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Shrub Control Studies in the Oak-Chaparral of Arizona.[1]

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Approximately six million acres of oak chaparral occur in Arizona (Humphrey, 1959; Nichol, 1952). The shrubs grow in stands of varying density, often forming impenetrable thickets which contain very little grass and consequently produce little forage, Figure 1.

Mechanical, biological, chemical and burning methods of control have been tested, alone and in combination, with varying degrees of success. Mechanical treatments have generally been difficult and unsuccessful because of shallow rocky soils and steep slopes. Burning has been commonly used but the chaparral species are unusually well adapted to overcome the injurious effect of fire, either through sprouting or stimulation of seed germination. Chemical treatments are partially effective on certain species, but others, especially the oaks, are resistant. Biological methods, such as grass competition, may slow down reinvasion of treated shrub lands.

In 1957 a three-year study was started to test the effect of single and multiple applications of various herbicides on the fire sprouts of the chaparral species. In 1959 data were also collected to measure the effect of the herbicide treatments on grass-shrub relationships and forage production and an economic evaluation was made of the cost and benefits of the spraying treatments.

Literature Review

The use of fire to control western chaparral species has been discussed by Burcham (1959); Horton & Kraebel (1955); Pond & Cable (1960); Rowe (1948); Sampson (1944a), Sampson (1944b), (1952); Sampson & Burcham (1954); Shantz (1947); Stoddart & Smith (1955); and others. In general they concluded that burning temporarily reduced the canopy but recovery by sprouting and reseeding was rapid. Therefore, control by fire alone would require frequent burning with possible serious consequences in soil erosion and fire damage to forage species.

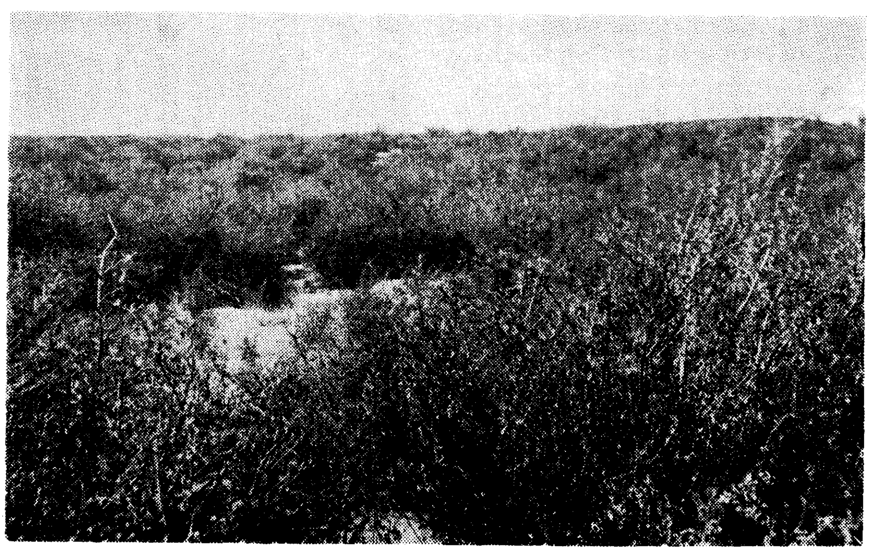

FIGURE 1. A typical stand of Arizona oak-chaparral.

[1] *This study was carried out by the Arizona Agricultural Experiment Station in cooperation with the Rocky Mountain Forest and Range Experiment Station, the Prescott National Forest, the Arizona Game and Fish Department. Also, members of the Agricultural Research Service, Soil Conservation Service, Upper Agua Fria Basin Soil Conservation District, Arizona Agricultural Extension Service and Arizona Agricultural Experiment Station assisted in conducting the study. Part of the chemicals were furnished by the Dow Chemical Company; part of the airplane application of chemicals was contributed by the Neace Aviation Company, and the study was supported in part by Arizona W-63 Regional Research funds. Published as Technical Paper No. 691, Arizona Agricultural Experiment Station, Tucson, Arizona, Projects 285 and 292.*

