggressive that within its preferred range it will eventually (within 15 to 20 years) crowd out and replace most of the native grasses (Cable 1971).

The accidental fire (June 1963) that burned the black grama area also burned an area of nearly pure Lehmann lovegrass. Air-dry weight of lovegrass on this area averaged 4480 lbs/acre, about twice the herbage weight on the black grama area. As a result of the large amount of fuel, the fire was relatively hot and killed 98 percent of the lovegrass plants. In contrast to the black grama, however, the lovegrass reseeded itself, producing about 17 new plants per ft^2 within 4 months after the fire, many of which matured seed (Fig. 6).

In contrast to these results of a hot June fire, Pase (1971) reported that a relatively cool February test burn of an established stand of Lehmann lovegrass in central Arizona killed less than

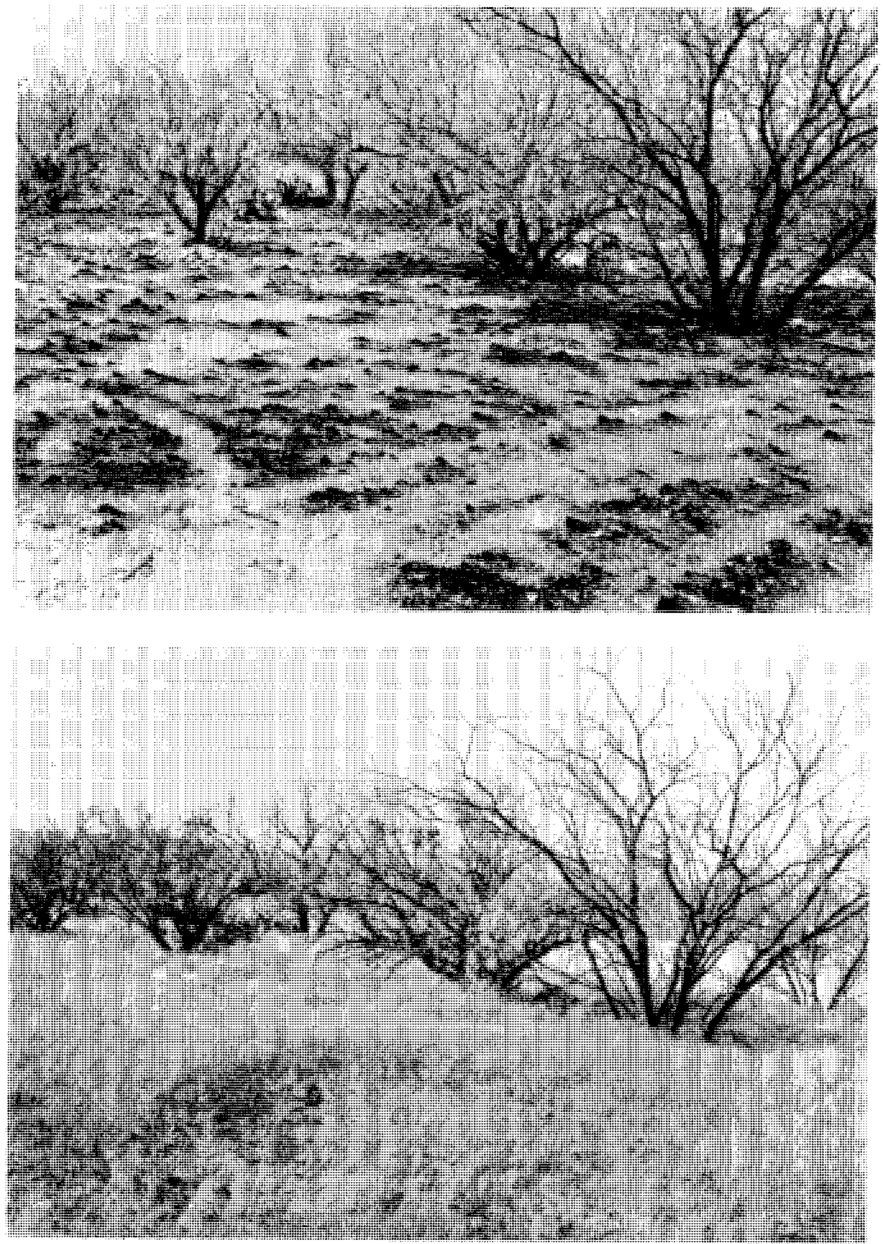


FIG. 6. Mesquite stand with Lehmann lovegrass ground cover: Top, Twelve days after accidental fire killed 98 percent of lovegrass plants; Bottom, 4 months later, showing natural reseeding of lovegrass, about 17 plants per ft^2, many with mature seed heads. Little permanent damage was done to the larger mesquites.

5 percent of lovegrass plants, and had no effect on herbage production. It thus appears that the susceptibility of grasses to fire, like that of shrubs, varies seasonally and that both are most susceptible in June, the hottest and driest part of the year.

From these studies we can conclude that perennial grasses as a group are relatively resistant to fire, in that the harmful effects of burning are usually only temporary. The individual species differ in their ability to withstand and recover from burning, however, so that changes in species composition might be expected following fire. The inherent ability of the various species to withstand and recover from burning is related to: (1) the abundance of buds at the base of the shoots, and their location above or below ground level, (2) their ability to establish new plants from seed following a fire, and (3) natural distribution patterns in relation to flammable shrubs.

The lack of improvement in perennial grass production following burning of semidesert ranges appears to involve an interaction between (1) improved soil moisture conditions resulting from reduction or elimination of the shrubs and (2) a deterioration in the microclimate due to reduced shade and the resulting higher surface soil temperatures and evaporation rates. The fact that most burning studies in the semidesert have shown little or no permanent damage or benefit to the perennial grass stand indicates that these two opposing factors probably in most cases cancel each other out.

SUMMARY AND CONCLUSIONS

