[redacted] 514

Persistence of 2, 4-D and 2, 4, 5-T in Chaparral Soil and Vegetation

T. R. Plumb[1], L. A. Norris[2], and M. L. Montgomery[3]
[1]*Pacific Southwest Forest and Range Experiment Station,*
Riverside, Calif. 92507;
[2]*Pacific Northwest Forest and Range Experiment Station;*
[3]*Oregon State University,*
Corvallis, Ore. 97331

INTRODUCTION

The behavior of 2,4-D and 2,4,5-T has been widely studied in the cool moist forests of the Pacific Northwest (NORRIS 1971). Little data are available, however, for the unique conditions in arid southern California, where the two compounds are used for maintenance of fuelbreaks in chaparral vegetation. Reported here is a study to determine the movement and persistence of 2,4-D and 2,4,5-T in soil and sprouting chamise vegetation for 1 year after application in a southern California chaparral site.[1]

MATERIALS AND METHODS

The test was conducted on a gently sloping (5% to 9%) chaparral site 64 km east of San Diego at 1020 m elevation. Plant cover was sprouting chamise (Adenostoma fasciculatum Hook. and Arn.) in its second season of regrowth after a wildfire in September 1970. The ground surface was essentially bare, and only occasional herbaceous plants were present. The soil is a well-drained, very deep, coarse, sandy loam formed from granitic alluvium (USDA 1973). At the time of treatment, the soil moisture content was: 1.7% (0-10 cm), 3.8% (10-20 cm), and 3.3% (20-30 cm). Organic matter content was 1.5% (0-10 cm), 0.9% (10-20 cm), and 0.5% (20-30 cm).

The experiment was set up in a randomized block design with five replications. The 15-m by 15-m plots (with a 15-m buffer) were treated with the propylene glycol butyl ether esters of 2,4-D and 2,4,5-T at 3.4 kg ae each in 187 L of water per hectare. They were sprayed between 6 a.m. and 8:30 a.m. with a portable spray boom outfitted with six #8002 fanjet nozzles.

---

[1] This paper reports research involving chemical pesticides. It does not include recommendation for their use, nor does it imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended.

Bulletin of Environmental Contamination & Toxicology,
Vol. 17, No. 1 © 1977 by Springer-Verlag New York Inc.

The terminal 15 cm of sprouts from several randomly selected chamise plants in each plot were collected into plastic bottles immediately after spraying (0 days) and 14, 29, 65, 146, and 379 days later. The samples were frozen immediately. Moisture content of additional sprout material and terminal shoots of adjacent unburned mature plants was determined by xylene distillation.

Multiple soil samples from depths of 0 to 10, 10 to 20, and 20 to 30 cm were collected 14, 29, 69, 146, and 379 days after treatment. Samples were scraped from the side of a 36-cm deep pit and were frozen immediately. Six samples for each depth from each plot were composited on an equal weight basis before residue analysis. Herbicide residues were determined in soil and vegetation by basic digestion, extraction, purification, and microcoulometric gas chromatography (BEVENUE et al. 1963, BJERKE et al. 1967, NORRIS 1970). Results are expressed as ppm air dry weight for soil and fresh weight for vegetation.

The 4-month pretreatment period had only 1.5 cm of rainfall (22-year average is 25.0 cm). No rain fell during the first two weeks after herbicide application on May 2, and only 2.5 cm were recorded by July 10. Between September and the following May however, about 1.5 times the normal rainfall occurred (Table 1).

TABLE 1

Precipitation and plant moisture content

Date	Time after treatment (days)	Cumulative rainfall: Actual rainfall	Cumulative rainfall: Normal rainfall	Moisture content[a/]: Chamise sprouts: Untreated	Moisture content[a/]: Chamise sprouts: Treated	Moisture content[a/]: Mature plants
		cm	cm	percent	percent	percent
May 2, 1972	0	0.00	0.00	87	87	44
May 14, 1972	14	0.00	0.51	91	88	60
May 31, 1972	29	0.53	1.12	78	54	52
July 10, 1972	69	2.44	1.70	64	27	46
Sept 25, 1972	146	3.20	5.11	63	31	49
May 16, 1973	379	57.43	41.99	--	--	--

[a/] Moisture content as percent of the plant dry weight.