The need for burning, reseeding and chemical treatment in combination with grazing management to control chaparral species was emphasized by Biswell (1954); Burcham (1957); Graham (1958); Juhren, Pole & O'Keefe (1955); Leonard & Carlson (1958); Leonard & Harvey (1956); Manley & Walker (1956); Raynor (1958); Reynolds & Glendening (1959); and Schultz, Launchbaugh & Biswell (1955). They found that burning removed the dense brush and provided an ash seedbed in which grasses and legumes could be drilled or broadcast. Reseeding was generally necessary since most chaparral lands have a poor understory of grasses and the hot chaparral fire usually killed many of the existing grasses, especially in dense brush. Followup chemical treatment was necessary to control undesirable brush sprouts and seedlings.

Chemical treatment of brush sprouts after fire was most effective when full sprouting had occurred and sprouts were 12-18 inches high. Also, it was generally recommended that spraying be done when soil moisture was available and sprouts were actively growing. However, due to the marked resistance of some chaparral species to chemicals, several applications were needed for effective control of resistant species (Cable, 1957; Graham, 1958; Juhren, Pole & O'Keefe, 1955; Leonard, 1960; Leonard & Carlson, 1958; and Leonard & Carlson, 1959).

In the Arizona chaparral, preliminary work by Turner and Tschirley[2] showed that mature shrub live oak or turbinella oak (*Quercus turbinella* Greene)[3], the major dominant, was highly resistant to single aerial applications of 2,4-D and 2,4,5-T[4]. Followup studies by Schmutz and Turner (1957) on fire sprouts of shrub live oak with eight herbicides showed that hand-spray applications gave high topkill, 65 to 80 percent for 2,4,5-T and silvex, respectively, but practically no total-kill. These same studies indicated that 2,4,5-T formulations were more effective than 2,4-D and that propionic forms were more effective than acetic. Time of application studies showed that 6 months regrowth after burning was necessary for high topkill and that susceptibility of plants from 2,4,5-T formulations remained high for at least 6 months thereafter, from December to June.

As a result of these preliminary investigations the present study was set up to measure the effect of single and multiple applications of herbicides on burned chaparral lands.

Description of Study Area

The study area was located on the south slope of Mingus Mountain in the Prescott National Forest approximately 5 miles northeast of Dewey, Yavapai County, Arizona. The site was a moderately-sloping, southern exposure, approximately 5,500 feet in elevation, Figure 2.

Soils of the area belong in the Cordes and Gaddes series of the alluvial and noncalcic brown soil groups, respectively. They were developed from granite, basalt, schist and limestone parent materials and varied from shallow residual gravelly and stony clay loam soils to deep alluvial sandy loam soils along the drainages. Slopes varied from 3 to 30 percent.[5]

Shrubs of the area included the dominant shrub live oak, pointleaf manzanita (*Arctostaphylos pungens* H.B.K.), skunkbush (*Rhus trilobata Nutt.*), wait-a-minute bush (*Mimosa biuncifera* Benth.), hairy mountain-mahogany (*Cercocarpus breviflorus* Gray) and desert ceanothus (*Ceanothus greggii* Gray). Dominant half-shrubs were broom snakeweed (*Gutierrezia saro-*

