Reprinted from Journal of Range Management
Vol. 39, No. 4, July 1986 p. 320-326

Some Impacts of 2,4,5-T on a Mesquite Duneland Ecosystem in Southern New Mexico: A Synthesis

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Abstract

Two aerial applications of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] were applied to 3,634 ha of mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*) dunelands in southern New Mexico. Herbicide residuals; herbaceous plant production; soil microorganisms; insect, small mammal, and bird populations; cattle weights; travel; time budgets; and diets were studied on the treated area and an adjacent, untreated area. Stem kill of mesquite ranged from 17 to 66%. Herbicide residuals in soils and plant tissue on the treated area dissipated within a single season. Herbaceous plant production was measured for 5 years on a small area sprayed in 3 consecutive years and on untreated rangeland. Production was greater on the sprayed than on the unsprayed area for the first 3 years and was about the same on both areas for the next 2 years. Microbial populations were not numerically different between treatments but dehydrogenase activity and CO_2 evolution were greater in dunal than interdunal soils. Numbers of tenebrionid beetles *(Coleoptera: Tenebrionidae)* did not differ between treatments. More mesquite leaf tiers *(Tetralopha euphemella)* were found on the sprayed area than on the untreated area. Population statistics for small mammals were similar on both treatments. More bird species were found on untreated than on sprayed areas. Cattle weights, travel, and time budgets did not differ between treatments and there were only minor differences between treatments in cattle diet quality. The sprayed area supported over twice as many AUM's of grazing as the untreated area in the first 3 post-treatment years. In the second post-treatment year, cattle liveweight produced was 2.9 and 1.5 kg/ha on the sprayed and untreated areas, respectively. Overall, the 2,4,5-T treatment caused relatively minor perturbations in measured ecosystem components.

Shrubs have increased in distribution and abundance on southwestern rangelands during the past 100 years (Glendening 1952, Buffington and Herbel 1965, York and Dick-Peddie 1969). The increased woody cover has resulted in greatly reduced carrying capacities for domestic livestock (Paulsen and Ares 1962). Poor grazing management, primarily continuous, yearlong grazing with excessive numbers of animals, contributed to the spread of shrubs into former grasslands. However, the spread of shrubs cannot be reversed by grazing management alone. Brush control methods employed by ranchers and land management agencies have included hand and power grubbing, cutting, chopping, shredding, chaining, burning, rootplowing, and herbicide applications from the ground and air. Success has often been based on suppression of target species (percentage of shrubs killed or percent canopy reduction) or herbaceous forage production. While these are useful criteria in rating the effectiveness of brush control practices, they do not evaluate the full impact on the range ecosystem. With the increased emphasis on multiple use of rangeland, particularly nonconsumptive uses, more information on the impact of brush control measures on range ecosystems *in toto* is needed.

Brush management practices can affect the structure and function of ecosystems but there have been few holistic studies (Pimental and Edwards 1982). The purpose of this study was to examine the effects of 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] applications in a mesquite [*Prosopis glandulosa* (Torr.) var. *glandulosa*] duneland ecosystem on mesquite, herbaceous plant production, soil microorganism populations, selected insect populations, small mammal and bird populations, and cattle weights, diets, and time budgets. Herbicide residuals were also measured. This paper is a synthesis of numerous studies conducted on the research area and includes previously unpublished data as well as published data. The Environmental Protection Agency has cancelled the registration of 2,4,5-T and it is no longer manufactured in the United States. Thus, the specific effects of 2,4,5-T are of academic interest only. The impacts resulting from killing mesquite, which can be accomplished with other registered herbicides, are still of general interest.

Study Area

The studies were conducted on the Jornada Experimental Range 37 km north of Las Cruces, N. Mex. The Experimental Range has an arid climate with 52% of the average annual rainfall (230 mm) occurring in July, August, and September. Summer precipitation usually occurs as intense, convective storms of short duration and covering small areas. Winter precipitation normally comes from low intensity frontal storms covering large areas. The average maximum temperature is highest in June (36° C) and lowest in January (13° C). The frost-free period averages 200 days/yr but the effective growing season, when both temperature and soil water contents are favorable, is often 90 days or less.

Soils of the study area include coarse-loamy, mixed, thermic Typic Paleorthids (Harrisburg series), coarse-loamy, mixed, thermic Typic Haplargids (Onite series), coarse-loamy, mixed, thermic Typic Camborthids (Pajarito series), mixed, thermic Typic Torripsaments (Pintura series), and coarse-loamy, mixed thermic Typic Calciorthids (Wink series). They occur as the Onite-Pintura and the Wink-Pintura complexes and the Onite-Pajarito and Wink-Harrisburg associations (Bullock and Neher 1980). Topography is undulating and a caliche layer is present at depths of a few cm to >1m.

