Fire Effects on Semidesert Grasses and Shrubs

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Highlight

Immediate effects of fire on perennial grasses lasted only 1 or 2 years. Burroweed was easily killed, but came back quickly with adequate cool-season moisture. Fire was relatively ineffective against mesquite, fair against cactus.

The use of fire to control shrubs has been studied intermittently in the Southwest for many years. This has been encouraged by the belief that repeated burning has been responsible for maintaining certain subclimax and disclimax grassland types in various parts of the world (Humphrey, 1958; Weaver and Clements, 1938). Thornber (1910) observed that several semidesert shrubs were killed by fire in southern Arizona. More recently, Humphrey (1949), Humphrey and Everson (1951), and Reynolds and Bohning (1956) have reported on the effects of fires in killing semidesert shrubs. The effects of burning on associated annual and perennial grasses have received less attention.

The present studies consisted of measuring changes in grass and shrub cover after burning and reburning to determine (1) the effectiveness of planned burning for shrub control, and (2) the direct and indirect effects of burning on perennial grasses. The study period, 1952-1965, included several years with precipitation above average and several years with precipitation below average.

The Study Areas

Two studies were conducted on the Santa Rita Experimental Range, about 25 miles south of Tucson, Arizona: one at about 3,100 ft elevation, and the other at about 3,700 ft elevation. The two areas lie about 3 miles apart on a gently sloping northwest exposure.

Vegetation.—Before treatment, perennial vegetation on the study areas consisted of an overstory of desert shrubs and cactuses, and an understory of low-growing shrubs and grasses (Fig. 1). The most conspicuous overstory species at the upper site was velvet mesquite *(Prosopis juliflora* var. *velutina* (Woot.) Sarg.);[2] at the lower site the most conspicuous overstory species were jumping cholla *(Opun-*