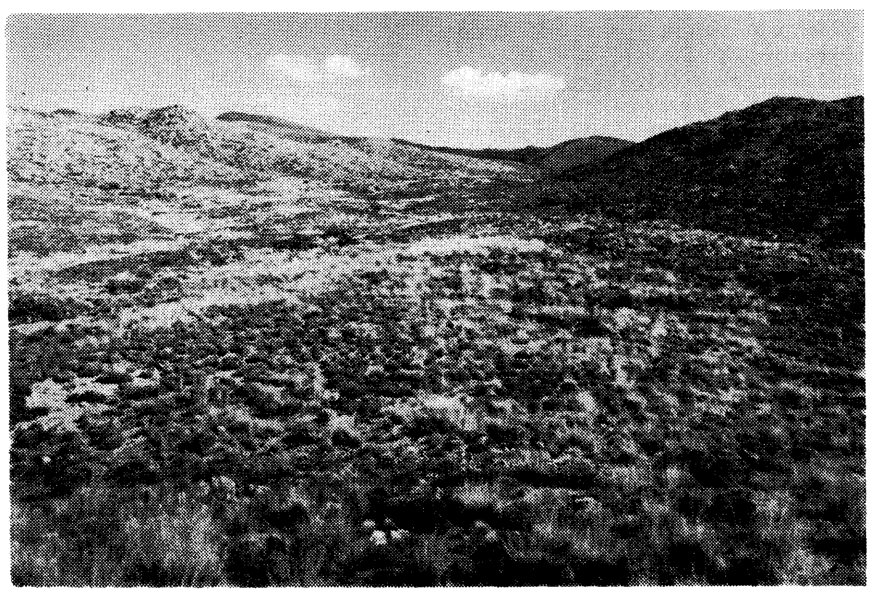

FIGURE 2. Burned chaparral study area on the south slope of Mingus Mountain near Dewey, Arizona.

[2] *Unpublished data from Turner, R. M. and F. H. Tschirley. 1956. Effect of 2,4-D and 2,4,5-T upon three species of shrubs in Arizona chaparral. Univ. Ariz. Agron. & Range Mangt. Dept., Tucson, Arizona. 11 pp.*

[3] *Scientific plant nomenclature follows Kearney & Peebles (1951); common names follow local preference.*

[4] *Terminology used in accordance with that recommended by the Weed Society of America, Terminology Committee (1958).*

[5] *Soils data taken from unpublished manuscript by Wendt, G. E. 1960. Description of soils on the Perry Henderson ranch. Soil Conservation Service Soil Survey, Prescott, Arizona, 11 pp.*

thrae (Pursh) Britt. & Rusby) and Wright or shrubby buckwheat (*Eriogonum wrightii* Torr.). Important native perennial grasses included sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Black grama (*B. eriopoda* Torr.), blue grama (*B. gracilis* (H.B.K.) Lag.), sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray) and red threeawn (*Aristida longiseta* Stend.).

The climate of the chaparral type is semi-arid with a summer and winter rainfall pattern. Highest precipitation occurs in the summer during July and August, and in the winter from December through April (Sellers, 1960).

A recording raingage was set up near the area to measure rainfall but due to mechanical difficulties and remoteness of the area, only partial records were obtained. In lieu of complete local data, a comparison was made with 17-year-records for Poland Junction, a similar site located 11 miles southwest at an elevation of 4,900 feet. This station shows an average annual precipitation of 14.9 inches (U. S. Weather Bureau, 1942-59). Using this average and the Greene (1959) altitude-precipitation curve for central Arizona, the projected average annual precipitation for the study area was 17.2 inches. Similarly, since the rainfall at Poland Junction for the 3-year-period of the study averaged 2.16 inches above normal, the estimated average rainfall during the 3-year-period at the study site was 19.36 inches per year.

Nearest temperature and frost data are from Prescott, 18 miles northwest at an altitude of 5,410 feet. The 56-year record shows a mean monthly temperature of 52.8° F. and a mean growing season of 140 days, from May 19 to October 6 (Sellers, 1960).

Methods and Materials

Layout and Treatments

The study area accidentally burned in June, 1956. Weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees.) was seeded in the ashes by airplane and became the dominant grass species even though establishment was variable due to erratic rains, erosion and variable soil moisture. Grazing was deferred for two years. Thereafter only light grazing was permitted.