The vegetation is dominated by mesquite which, by trapping wind-blown sand, has caused the formation of dunes. The dunes are from 1 dm to 2 m in height. The dunes are mostly circular in outline with diameters of 3 to 8 m but some dunes are elongate with lengths to 27 m. Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] frequently grows on the dunes. The principal subdominants are broom snakeweed [*Xanthocephalum sarothrae* (Pursh) Shinners], mesa dropseed [*Sporobolus flexuosus* (Thurb.) Rydb.], and fluffgrass [*Erioneuron pulchellum* (H.B.K.) Tateoka]. Small numbers of perennial forbs occur but annual forbs are very abundant in years of favorable rainfall.

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Published as journal article 1067, Agr. Exp. Sta., New Mexico State Univ., Las Cruces. Research funded by the USDA, ARS Pilot Test Program—field application of pest control measures.

The mention of brand names should not be considered endorsement of a particular product by USDA.

Manuscript accepted 16 December 1985.

Methods

The mesquite control treatment consisted of 2 aerial applications of 2,4,5-T (propylene glycol butylether ester), each at 0.56 kg acid equivalent/ha applied in a 1:7 diesel oil to water emulsion at a total volume of 9.4 liters/ha. Herbicide was applied with a Cessna Agwagon. Two applications were used because previous work on the Experimental Range had shown that greater than additive kills of mesquite were obtained when an initial spraying was followed by a second application in 1 to 3 years. Also, 2 applications are often necessary to obtain a 30% kill of mesquite needed to get an increase in grass production which may last for 10 to 15 years (Herbel et al. 1983).

Herbicide was applied to 1,036 ha in early June 1975 and an additional 777 ha were treated in June 1976. Because sites selected to measure herbaceous production were very close to the edge of the 1975 treatment and likely to receive drift from the 1976 application, the 1976 application was deliberately overlapped on the 1975 treatment (approximately 140 ha) so that herbaceous production sites would receive a uniform treatment. The entire 3,634 ha was sprayed in June 1977, making the second application on the areas sprayed in 1975 and 1976 and the third application on the overlap area. The second application on the 1,821 ha first sprayed in 1977 was made in June 1978. While herbaceous and livestock studies began in 1976 and 1977, respectively, other studies did not start until 2 applications of herbicide had been made on the entire area (1979); also, budgetary constraints imposed by spraying costs precluded starting some studies before 1979.

Mesquite Kill

Percentage of dead mesquite stems per dune was visually estimated in 1981 for 16, 100-dune groups. Starting points for the 100-dune groups were randomly chosen within each of 16, 227-ha blocks on the sprayed area. A path perpendicular to the flight lines was followed until 100 dunes had been encountered. Mesquite stem kill was estimated on each cardinal quarter of each dune and the 4 estimates averaged. Mesquite kill was also estimated for 100 dunes at each of the 3 sites where herbaceous production estimates were made. No estimates of stem mortality were made on the nonsprayed area. Means of the 100-dune groups were used to calculate means and standard deviations for the various combinations of treatment years.

Herbicide Residuals

Plant and soil samples were collected for analysis of herbicide residuals on an area not previously sprayed on the day prior to herbicide application, immediately following the spray application (3 June 1977), and at 7, 14, 21, 29, 35, 63, and 131 days after application. Samples of green mesa dropseed foliage, green twigs and bark of fourwing saltbush, and soil samples were collected along 3 randomly located 30-m transects. Soils from dunes and dune interspaces were sampled at 0 to 2.5-, 2.5 to 30-, and 30 to 60-cm depths. The samples from each transect were composite samples consisting of parts of 10 to 20 grass plants, 4 to 6 fourwing saltbush plants, and soil from 5 pits on both dunes and dune interspaces. Thus, 3 samples of each item were available for analysis. Plant samples were dried, ground, and a 1-g subsample extracted with acidic acetone, methelated with diazomethane and separated from rinse water with hexane. Soil samples (10 g) were processed with the addition of 25 ml 0.5 N NaOH, acidified (pH 0.2) with 6 N HCl and extracted with diethyl ether before methylation (Bovey and Young 1980). Herbicide residues were determined on a Tracor Model 222 gas chromatograph equipped with a Model 770 autosampler, Spectra-Physics minigrator, and electron capture detector (N:63). Detection limits were about 10 parts per billion.

