Herbicide Conversion of a Sand Shinnery Oak (*Quercus havardii*) Community: Effects on Biomass

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Abstract

Seasonal biomass dynamics were documented in an undisturbed sand shinnery oak *(Quercus havardii)* community and adjacent areas treated with tebuthiuron 3 years and 6 years prior to sampling. Biomass was measured for above-ground and below-ground compartments during growth initiation, peak standing crop, and winter dormancy in 1981. Total biomass showed little change on plots treated 3 years prior to sampling compared to the untreated oak plot. However, there was a decrease in total biomass on the 6-year plot compared to the other 2 treatments. Above-ground biomass decreased on both treated sites compared to the untreated plot reflecting oak death and decomposition.. Above-ground herbaceous material increased appoximately 6-fold on both treated sites compared to the untreated plot. Oak root biomass decreased 12% at 3 years and 37% at 6 years following treatment. Herbaceous root biomass increased 3-fold on the 3-year-old treatment compared to the untreated oak community and was twice as much on the 6-year-old treatment compared to the untreated site. Distribution of herbaceous roots by soil depth was altered by treatment with a higher percentage of roots on the surface 30 cm on the treated sites compared to the untreated sites.

Sand shinnery oak *(Quercus havardii)* is a low-growing, rhizomatous shrub found primarily on deep sandy soils in northwestern Texas, eastern New Mexico, and western Oklahoma. As a component of the High Plains postclimax bluestem community (Allred 1956), it occurs as extensive "shinnery," forming dense thickets 0.5 to 1 m tall interspersed with "motts" of taller hybrid plants (Muller 1951). Forage production can be reduced as much as 90% under dense stands (McIlvain 1954). To control oak and increase herbaceous yield, oak-infested rangeland is currently treated with the pelleted herbicide tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,4,-thiadiazol-2-yl]-*N,N'*-dimethylurea). Pettit (1979) reported that 1.0 kg a.i./ha of tebuthiuron resulted in total oak kill in studies at the same research location. Grass yields following application of tebuthiuron increased from 3- to 9-fold 2 growing seasons after herbicide application (Pettit 1979).

Herbicides can alter internal ecosystem functions as well as external appearance. Little is known of the effects of herbicides on ecosystem functions such as biomass dynamics and nutrient cycling.

Since herbicidal-induced death of oak should alter biomass dynamics in the sand shinnery oak-grassland ecosystem, this study was designed to evaluate an untreated oak community as contrasted to similar areas treated with tebuthiuron 3 years (1978) and 6 years (1975) prior to sampling. One specific objective was to evaluate weights of above- and below-ground biomass on each of the 3 sites.

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This research was partially funded by Elanco Products Division of Eli Lilly and Company.

Manuscript accepted 26 December 1986.

Methods and Procedure

Research was conducted in south-central Cochran (33°23' N and 102°46' W) and north-central Yoakum (33°21' N and 102°38' W) counties, approximately 25 km north and 5 km east of Plains, Texas. Study areas are in the southern Great Plains in a sand dune system originating in eastern New Mexico. Sites are characterized by rolling sand hills interspersed with semistabilized dunes and blow-out areas.

Climate of the area is warm-temperate and continental with an average annual precipitation of 40 cm (Soil Survey Staff 1964). Rainfall for 1980 and 1981 was 33.4 and 55.6 cm, respectively, Precipitation patterns are characterized by widely scattered intense thunderstorms in spring and late summer. Temperatures range from 44° to -25° C with a frost-free period of approximately 200 days.

The primary soil on the study areas is a Brownfield fine sand (fine, mixed, thermic Arenic Aridic Paleustalf) (Soil Survey Staff 1964). It is characterized by an A horizon of approximately 95% sand, ranging from 40 to 70 cm deep, overlying a sandy clay loam argillic B horizon. The water holding capacity of this soil is low. Infiltration rates are rapid (up to 70 cm/hr), and percolation is rapid until the wetting front reaches the B horizon.

Species composition of the study area was described by Pettit (1979) and by Jones (1982). The plant community consists of tall-to mid-grass species and increaser short-grass species under a dense canopy of sand shinnery oak. Following treatment of this oak community with tebuthiuron, physiognomy was changed from oak shrubland to mixed-grass prairie. Sand shinnery oak and sand sagebrush were absent on the treated sites. The major grass species were the same. However, the number of forb species was higher on the 2 treated areas than on the control.