Several series of plots were laid out and treated with two herbicides, 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid) and silvex (2-(2,4,5-Trichlorophenoxy) propionic acid). Applications were made both by airplane and hand-spray methods at single-heavy-rates and at single- and multiple-light rates. The butoxy ethanol ester of 2,4,5-T was used in the airplane applications and the propylene glycol butyl ether (PGBE) esters in the hand-spray applications. The PGBE esters of silvex were used in both hand-spray and airplane applications. The first applications were made in late May and early June, 1957, and repeated annually.

Single-heavy-rate airplane applications were made on May 29, 1957, at the rate of 5 pounds acid equivalent per acre in a 12.5 percent diesel oil-water emulsion in a total volume of 10 gallons per acre. Both herbicides were applied on replicated, randomized, 10-acre, 330 x 1320-foot plots separated by 100-foot buffer strips.

The light-rate airplane applications were made once a year in the latter part of May to make single-year, alternate-year and 3-consecutive-year treatments for both herbicides. The light rates, 1.67 pounds acid equivalent per acre, were applied in a 12.5 percent diesel oil-water emulsion in a total volume of 10 gallons per acre. The plots were 2 acres, 126 x 690-feet, separated by 100-foot buffer strips. Three plot replications were designed for each herbicide in all yearly treatments. However, due to rough terrain, three single-year plots (two silvex and one 2,4,5-T) were left out and one-year readings on the other plots were substituted for total-kill and topkill of shrub live oak. Also, a flight error caused one of the 3-consecutive-year silvex plots to receive only an alternate-year treatment, resulting in two replications of the 3-consecutive-year silvex treatment and four replications of the alternate-year silvex treatment.

As a check on the airplane-spray plots, replicated hand-spray applications of the same herbicides were made on individual plants at single, alternate and 3-consecutive-year intervals. However, the hand-spray tests were applied in a 2 percent diesel oil-water emulsion in a volume of 50 gallons per acre at a rate of one pound of herbicide for the light application and 3 pounds for the heavy applications.

Vegetative Measurements

In order to measure the effect of the herbicide treatments on the airplane-spray plots, five 100-foot lines were located crosswise in the center of each plot at regular 100-foot intervals in the 2-acre plots and at 200-foot intervals in the 10-acre plots. Ten vigorous shrub live oak plants were randomly located on either side of each line, making a total of 50 plants per plot. These plants were located just prior to application of herbicides, approximately one year after the area was burned and reseeded. Similarly, on the hand-spray plots, six vigorous plants were randomly located along two replicated 50-foot lines.

In order to determine the percent total-kill and percent topkill for each treatment, previously located plants were evaluated as D (dead), A_1 (67 up to 100 percent topkill), A_2 (34 to 66 percent topkill), A_3 (5 to 33 percent topkill) and A_4 (no noticeable effect). Readings were made approximately one year after treatment in order to allow

Table 1. Results of three years (1957-59) of airplane and hand-spray herbicide tests on fire sprouts of shrub live oak near Dewey, Arizona.

TREATMENT	LIGHT APPLICATIONS				HEAVY APPLICATIONS
	Single Year 1957	Alternate Year 1957, 1959	Two-Consecutive Year 1957, 1958	Three-Consecutive Year 1957, 1958, 1959	Single Year 1957
	(Percent)				
Airplane-Spray Test					
Silvex					
Total-kill	7	7	30	44	20
Topkill	26	49	60	84	42
2,4,5-T					
Total-kill	4	14	6	14	6
Topkill	21	46	38	59	33
Hand-Spray Tests					
Silvex					
Total-kill	19	17	41	41	58
Topkill	65	83	86	89	89
2,4,5-T					
Total-kill	8	0	67	67	41
Topkill	60	75	93	93	83

for "residual" effect of chemicals. Total-kill was calculated from the percentage of plants completely dead. The percent topkill was calculated from weighted values, weighting D as 100 percent, A_1 as 80 percent, A_2 as 50 percent, A_3 as 20 percent and A_4 as no topkill.