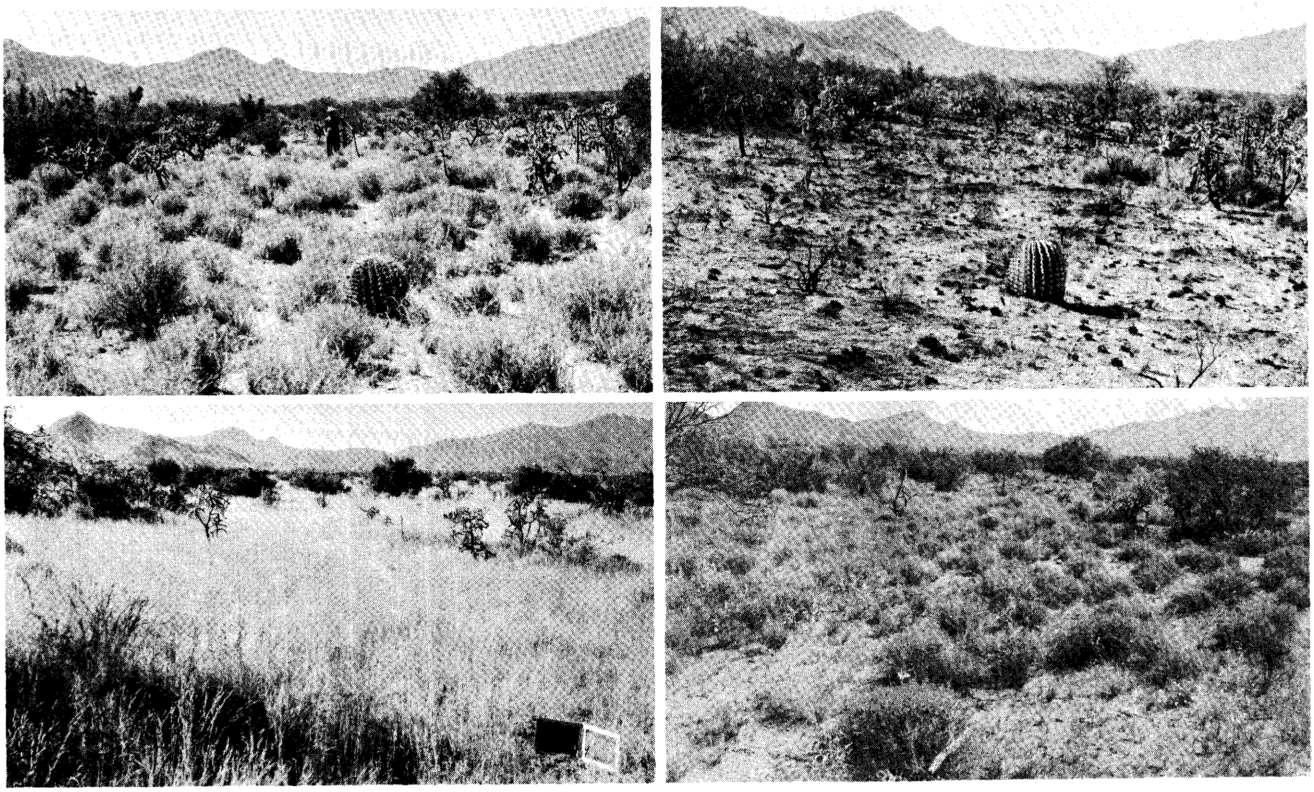

FIG. 1. Typical vegetation of the upper semidesert area: *Upper left,* June 30, 1952, before first burn; *Upper right,* July 8, 1952, 8 days after burning; *Lower left,* September 5, 1958, 6 years after burn; *Lower right,* September 1966, 14 years after burn. Burroweed has completely reinvaded.

[1] *Central headquarters maintained in cooperation with Colorado State University at Fort Collins. Author stationed at Tucson, Arizona, in cooperation with the University of Arizona.*

tia fulgida Engelm.), cane cholla (*O. spinosior* (Engelm. & Bigel.) Toumey), and Engelmann pricklypear (*O. engelmannii* Salm-Dyck). Burroweed (*Haplopappus tenuisectus* (Greene) Blake)[3] was the most abundant understory shrub at both sites.

Major perennial grasses at the upper site were Santa Rita threeawn (*Aristida glabrata* (Vasey) Hitchc.), other three-awns (primarily *A. hamulosa* Henr. and *A. ternipes* Cav.), Rothrock grama (*Bouteloua rothrockii* Vasey), Arizona cottontop (*Trichachne californica* (Benth.) Chase), and tanglehead (*Heteropogon contortus* (L.) Beauv.). At the lower site perennial grasses were very scarce.

The abundance of annual grasses and forbs varied with seasonal rainfall on both areas. The predominant annual grasses were needle grama (*B. aristidoides* (H.B.K.) Griseb.) and sixweeks three-awn (*A. adscensionis* L.).

Precipitation. — Precipitation on the areas is concentrated in two rainy seasons: a winter season from December into April, and a summer season from late June into September. These two rainy seasons are separated in the spring and fall by 2 to 3 months of relatively dry weather. Rain during the dry periods usually falls in light, infrequent showers and is of little apparent benefit to the vegetation.

Average annual precipitation at the lower site is 11.50 inches (19-year record). Of this total, 3.32 inches falls during the winter rainy season, and 6.90 inches during the summer rainy season.

Average annual precipitation at the upper site is 12.77 inches (38-year record). Of this total, 3.82 inches falls during the winter rainy season, and 7.44 inches during the summer rainy season.

Summer and winter precipitation both varied widely during the study period. At the upper site, summer rainfall ranged from 38% of average in 1956 to 172% of average in 1964. Winter precipitation varied from 15 to 136% of average. Similar variations in summer and winter precipitation were found at the lower site.

Between 1958 and 1965 at the upper site, winter rains averaged 19% below, and summer rains averaged 6% above the longtime average.

Soils.—The soils of both study areas are coarse sandy loams of the Whitehouse, Tumacacori, and Comoro series. Subsoil texture of the Whitehouse soil is a heavy clay loam, while that of the Tumacacori and Comoro soils is coarse sandy loam without developed horizons. These soils absorb and release water readily, and are important grass-producing soils (Youngs et al., 1931).

Grazing at upper site.—Grazing use records were not maintained on the study area, but utilization differences attributable to burning undoubtedly affected some of the results. The treated area at the upper site occupies about 25% of a small holding pasture that is used for cattle primarily at roundup time in the fall and for bulls during the winter. The pasture has not been grazed by cattle during the summer (July-September) for many years. The rate of stocking during the study period averaged 11 head/section on a yearlong basis, and utilization of perennial grasses averaged 54%. Utilization of perennial grasses on the study area, however, has averaged higher than the pasture mean because bulls that grazed the area during the winter were watered and usually fed supplement on the burned portion of the study area. Also, previous studies have shown that cattle and jackrabbits prefer burroweed-free areas. And, since fire killed most of the burroweed, heavier grazing on the burned area was to be expected for a few seasons at least. In terms of the effect of grazing on the plants, summer deferment may have compensated in part for heavy winter use in the case of cattle, but jackrabbits moved freely into the study area whenever green feed was available. Heavy concentrations of jackrabbits were observed, especially on the burned portions of the study area, for several seasons after the fire.

