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Movement of Tebuthiuron Applied to Wet and Dry Rangeland Soils[1]

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Abstract. Tebuthiuron was applied at 1 kg ai/ha to wet and dry Hathaway gravelly, sandy loam soil in the spring and fall to determine the amount of tebuthiuron removed in runoff water and the depth to which it would move within the soil profile by simulated rainfall. When pellets containing 20% ai of tebuthiuron were broadcast onto dry soil in the spring, the first simulated rainfall event, 37 mm, removed 5% of the applied tebuthiuron in runoff water and sediment. The second and third simulated rainfall events, 22 and 21 mm, respectively, removed an additional 2%. When tebuthiuron was applied to wet soil in the spring, the initial simulated rainfall events, totaling 42 mm, removed 15% of the tebuthiuron. When tebuthiuron was applied to wet soil in the fall, the initial rainfall events, totaling 40 mm, removed a total of 48% of the tebuthiuron in runoff water and sediment. No significant differences were found in the total amount of tebuthiuron within the soil profile after application to dry and wet soils. More than half of the tebuthiuron had moved into the surface 7 cm 1 day after application. Tebuthiuron was not detected below 90 cm after 165 mm of simulated rainfall and 270 mm of natural rainfall. Nomenclature: Tebuthiuron, *N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea.
Additional index words. Rainfall simulation, runoff, sediment, herbicide residue.

INTRODUCTION

Tebuthiuron, a broad-spectrum, soil-applied herbicide, is used to selectively kill woody plants on rangeland and all plants on rights-of-way and industrial sites. Tebuthiuron is stable, odorless, and colorless, and water solubility is 2300 ppm (16). For rangeland applications, tebuthiuron is formulated as a clay pellet containing 20 or 40% ai or as a briquette containing 15.25, 13.8, or 30.5% ai. Rainfall leaches tebuthiuron into the soil where it is absorbed by the roots, translocated into stems and leaves, and metabolized.

Tebuthiuron was leached to a depth of 15 cm in 8 months by 326 mm of precipitation in a soil in which gravel larger than 13 mm was removed (6). There was no further movement in 12 months during which 160 mm of additional precipitation occurred. In south-central Texas, tebuthiuron was applied at 2.2 and 4.4 kg/ha and was detected at 0- to 15- and 15- to 30-cm depths for more than 2 yr after application (2). Tebuthiuron and fluometuron {*N,N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl] urea} were most mobile in a soil with 0.3% organic matter and 2% clay and least mobile in a soil with 4.4% organic matter and 17.8% clay (3). Most arid rangeland soils in the Southwest contain less than 1.5% organic matter (7).

Tebuthiuron was applied as spot treatments under individual shrubs on 7.5 ha of an 18.8-ha chaparral watershed in central Arizona (4). It was not detected in water from springs that drained the treated area or in the creek into which the watershed stream flowed; however, a trace was found at the gauging station at the base of the watershed. An estimated 0.7% of the tebuthiuron applied was lost to stream flow during the 18 days following treatment. Of the tebuthiuron applied to a creosotebush [*Larrea tridentata* (Sesse & MOC. ex DC.) Cov.] infested watershed 0.47% was removed in runoff water (6). We have observed that after tebuthiuron application, susceptible plants were killed and less susceptible ones became chlorotic downslope from treated areas. This damage was more apparent when tebuthiuron was applied to wet or frozen soils. A partial explanation for these differences in tebuthiuron movement could be that greater runoff occurs from wet or frozen than from dry or unfrozen soils. Season of rainfall can also influence the amount of runoff water from a watershed. Greater runoff and soil erosion were consistently measured in the fall after intense summer thunderstorms than in the spring (14). Raindrops from intense storms tend to disperse exposed soil aggregates, thus sealing the surface and reducing infiltration until the soil surface is loosened by freezing and thawing during the winter (8).

We applied tebuthiuron to rangeland soils and used rainfall simulation to: a) compare relative movement of tebuthiuron after application on dry and wet soils as indicated by amount in runoff water and sediment, b) determine amount and distribution of tebuthiuron in soil, and c) examine movement of tebuthiuron after application in spring and fall.