Herbaceous Plant Production

Time and budgetary constraints precluded sampling herbaceous production in a manner which would estimate production on the large sprayed and unsprayed areas as a whole. Consequently, measurements were confined to Wink-Pintura and Onite-Pentura soil complexes where soils were relatively deep, and to a single spray treatment (sprayed in 1975, 1976 and 1977) where mesquite kill would be maximal. Production of herbaceous plants was estimated at 3 sites on both the treated and untreated areas from 1976 to 1980. Exclosures (0.4 ha) were built at each site to exclude livestock during the sampling season and the exclosures were moved to a new, adjacent location each year. Recording raingauges were maintained at each exclosure. Dunes within the exclosures were marked with numbered stakes and at each sampling date 3 dunes in each exlosure were drawn at random for sampling. A dune-centered sampling system was used. The point of a wedge-shaped clipping frame was placed at the center of a dune and the angle subtended by the sides of the frame (18.4°) included a proportional sample of the center and periphery of the circular-shaped dunes. Herbaceous plants, broom snakeweed, and soap-tree yucca (*Yucca elata* Engelm.) were harvested from the wedge-shaped area in each of the cardinal directions on each dune. At the base of the dune a 1 m-wide transect was clipped that extended across the interdune area halfway to the next dune, also in each of the cardinal directions. The area clipped varied but an average of 178 m^2 were harvested at each sampling date on both sprayed and untreated areas. Harvested plants were segregated by species, separated into live and dead components, and oven-dried (60° C) before weighing. Recent dead from the current year were included in the live category. Yields per unit area were calculated separately for dune and interdune areas. Area covered by dunes at each study site was determined from dune intercept on 2 surveyed lines ca. 200 m long. Yields for sprayed and nonsprayed treatments were calculated using 28% dune area and 72% interdune area, the average for all sampling sites. Mean production at the 3 sampling sites in each treatment were used to calculate means and standard deviations for treatments.

Utilization of the principal forage grass (mesa dropseed) by livestock was determined each fall at 15 sites in both sprayed and untreated areas. At each site 100 plants were examined and grazed heights recorded. Height-weight tables were used to determine percentage use by weight.

Microbial Activities

Four sites were chosen on the area sprayed in 1977 and 1978 and on untreated rangeland, each 75 m from the boundary between treatments. Transects were established at each site and 2 dunes (1 to 2 m in height) and their proximate interdune areas (1 m from toe of dune slope) were randomly chosen from dunes on the transects. All sampling was done on the north aspect of the dunes to minimize variability as a result of position on the dune. All interdunal areas were also sampled on the north side of the dunes.

Carbon dioxide evolution and dehydrogenase enzyme activity were used as indices of microbial activity. Measurements were made at each of the 8 study sites at approximately 2-week intervals from April to October 1979 for a total of 15 measurement dates. Carbon dioxide evolution was measured in the field using alkali traps made from 25-cm lengths of 15-cm diameter polyvinyl chloride pipe inserted in the soil 15 cm and projecting 10 cm above the soil surface. Open, screw-cap vials containing 20 ml of 0.5 N NaOH were placed on the soil surface inside each pipe. The pipes were covered with polyethylene film to prevent CO_2 escape and with aluminum foil to reflect solar radiation. To estimate the amount of ambient CO_2 in the 10 cm of pipe above the soil surface, vials were placed in 4, 10-cm sections of pipe sealed on both ends with polyethylene film and aluminum foil. These 4 controls were randomly allocated among the 8 study sites. Vials were left in the field for 24 hours, sealed, transported to the laboratory, titrated with 0.5N HCl, and the amount of CO_2 calculated (Pramer and Schmidt 1964). Soil samples for the determination of dehydrogenase enzyme activity and microbial numbers were taken from the 0 to 15-cm soil depth and thoroughly mixed before subsampling. Dehydrogenase enzyme activity (μg formazan/g soil/day) was determined by the method described by Skujins (1973), using 6 g of soil incubated at 30° C for 24 hours. Microbial numbers (number/g soil) were determined 4 times, August and October 1979, February and June 1980. Martin's medium (Martin 1950) was used to enumerate fungal propagules and to identify (to genus) common soil fungi. *Streptomyce* were enumerated on a glucose-sodium nitrate medium (Kinknight and Muncie 1939). Difco nutrient agar and an ammonium-carbonate medium (Alexander 1965) were used for the enumeration of heterotrophic aerobic bacteria and ammonium oxidizers, respectively. Means were calcuated across sampling dates for the 4 sampling sites in each treatment and the 4 site means used to calculate treatment means and standard deviations.

Insects

Tenebrionid beetle *(Coleoptera: Tenebrionidae)* populations were sampled at 2 sites, 1 in the area sprayed in 1975 and 1977 and 1 in the unsprayed area, which where chosen for similarity of soil and vegetation. Pitfall traps were made by burying 0.95-liter plastic cups so that the rim of the cups were flush with the soil surface. A 1:1 mixture of ethylene glycol and water was placed inside cups of the same size which were placed inside the buried cups for easy collection and replacement. A total of 20 traps, 15 m apart in 2 rows 137 m long and 15 m apart, were placed at each site. Samples of tenebrionid beetles usually were collected at 2-week intervals, with some at 1-week and some at 1-month intervals from December 1978 to December 1979. Specimens were identified and counted and the number of beetles per trap-day calculated for each sampling date. Sampling dates were averaged to provide a mean value for each treatment. Mesquite leaf tiers (*Tetralopha euphemella* Hulet) were sampled at random sample points every 0.16 km for 3.2 km in each treatment along a road bisecting the sprayed (1977 and 1978) and undisturbed areas. On 17 Oct. 1979, 25 mesquite branches were sampled from each of the 5 dunes closest to each random point. The number of leaf tier nests were recorded and the mean and standard deviation of number of nests per dune were calculated for each treatment.