Three, 15 ×30-m study areas were established (1) in an untreated sand shinnery oak grassland, (2) in a similar community treated with tebuthiuron at 0.6 kg a.i./ha 3 years (1978) prior to sampling, and (3) in a similar community treated 6 years (1975) prior to sampling. All 3 sites had similar vegetative composition, occur on Brownfield soils and have been grazed lightly from June to September. All 9 study areas were fenced prior to sampling to exclude grazing during the study. A 30-point grid was established within each study area, and 4 sample points were randomly selected per area for each sampling date (April, growth initiation; July, peak standing crop; and December, dormancy). Samples were collected for above- and below-ground plant compartments.

Above-ground biomass was harvested at ground level in a 1-m² circular quadrat at each sample point and separated by compartment. Above-ground compartments sampled were: live oak stems, dead oak stems, live oak leaves, live herbaceous shoots (grass and forb shoots combined), dead herbaceous shoots, and litter.

Soil in a 0.25-m^2 circular plot at each sample point was excavated to depths of (1) 0 to 15 cm, (2) 15 to 30 cm, (3) 30 cm to the top of the B_2t horizon, and (4) 15 cm into the B_2t horizon. Depth effects were evaluated using weights adjusted to 15-cm increments for the variable increment (30 cm to the top of the argillic horizon) resulting in a 60-cm soil profile sample for all 3 treatments. The soil in each depth increment was placed in separate burlap bags and transported to the laboratory for root separation. Soil from each depth layer was sieved to pass a double layer of 1.6-mm mesh screen to recover the fine root fragments. Below-ground biomass was separated into large oak roots (>2 mm), small oak roots (<2 mm), and herbaceous roots (grass and forb roots combined). Vegetative samples were dried to a constant weight in a forced air oven (60° C) and then weighed to the nearest 0.01 g.

Total seasonal biomass was calculated by adding biomass across sampling dates for each treatment. Biomass for each compartment was analyzed in a completely randomized design with 3 replications and 4 samples per replication. Treatments were main plots and sampling dates were subplots in a repeated measured analysis.

Table 1. Seasonal biomass (kg/ha) for major compartments on control, 3-year old and 6-year old tebuthiuron treated sand shinnery rangeland in west Texas.

	Treatment											
	Control			3-Year			6-Year			Average		
Compartment	April	July	Dec.	April	July	Dec.	April	July	Dec.	Control	3-Year	6-Year
Total oak	23909	21913	21713	19671	20236	16325	14894	12918	11937	22512A[1]	18744B	13250C
Total herbaceous	1355b[2]	1601c	1887c	3746a	6986a	7001a	3838a	4815b	3969b	1614	5911	4207
Total litter	7671	6288	8987	5076	6676	7364	5221	3679	6715	7649A	6372AB	5205B
Total biomass	32935	29803	32588	28494	33898	30689	23953	21413	22621	31775A	31027A	22663B

[1]Treatment averages for each compartment followed by the same upper case letter are not significantly different (P>0.05).
[2]Treatment means for each compartment within a sampling date followed by the same lower case letter are not significantly different (P>0.05).

Table 2. Seasonal biomass (kg/ha) dynamics for above-ground compartments on control, 3-year old and 6-year old tebuthiuron treated sand shinnery rangeland in west Texas.

	Treatment											
	Control			3-Year			6-Year			Average		
Compartment	April	July	Dec.	April	July	Dec.	April	July	Dec.	Control	3-Year	6-Year
Live oak stems[1]	724	681	691	0	0	0	0	0	0	699	0	0
Dead oak stems[1]	530	253	0	0	0	0	0	0	0	261	0	0
Live oak leaves[1]	0	1140	0	0	0	0	0	0	0	380	0	0
Total above-ground[1] oak	1254	2072	692	0	0	0	0	0	0	1139	0	0
Live herbaceous shoots	24a[2]	183c	75a	18a	1536b	35a	39a	1826a	121a	94	530	662
Dead herbaceous shoots	239b	24b	202c	291b	193a	2252a	706a	459a	1431b	155	912	865
Total above-ground herbaceous	263b	207c	277c	309ab	1730b	2287a	745a	2285a	1552b	249	1442	1527
Above-ground liter	4081a	2047a	3252a	2666b	2509a	2384ab	1732c	1748a	2109b	3126	2519	1863
Total above-ground biomass	5598a	4327a	4220a	2975b	4238a	4671a	2477b	4033a	3661a	4715	3961	3390

[1]Biomass in these compartments was not present in 3-year old and 6-year old treatments.
[2]Treatment means for each compartment at each sampling date followed by the same letter are not significantly different (P>0.05).