Methods

The lower study area consisted of four 2-acre plots, of which two were burned June 23, 1955. Approximately 300 lb/acre of air-dry herbage, almost entirely annual grasses, provided fuel for the burn. The area was burned between 6 and 8 AM. Average air temperature was 77 F, relative humidity was 18%, and the wind was 3 to 6 mph. Fuel moisture was low. Grass herbage production and shrub densities were determined in June 1955 before burning and in the fall of 1955, 1956, and 1958.

Approximately 100 acres were broadcast burned on June 30, 1952, at the upper site. An adjacent unburned area served as a check. Fuel consisted of about 600 lb/acre of annual and perennial grasses and burroweed. At the time of burning, the relative humidity was 15% and the wind less than 8 mph.

In June 1955, half the burned area at the upper site was reburned by the same methods as in 1952. Annual and perennial grasses provided approximately 700 lb/acre of fuel.

Vegetation data obtained at the upper site included: (1) basal intercept of perennial grasses (Canfield, 1942), (2) herbage production of annual and perennial grasses, (3) density of shrubs, and

[2] *Nomenclature follows Kearney and Peebles (1951).*

[3] *"Haplopappus" adopted as nomen conservandum in 1950 under the International Code of Botanical Nomenclature.*

(4) number of perennial grasses by species encountered on the transect lines. All vegetation measurements were taken on or adjacent to permanent 100-ft line transects on the burned area and the adjacent unburned area. Measurements were made annually from 1952 to 1956, in 1958, and in 1965.

Results

Burning at the lower site reduced the density of burroweed from 2,808 plants/acre before the burn to 416 plants/acre the first fall after the burn (Table 1). Three years later the burroweed stand had recovered about 17% of the density lost due to the burn. Cactus numbers were not changed significantly by the fire. Annual grass herbage production at the lower site varied from essentially nothing in 1956 to 536 lb/acre in 1958, but was not affected by the fire.

The rest of the results discussed here apply to the upper site only.

Striking changes were observed in numbers of plants, cover, and herbage production at the upper site during the study period. Some of these differences are attributed to burning and some to other factors. The changes in vegetation on the unburned area during the study period are assumed to reflect responses to normal ecological processes, including climatic variation. The changes on the burned areas represent the combined effects of burning and fire-induced changes in various ecological factors.

Changes in Shrub Densities.—Densities of some shrub species changed markedly, while those of other species changed little during the study period.

Live mesquite plants decreased from an average of 35/acre before the 1952 burn to 24/acre in the fall of 1952 (Table 2) (difference not significant at p = .05). On that part of the area

Table 1. Shrub densities and annual grass production before and after burning at the lower semidesert site.

Species	Treatment	Before burning 1955	Before burning 1955	After burning 1956	After burning 1958
Shrubs (plants/acre)					
Burroweed	Unburned	2120	2100	2204	2288
	Burned	2808	416**	548**	832**
Cane cholla	Unburned	349	319	356	284
	Burned	235	214	223	140
Jumping cholla	Unburned	128	130	133	171
	Burned	51	63	99	57
Pricklypear	Unburned	88	84	108	80
	Burned	66	67	56	39
Annual grass (lb/acre)					
	Unburned	211	156	0	418
	Burned	212	137	0	536

** Decrease from preburn number significant at p = 0.01. No other differences significant.

Table 2. Shrub densities (plants per acre) before and after bruning at the upper site[1].