In addition, on both the airplane-spray and hand-spray plots, readings were made on the 3-consecutive-year plots just prior to the 3rd-year treatment to measure the effect of 2-consecutive applications on total and topkill.

During August, September and October, 1959, plant measurements were made on each plot treated by airplane to determine the effect of the different treatments on shrub numbers, shrub ground cover and grass production. These measurements were made in paired, 43.6 x 100-foot sampling areas located 100 feet inside each treated plot and, where possible, 100 feet outside in an adjacent unsprayed area. One pair of sampling areas was used to evaluate each 2-acre treated plot and two pairs for each 10-acre treated plot. However, since adjacent unsprayed areas were not available for treated plots B_2 and B_3, these two treated plots were compared with similar unsprayed areas adjacent to plots C_1 and C_2, respectively.

The effects of herbicide treatment on shrub numbers and ground cover were measured on twenty, 2 x21.8-foot sample plots located by grid method within each sampling area. Three classes of shrubs were identified and recorded: shrub live oak, other-shrubs and half-shrubs. Each shrub was listed by class and its area of ground cover estimated using a one-square-foot grid sub-divided into one one-half and two quarters. (See description of study area for dominant species.)

Perennial grass production was measured by clipping twenty, 9.6-square-foot sample plots located by grid within each sampling area. Both native and introduced perennial grasses were

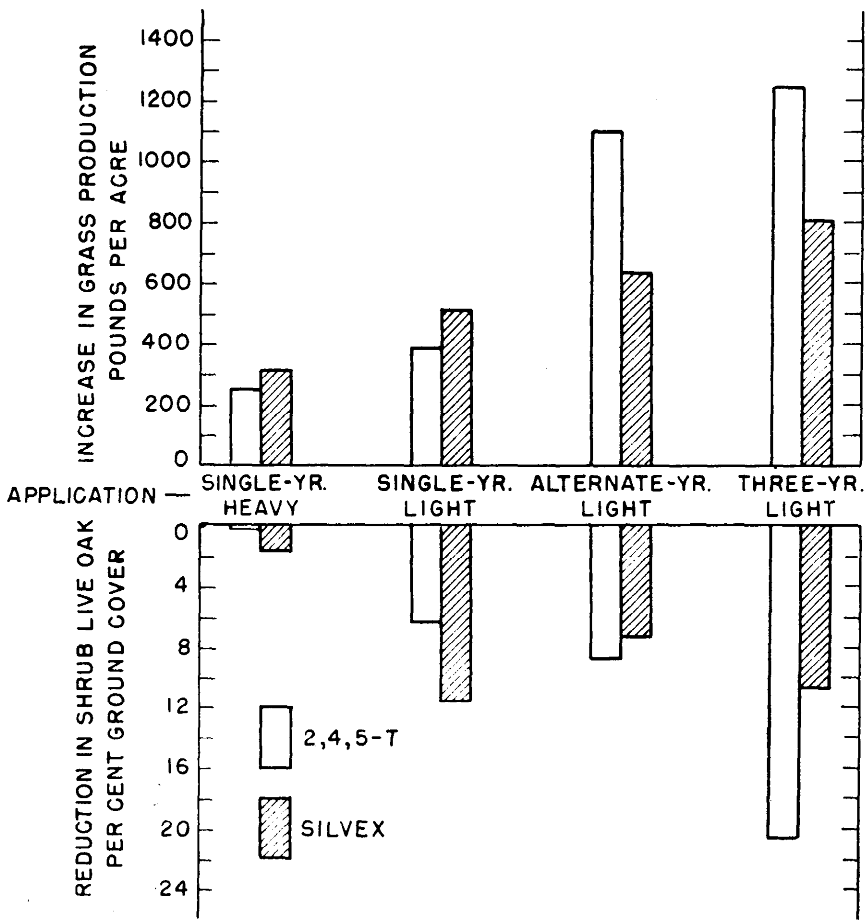

FIGURE 3. The effect of various applications of 2,4,5-T and silvex in reducing ground cover of shrub live oak and increasing grass production.