Table 3. Seasonal biomass (kg/ha) for below-ground compartments on control, 3-year old and 6-year old tebuthiuron treated sand shinnery rangeland in west Texas.

	Treatment											
	Control			3-Year			6-Year			Average		
Compartment	April	July	Dec.	April	July	Dec.	April	July	Dec.	Control	3-Year	6-Year
Large oak roots (>2 mm)	16161	14003	14609	15627	14610	10827	10829	8329	7213	14924A[1]	13688A	8790B
Small oak roots (<2 mm)	6494	5839	6412	4044	5626	5497	4066	4589	4725	6248A	5056B	4460B
Total oak roots	22655	19841	21022	19671	20236	16325	14894	12918	11937	21173A	18744B	13250C
Herbaceous roots	1092	1394	1610	3437	5256	4714	3093	2530	2418	1365C	4469A	2680B
Belowground litter	3591	4241	5735	2410	4167	4980	3489	1931	4606	4522A	3852A	3342A
Total belowground	27338	25476	28367	25519	29659	26018	21476	17380	18961	27060A	27065A	19272B

[1]Treatment averages for each compartment followed by the same letter are not significantly different (P>0.05).

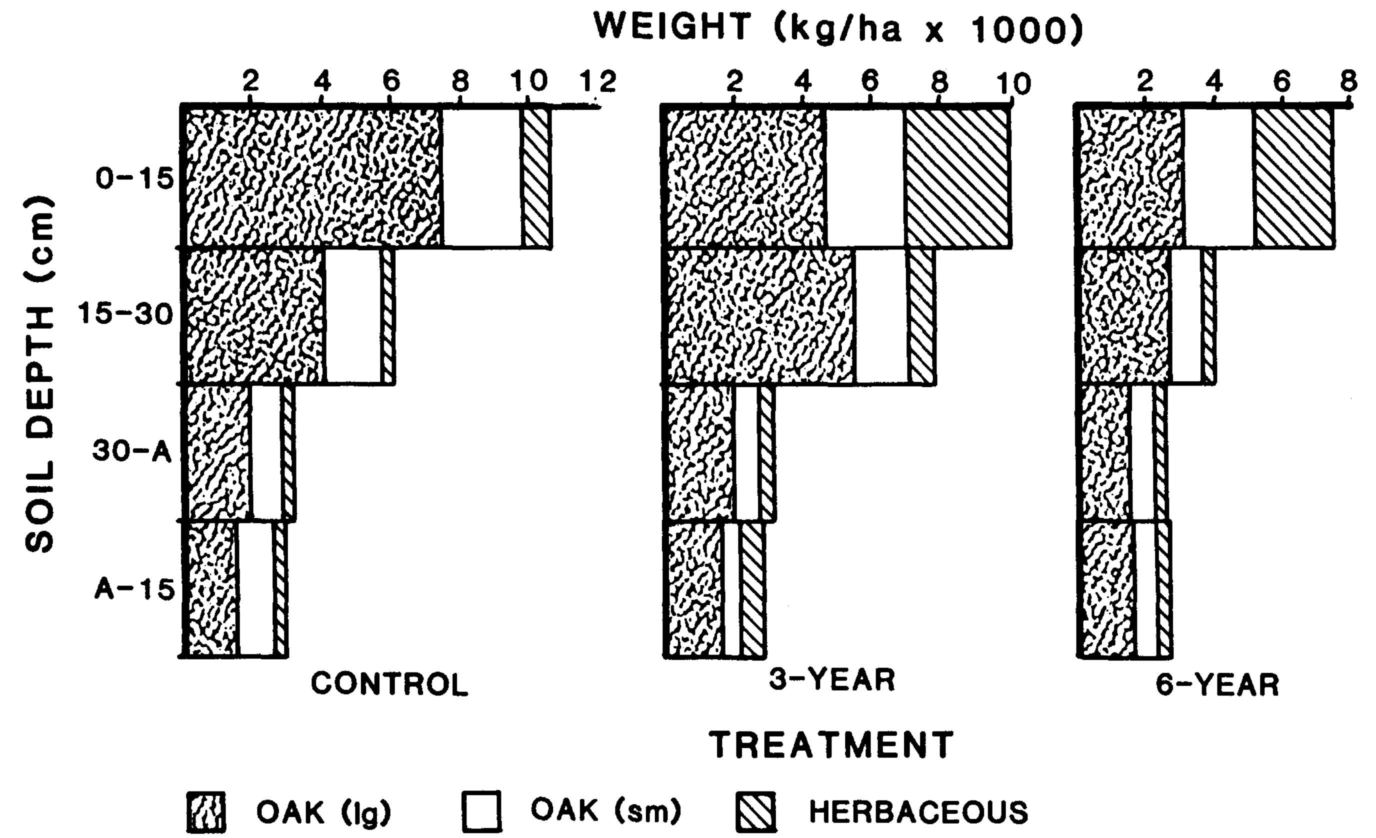

Fig. 1. *Root biomass (kg/ha) by soil depth for herbicide treated sand shinnery oak rangeland in west Texas as affected by treatment.*

Primary interest focused on treatment comparison. When dates and treatments interacted, treatments were compared within each date (e.g., Steel and Torrie 1980:386) with Duncan's new multiple range Test. Below-ground biomass was analyzed as a completely randomized design in a split-plot arrangement. Each sampling date was analyzed separately; treatments were main plots and depths were subplots in the split-plot arrangement. Primary interest focused on treatment comparison. When depths and treatments interacted, treatments were compared within each depth with Duncan's new multiple range test.

Results and Discussion