Species and treatment	Before burn 1952	After burn 1952	After burn 1953	Bef. burn 1955	After burn 1955	After burn 1956	After burn 1958	After burn 1965
Mesquite								
Unburned	19	16	22		27	27	27	52
Once-burn	35	24	27		26	28	28	25
Twice-burn				43	41	50	48	48
Burroweed								
Unburned	2641	2543	2145		1563	1727	2695	4492
Once-burn	3762	327**	87**		196**	236**	1078**	7175
Twice-burn				173	15***	14***	206	4462
Jump. cholla								
Unburned	152	139	122		124	218	82	158
Once-burn	133	74	49*		62	107	17*	156
Twice-burn				44	52	156	28*	173
Cane cholla								
Unburned	158	212	152		115	162	161	155
Once-burn	332**	215	182		196	236	162	194
Twice-burn				105	118	166	86*	136
Pricklypear								
Unburned	68	63	65		48	86	49	166
Once-burn	161**	101	109		78	103	48	118
Twice-burn				83	60	75	48	52

[1] Data derived from: Unburned – 16 plots. Once-burned – 16 plots for 1952 and 1953; 14 plots for 1955-58 (8 of original 16 plots plus 6 plots established in 1955). Twice-burned – 16 plots (8 of original 16 plots plus 8 plots established in 1955).

* = significantly different at p = 0.05 from unburned area in the particular year.

** = significantly different at p = 0.01.

*** = significantly different at p = 0.01 from once-burned and unburned areas.

burned twice, mesquite density changed from 43 trees/acre before the second burn to 41 in the fall following the burn. Low mortality following the second burn probably was because most of the small, more susceptible trees were killed by the first burn. No mesquite larger than 6 inches in basal diameter was killed, and most of the trees that were top-killed by the fire sprouted later.

During the study period, more mesquite seedlings were established on unburned than on burned plots. A few new seedlings appeared on the burned areas by the second fall after each burn, but subsequent changes were small (Table 2). Mesquite numbers on the unburned area, however, increased substantially, from 16/acre in 1952 to 52/acre in 1965 (increase significant at $p = .01$). The denser initial stand of mesquite on the burned area might indicate that it was basically the more favorable site for mesquite. If so, we would expect at least as much mesquite seedling establishment on the burned areas as on the unburned. Failure of mesquite seedlings to become established in greater numbers on the burned areas, therefore, indicates that the burning in some way impeded normal mesquite establishment. The reduced yield of mesquite seed on trees partially top-killed would represent one such effect. Also, some reduction in numbers of Merriam kangaroo rats probably resulted from the burning of cactus and other shrubs that formerly sheltered the rats, with a consequent reduction in the amount of seed cached on the burned area. And, previous studies have shown that mortality of mesquite seedlings is much higher on areas grazed by cattle and jackrabbits than in cattle-jackrabbit exclosures. Some combination of secondary effects such as these probably was responsible for the reduced mesquite seedling establishment measured on the burned areas.

Ninety-eight percent of the burroweed plants on the area burned in 1952 were dead by the end of the second growing season following the burn (Fig. 1 and Table 2). Burroweed density remained low for the next 3 years, during which winter moisture was deficient. Between 1956 and 1958, however, following two relatively wet winters, burroweed numbers increased about 4.5 times. Between 1958 and 1965, burroweed numbers increased further from 1,078 to 7,175 plants/acre, nearly double the 1952 preburn density.

On the area burned twice, only 173 plants/acre were present before the second burn, and 92% of them were killed by the burn. Most burroweeds that survived either or both fires were found on unburned or lightly burned patches within the burned area. Favorable winter moisture in 1957 and 1958 permitted the establishment of more burroweed seedlings by the fall of 1958 than were killed by the second fire. The correlation between burroweed density and winter precipitation between 1952 and 1958 was 0.91. Between 1958 and 1965, burroweed numbers increased from 206 to 4,462 plants/acre, essentially equal to that on the unburned area. These results show that, while fire will kill nearly all burroweed plants, seedlings can quickly reinvade if winter-spring moisture is favorable.

The first burn, in 1952, killed about 63% of the jumping cholla, 45% of the cane cholla, and 32% of the pricklypear. By 1958, densities of all species of cactus on the once-burned area were considerably lower, relative to their 1952 densities, than were densities of the same species on the unburned area. By 1965, jumping cholla had increased greatly, to more than the preburn density; cane cholla had increased about 20%; and pricklypear numbers more than doubled, but were still below preburn density.

