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Tebuthiuron Effects on Elemental Nutrients in Blue Grama (*Bouteloua gracilis*) Forage[1]

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Abstract. Tebuthiuron has been found in soils and plants a decade after application to rangelands in semi-arid areas. Forage production, length of growing season, and preference by grazing animals are greater on treated than on untreated areas. It is not understood how these differences occur. Blue grama forage was assayed for concentrations of N, P, K, Ca, Cu, Fe, Mg, Mn, and Zn in treated and untreated plants on adjacent paired plots in the field, 6 to 11 yr after tebuthiuron applications at three locations in Arizona. Only Fe and Mn concentration differed among treatments, being significantly higher ($P = 0.05$) in blue grama from treated plots. **Nomenclature:** Tebuthiuron, *N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea; blue grama, *Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths.

Additional index words: Grass, herbicide.

INTRODUCTION

Tebuthiuron is used to control weeds and woody plants on rangelands (5, 10, 18, 20, 21, 23), and has been found in soils and grasses a decade after applications (12, 13). Forage production following tebuthiuron treatments has varied from reduction to several-fold increases, depending on the species and degree of release from competition (1, 25, 26, 29). Plants had 3- to 6-wk longer growing seasons on some treated areas than those on adjacent untreated areas (2, 14). The increased forage production and a longer growing season could be a result of less weed and woody plant competition.

Cattle (*Bos taurus*) and goats (*Capra hircus*) have shown a grazing preference for plants on tebuthiuron treated areas over plants on untreated areas, especially during the initial year after treatment (2, 15, 16, 19, 24). This preference for tebuthiuron treated plants is not understood. Plants on treated areas may have a higher water content than those on untreated areas (2, 28), but cattle still preferred tebuthiuron-treated plants when both treated and untreated plants had succulent regrowth following mowing (24).

Some studies indicated that the protein content of tebuthiuron treated plants was increased (2, 15, 16, 17). Other studies indicated little or no difference (1, 28). Tebuthiuron effects on crude protein have been reported as being limited to the growing season after treatment (2, 17); however, crude protein was reported to be highest in the winter and spring in the diets of goats grazing on treated areas 3 yr after treatment (16). Phosphorus content was reported both as being increased (2) or not being affected (28). Carotene content (28) and cell wall contents (2) were not affected. Dry matter increased without consistent differences in forage quality (6).

Organic matter digestibility increased the initial year following tebuthiuron applications (2, 15). Lopes and Stuth (16) reported that in vitro digestible organic matter was higher in summer and winter on treated areas than on untreated areas 3 to 4 yr after applications, but others indicated tebuthiuron did not affect in vitro digestibility (17). Nitrogen was increased in treated soils 6 yr after applications in the field (26). However, soil nitrogen mineralization or nitrification nutrients were not affected in laboratory studies when tebuthiuron concentrations were ≤ 1 $\mu g\ g^{-1}$; but small, temporary, localized effects were reported with tebuthiuron concentrations of 100 and 1000 $\mu g\ g^{-1}$ (8). Soil tebuthiuron concentrations in the field are usually less than 1 $\mu g\ g^{-1}$ (3, 12).

The increased palatability of forage plants following tebuthiuron treatments could result from increased concentrations of essential elements. The objective of this study was to determine if tebuthiuron treated and untreated blue grama plants contained different concentrations of nine essential nutrient elements.

MATERIALS AND METHODS

Study locations. Three locations in north-central Arizona were studied: Drake, north of Prescott; Indian Flat

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and Red Mountain, both north of Flagstaff. Mean annual rainfall was 330 mm at Drake, 430 mm at Indian Flat, and 310 mm at Red Mountain, all with the highest amounts of rain falling in summer and winter.

All the soils are classed as Mollisols. The soil at Drake is a Tajo loam, a fine-loamy, mixed, mesic, Petrocalcic Paleustoll. The soil at Indian Flat and Red Mountain is a Thunderbird clay loam, a fine, montmorillontic, mesic, Aridic Argiustoll.

Pinyon-juniper was the dominant vegetation at all locations. Blue grama was the major understory grass at all locations, growing in open areas in the juniper stands. The study sites were fenced to exclude livestock.

Treatments. The plots were part of previously established tebuthiuron efficacy evaluations. At Drake, pellets containing 160 g ai tebuthiuron kg^{-1} were applied in April 1975 in a 2.7- by 2.7-m grid pattern on a non-replicated 16.4- by 19.2-m plot at a rate equivalent to 2.2 kg ai ha^{-1} to control Utah junipers [*Juniperus osteosperma* (Torr.) Little]. At Indian Flat and Red Mountain, pellets containing 100 g ai tebuthiuron kg^{-1} were hand-broadcast at the rate of 4.0 kg ai ha^{-1} onto 5- by 10-m plots in two randomized complete blocks in October 1976 and August 1977 to control mixed-species stands of half-shrubs in open, tree free sites. All the half-shrubs died on all the plots 3 to 4 yr after applications.