Small Mammals

For rodent trapping, maps of the sprayed and untreated areas were divided into 16.2-ha squares and randomly chosen coordinate intersections served as a starting point for the random placement of trap lines, subject to the restriction that no location be trapped twice during any 3-month period to allow population recovery from the trapping efforts. At each sampling date, 2 parallel lines 100 m apart were established at 1 site in each treatment. Each line consisted of 20 stations 15 m apart. Two museum special and 1 Victor rat trap (all are kill traps) were set at each station on 3 consecutive nights every 2 weeks from 15 Feb. 1979 to 8 May 1981. Traps were baited with a peanut butter and oatmeal mixture. Data from each 3-night trapping effort were pooled into 59 trap periods (a total of 42,280 trap nights) and analyzed to determine species richness (average number of species caught per trapping effort), concentration (Simpson 1949) diversity (Shannon and Weaver 1949), and evenness (Pielou 1975). Concentration, diversity, and evenness are commonly used population statistics which portray in different mathematical terms the number of species and the relative proportions of their abundances. Because the same species were found on both treatments, one can hypothesize that a partial removal of shrub cover could affect species populations and, if populations changed, the changes would be reflected in the population statistics.

Birds

The sprayed and untreated areas were stratified into a flat mesquite subtype (dunes < 30 cm) and a dune mesquite subtype (dunes > 30 cm) for estimating avian populations. Bird census transects patterned after Emlen's (1971, 1977) variable strip, line transect method were used. Four, 5-km walking transects were established in each treatment, 3 in the dune subtype and 1 in the flat subtype. From June through August in 1979 and 1980, birds were counted along each transect (1 transect per day) twice per month with 10 days between counts for the same transect. Transect counts were alternated between treatments on a daily basis, beginning 30 min before sunrise and continuing for 3 hr. Only birds actually observed perched within 183 m were counted. Lateral distances from the transect center line were estimated visually and distances along the transect were determined by pacing from distance-marked flags placed every 152 m. Observations were recorded on gridded map sheets of each transect. Counts were conducted only on days with favorable weather conditions, i.e., no precipitation or strong winds. Data were analyzed to determine species richness (number observed in each treatment in each sampling period), diversity (Simpson 1949) and an activity index. The activity index is the sum of three factors; abundance, ranked as scarce (1), uncommon (2), common (3), and abundant (4); regularity, ranked as single (1), casual (2), occasional (3), irregular (4), and regular (5); and breeding status, ranked as transient (1), expected to breed (2), and breeding resident (2). The factor ranks for each species were summed to obtain a species activity level and the activity levels of all species were summed to obtain an activity level for treatments. Dominant bird species were defined by listing the species in declining order of total number of observations and summing their number of observations until 90% of the total number of observations were included.

Livestock

Livestock studies were initiated in 1977 to determine if cattle performance (average daily gain), cattle activities (distance traveled and time spent grazing), and cattle diet quality differed on sprayed and untreated areas. Similar proportions of Hereford (H), Santa Gertrudis (SG), and H $\times$ SG heifers were used to stock the sprayed and untreated areas in July 1977. Additional heifers were added to the herds in subsequent years and other animals were grazed on a put-and-take basis depending on forage availability. All cattle were weighed upon entering or leaving the study areas. Stocking density varied considerably between seasons and year but the sprayed area always had a stocking density of 1.3 to 4.7 times that of the unsprayed area. Average daily gain of heifers was calculated from liveweight data obtained approximately every 28 days between July 1977 and November 1980. Most liveweights were obtained after an overnight period of drylot shrink. Cattle travel data were obtained by equipping 24 to 66 heifers in each pasture with digital pedometers attached to the metacarpal area of the left front leg. The pedometers were read bimonthly and calibrated in km/day. Continuous travel data were obtained between July 1977 and July 1980. Cattle time budgets were monitored with TFW 24/8 stop-and-go Vibracorders during the months of March, April, July, September, and December for the period September 1978 to July 1980. The instruments were attached to a saddle worn around the animal's neck. Vibracorder charts were changed each week. Time budget records were obtained from 1 to 3 animals at each sampling period in each treatment with the exception of March 1980 when no records were obtained due to instrument malfunction. Detailed study of Vibracorder-equipped animals permitted identification of 4 major activities on the Vibracorder charts: resting with no head movement, resting with head movement, grazing or searching for forage, and fast walking or running. Least-squares means were used to calculate treatment means and standard deviations for cattle weights, travel, and time budgets.