RESULTS AND DISCUSSION

Vegetation

The dry conditions in May were reflected in the low moisture content of the shoots and lack of new shoot growth (Table 1). The leaves of the treated plants were dry and brown about 1 month after treatment, but the root crown of most of the plants survived and vigorous sprouts appeared the next spring. Very low soil moisture content before and for several months after spraying was probably responsible for the poor overall chamise control (PLUMB 1963).

Maximum herbicide concentrations of 95.2 ppmw of 2,4-D and 92.4 ppmw of 2,4,5-T were in vegetation samples collected within 15 minutes after the application (Figure 1). The similar initial values for the two herbicides indicates approximately equal amounts of each herbicide were applied. Mean levels declined rapidly, and 3.8 ppmw of 2,4-D and 2.5 ppmw of 2,4,5-T remained 12.5 months after application in the chamise shoots that had been originally sprayed. MORTON et al. (1967) reported similar initial values in range forage grasses, but they measured a shorter persistence.

Samples of live chamise sprouts taken 12.5 months after application contained 0.27 ppmw of 2,4-D and 0.31 ppmw of 2,4,5-T, although these plant parts were not present at the time of application. The sprouts were vigorous and showed no formative effects, indicating chamise can readily tolerate these residue levels. It is possible the residues were in a "bound form" or were otherwise unavailable to the plant.

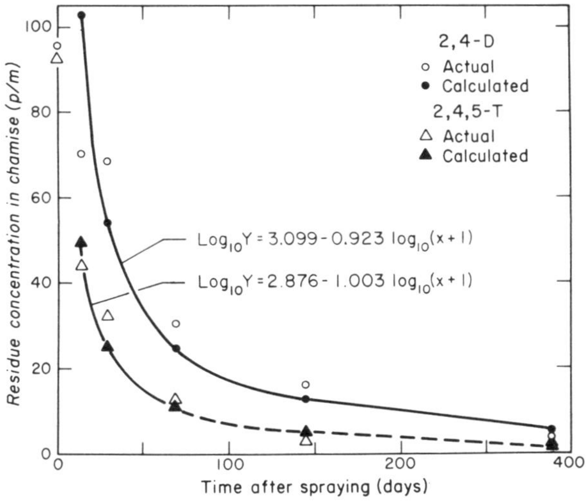

Figure 1--Concentration of 2,4-D and 2,4,5-T in chamise vegetation. Actual data are plotted along with curves generated from transformed data where herbicide concentration is expressed as $\log_{10}$ ppm and time is $\log_{10}$ (days + 1).

Mean residue levels for the two herbicides suggest 2,4,5-T declined more rapidly than 2,4-D, at least initially, but by 69 days the rate of loss appears similar. And between 146 and 379 days the curves appeared to converge. The average levels of 2,4-D and 2,4,5-T differed significantly when data for all dates were combined ($P<0.001$). We were not able to derive equations which both describe these curves and have some biological meaning. By eliminating the data on zero time and transforming herbicide concentration (Y) to $\log_{10}$ (Y) and days after application (X) to $\log_{10}$ (X+1), we formulated the equations: for 2,4-D, $\log_{10} Y = 3.099 - 0.923 \log_{10} (X+1)$, with $r^2 = 0.93$; and for 2,4,5-T, $\log_{10} Y = 2.876 - 1.003 \log_{10} (X+1)$, with $r^2 = 0.93$, where Y = ppmw of herbicide and X = days after application.

Using these equations we generated the curves in Figure 1 to show the fit of actual and calculated values. Analysis of variance showed that the slopes of the two average regression lines were not significantly different, and that there was no time-chemical interaction ($P>0.05$).

A combination of greater absorption and metabolism probably resulted in the differences in the residue levels of 2,4-D and 2,4,5-T, at least for the first 14 days after application in our study. By 29 days, plant moisture levels were definitely declining (Table 1), and by 69 days, the vegetation had been desiccated. Sometime after 14 and before 69 days, plant metabolism was no longer important, and other processes must have been operating to reduce herbicide residue levels (Figure 1). Volatility and photodecomposition may have been involved (BOVEY and BAUR 1971, KLINGMAN 1961), but it is not possible to determine their relative importance in this study.