Total biomass on 3-year and 6-year post tebuthiuron treatment plots was 3% and 29%, respectively, less than the untreated plot (Table 1). Yearly biomass production increased following application of tebuthiuron, whereas total biomass was only slightly changed. The increase occurred because grasses and forbs, dominants on the treated areas, regenerated the majority of their above-ground biomass and a percentage of their below-ground biomass each year, while the majority of the oak biomass is woody and long-lived. The total biomass remained relatively unchanged because of the slow decomposition of oak roots on the 2 treated

Table 4. Below-ground biomass (kg/ha) for major compartments at four soil depths on control, 3-year-old and 6-year old tebuthiuron treated sand shinnery oak rangeland in west Texas.

		April			July			December		
Compartment	Depth	Control	3-Year	6-Year	Control	3-Year	6-Year	Control	3-Year	6-Year
Large oak roots	1	7509a[1]	4621b	4140b	7087a	6340a	2795b	7702a	3063b	2440b
	2	5118b	7193a	3218b	4007ab	5003ab	2553b	3273a	4386a	2464a
	3	2028a	2160a	1273a	1561a	1570a	1293a	2139a	1797a	1170a
	4	1506a	1653a	2198a	1348a	1698a	1688a	1495a	1582a	1138a
	Avg	4040	3907	2707	3501	3653	2082	3652	2707	1803
Small oak roots	1	2112a	1539b	2157a	2462	2814	2159	2314	2280	2207
	2	1804a	1293b	1042b	1374	1579	987	2112	1740	1091
	3	1220a	613b	368b	918	605	586	1043	992	818
	4	1358a	600b	499b	1085	628	857	943	485	610
	Avg	1624	1011	1017	1460A[2]	1407A	1147A	1603A	1374A	1182A
Herbaceous roots	1	589b	2422a	2817a	870c	3697a	2003b	824c	3179a	1924b
	2	185a	385a	153a	162b	873a	259b	158a	746a	217a
	3	147a	195a	44a	128a	242a	121a	301a	363a	115a
	4	170a	436a	79a	233a	444a	148a	327a	426a	161a
	Avg	273	860	773	348	1314	633	403	1179	604

[1]Treatment means within a depth for each compartment and each sampling date followed by the same lower case letter are not significantly different ($P>0.05$).
[2]Treatment means for each compartment and each sampling date followed by the same upper case letter are not significantly different ($P>0.05$).

plots. Below-ground oak biomass comprised 67% of the total biomass on the control and was 60% on the 3-year-old and 58% on the 6-year-old treated plots.