Table 2. Estimated cost of large-scale airplane applications of 2,4,5-T and silvex herbicides on burned chaparral ranges compared with the value of expected annual forage increase[1]

Treatment	Total herbicide applied, per acre	Total estimated cost of treatment per acre	Estimated value of annual forage increase per acre	Years of sustained forage production required to repay cost
	pounds	dollars	dollars	number
Single heavy applications	5.00	$16.84	$1.22 - 1.56	11-14
Single light applications	1.67	6.85	1.92 - 2.55	3-4
Two-alternate-year light applications	3.33	13.68	3.18 - 5.49	3-4
Three-consecutive-year light applications	5.00	20.52	4.04 - 6.26	3-5

[1] Estimates were based on herbicide costs at $3 per pound (acid equivalent); diesel oil costs at $ .15 per gallon; aerial application costs at $1.65 per acre, including mixing, loading and flagging; grass hay values at $20.00 per ton; and proper use of increased forage at 50 percent.

clipped at ground line and field weighed. Representative field samples were taken, oven-dried, and the data used to convert field weights to oven-dry weight per acre.

Results and Discussion

Vegetative Evaluation

Results of the 3-year, airplane-spray, herbicide study showed that repeated light applications of equivalent herbicide were more effective in controlling fire sprouts of shrub live oak than single heavy applications, Table 1. The 3-consecutive-year light applications were most effective but only slightly more so than the 2-consecutive-year light applications. Single and alternate-year light applications were usually least effective, generally being less even than the single heavy application. In part these tests confirmed previous studies which showed that propionic 2,4,5-T formulations were more effective on shrub live oak than the acetic formulations but results were not consistent. In general, topkill was usually more than twice as high as total-kill.

The hand-spray tests generally confirmed the results of the airplane-spray tests, Table 1. However, both total-kill and topkill figures were higher for the hand-spray tests even though herbicide application rates were less. This suggests a difference due to the volume of carrier and/or method of application.

The measurements on shrub numbers and ground cover also show that the airplane-spray applications generally reduced shrub numbers. Again silvex was usually more effective. However, the reduction in shrub numbers was greater on other shrubs and half-shrubs than on shrub live oak.

In general as the percent ground cover of shrub live oak (and other shrubs) was decreased by the herbicides, grass production increased proportionately, Figure 3. There was no consistent difference in effect between the two herbicides. Single applications of silvex were somewhat more effective than 2,4,5-T and multiple applications of 2,4,5-T were more effective than silvex.

The average effect of all aerial herbicide treatments was to increase grass production 655 pounds per acre, from 345 pounds to over 1,000 pounds per acre. Increases from the three-consecutive-year light applications were greatest, averaging 1030 pounds per acre, with the two-alternate-year light applications, single light applications and single heavy applications averaging 867, 448 and 278 pounds, respectively. Plots were not available to determine yields from two-consecutive-year applications.

The contrasting effect of unsprayed versus three-consecutive-year light applications on shrub growth and grass production can be observed in Figure 4.

Economic Evaluation

A cost-benefit evaluation was made of the various herbicidal treatments to determine their relative value and to estimate