In contrast to the first burn, the second burn produced no significant changes in density of any of the cactuses. The greater effectiveness of the first burn in killing cactus is believed to have been due to the accumulation of grass herbage and dry plant litter and the presence of many small plants around the base of large plants. This accumulated fuel provided enough heat to kill some mature plants and most of the small plants and viable joints within these zones of fuel accumulation. At the time of the second burn there was little fuel accumulation and few susceptible

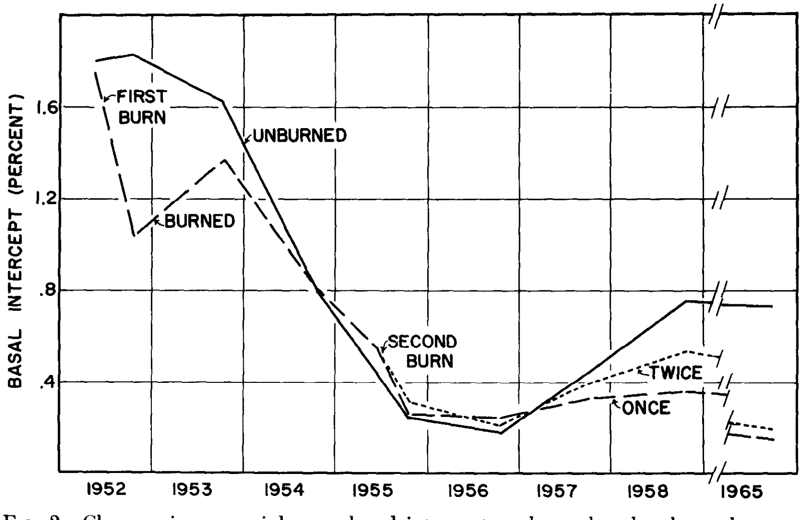

FIG. 2. Changes in perennial grass basal intercept on burned and unburned areas, upper semidesert site.

small plants. Numbers of jumping and cane chollas increased substantially between 1958 and 1965 on the area burned twice, but pricklypear remained essentially unchanged.

Cactus numbers changed erratically on the unburned area, but all three species increased in the dry year of 1956. Jumping cholla and pricklypear decreased substantially between 1956 and 1958, then increased markedly between 1958 and 1965. Cane cholla changed very little during this period. The basic reasons for these density changes are not known.

Changes in Perennial Grass Intercept.—The basal intercept of perennial grass at the end of the first growing season following the first burn was 36% below the intercept just before the burn (Fig. 2). During the second growing season, intercept of perennial grass on the burned area increased somewhat, while that on the unburned area declined. Thereafter, until 1957, basal intercepts of perennial grasses on the various areas were generally similar. In 1958 and in 1965, however, basal intercept on the unburned area was significantly higher than on either of the burned areas.

Fire may kill or damage individual perennial grass plants, or may indirectly increase grass growth by reducing the density of competing shrubs. Although the average intercept of all perennial grasses decreased following the first burn, individual perennial grass species responded differently. Santa Rita three-awn increased in intercept the first two summers, while other three-awns declined sharply, especially the first year (Fig. 3). Intercepts of Rothrock grama, Arizona cottontop, and tanglehead also declined the first year, though not as sharply as those of other three-awns.

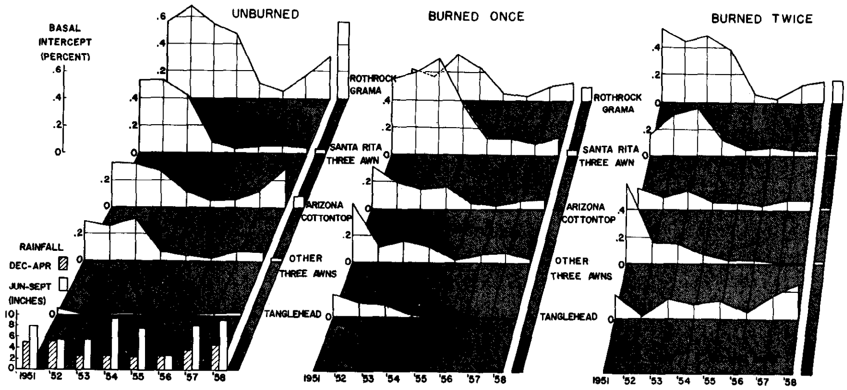

FIG. 3. Basal intercept of perennial grasses by species on burned and unburned areas, upper semidesert site.