Above-ground Biomass

Total above-ground biomass decreased 16% on the plots sampled 3 years after treatment but decreased 28% on the plots sampled 6 years after treatment compared to untreated rangeland (Table 2). Above-ground biomass decreased following herbicide treatment because of the loss of oak and the decline in litter. Standing oak comprised 28% of the above-ground biomass on the control but was absent on the 2 treated areas.

Herbaceous biomass was 6-fold greater on the 3-year-old and 6-year-old treatments compared to the untreated rangeland. The 6-fold increase in above-ground herbaceous matter following herbicide treatment was similar to the 4- to 9-fold increases reported by Pettit (1979). Herbaceous yield (live and standing dead) on the untreated plots (249 kg/ha) was below the range of weights (820 to 5,980 kg/ha) listed for 10 North American grassland communities by Sims and Coupland (1979). However, the 3-year-old and 6-year-old treatments (1,442 and 1,527 kg/ha, respectively) were in that range. The decrease in standing dead biomass from April to July and the increase from July to December reflected dynamics of recent-dead material as discussed by Sims and Coupland (1979). The recent-dead material increased as the growing season progressed, usually beginning midway through the season and peaking at the end of the season. The decrease from April to July was due to dead material being transferred to the litter compartment.

Above-ground litter biomass decreased 20% from the untreated plots to the 3-year-old treatment and 41% from the control to the 6-year-old treatment. Above-ground litter dynamics were different on all 3 treatments. Litter on the untreated plot consisted primarily of oak stem and leaf material with a small portion of herbaceous leaves and stems. The 3-year-old treatment still had decomposing oak stems and a large amount of fine herbaceous material. On the 6-year-old treatment there were no leaves and few oak stems but large amounts of fine herbaceous material. The varied sources for litter, coupled with the variable rates of litter disappearance, lead to erratic litter dynamics; however, most grasslands display a peak in litter biomass early in the season (Sim and Coupland 1979).

Below-ground Biomass

Total below-ground biomass was essentially the same on the 3-year-old treatment and on the control but decreased 28% on the 6-year-old treatment when compared to the control (Table 3). Below-ground biomass ranged from 85 to 88% of the total biomass for the 3 treatments and corresponded to the 68 to 98% reported for 10 North American grassland communities (Sims and Singh 1971).

Mean root biomass on the IBP grassland study areas ranged from 1,870 kg/ha in a desert grassland to 19,600 kg/ha in mixed-grass prairie (Sims and Coupland 1979). Root biomass on the 6-year-old treatment (15,930 kg/ha) fit into that range, while weights for the untreated plot (22,538 kg/ha) and 3-year-old treatment (23,213 kg/ha) were slightly higher. The large amount of oak roots was responsible for the higher weights.

Root biomass decreased with soil depth and the pattern of vertical distribution was similar on all treatments (Table 4). The decrease in total roots with depth has been previously documented (Weaver and Zink 1946, Dahlman and Kucera 1965, Christie 1981).

Oak roots made up 94, 81, and 83% of the total root biomass on the untreated 3-year-old and 6-year-old plots, respectively. Large oak root biomass was 8% less on the 3-year-old treatment and 41% less on the 6-year-old treatment compared to the untreated rangeland (Table 3). Small oak root biomass was reduced 19% on the 3-year-old plot and 29% on the 6-year-old plot compared to the untreated plot. The low rate of oak root decomposition on the treated sites may reflect high lignin content and low soil and root nitrogen. High initial levels of lignin may slow decomposition (Melillo et al. 1982) and low amounts of nitrogen limit decomposition (Weaver 1947). The C/N ratio for the large oak roots ranged from 86 to 92. Alexander (1961) indicated that C/N ratios greater than 20 favor immobilization of nitrogen and slow decomposition rates.