Plant sampling. Blue grama foliage and culms were harvested from eight sets of adjacent paired treated and untreated plots by cutting the plants to a 2.5-cm stubble height during the last week of September or the first week of October in 1983, 1985, and 1986. Blue grama was not uniformly available for collection every year at each location or plot, especially on untreated plots, because of dry summers. Plot samples were a composite of approximately equal samples from 10 or more blue grama clumps randomly selected from throughout the plot. Current season top growth was collected, placed in paper bags, dried in a forced-draft oven at 60 C for 48 h, ground in a Wiley Mill to pass a 40-mesh stainless-steel screen, and stored in the dark in air-tight glass bottles at room temperature.

Assays. Concentrations of Ca, Cu, Fe, K, Mg, Mn, N, P, and Zn were determined with duplicate, oven-dry 0.2-g subsamples. In addition, National Bureau of Standards samples and multiple assays of randomly selected samples were used to confirm the accuracy of the assays. Following micro-Kjeldahl digestion in a Technicon BD-40 Block Digestor[3], total N and P were determined with a Technicon AutoAnalyzer II[3]. Following nitric-perchloric acid digestion, concentrations of the remaining elements were determined with a Perkin-Elmer 403 Atomic Absorption Spectrophotometer[4]. The samples were concurrently assayed for tebuthiuron and tebuthiuron metabolites (13).

Statistical analysis. Data for each element were averaged and standard deviations from treatment means were determined. Each sample represents at least 10 plants, for a total of at least 80 plants for each treatment. Because sampled population distributions were unknown, treatment differences for each element were determined by the nonparametric Wilcoxson rank-sum test for matched pairs of samples at the 0.05% level (4).

RESULTS AND DISCUSSION

Iron and Mn were the only elements significantly higher ($P = 0.05$) in treated blue grama than in untreated blue grama 6 to 11 yr after applications (Table 1). The additional Fe and Mn in treated blue grama forage could be due to elements released from herbicide-killed plants; woody plant roots decay slowly (27), so such effects may last several years. However, low concentrations of tebuthiuron were found in the soils of these plots (12) and low concentrations of tebuthiuron metabolites were detected in concurrently assayed treated blue grama forage (Table 1, 13). Sublethal amounts of some herbicides enhance plant growth (30) as indicated by the long-term increased vigor and longer green-forage period observed on treated plots in this study. Thus, the more vigorous treated blue grama plants may be more efficient in accumulating mineral nutrients. In addition, since only Fe and Mn concentrations were increased, higher Fe and Mn concentrations in treated blue grama indicate tebuthiuron may enhance Fe and Mn dependent processes influencing plant growth.

Iron is essential for chlorophyll formation with small amounts of Fe firmly bound in the grana of the chloroplast (11). Iron is also in some enzymes, being essential for the prosthetic group of enzymes, and incorporated in more complex molecules, such as Fe porphyrin.

[3]Mention of trade names does not imply endorsement by U.S. Dep. Agric. Technicon Industrial Systems, Tarrytown, NY 10591.

[4]Perkin-Elmer Corp., Norwalk, CT 06859.

Table 1. Essential element and tebuthiuron metabolites (TM) concentrations in blue grama from paired tebuthiuron treated (T) and untreated (C) plots at Drake (DK), Indiana Flat (IF), and Red Mountain (RM) in northcentral Arizona. Each value represents a composite of 10 or more plants.

		Elements																		
	Yr treatment/	Ca		Cu		Fe		K		Mg		Mn		N		P		Zn		TM[a]
Location	yr sample	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	T
		mg kg^{-1}																		
DK	75/86	7630	7240	5	5	850	990	4200	3700	1180	1090	50	66	7990	9230	910	880	15	15	2.3
IF	76/85	5050	4550	6	5	1920	2430	4300	4990	2300	2500	50	62	8340	8190	930	1000	18	20	2.0
	76/86	3830	3470	3	3	670	1430	2800	2600	1600	1680	32	45	7670	7910	980	1080	15	11	2.0
	77/83	2990	3710	5	5	3180	4100	4200	3700	2180	2420	75	92	5850	7690	1070	1250	15	19	0.6
	77/86	4930	3740	3	4	1300	2250	2700	3290	2460	2180	40	55	9290	7710	1210	1080	12	14	0.5
RM	76/86	4600	4490	3	5	760	2260	3400	2900	2180	2390	31	57	8550	7950	1040	1170	13	15	2.1
	77/86	5040	3760	4	5	1360	1600	2700	3290	2470	2200	39	39	7630	8190	1110	1340	14	14	2.2
	77/86	3910	3680	3	3	690	550	5290	5500	1240	1210	41	43	7250	8720	1070	1440	13	10	2.6
Mean		4750	4330	4	4	1340	1950	3700	3750	1950	1960	45	57	7820	8200	1040	1155	15	15	1.8
SD		1370	1240	1	1	860	1090	950	1010	530	560	14	17	1020	530	99	183	2	3	0.8
Signif.[b]		NS		NS		*		NS		NS		*		NS		NS		NS		