Diet samples were obtained from sprayed and untreated areas at approximately 1-month intervals between July 1977 and December 1978 to determine nutritional changes in cattle diets. A total of 14 esophageally fistulated cattle were used but most of the approximately 300 usable diet samples (not contaminated by regurgiation) were obtained from the same 6 fisulated steers. The fistulated cattle grazed pastures similar to the study areas between collections. The night before collections were to be made the fistulated cattle were placed in a 1-ha exclosure on the study area from which they were gathered at dawn the following morning. The day prior to diet collections, location of the largest grazing herd was determined for each treatment. The fistulated animals were walked to the grazing site by horseback riders. Once at the site they were allowed to graze for approximately 30 min. Two randomly selected animals were followed closely by riders and the species of plant from which the animal took a bite was recorded at 2-min intervals to aid in identifying the botanical composition of the diets. The same fistulated cattle were used on each treatment with the sequence of treatment grazing determined at random. Each animal's diet sample was thoroughly mixed and 2 subsamples of each individual diet sample were bagged separately and frozen. One sample was lyophilized and ground to pass a 40-mesh (0.5-mm) screen. Diet samples collected from 4 animals during March, July, September, and December on both sprayed and untreated areas were analyzed using standard laboratory procedures (Harris 1970). The 32 samples were analyzed for crude protein (CP), in vitro dry matter digestibility (IVDMD), acid detergent fiber (ADF), acid detergent lignin (ADL), dry matter (DM), and ash. The results of the above analyses were used to calibrate a Neotec Model 6100 monochrometer (instrument which measures reflected near-infrared light) located at the USDA's regional Pasture Research Laboratory, Pennsylvania State University, State College, Pa. from which the composition of all samples were predicted. CP, ADF, and ADL were expressed on an ash-free basis and IVDMD on a dry matter basis. Treatment means and standard deviations for dietary components are based on unadjusted values.

Results and Discussion

Mesquite Kill

Mesquite stem kill on the area sprayed in 1975 and 1977 (6 sampling sites) was 31 ± 17%. On the area sprayed in 1976 and 1977 (2 sampling sites), mesquite stem kill was 26 ± 7%. The area sprayed in 1977 and 1978 (8 sampling sites) had a mesquite stem kill of 39 ± 8%. On the area sprayed in 1975, 1976, and 1977 (3 sampling sites) mesquite stem kill was 54 ± 16%. While 3 consecutive years of spraying resulted in the highest average kill, some sampling sites on areas sprayed only twice had kills of 48 to 62%. Stem kill for the 19 sampling sites ranged from 17 to 66%. The high variability in stem kill is probably the result of many interacting factors, e.g., varying height of aircraft during application, spray drift, soil type, soil temperature, soil water content, and phenological stage of plants. Dahl et al. (1971) found the efficacy of 2,4,5-T in killing mesquite was reduced if soil temperatures at 46 cm were below 27° C or if mature leaves and seed pods were not present.

Herbicide Residuals

Only 150 mm of rainfall occurred between the spray application and the final residual sample collection, yet 2,4,5-T was quickly dissipated to very low levels in both soils and plants. Rainfall is an important environmental factor influencing persistence of phenoxy herbicides (Morton et al. 1967). Residuals of 2,4,5-T in the 0 to 2.5-cm depth were 3.7 ppm on interdune soils and 1.9 ppm on dune soils 7 days after treatment, reflecting the interception of 2,4,5-T by the mesquite canopy. The 2,4,5-T dissipated rapidly in both dune and interdune soils with little downward movement, and none was detected at any depth after 63 days (Table 1). Levels of 2,4,5-T in green mesa dropseed tissue declined rapidly and were only 0.6 ppm after 131 days (Table 1). Fourwing saltbush tissue contained maximum amounts of 2,4,5-T at 21 days after spraying (5.0 ppm) but none was detected after 131 days. These results support findings of other studies (Baur et al. 1969, Bovey and Baur 1972, Scifres et al. 1977) that 2,4,5-T dissipates rapidly from rangeland soils and vegetation.

Table 1. Herbicide residuals in soils and plant tissue following application of 0.56 kg acid equivalent/ha of 2,4,5-T on an untreated area in June 1977.

Parameter and time interval	Residuals, ppm (mean ± SD)
Average of dune and interdune soils	
0 to 2.5-cm depth after 7 days	2.76 ± 1.28
0 to 2.5-cm depth after 21 days	0.51 ± 0.26
0 to 2.5-cm depth after 35	0.02 ± 0.003
2.5 to 30-cm depth after 35 days	0.01 ± 0.01
all depths after 63 days	0
Green mesa dropseed tissue after 7 days	4.37 ± 3.50
Green mesa dropseed tissue after 21 days	2.01 ± 1.03
Green mesa dropseed tissue after 131 days	0.64 ± 0.45
Fourwing saltbush tissue after 7 days	1.24 ± 0.47
Fourwing saltbush tissue after 21 days	5.03 ± 1.20
Fourwing saltbush tissue after 131 days	0