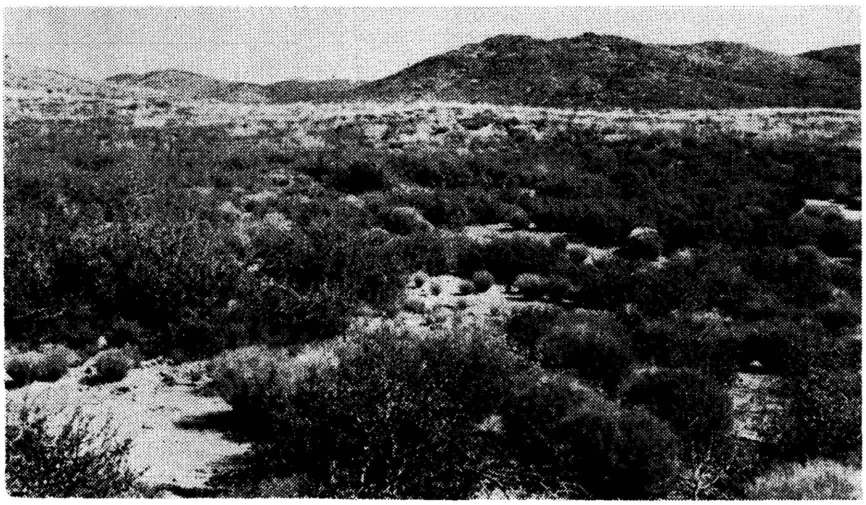

FIGURE 4. The contrasting effect of unsprayed (foreground) versus three-consecutive-year light applications (background) on shrub growth and grass production.

the number of years of sustained forage production required to repay costs. These evaluations indicate that based on grass hay values, 3 to 5 years of sustained forage production would be required to repay costs of light applications and 11 to 14 years would be required to repay the costs of a single heavy application, Table 2.

These studies indicate that on many burned and reseeded areas of oak-chaparral in Arizona multiple light applications of silvex or 2,4,5-T herbicides may provide an economical means of reducing shrub growth and increasing forage production under favorable moisture conditions.

It should be pointed out, however, that in determining the total value of the land treatment, both the costs and benefits from preliminary burning and reseeding must be considered. Based on verbal reports from two field trials by Perry Henderson at Dewey, Arizona, burning and reseeding can also be an economical operation, provided grass establishment is successful and proper grazing management is practiced.

Summary

During the three-year period, 1957-1959, both airplane- and hand-spray herbicide tests were made on a burned and reseeded oak-chaparral area near Dewey, Arizona. Beginning one year after burning, silvex and 2,4,5-T herbicides were applied to replicated plots at single heavy rates (3 to 5 pounds per acre) and at light rates (1-1.67 pounds per acre) at single-, alternate-, two-consecutive- and three-consecutive-year intervals.

Evaluations were made of the effect of herbicide treatments on total-kill and topkill of shrub live oak, on ground cover and numbers of various shrubs, and on the production of grass. An economic analysis was made based on herbicide treatment costs and increased forage production.

Results were variable but data show that whether applied by hand or airplane methods, repeated light applications of silvex and 2,4,5-T herbicides were generally more effective in controlling shrub live oak than single heavy applications. The three-consecutive-year light applications, which averaged about 40 percent total-kill and 80 percent topkill, were most effective but only slightly more effective than the two-consecutive-year aerial application. In general, topkill was more than twice as high as total-kill and high-volume hand-spray applications were more effective than low-volume aerial-spray applications. Propionic formulations of 2,4,5-T were usually more effective than acetic formulations but results were not consistent.

In general, as shrub cover and shrub numbers were reduced, grass production increased. The average effect of all aerial herbicide treatments was to increase grass production 655 pounds per acre, from 345 pounds on the unsprayed areas to over 1,000 pounds per acre on the treated plots. The greatest increase was 1030 pounds per acre from the three-consecutive-year treatments with the two-alternative-year-light, single-year-light and single-year-heavy applications resulting in smaller increases of 867, 448 and 278 pounds per acre, respectively.

An economic evaluation of herbicide treatment costs versus corresponding increased forage production indicated that, based on grass hay values, 3 to 5 years of sustained forage production would be required to repay costs of light applications and 11 to 14 years would be required to repay the cost of a single heavy application.

It was concluded from these studies that on many burned and reseeded areas of oak-chaparral in Arizona, multiple-light applications of 2,4,5-T or silvex herbicides may provide an economic means of reducing shrub growth and increasing forage production.

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