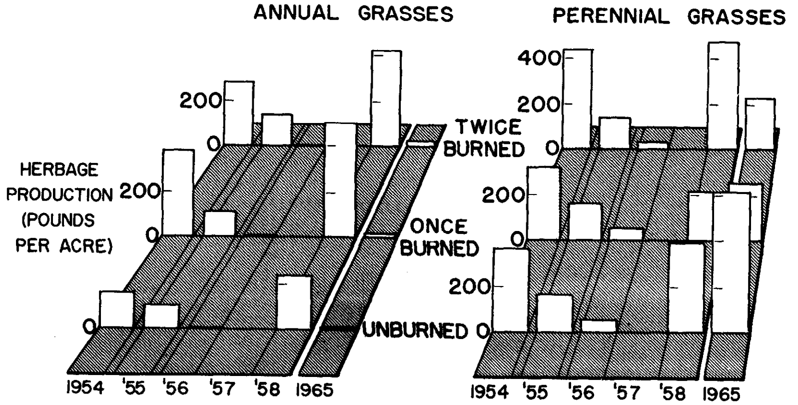

FIG. 4. Herbage production of annual and perennial grasses on burned and unburned areas, upper semidesert site.

These differences among grass species in response to burning appear to be due in part to differences in growth habits and distribution patterns. For example, the other three-awns frequently grow within the crowns of burroweeds. Because of the extra fuel provided by the fine-stemmed resinous burroweed, grass plants so located were subjected to more heat during the burning than were plants in the open, where dried grass herbage constituted the only fuel. This may explain the sharp reduction in intercept of other three-awns following the first burn, during which over 3,700 burroweeds/acre provided fuel for "hot-spots."

In contrast to other three-awns, Santa Rita three-awn tends to be evenly dispersed in the openings. Therefore, comparatively few of these plants were subjected to the extra heat generated by burning burroweeds. Consequently, most plants of Santa Rita three-awn were damaged less severely by fire and, perhaps, were thereby able to utilize available soil moisture more efficiently, as indicated by the sharp increase in intercept of Santa Rita three-awn after the first burn.

Arizona cottontop, Rothrock grama, and tanglehead were intermediate between Santa Rita three-awn and other three-awns with respect to degree of dispersion and association with burroweed. They were also intermediate in their reactions to burning.

In contrast to the first burn, the second burn, in 1955, had no measurable effect on basal intercept of perennial grasses (Fig. 2) either in total or by individual species. Presumably the low density of burroweed at the time of the second burn permitted few "hot-spots" and provided little release from burroweed competition. Also, summer rainfall after the burns was not the same. The dry summer immediately following the first burn undoubtedly delayed recovery of the grasses. Favorable summer moisture following the second burn permitted more rapid grass recovery.

The basal intercept of perennial grasses declined sharply under all treatments from 1952 to 1956, presumably in response to adverse climatic factors. Recovery of perennial grasses after 1956, however, differed among the three treatments. Recovery was greatest on the unburned area, followed by the twice-burned and once-burned areas. Obviously, burning did not increase total perennial grass intercept.

Changes in species composition were recorded during the study period, particularly between 1958 and 1965. In 1958, tanglehead and Rothrock grama were dominant on the twice-burned area, while Rothrock grama and Santa Rita three-awn dominated the once-burned area (Fig. 3). On the unburned area, Rothrock grama and Arizona cottontop accounted for most of the intercept both in 1958 and 1965. By 1965, Rothrock grama was the dominant grass on all three areas, tanglehead had nearly disappeared, and Arizona cottontop was down sharply.

The results of this study indicate that burning had no lasting effects, beneficial or detrimental, on perennial grass cover. It is true that intercept measurements in 1958 and 1965 were lower on the burned areas, but the connection between this reduction in cover and the burning in 1952 or 1955 becomes increasingly tenuous as time passes. It is more likely that indirect after-effects of burning, such as concentration of grazing on burned areas, account for the lower perennial grass cover on burned areas in 1958 and 1965.

Changes in Grass Production.—Herbage production measurements by species were started in 1954. Production of perennial grasses on burned and unburned areas did not differ significantly in 1954, 1955, or 1956 (Fig. 4). By 1958, however, perennial grass production was significantly higher on the unburned area than on the once-burned area. And, in 1965, perennial grass production on the unburned area was higher than on either burned area. Presumably, if effects of burning had been beneficial and lasting, grass production would have been higher on the burned areas. Similar yields on the burned and unburned areas in 1954, 1955, and 1956 indicate that burning had no immediate effect on total yield of perennial grasses.

The smaller yields on burned areas in 1958 and 1965 must be attributed to secondary effects brought on by burning or to other unknown factors. Heavier grazing by both cattle and rabbits on the burned areas during the first few seasons after burning may have been a contributing factor. Tschirley and Martin (1961) found that grazing was consistently heavier on plots where burroweed had been removed, and that burning of burroweed markedly increased grass intercept only on plots protected from both cattle and rodents.