Herbaceous Plant Production

Production of herbaceous plants on the area sprayed in 1975, 1976 and 1977 was higher than on the untreated area in 1976, 1977, and 1978 (Table 2). In 1979, when precipitation was above average, production on the sprayed and untreated areas was greater than in other years and there was little difference in production between the sprayed and untreated areas (Table 2). The high precipitation in 1979 resulted in an abundance of annual forbs which made up 40 and 54% of the total production on the sprayed and untreated areas, respectively. In 1980, a year of low rainfall, production was much lower than in 1979 and there was little difference in production between treatments (Table 2). The variability in precipitation led to differences in herbaceous plant production among years that were as large as the differences between sprayed and untreated areas. The increase in herbaceous production following spraying is in agreement with the findings of Scifres and Polk (1974) and Dahl et al. (1978). McDaniel et al. (1982) found that, depending upon rainfall, a significant grass response might occur within 120 days to 3 years after spraying. This emphasizes the importance of amount and seasonal distribution of rainfall. Interviews with ranchers in Texas suggested that increased carrying capacity was greatest in the first 3 years following spraying with 2,4,5-T for mesquite control and then declined rapidly with no increase on bottomland sites after 10 years and upland sites after 12 years (Workman et al. 1965). In more arid areas the effects of mesquite control appear to last longer. Grass production on a sprayed area in Arizona was still significantly higher than on a nonsprayed area after 10 years (Cable 1976). Areas sprayed on the Jornada Experimental Range still had higher grass production than untreated areas after 16 years (Herbel et al. 1983).

Table 2. Herbaceous production (mean ± SD) and crop-year precipitation (Oct. to Sept.) for an area sprayed with 2,4,5-T in 3 consecutive yr (1975, 1976, 1977) and an untreated area from 1976 to 1980. Production for both sprayed and non-sprayed areas has been calculated on the basis of 28% dune area and 72% interdune area.

Year	Herbaceous production (kg/ha)[1]		Precipitation (mm)[2]	
	Sprayed	Untreated	Sprayed	Untreated
1976	920 ± 332	336 ± 50	284	240
1977	660 ± 149	148 ± 12	180	187
1978	554 ± 207	220 ± 96	211	247
1979	945 ± 125	1,108 ± 436	333	382
1980	508 ± 99	327 ± 126	162	178

[1]Average of the 3 sites sampled in each treatment.
[2]Average of the 3 raingauges for each treatment. A raingauge was located at each sampling site.

Microbial Activities

Microbial numbers were similar both in sprayed and untreated areas and in dunal and interdunal soils (Table 3). Acute short-term

Table 3. Mean (± SD) numbers of fungal propagules, *Streptomyces* propagules, and heterotropic aerobic bacteria, and amount of CO_2 evolution and formazan production on sprayed and unsprayed dunal soils and sprayed and unsprayed interdunal soils.

Parameters	Units	No. of Sampling Dates	Dunal Soil		Interdunal Soil	
			Sprayed[1]	Unsprayed[2]	Sprayed[1]	Unsprayed[1]
Fungal propagules	1×10^4/g soil/day	4	1.6 ± 0.4	2.6 ± 0.3	1.3 ± 0.7	0.8 ± 0.4
Streptomyces propagules	1×10^4/g soil/day	4	18.4 ± 6.0	20.0 ± 7.3	30.8 ± 18.1	19.5 ± 7.5
Heterotropic aerobic bacteria	1×10^4/g soil/day	4	85.1 ± 27.2	54.2 ± 19.6	55.9 ± 20.5	21.3 ± 3.4
CO_2 evolution	mg CO_2/m^2/day	15	1933 ± 132	2276 ± 150	1657 ± 150	1761 ± 138
Formazan production	μg formazan/g soil/day	11	8.8 ± 2.8	6.2 ± 1.9	2.3 ± 0.7	2.3 ± 1.0

[1]Means calculated across sampling dates for 4 sites in each treatment and site means used to calculate treatment means and standard deviations.

effects of spraying on the soil microflora may have been missed because measurements were not made until the year following herbicide application. However, normal application rates of 2,4,5-T generally have no effect on microbial numbers (Audus 1964).

Both dehydrogenase activity (formazan production) and CO_2 evolution were greater in dunal than in interdunal soils (Table 3). Microbial activity as measured by dehydrogenase and CO_2 are generally a direct function of substrate availability. Dunal soils were expected to have higher microbial activities because of the greater abundance of substrate in the form of plant roots, root exudates, and debris. Dehydrogenase activity was similar in sprayed and untreated areas (Table 3). CO_2 evolution from sprayed and untreated interdunal soils was similar. However, CO_2 evolution from sprayed dunal soil was substantially lower than untreated dunal soil on 4 of the 15 sampling dates (12 June, 9 July, 25 July, and 15 August). For these dates, the mean CO_2 evolution for the sprayed and untreated dunal soils was 2,289 ± 165 and 3,243 ± 205 mg CO_2/m^2/day, respectively. Herbicides can inhibit, enhance, or have no effect on microbial respiration (Grossbard 1971, Utter 1972). Although about two-thirds of the CO_2 leaving the soil is attributed to the microflora (Alexander 1977), plant roots, soil fauna, and abiological CO_2 evolution may also contribute to the CO_2 measured. The greater CO_2 evolution on unsprayed dune soils was attributed to carbon availability for microbial metabolism and root respiration, rather than a direct effect on soil microbial activities. The surface of sprayed dunes appeared to have less organic debris available for decomposition. Also, the mesquite on sprayed dunes were partially defoliated. Thus, less carbon would be translocated to the roots for direct root respiration or microbial respiration of root exudates.