[a]Concurrent tebuthiuron and tebuthiuron metabolites assays reported by Johnsen and Morton (13). Only metabolites detected in these samples.

[b]* = significantly different at the 5% level according to the Wilcoxson rank sums test of paired treated and untreated samples.

Iron is included in several catalysts making up essential links in the process of respiration, and, as a reducing substance, also is involved in the electrons passing from plastoquinone to non-heme Fe-S proteins.

Manganese is essential to chlorophyll formation; also, some enzymes contain Mn (10). Manganese may be involved in non-cyclic transport in photosynthesis and is implicated in the evolution of oxygen in its multiplicity of oxidation states, and in charge storage.

Tebuthiuron kills plants by disrupting photosynthetic electron transport (9), low concentrations may somehow enhance these systems. Perhaps increased Fe and Mn concentrations reflect an increase in photosynthetic efficiency in tebuthiuron-treated blue grama.

Concentrations of the other elements (Ca, Cu, K, Mg, N, P, and Zn) did not differ significantly between treated and untreated blue grama (Table 1). Concentrations of these elements are similar to previous reports for this and similar grasses (7, 22). These results agree with Sosebee (29) who reported P concentration in forage was not affected by tebuthiuron; however, Biondini et al. (2) reported P increased. Nitrogen concentrations did not change; increases (2, 15, 16, 17), and no change (1, 6, 29) in protein N following tebuthiuron treatment have both been reported.

Implications. If increased Fe and Mn concentrations in tebuthiuron-treated blue grama indicates increased photosynthetic activity or efficiency, that can partially explain the reported increased growth, longer growing season, and better growth during dry periods of treated grasses than of nearby untreated grasses. If the plant is more efficient photosynthetically, it might improve palatability of top growth, thereby causing the reported selective grazing of tebuthiuron treated grasses by livestock. Additional root growth could occur due to increased photosynthate, resulting in treated plants accumulating water and nutrients, including Fe and Mn, more efficiently than untreated plants. That may account for tebuthiuron-treated grasses having a longer growing season than untreated grasses.

Long-term effects of sublethal amounts of tebuthiuron are indicated by treated blue grama having higher concentrations of Fe and Mn than untreated blue grama 6 to 11 yr after applications. Low concentrations of tebuthiuron have been reported in concurrently collected soil and plant samples from areas treated a decade earlier (12, 13). These low concentrations may be beneficial to plants, as is common for many toxic materials. However, it is not known if the increased Fe and Mn concentrations following tebuthiuron applications are limited to blue grama and/or the two soils used in this study.

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LITERATURE CITED

1. Baur, J. R., R. W. Bovey, and E. C. Holt. 1977. Effect of herbicides on production and protein levels in pasture grasses. Agron. J. 69:846–851.
2. Biondini, M., R. D. Pettit, and V. Jones. 1986. Nutritive value of forages on sandy soils as affected by tebuthiuron. J. Range Manage. 39: 396–399.