MATERIALS AND METHODS

Study site. The study was conducted on the Walnut Gulch Experimental Watershed in southeastern Arizona. Average annual precipitation (300 mm) is distributed bimodally, 70% in the summer thunderstorm season and the remainder as winter frontal storms. Plant species on the experimental plots were creosote bush (#[3] LARTR), whitethorn acacia (*Acacia constricta* Benth. # ACACS), mariola (*Parthenium incanum* H.B.K.), desert zinnia (*Zinnia pumila* Gray), false mesquite (*Calliandra eriophylla* Benth.), jointfur (*Ephedra trifurca* Torr. # EPETR), littleleaf sumac (*Rhus microphylla* Engelm. # RHUMC), yucca (*Yucca bacata* Torr.), and fluffgrass [*Erioneuron pulchellum* (H.B.K.) Takeoka].

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[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

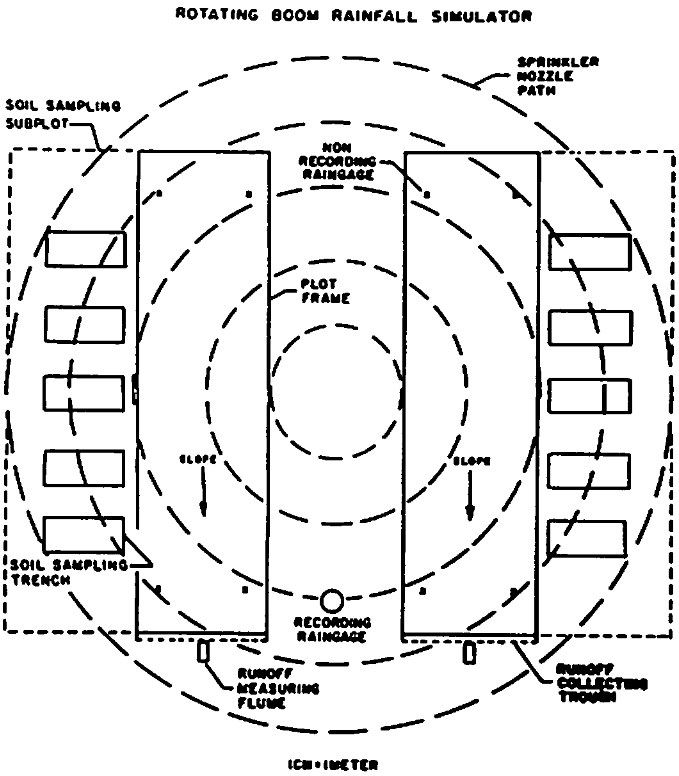

Figure 1. Plot layout with schematic of simulator nozzle path and soil sampling trenches in subplots. Four soil sampling trenches were dug in each soil sampling subplot.

The experimental plots were located on a Hathaway gravelly, sandy loam soil (loamy-skeletal, mixed, thermic Aridic Calciustoll). Hathaway soil is a deep, well-drained, gravelly, coarse-textured alluvium deposited over very gravelly, coarse-textured materials (12). The upper 10 cm of soil had up to 70%, by volume, gravel and occasional cobbles and usually less than 50% gravel in the remainder of the profile. Percentages of sand, silt, clay, and organic matter in the surface 5 cm were 74, 17, 9, and 1.5, respectively. The plots had slopes ranging from 7.7 to 8.0%.

Experimental design. We established eight 6.5- by 10.7-m plots in four pairs with a 3.05-m alley between each pair (Figure 1). The plots were randomly designated "dry" and "wet". The dry plot was treated with tebuthiuron before the first 45-min rainfall simulation event, and the dry plot was treated with tebuthiuron 24 h after the first 45-min rainfall simulation event. Three pairs of plots were treated with tebuthiuron; the fourth pair was not treated with tebuthiuron to determine if tebuthiuron application influenced plot hydrology. Plots were divided into 3.05- by 10.7-m "plot halves." The interior half was bordered with 3.2-mm-thick by 24-cm-wide steel sheets, driven into the ground until 12 cm remained above ground level to control runoff in that plot half (Figure 1). The external, unenclosed half was used for soil sampling. The experimental design was a paired-plot randomized block with three replications.