Insects

Nine species of tenebrionid beetles were trapped. Five *Eleodes* spp. were the most abundant tenebrionids. Total tenebrionids caught per trap day were similar on sprayed (0.41 ± 0.35) and untreated areas (0.32 ± 0.30). Activity patterns of the tenebrionid beetles were species specific with different species being active in spring, summer, and fall (Richman et al. 1982). Dunes sampled for mesquite leaf tiers in the first post-treatment season had 54.9 ± 25.5% dead branches in the sprayed area and 6.7 ± 6.9% dead branches in the untreated area. Mesquite leaf tier nests were more abundant in the sprayed area than in the untreated area with 4.8 ± 4.4 and 2.1 ± 1.7 nests per dune, respectively. In Texas, mesquite leaf tiers were found to pass through 6 instars in the larval feeding stage and were believed to pupate in litter on the soil surface. Also, 22% of 5th and 6th instars were parasitized (DeLoach 1982). The greater abundance of leaf tiers on the sprayed than on the untreated area could arise from more favorable conditions for larvae or pupae or, conversely, from less favorable conditions for parasites and predators.

An independent study of ant populations included, among others, 2 sites on the study area, a site sprayed in 1976-77 and an untreated mesquite dune site (Wisdom and Whitford 1981). Data collected during June, July, August, and September 1979 showed that maximum ant nest densities were higher on the untreated dune site (2,533 nests/ha) than on the sprayed site (1,600 nests/ha). More ant species (14 vs. 10) with a greater variety of diets occurred on the 1976-77 spray site than on the unsprayed site where a few generalist feeders were dominant. Densities of fungus-growing ant [*Trachymyrmex smithi neomexicanus* (Cole)] colonies were greater on the sprayed site. Synchronization of nuptial flights of the fungus-rearing ants and mesquite leaf fall resulting from the herbicide applications was advanced as a hypothesis accounting for the higher population of fungus-growing ants on the sprayed area (Wisdom and Whitford 1981). Food is a limiting factor in desert ant communities (Davidson 1977) and the increase in herbaceous plant production following spraying probably provided a food base which supported more ant species.

Some soil-dwelling insects have decreased survival after exposure to 2,4,5-T in laboratory studies (Eijsackers 1975, 1978). However, some individuals of the carabid beetle *Notiophilus biguttatus* Fabr. were not affected by 2,4,5-T, which might lead to selection of individuals resistant to 2,4,5-T (Eijsackers 1978). It seems probable that mesquite control will cause shifts in the relative abundance of certain arthropods. New levels of equilibrium in balance with available habitat and food supplies occur. It seems unlikely that 2,4,5-T applications will cause any long-term major changes in insect populations.

Small Mammals

Twelve rodent and 2 leporid species were recorded on the study area. Ord's kangaroo rat (*Dipodomys ordii* Woodhouse) was most abundant (1,014 captures) and the northern grasshopper mouse [*Onychomys leucogaster* (Weid-Neuweid)] was second in abundance (393 captures). The mean number of species caught per trapping effort (species richness) was 3.62 on the sprayed area and 3.82 on the untreated area. Rodent species diversity (Shannon-Weaver H') was 0.98 on both sprayed and untreated areas. Another measure of diversity (Simpson's D) was 0.60 and 0.58 on sprayed and untreated areas, respectively. Simpson's concentration statistic was 0.39 and 0.41 on sprayed and untreated areas, respectively. Species evenness (Pielou's J') was 0.70 on the sprayed area and 0.68 on the untreated area. These results agree with findings of Kirkland (1978) that no major shifts in rodent composition occurred after application of 2,4,5-T, although Kirkland found a slight increase in the cricetine to microtine ratio. Microtines do not occur on the Jornada. Savidge (1978) found an increase of some small mammals 6 years after small (4.5 ha) plots were sprayed with 2,4,5-T in the Jeffry pine (*Pinus jeffreyi* Grev. & Balf. in A. Murr.) type on the east slope of the Sierra Nevada. In Arizona, fewer lagomorphs and significantly fewer pellet numbers were observed on a mesquite-free range than in undisturbed mesquite or in mesquite with clearings (Germano et al. 1983).

Rodents can have an appreciable impact on rangelands in this arid area. The 6 major rodent species populations consumed about 23 kg/ha of plant and insect foods per year (Wood 1969). Vegetation made up 61% of the rodents' diets and the rodents on 2.6 km^2

(640 acres) would be equivalent to 1 A.U. in terms of forage consumption. In addition, kangaroo rats and wood rats (*Neotoma* spp.) stored as much as 10 kg/ha of plant materials in their dens (Wood 1969).