Both large and small oak roots decreased on the untreated area from April to July. A decrease in small oak roots (< mm dia.) through the growing season was reported for tree roots by Hermann (1977). A decrease has not been reported for large roots, however, Harris et al. (1977) stated that large roots (>5 mm dia.) were more stable and showed no significant or annual change. The trend towards a decrease in large oak root biomass from April to July on the untreated site may reflect decomposition of the component dead oak root material. Herbaceous roots increased 3-fold 3 years and 2-fold 6 years following treatment compared to the untreated plots (Table 3). These increases corresponded to increases in above-ground herbaceous biomass. Changes in herbaceous roots through the growing season on the untreated and 3-year-old treated plots were consistent with data reported for grassland ecosystems (Wiegert and Evans 1964, Dahlman and Kucera 1965, Hulett and Tomanek 1971). The trend toward decreased amounts of herbaceous roots later in the season on the 6-year-old treatment may reflect the high density of winter annual forbs on the site that died before July then decomposed rapidly.

Herbaceous root distribution with depth differed by treatment as a result of changed rooting behavior following herbicidal treatment (Table 4). On the 3-year-old and 6-year-old treatments 84 and 92% of the herbaceous roots were in the surface 30 cm, which was similar to, although slightly higher than, the 80% average reported by Sims and Singh (1971) for 10 IBP grasslands and the 81 to 87% range in the surface 25 cm reported by Dahlman and Kucera (1975). The untreated area, with only 68% of the herbaceous roots in the surface 30 cm, was below the average values for grasslands. The untreated area had a greater percentage of herbaceous roots in the argillic layer than the 2 treated sites. All 3 sites showed an increase in herbaceous roots in the argillic layer compared to the soil layer above. This increase, although not the normal situation in most grasslands, was described by Cannon (1913). In soils with a subsoil of adjacent layers of sand and clay, the roots often occur abundantly near the bottom of the sandy layers and in the clay layer when the latter, acting as a rather impervious layer, has retained much more soil moisture. Test (1972) described this phenomenon in the Brownfield soil.

Root/Shoot Ratios

Root/shoot ratios were important for understanding the distribution of energy between below-ground and above-ground compartments. The root/shoot ratio for sand shinnery oak (recorded for July only) was 11 on the untreated control area, which was similar to the ratio of 9 reported by Pettit and Deering (1970). No root/shoot ratios for oak on the 2 treated areas were calculated due to oak death and the absence of oak shoot biomass.

Root/shoot ratios of herbaceous matter decreased from 6 on the untreated plot to 3 on the 3-year-old treatment to 1.8 on the 6-year-old treatment. Ratios for IBP grasslands ranged from 2 to 13 (Sims et al. 1978). The ratios on the untreated and 3-year-old treatments were within that range. The ratio on the 6-year-old treatment was slightly lower than the average range of values for grasslands. The low root/shoot ratio on the 6-year-old treatment was probably due to the abundance of annual forbs and short grass species with small root systems. The high ratio on the untreated site reflected low herbaceous production in the untreated oak community because of competition with the oak.

Summary and Conclusions

Following tebuthiuron application to sand shinnery oak communities, the most obvious change has been in oak biomass. Even with the fairly rapid disappearance of above-ground oak biomass, oak roots have decomposed slowly. There was a 12% decrease of oak root biomass from the control to the 3-year-old treatment and a 37% decrease from the control to the 6-year-old treatment. The slow breakdown of oak root material may be a result of the low natural fertility of these sandy soils and the high C/N ratios of the oak root and rhizome material.

Another obvious change has been an increase in herbaceous yield on the treated sites. Reduction in oak competition resulted in increased availability of moisture and nutrients for grass growth. Increased herbaceous yield has continued for 6 years following treatment. The increase in herbaceous roots and the change to a more shallow root system has increased the ability of the herbaceous plants to obtain water and nutrients.

Total biomass will probably continue to decrease on the treated areas as the oak decomposes. This should not be misconstrued as a decrease in productivity on the site. Above-ground live biomass on the control area was approximately double that on the 2 treated areas. Ninety-two percent of the above-ground live biomass on untreated areas was long-lived woody oak material. Only 8% of the live material was herbaceous on the untreated area, whereas on the treated sites 100% of the above-ground biomass was herbaceous.

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