Tebuthiuron treatments. Tebuthiuron at 1 kg/ha was applied as clay pellets, 3.2 by 4.8 mm containing 20% ai, on May 14, 1985, to the three dry-soil plots, and to the wet-soil plots on May 15 and October 30, 1985, after the first simulated rainfall events. To ensure uniform application, formulated tebuthiuron was weighed and thoroughly mixed with 100 g of inert pellets of the same dimensions for each plot. The diluted mixture was then subdivided into four aliquots. Two aliquots were separately applied in four swaths each (eight total swaths) parallel to the long axis of the plot and two aliquots were applied separately in six swaths each (12 total swaths) perpendicular to the long axis of the plot.

In addition, during two runs 100 clay pellets containing no tebuthiuron were placed on bare ground near a nonrecording rain gauge in the plot half used for soil sampling. These pellets were observed to determine the length of time and amount of simulated rainfall needed to cause disintegration of the pellets and dispersion of the clay. During other runs, pellets containing tebuthiuron were observed to determine if tebuthiuron in the pellets changed the breakdown and dispersal characteristics.

Rainfall simulation. Water was applied to paired plots with a rotating boom simulator (15) positioned in the alley between the wet and dry paired plots (Figure 1). The nozzles, mounted on 10 booms, applied rainfall at an intensity of about 65 mm/h and produced drop-size distributions similar to natural rainfall and impact energies of about 80% of natural rainfall. A storm of this intensity is expected to occur once every 50 yr at Walnut Gulch (11).

Three rainfall simulation events were made on each plot pair in the spring and again in the fall. They were: an initial 45-min rainfall on dry soil, a 23-min rainfall 24 h after the first, and a 23-min rainfall 30 min after the second. Rainfall application rate was measured with a recording rain gauge and plot rainfall distribution was measured with four nonrecording rain gauges. Runoff was measured with portable flumes (4 L/s maximum capacity) equipped with FW-1 water level recorders that permitted instantaneous measurement of discharge. Water for the rainfall simulation had a pH of 6.9 and an electrical conductivity of 112.2 ds/M.

Soil particles were found in all the water samples and are referred to hereafter as sediment. Sediment and herbicide levels were determined from periodic 1-L water samples. Sampling frequency was dependent on the runoff rate, with more frequent sampling during periods of changing discharge rates (13). Initiation of rainfall simulation, runoff, water sampling, and end of runoff were recorded. Water samples were centrifuged at 1600 *g* for 10 min to separate sediment from water. Sediment and herbicide amounts removed from the half plots were calculated by integrating their concentrations in the water samples with the hydrographs from the FW-1 water level recorders.

Surface sampling. A pinpoint frame was used to measure the proportion of the soil surface covered by bare soil (particles <2 mm), gravel (particles 2 to 20 mm), rock (particles >20 mm), litter, and canopy cover of grasses, forbs, and shrubs (9, 13). The frame was placed perpendicular to the plot slope and rested on the metal plot border at 10 positions evenly spaced along the plot. At each position, 49 pinpoint surface and vegetation canopy interceptions were recorded by dropping a pin through each pinhole.

Soil sampling. Soil samples were taken in each external 3.05- by 10-m half plot from four trenches 0.8 m wide by 2.5 m long by 1.5 m deep excavated perpendicular to the slope (Figure 1). The first trenches were randomly located within the lower one-fifth of each subplot. Subsequent trenches were sequentially placed upslope but no closer than 1 m from previously excavated trenches. This prevented tebuthiuron contamination of the soil from upslope runoff water. The first trenches in the dry subplots were sampled on May 15, 24 h after the application of tebuthiuron and the first rainfall event, but before the second and third rainfall events. The second trenches in the dry and the first trenches in the wet subplots were excavated and sampled on May 16, 24 h after the second and third rainfall events. The second trenches in wet plots were sampled on May 17, 48 h after the second and third rainfall events. The third trenches in all plots were sampled on October 29 before the first fall rainfall event. The fourth trenches in all plots were sampled on November 7. All trenches were refilled after sampling. Soil samples were taken at 0- to 7-, 7- to 15-, 15- to 30-, and at 15-cm increments to 135-cm depths. Fifteen subsamples, taken at 30-cm intervals around the trench perimeter at the same soil depth, were combined. The bulk samples ranged from 1500 to 1900 g. Samples were placed in double plastic bags within paper bags for transportation, air dried in the laboratory, screened through a 2-mm soil sieve, thoroughly mixed, and stored in the original bags at room temperature.