Data on herbicide residues in vegetation are useful for understanding the response of treated plants, but of greater importance is the use of this data to determine potential toxicological impact. In reviewing the literature, NORRIS (1971) found "no effect," acute, and chronic exposure levels for 2,4-D and 2,4,5-T for several animal and bird species. These values ranged from 500 to 2,400 ppmw for 2,4-D and 200 to 1,200 ppmw for 2,4,5-T for acute toxicity levels and from 100 to 500 ppmw for chronic exposure to 2,4-D and 2,4,5-T. The initial residue levels in vegetation in our study were less than these values. The dead, dry foliage present 1 month after application is probably not attractive as food. Neither the magnitude nor duration of exposure to 2,4-D and 2,4,5-T, which would result from consumption of any of this vegetation, is sufficient to produce either an acute or a chronic toxic response.

Soil

The concentration of 2,4-D and 2,4,5-T in the upper 10 cm of soil were 1.16 and 0.88 ppmw, respectively, 14 days after spraying (Table 2). Within 69 days, an average of 0.22 ppmw of 2,4-D and 0.29 ppmw of 2,4,5-T remained, and 12.5 months after spraying only 0.04 to 0.05 ppmw of either chemical could be detected.

TABLE 2

Average concentration of 2,4-D and 2,4,5-T in composite soil samples collected from three soil depths

Days after treatment	2,4-D Soil depth (cm) 0-10	2,4-D Soil depth (cm) 10-20	2,4-D Soil depth (cm) 20-30	2,4,5-T Soil depth (cm) 0-10	2,4,5-T Soil depth (cm) 10-20	2,4,5-T Soil depth (cm) 20-30
		(ppm)			(ppm)	
14	1.16	0.16	0.09	0.88	0.06	0.03
29	0.71	0.07	0.05	0.53	0.02	0.02
69	0.22	0.02	0.02	0.29	0.01	0.03
146	0.11	0.02	0.01	0.21	0.02	0.01
379	0.04	0.02	0.02	0.05	0.03	0.03

In our study, 2,4,5-T disappeared at a faster rate at first than 2,4-D if we assume both chemicals were present initially at the same concentration (Figure 1). This faster rate may be contrary to the expected pattern since NORRIS (1970) and ALTOM and STRITZKE (1973) reported 2,4-D had a shorter half life than 2,4,5-T in laboratory studies using forest floor or soil materials. However, if only data between 14 and 146 days are considered, 2,4-D does show a shorter half life than 2,4,5-T in this study as well.

The rate of decline 12 months after application was slow, and minute herbicide residues may be detected for considerably longer than 1 year after spraying. We believe that a concentration of 0.05 ppmw of 2,4-D or 2,4,5-T has no important biological significance. It may be chemically or physically "bound" to soil particles and organic matter, and while not readily available under natural conditions, is removed by our rigorous sample extraction procedures. ALTOM and STRITZKE (1973) also found a reduction in rate of degradation as residue levels declined.

Using the data obtained at depths of 0 to 10 cm, we transformed herbicide concentration (Y) to $\log_{10} Y$ and days after application (X) to $\log_{10} (X+1)$ to obtain equations which described the soil residue. The equation for 2,4-D was:

$\log_{10} Y = 1.278 - 1.014 \log_{10} (X+1)$, with an r^2 of 0.99, and for 2,4,5-T: $\log_{10} Y = 0.979 - 0.836 \log_{10} (X+1)$ with an r^2 of 0.95. This log-log relationship produced a good fit of the observed data starting from 14 days after spraying (Figure 2).

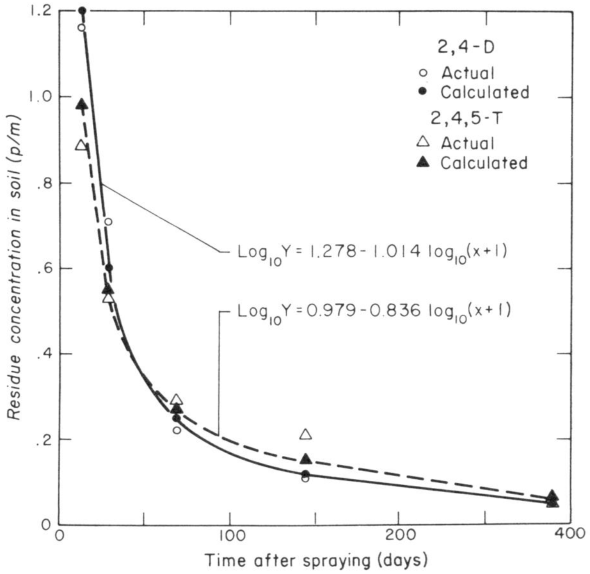

Figure 2--Concentration of 2,4-D and 2,4,5-T in the 0 to 10 cm soil zone. Actual data are plotted along with curves generated from transformed data where herbicide concentration is expressed as $\log_{10}$ ppm and time is $\log_{10}$ (days + 1).