Results from over 20 years of research on the effects of burning on semidesert grasses and shrubs in southern Arizona indicate that shrubs are most susceptible to burning in June, the hottest and driest part of the year. Some shrub species are highly susceptible to burning, others are relatively resistant, and others are intermediate. However, lack of sufficient herbaceous ground fuel in most years, except at higher elevations where perennial grasses are abundant, seriously restricts opportunities for planned burning in the semidesert:

1. Burroweed and larchleaf goldenweed are susceptible to fire,

and can be adequately controlled by periodic burning (periodic burning is required because new stands develop from seed). Since burroweed (and probably larchleaf goldenweed) does not compete seriously with perennial grasses for moisture, adequate herbaceous fuel will be available in years of high grass production.

2. Cacti are moderately susceptible to fire, depending on presence of sufficient fuel. Because of little competition for soil moisture between cacti and perennial grasses, adequate fuel should be present following wet years.

3. Small velvet mesquites in a good grass stand can be kept small by periodic burning to top-kill the trees, but such fire will kill few if any mature trees. In dense stands of mesquite, high natural resistance of mature trees and lack of adequate herbaceous fuel usually results in low mortality from burning.

4. Small creosotebushes invading grassland areas can be controlled by fire, but sufficient herbaceous fuel to carry a fire is usually lacking in dense mature stands.

5. False-mesquite and velvet-pod mimosa sprout readily following burning, and probably are not susceptible to other than top-killing by fire.

6. Fire can thus be used, when fuel is adequate, to reduce the encroachment of shrubby species and prevent them from reaching seed-bearing size. Sizeable reductions in shrub numbers can be expected only for burroweed, larchleaf goldenweed, and possibily for cacti.

7. Some perennial grass stands survive burning very well, either by their ability to reseed themselves following burning (Lehmann lovegrass) or by their distribution with respect to fuel concentrations (Santa Rita threeawn). Others are easily damaged by burning because of low resistance to burning and poor natural reseeding (black grama, tall threeawns), and some are intermediate (Arizona cottontop, Rothrock grama, tanglehead).

8. Prescribed burning will seldom increase total perennial grass production in the southwestern semidesert, may reduce production temporarily, and probably will change the relative abundance of the several perennial grass species present.

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