Tebuthiuron analyses. Water samples were centrifuged at 1600 *g* for 10 min to separate sediments from water. The water was decanted, filtered through Whatman #1 filter paper to remove plant debris, and the debris discarded. Plant debris weighed less than 100 mg and preliminary analysis failed to detect tebuthiuron. Sediments were dried in a forced-draft oven for 12 h at 60 C, weighed, and analyzed for tebuthiuron. Two 100-ml aliquots were taken from each water sample after sediment was removed for tebuthiuron analysis by the method described by Loh et al. (10). Tebuthiuron was transferred from water into ethyl acetate by liquid-liquid partition, passed through an alumina column, and quantified by gas chromatography with flame photometric detection. The gas chromatograph was a Tracor[4] Model 222 equipped with a borosilicate column 122 cm by 0.3 cm containing 5% Carbowax 20M on Chromosorb HP. Column, injector, and detector temperatures were 215, 300, and 190 C, respectively. A Spectra Physics Minigrator[4] was used to quantify tebuthiuron. Counts of unknown samples were compared with tebuthiuron standards at concentrations ranging from 0 to 1.5 mg/L, the range with a linear relationship between tebuthiuron concentration and apparatus response. Samples were diluted to attain this concentration range as needed. Tebuthiuron was added to untreated water, soil, and sediment to determine recovery rates. Recovery from soil and sediment averaged 75% and from water 95%.

Table 1. Mean surface cover and plant cover of plots measured in May and October 1985 before spring and fall rainfall simulations[a].

Treatment	Surface cover: Rock	Gravel	Soil	Litter	Plant canopy cover: Grass	Forb	Shrub	Total
	(%)							
Spring:								
Control	14 a	36 a	38 a	12 a	2 a	1 a	27 a	30 a
Tebuthiuron:								
Dry soil	16 a	31 a	39 a	14 a	1 a	0 a	36 a	37 a
Wet soil	14 a	27 a	42 a	16 a	1 a	0 a	42 a	43 a
Fall:								
Control	18 a	42 a	22 a	18 a	0 a	10 a	34 a	44 a
Tebuthiuron:								
Dry soil	20 a	32 b	33 a	15 a	0 a	3 a	32 a	35 a
Wet soil	19 a	30 b	33 a	18 a	0 a	T[b] a	37 a	37 a

[a]Means in the same column and season followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

[b]T indicates less than 0.5% cover.

Tebuthiuron was extracted from 20-g sediment and soil samples with acidified methanol. When sediment samples weighed less than 20 g the entire sample was used for tebuthiuron analysis. The detection limits were 1.0 µg/L for water and 0.05 mg/kg for sediment and soil. Tebuthiuron metabolite analyses were not conducted because the major metabolite had not been detected in soil (5). Concentrations of tebuthiuron in runoff water, sediment, and soil were converted to amounts/unit area (kg/ha) in order to partition tebuthiuron between these three components.

Statistical analysis. Data from the soil analyses were analyzed using a split-split-plot design with three replications. Major plots were soil moisture (dry or wet) before herbicide application, subplots were days after application, and sub-subplots were soil depths. Significant main factor effects were partitioned orthogonally into single-degree-of-freedom components and significant interaction means separated with Duncan's multiple range test. Tebuthiuron content of samples from one dry soil subplot was several times greater than the application amount, and these samples were discarded. Missing-plot techniques were substituted, resulting in loss of 7 degrees of freedom in the sub-subplot error term (1). Percentage cover values (Table 1) were transformed to angles by the arc sin transformation, subjected to analyses of variance, and means separated by Duncan's multiple range test.

RESULTS AND DISCUSSION

Site descriptions. Surface cover and plant cover were similar on tebuthiuron-treated and control plots in both the spring

[4]Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Dep. Agric. over others not mentioned.

and fall, but gravel cover increased on the control plots in the fall (Table 1). Greater gravel amounts were probably due to runoff that removed soil during intense summer rainfall (11) but this does not explain the increase in gravel on the control plots compared to the tebuthiuron-treated plots.