The rapid initial disappearance of both herbicides from the 0 to 10 cm soil zone was somewhat surprising. Microbial metabolism, often cited as the primary means of herbicide detoxification in the soil (AUDUS 1964, KLINGMAN 1961), would appear to be extremely limited under the dry conditions encountered during the first 5 months after spraying. Neither soil organic matter content, nor soil texture favored a large microbial population (AUDUS 1964). Volatilization and photodecomposition appear the more likely processes of degradation.

The difference between average concentration of herbicide at different depths was highly significant ($P<0.001$). The chemical residues detected in the lower zones were probably due to contamination from the dry, loose surface soil sifting into the pit during sample collection because no rain fell during the first 2 weeks after spraying; furthermore, diffusion through the soil is limited (Table 2).

Analysis of variance with orthogonal polynomial contrasts showed that the residues in the lower soil zones declined with time according to a quadratic function ($P<0.001$), with no significant interaction ($P>0.05$) between date and depth. This decline indicates that curves describing herbicide residue levels with time at the different depths are the same shape. The lack of interaction is expected if residues in samples below 10 cm were the result of sample contamination, rather than leaching.

Our results suggest that concern about the potential hazard of 2,4-D and 2,4,5-T residues in arid southern California soils seems unwarranted. Even under conditions which are considered poor for rapid herbicide degradation--namely, low rainfall and moderately coarse soils with relatively low organic matter content--residues of 2,4-D and 2,4,5-T disappeared rapidly. Normally there would be little opportunity for chemical leaching after a spring herbicide application in southern California since little rainfall is expected until the fall. In fact, only a slight amount of leaching of phenoxy herbicides is expected under wetter climatic conditions (MORTON et al. 1967, NORRIS 1971).

The major potential hazard to water quality is through surface water contamination (NORRIS 1971); even then, peak concentrations are usually low and of short duration. In an average rainfall year, most streams are dry in California chaparral areas during late spring and summer; consequently, direct water contamination should be minimal. Where streams or standing water are present, buffer zones can be used to minimize direct application to surface waters.

We conclude that the use of 2,4-D and 2,4,5-T for management of fuelbreak vegetation does not present a significant hazard to the quality of the environment nor to its inhabitants.

Acknowledgments

We thank Floyd Johnson and Patricia Williams, Pacific Northwest Forest and Range Experiment Station, and Charles Huszar, University of California, Riverside, for their advice on the statistical design and analysis of data for this study.

References

ALTOM, J. D., and J. F. STRITZKE: Weed Sci. 21, 556 (1973).

AUDUS, L. J.: Herbicide behavior in the soil: II. Interactions with soil micro-organisms. In, The physiology and biochemistry of herbicides (L. J. AUDUS, ED.), pp. 163-206 , London and New York, Academic Press 1964.

BEVENUE, A. G., G. ZWEIG, and N. L. NASH: J. Assoc. Office Agr. Chem. 46, 881 (1963).

BJERKE, E. L., A. H. KUTSCHINSKI, and J. C. RAMSEY: J. Agr. Food Chem. 15, 469 (1967).

BOVEY, R. W., and J. R. BAUR: Bull. Environ. Contam. Toxicol. 8, 229 (1971).

KLINGMAN, G. C.: Weed control: as a science. New York: John Wiley & Sons 1961.

MORTON, H. L., E. D. ROBINSON, and R. E. MEYER: Weeds 15, 268 (1967).

NORRIS, L. A.: Degradation of herbicides in the forest floor. In, Tree growth and forest soils (C. T. YOUNGBERG and C. B. CAVEY, EDS.), pp. 397-411, Corvallis: Oregon State Univ. Press 1970.

NORRIS, L. A.: J. For. 69, 715 (1971).

PLUMB, T. R.: Three years of broadcast spraying chamise sprouts in southern California. U.S. Forest Serv. Res. Note 197, Berkeley, Calif.: Pacific Southwest Forest and Range Exp. Stn. (1963).

U.S. DEPARTMENT OF AGRICULTURE: Part I. Soil survey: San Diego area, California. Soil Conserv. Serv. and Forest Serv. (1973).