Birds

Thirty-six species of birds, representing 10 families and 8 orders, were identified during the 2-year study period. The most abundant species were the black-throated sparrow [*Amphispiza bilineata* (Cassin)], loggerhead shrike (*Lanius ludovicianus* L.), northern mocking bird (*Mimus polyglottos* L.), scaled quail [*Callipepla squamata* (Vigors)], and cactus wren [*Campylorhynchus brunneicapillus* (Lafresnage)]. Only data obtained from the dune subtype, which covered 88 and 87% of the sprayed and untreated areas, respectively, will be reported for treatment comparisons. A complete report is given by Reitzel (1982).

More species (26) were found in the untreated dune type than in the sprayed dune type (20) in 1979. In 1980, 25 and 19 species were found on untreated and sprayed areas, respectively. The number of dominant bird species was slightly greater in the untreated area (10 in both 1979 and 1980) than in the sprayed area (8 in 1979 and 9 in 1980). Bird species diversity, averaged for 1979 and 1980, was similar on the untreated area (0.83) and sprayed area (0.80). Activity levels were higher on the untreated area than on the sprayed area in both 1979 (168 vs. 129) and 1980 (163 vs. 127).

The greater number of species and somewhat higher activity levels in the untreated area indicate that spraying had some effect on bird populations. A study of the avifauna in a shrub-grassland area in southeastern New Mexico showed that 32 of 46 species of birds observed were adapted primarily or exclusively for living in habitats with woody vegetation (Davis et al. 1974). The preponderence of nongame birds which depend on woody species has led to recommendations that shrub-control work be done in strips or patches, preserving some undisturbed vegetation (Davis et al. 1974, Castrale 1982).

Livestock

Livestock average daily gain, livestock travel, and time spent grazing and resting were similar on the sprayed and untreated pastures. Daily gain of 1-, 2-, and 3-year old heifers averaged over 3 years was 0.30 ± 0.03 kg/day on the sprayed area and 0.25 ± 0.04 kg/day on the untreated area. Weight gains were highest on both areas in the July to October period when green forage was most abundant. Livestock travel averaged over 3 years was 7.2 ± 5.4 and 75. ± 4.5 km/day on the sprayed and untreated areas, respectively. Percent of time spent grazing (averaged over 9 measurement periods) was 46.6 ± 0.2% on the sprayed area and 44.1 ± 0.2% on the untreated area. Percent of time spent resting was 49.2 ± 0.2% and 43.5 ± 0.2% on the sprayed and untreated areas, respectively. There were seasonal and individual animal differences in travel and animal activities (Guiao 1982).

Botanical composition of the esophageal diets has not been determined. A qualitative visual appraisal of the diets and the plants recorded as being eaten during collections indicate that mesa dropseed was the principal grass in cattle diets on both the sprayed and untreated areas. Fourwing saltbush appeared to be more abundant in diets of cattle on untreated rangeland than on the sprayed area. Forbs were grazed when available. The plants grazed during collection periods agree with the findings of Herbel and Nelson (1966) and Rosiere et al. (1975) on nearby ranges. Shrubs and forbs can be important items in cattle diets during some seasons of the year.

Crude protein in the cattle diets (18-month average) was slightly higher on the untreated area (10.1 ± 2.8%) than on the sprayed area (9.2 ± 2.0%). Diet CP content was highest during July to October and differed among years (Guiao 1982). Diet ADF content was slightly greater on the sprayed area (43.6 ± 3.3%) than on the untreated area (40.3 ± 5.5%) while diet ADL content was similiar among treatments (6.8 ± 2.2% vs. 6.4 ± 2.3%). In vitro dry matter digestibility of diets was slightly greater on the untreated area (41.2 ± 8.5%) than on the sprayed area (37.9 ± 8.3%). Like CP content, IVDMD values were highest from July to October.

Fencing to separate the 2 treatments was not completed until 1977. In 1978, grazing use on the sprayed area (688 AUM's) was over 2-fold greater than on the untreated area (305 AUM's) although cattle were removed from the sprayed area for 30 days following 2,4,5-T application. Stocking density was increased in 1979 and grazing use was 1,698 AUM's on the sprayed area and 536 AUM's on the untreated area. Although grazing use was over 3-fold greater on the sprayed than on the untreated area, utilization of mesa dropseed (% by weight) at the end of October 1979 was 8 ± 5% on the sprayed area and 12 ± 4% on the untreated area. Due to low rainfall in 1980, grazing use was reduced on the sprayed area to 506 AUM's of use during the January to September period. Thus, in slightly less than 3 years, the sprayed area supported 2,892 AUM's of grazing vs. 1,348 AUM's on the untreated rangeland. In 1979 there was 1.5 kg/ha of cattle liveweight produced in the untreated area compared to 2.9 kg/ha of liveweight produced in the sprayed area in a 308-day period.

Management Implications

The 2,4,5-T treatment did not cause drastic perturbations in the ecosystem attributes we evaluated. Avian elements appeared to be most affected and, as they are conspicuous elements of interest to many people, should be considered in management planning. There is little danger of destroying all habitat niches for any avian species if chemicals are used which, like 2,4,5-T, result in only partial kill of mesquite. The increased forage production and greater livestock carrying capacity resulting from mesquite control are highly desirable benefits yielding direct economic returns.

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