Infiltration, runoff, and sediment. Infiltration, runoff, and soil loss from tebuthiuron and control rainfall simulation (Table 2) plots were similar. There was a decrease of infiltration in the fall (Table 2). Average infiltration percentages in the spring for the three simulated rainfall events were 91, 84, and 73%, respectively, but in the fall, infiltration percentages were 49, 52, and 41%, respectively. The reductions in infiltration rates between the first rainfall simulation and the second and third is to be expected as hydraulic conductivity of a soil changes with wetness of the soil (8). The surface soil of the dry plots contained 6% moisture before the first rainfall simulation event, whereas the surface soil moisture contents before the second and third rainfall simulations ranged from 17 to 24%. Reduced infiltration in the fall compared with the spring frequently occurs in areas that experience intense summer thunderstorms (13). Reduced infiltration resulted in increased runoff in the fall. We applied simulated rainfall at approximately the same intensities in the spring and fall, but fall runoff was between 3.4 and 3.9 times greater than spring runoff and greater sediment amounts were measured in the fall (Table 2).

Distribution of tebuthiuron. ***Breakdown of pellets.*** After rainfall simulation began, pellets began to disintegrate within 2 min (Table 3). Pellets were fragmented after approximately 7 min (7 to 8 mm of rainfall) and disappeared 12 min after rainfall simulation began (10 to 12 mm of simulated rainfall). Pellets containing no tebuthiuron disintegrated and were dispersed in the same time and after the same amount of simulated rainfall as pellets containing tebuthiuron.

Dry plots. When tebuthiuron pellets were applied to dry plots in the spring and simulated rainfall applied, 5% of the applied tebuthiuron was detected in the runoff water/sediment mixture (Table 4). Tebuthiuron was detected to a depth of 30 cm, with 52% of the applied tebuthiuron in the surface 7 cm when the soil from these plots was sampled 24 h after rainfall simulation. With the application of the second and third rainfall simulations, 1% of the applied tebuthiuron was in runoff water and 1% was in the sediment fractions. Soils sampled from the dry plots 24 h after the third rainfall simulation were moist at 45- to 60-cm depths and contained tebuthiuron at 30-cm depths, with 21, 35, and 78% of the applied tebuthiuron at depths of 0 to 7, 7 to 15, and 15 to 30 cm, respectively.

Dry-plot soils were sampled 168 days after treatment and before fall-simulated rainfall. Tebuthiuron was detected at 0- to 60-cm depths and a trace at 75- to 90-cm depths (Table 4). Highest concentrations were measured at the 30- to 45-cm depth. Tebuthiuron was detected in both the runoff and sediment after each fall rainfall simulation; however, the detected quantities were less than the equivalent of 0.001 kg/ha. Dry-plot tebuthiuron residues 177 days after the initial treatment on May 14 were detected between 0- to 45-cm depths.

Table 2. Mean rainfall, runoff, infiltration, and sediment from rainfall simulation plots[a].

Treatment	Rainfall	Infiltration	Runoff	Sediment removed
	(mm)			(kg/ha)
Spring:				
Control:				
First event	38	35	3	61
Second event	21	18	3	66
Third event	21	15	6	112
Total	80	68	12	239
Dry soil, tebuthiuron:				
First event	37	33	4	65
Second event	22	18	4	73
Third event	21	15	6	82
Total	80	66	14	220
Wet soil, tebuthiuron:				
First event	33	30	3	93
Second event	21	18	3	80
Third event	21	16	5	97
Total	75	64	11	270
Fall:				
Control:				
First event	40	18	22	194
Second event	22	9	13	123
Third event	24	9	15	153
Total	86	36	50	470
Dry soil, tebuthiuron:				
First event	40	18	22	179
Second event	22	13	9	102
Third event	23	9	14	106
Total	85	40	45	387
Wet soil, tebuthiuron:				
First event	38	21	17	281
Second event	20	11	9	192
Third event	20	9	11	229
Total	78	41	37	702

[a]Values for controls are means of two plots and for dry- and wet-soil means of three plots.

Table 3. Time and amount of simulated rainfall required to disperse clay pellets 3.2 mm in diameter.

Time	Amount of rainfall: Run #1	Amount of rainfall: Run #2	Comments[a]
(min)	(mm)		
0	0	0	Pellets intact
1.8	5	...	Less than 10% of pellets fragmented
3.0	...	3	More than 80% of pellets fragmented
7.2	8	7	All pellets fragmenting
12.0	10	12	All pellets dispersed

[a]Based on observation of 100 pellets/run placed on dry bare soil near nonrecording rain gauge.

Table 4. Distribution of tebuthiuron in runoff water, sediment, and soil after application to dry and wet soils.