Differences in grass composition and in size-weight relationships account in part for differences in herbage yield among the three areas in 1958 and 1965. For example, tanglehead, a taller grass, produces more herbage per unit of basal intercept than does cottontop or Rothrock grama. Thus, herbage yield of perennial grasses in 1958 was higher on the twice-burned area, where tanglehead was the most abundant species, than on the unburned area, where tanglehead was almost absent, even though total basal intercept of perennial grasses on the unburned area was 50 percent higher. In 1965, when tanglehead had largely disappeared from the twice-burned area, perennial grass intercept and production were similar for both burned areas, and much lower than on the unburned area.

In contrast to the small effects of burning on perennial grass production, burning apparently resulted in an increase in herbage production of annual grasses in wet years. Annual grass production was about twice as high on the burned as on the unburned areas in the wet years, 1954 and 1958, but little or no higher in the average and dry years, 1955 and 1956 (Fig. 4). Similar responses have been noted in burroweed-control studies on the Santa Rita, i.e., yields of annual grasses on the burroweed-free areas markedly exceeded yields on burroweed-infested areas only in wet years. Since the most striking effect of burning is the elimination of almost all of the burroweed, at least temporarily, the increases in annual grass yields in wet years on the burned areas are believed to be due to the elimination of burroweed competition. This hypothesis is supported by the fact that, after burroweed cover had become reestablished on the burned areas, relatively high rainfall in 1965 produced only from 3 to 7% as much annual grass as in 1958.

The increased yield of annual grasses on burned areas in favorable years is attributed to the presence of soil water excess to the needs of perennial grasses and other perennial plants. These perennials apparently use most of the available moisture in average or drier years. Excess, or more than average, rainfall permits the germination and growth of thick stands of annuals. Under certain conditions these annuals can significantly reduce perennial grass production.

Summary and Conclusions

Effects of controlled burning in a semidesert grass-shrub type were observed at two locations on the Santa Rita Experimental Range in southern Arizona. One area, at 3,100 ft elevation, was burned in June 1955. The other area, at 3,700 ft elevation, was burned in June 1952, and half of this area was reburned in June 1955. Basal intercept of perennial grasses, herbage production of annual and perennial grasses, and shrub densities were measured before each burn and periodically during the study (1952-1965).

At the lower site, the fire killed 85% of the burroweed but had no effect on cactus density or annual grass production.

Results and conclusions at the upper site:

1. A few small mesquites were killed by the first fire, almost none by the second. Mesquite seedling establishment was significantly higher on the unburned area than on the burned area.

2. Burroweed was easily killed by burning, 98% by the first burn and 92% by the second burn. Burroweed density increased when winter precipitation was high and decreased when winter precipitation was low. By 1965, burroweed numbers exceeded the preburn count on both burned areas.

3. The first burn killed from 32 to 64% of the cactus plants, depending on fuel conditions. The second burn had little effect on cactus.

4. Herbage yields of summer annual grasses were higher on burned plots in wet summers as long as burroweed numbers were low, presumably because of the reduction in burroweed.

5. Individual perennial grass species differed in their response to fire, largely due to differences in patterns of distribution with respect to burroweed plants and other fuel accumulations.

6. Most perennial grasses decreased in basal intercept during the growing season immediately following the first fire, but showed no effect following the second fire. Differences in fuel accumulation at the time of the two burns, and in the amount of rainfall following the burns, are believed responsible for the different reactions.

7. Adverse growing conditions from 1952 to 1956 resulted in a marked decrease in total basal intercept of perennial grasses regardless of fire. Increases in basal intercept after 1956 were greater on the unburned area.

8. Yields of perennial grasses were about the same on burned and unburned areas during the first few seasons after burning. However, yields were lower on the burned areas in 1958 and 1965, probably because of consistently heavier grazing of these areas after they were burned.

These results show that fire was relatively ineffective against mesquite and only fair for controlling cactus. Burroweed was very susceptible to fire, but rapidly reinfested the burned area when cool-season moisture was adequate. Burning, by controlling burroweed, increased annual grass yields in wet summers. The immediate effects of burning on perennial grasses lasted only one or two seasons, but the pattern of heavier use of the burned areas, which began soon after burning, reduced cover and yield of perennial grasses in the later years of the study.

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