3. Bovey, R. W., E. Burnett, R. E. Meyer, C. Richardson, and A. Loh. 1978. Persistence of tebuthiuron in surface runoff water, soil, and vegetation in Texas blacklands prairie. J. Environ. Qual. 7:233–236.
4. Chou, Ya-lun. 1969. Statistical Analysis. Holt, Rinehart and Winston, Inc., New York. 794 p.
5. Clary, W. P., S. Goodrich, and B. M. Smith. 1985. Response to tebuthiuron by Utah juniper and mountain big sagebrush communities. J. Range Manage. 38:56–60.
6. Crowder, S. H., A. W. Cole, and V. H. Watson. 1983. Weed control and forage quality in tebuthiuron treated pastures. Weed Sci. 31: 585–587.
7. Everitt, J. H., M. A. Alaniz, A. H. Gerbermann, and H. W. Gausman. 1980. Nutrient content of native grasses on sandy and red sandy loam range sites in south Texas. U.S. Dep. Agric., Sci. Ed. Adm., Agric. Res. Serv., ARR-S-7.
8. Goodroad, L. L. 1987. Effect of tebuthiuron on soil N mineralization and nitrification. Comm. Soil Sci. Plant Anal. 18:473–481.
9. Hatzios, K. K., D. Penner, and D. Bell. 1980. Inhibition of photosynthetic electron transport in isolated spinach chloroplasts by two 1,3,4-thiadiazolyl derivatives. Plant Physiol. 65:319–321.
10. Herbel, C. H., H. L. Morton, and R. P. Gibbens. 1985. Controlling shrubs in the arid southwest with tebuthiuron. J. Range Manage. 38: 391–394.
11. Hipkins, M. F. 1984. Photosynthesis. p. 219–248 *in* M. B. Wilkins, ed. Advanced Plant Physiology. Pitman Publishing, Inc., Marshfield, MA.
12. Johnsen, T. N., Jr., and H. L. Morton. 1989. Tebuthiuron persistence and distribution in some semiarid soils. J. Environ. Qual. 18:433–438.
13. Johnsen, T. N., Jr., and H. L. Morton. 1991. Long-term tebuthiuron content of grasses and shrubs on semiarid rangelands. J. Range Manage. 44:(in press).
14. Jones, V. E., and R. D. Pettit. 1984. Low rates of tebuthiuron for control of sand shinnery oak. J. Range Manage. 37:488–490.
15. Kirby, D. R., and J. W. Stuth. 1982. Botanical composition of cattle diets grazing brush managed pastures in east-central Texas. J. Range Manage. 35:434–436.
16. Lopes, E. A., and J. W. Stuth. 1984. Dietary selection and nutrition of Spanish goats as influenced by brush management. J. Range Manage. 37:554–560.
17. Masters, R. A., and C. J. Scifres. 1984. Forage quality responses of selected grasses to tebuthiuron. J. Range Manage. 37:83–87.
18. Mayeux, H. S., Jr., and W. T. Hamilton. 1983. Response of common goldenweed (*Isocoma coronopifolia*) and buffelgrass (*Cenchrus ciliaris*) to fire and soil-applied herbicides. Weed Sci. 31:355–360.
19. McDaniel, K. C., and J. F. Balliette. 1986. Control of big sagebrush (*Artemisia tridentata*). Weed Sci. 34:276–280.
20. Meyer, R. E., and R. W. Bovey. 1985. Response of yaupon (*Ilex vomitoria*) and understory vegetation to herbicides. Weed Sci. 33: 415–419.
21. Murray, R. B. 1988. Response of three shrub communities in southeastern Idaho to spring-applied tebuthiuron. J. Range Manage. 41:16–22.
22. Nelson, A. B., C. H. Herbel, and M. M. Jackson. 1970. Chemical composition of forage species grazed by cattle on an arid New Mexico range. N. Mex. State Univ. Agric. Exp. Stn. Bull. 561.
23. Pettit, R. D. 1979. Effects of picloram and tebuthiuron pellets on sand shinnery oak communities. J. Range Manage. 32:196–200.
24. Scifres, C. J., J. R. Scifres, and M. M. Kothmann. 1983. Differential grazing use of herbicide treated areas by cattle. J. Range Manage. 36: 65–69.
25. Scifres, C. J., J. W. Stuth, D. R. Kirby, and R. F. Angell. 1981. Forage and livestock production following oak (*Quercus* spp.) control with tebuthiuron. Weed Sci. 28:535–539.
26. Sears, W. E., C. M. Britton, D. B. Wester, and R. D. Pettit. 1986. Herbicide conversion of a sand shinnery oak (*Quercus harvardii*) community: effects on biomass. J. Range Manage. 39:399–403.
27. Sears, W. E., C. M. Britton, D. B. Wester, and R. D. Pettit. 1986. Herbicide conversion of a sand shinnery oak (*Quercus harvardii*) community: effects on nitrogen. J. Range Manage. 39:403–407.
28. Sosebee, R. E. 1979. Influence of tebuthiuron on forage quality of selected grasses – preliminary evaluations. Proc. South. Weed Sci. Soc. 33:334–346.
29. Sosebee, R. E., W. E. Boyd, and C. S. Brumly. 1979. Broom snakeweed control with tebuthiuron. J. Range Manage. 32:179–182.
30. Wieldman, S. J., and A. P. Appleby. 1972. Plant growth stimulation by sublethal concentrations of herbicides. Weed Res. 12:65–74.