	Amount of tebuthiuron[a]							
	Dry soils				Wet soils			
	Days after tebuthiuron application[b]				Days after tebuthiuron application[c]			
Source	0	1	168	177	0	1	167	176
	(g ai/ha)							
Runoff water[d]	30	10	T	T	80	...	T	320
Sediment[d]	20	10	T	T	70	...	T	160
Soil[e]								
0–7 cm	520 uv	210 w-z	80 yz	20 z	540 tu	480 uv	50 yz	500 uv
7–15 cm	380 uvw	350 t-x	90 xyz	120 w-z	370 uvw	160 w-z	100 xyz	190 wxy
15–30 cm	30 z	780 t	120 w-z	190 q-z	0 z	100 xyz	270 v-y	50 yz
30–45 cm	0 z	0 z	150 w-z	130 w-z	0 z	0 z	50 yz	0 z
45–60 cm	0 z	0 z	20 z	0 z	0 z	0 z	20 z	0 z
60–75 cm	0 z	0 z	0 z	0 z	0 z	0 z	0 z	0 z
75–90 cm	0 z	0 z	T z	0 z	0 z	0 z	0 z	0 z
Total	980	1360	460	460	910	890	490	1220

[a]All soil values followed by the same letter are not significantly different ($P>0.05$) according to Duncan's multiple range test. T = less than 1 g ai/ha detected in water and sediment.

[b]Applied May 14, 1985, at 1 kg/ha before first rainfall simulation.

[c]Applied May 15, 1985, and October 30, 1985, each at 1 kg/ha 24 h after first rainfall simulation.

[d]Quantities in runoff water and sediment are from first simulated rainfall on days 0 and 168 and from second and third simulated rainfalls on days 1 and 177 for dry soils. Quantities in runoff water and sediment are from first simulated rainfall on day 167 and from second and third simulated rainfalls on days 0 and 176 for wet soils.

[e]Tebuthiuron was analyzed in soils collected 1 and 2 days after tebuthiuron application in the spring, before rainfall simulation, on days 168 and 167 and on days 177 and 178 in the fall.

Wet plots. Measured tebuthiuron quantities were more than twofold greater (15 vs. 7% of applied) in the runoff water and sediment from the wet plots than from the dry plots in the spring (Table 4). These quantities are even more ominous because they were removed by 42 mm of rainfall compared to 80 mm on the dry plots (Table 2). In the wet-plot soil, tebuthiuron was detected at the 0- to 15- and 0- to 30-cm depths 24 and 48 h, respectively, after rainfall simulation. Wet-plot soils were sampled for the third time 167 days after tebuthiuron treatment before the fall-simulated rainfall. Tebuthiuron was detected at 0- to 60-cm depths, but no differences in tebuthiuron amounts were found between the dry- and wet-plot soils (Table 4). Tebuthiuron traces were detected in water and sediment collections from the first fall rainfall simulation. Runoff water from the second and third rainfall simulations (after tebuthiuron application of 1 kg/ha) contained 32% of the tebuthiuron applied while sediment contained 16%. When wet-plot soils were sampled 176 days after the spring treatment, tebuthiuron was detected at 0- to 30-cm depths.

Wet-soil tebuthiuron applications in spring and subsequent rainfall simulations resulted in a threefold increase (5 to 15% of applied) of tebuthiuron in the runoff water and sediment from the initial rainfall event after treatment over that from dry soil. These values were low compared to the 0.48 kg/ha (48% of applied) tebuthiuron removed from wet soil in the fall. The increase in tebuthiuron movement in the fall is directly attributable to the high rates of runoff and soil loss from all rainfall simulation plots in the fall (Table 2) due to lower infiltration rates associated with the intense summer thunderstorms and the sealing of the surface soil (8, 11). We did not re-treat the dry plots in the fall. Based on the greater amount of runoff and sediment from all dry plots in the fall compared to the spring, tebuthiuron concentration probably would have been high in both runoff water and sediment.

Formulation of tebuthiuron apparently is an important factor in the movement of tebuthiuron on the soil surface. Arias-Rojo[5] found only 0.3 and 0.03% of applied tebuthiuron in runoff and sediment, respectively, when he applied an 80% wettable powder of tebuthiuron to wet soil. In contrast, we found 8 and 7% of the applied tebuthiuron in runoff and sediment, respectively, when we applied the pelleted formulation to wet soil, and 4 and 3% of applied tebuthiuron in runoff and sediment, respectively, when we applied pelleted tebuthiuron to dry soil. Tebuthiuron is adsorbed on the clay particles in the pelleted formulation. When the pellets are wetted by rainfall and disintegrated, the clay particles containing tebuthiuron are much more readily moved by runoff water than tebuthiuron from the wettable powder formulation spray.

[5]Arias-Rojo, H. M. 1986. Modeling the movement of tebuthiuron in runoff and soil water. Ph.D. Dissertation, Univ. Arizona.

While there was an increase in the amount of tebuthiuron transported from wet soils compared to dry soils during spring rainfall simulation, the increase was less than one-third of the tebuthiuron transport increase found between spring and fall wet-soil plots. Application to wet soil in the spring increased tebuthiuron amounts in runoff and sediment. Application of tebuthiuron after intense thunderstorms will greatly increase tebuthiuron amounts in runoff and sediment (Tables 2 and 4). Tebuthiuron concentrations in runoff and sediment were not always higher in the fall than in the spring (data not shown) but the amounts of runoff water and sediment were much greater in the fall than in the spring.

Results of this study suggest that pelleted tebuthiuron should be applied to dry rather than wet soil. Applications in the fall and early winter should be avoided in areas subjected to intense summer thunderstorms until after freeze-thaw or swell-shrink processes loosen the soil surface.

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LITERATURE CITED

1. Anderson, R. L. 1946. Missing plot techniques. Biom. Bull. 2:41–47.
2. Bovey, R. W., R. E. Meyer, and H. Hein, Jr. 1982. Soil persistence of tebuthiuron in the claypan resource area of Texas. Weed Sci. 30:140–144.
3. Chang, S. S. and J. F. Stritzke. 1977. Sorption, movement and dissipation of tebuthiuron in soils. Weed Sci. 25:184–187.
4. Davis, E. A. 1981. Tebuthiuron residues in stream water from a spot treated chaparral watershed in Arizona. West. Soc. Weed Sci. Res. Prog. Rep. Pages 52–53.
5. Eaton, B. J., J. D. Magnussen, and D. P. Rainey. 1976. Metabolism of tebuthiuron in soil and plants. Abstr. Weed Sci. Soc. Am. Abstr. 199.
6. Emmerich, W. E., J. D. Helmer, K. G. Renard, and L. J. Lane. 1983. Fate and effectiveness of tebuthiuron applied to a rangeland watershed. J. Environ. Qual. 13:382–386.
7. Hendricks, D. M. 1985. Arizona soils. College of Agric., Univ. Arizona, Tucson. 244 pp.
8. Hillel, D. 1980. Fundamentals of Soil Physics. Academic Press, New York. 413 pp.
9. Levy, E. B. and E. A. Madden. 1933. The point method of pasture analysis. New Zealand J. Agric. 46:276–279.
10. Loh, A., R. Frank, and O. D. Decker. 1980. Tebuthiuron. Anal. Methods Pestic. Plant Growth Regul. 11:351–361.
11. Osborn, H. B. and L. J. Lane. 1981. Point-area-frequency conversions for summer rainfall in southeastern Arizona. Hydrol. and Water Resources in Arizona and the Southwest. 11:37–46.
12. Richmond, D. L. 1971. General soil map Cochise County, Arizona. Soil Conserv. Serv., U.S. Dep. Agric., Washington, DC.
13. Simanton, J. R. and K. G. Renard. 1982. Seasonal change in infiltration and erosion from USLE plots in southeastern Arizona. Hydrol. and Water Resources in Arizona and the Southwest 12:37–46.
14. Simanton, J. R., C. W. Johnson, J. W. Nyhan, and E. M. Romney. 1986. Rainfall simulation on rangeland erosion plots. Pages 11–17 *in* L. J. Lane, ed. Erosion on rangelands: emerging technology and data base. Proc. Rainfall Simulator Workshop, Jan. 14–15, 1985, Tucson, AZ. Society for Range Management, Denver.
15. Swanson, J. P. 1965. Rotating-boom rainfall simulator. Trans. ASAE 8:71–72.
16. Weed Science Society of America. 1983. Herbicide Handbook. 5th ed. Weed Sci. Soc. Am., Champaign, IL.