October 1987

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ABSTRACT

Silviculturists use a variety of techniques, including repellents, to reduce browse damage by white-tailed deer (Odocoileus virginianus) to valuable eastern hardwood seedlings. Systemic selenium, sodium selenite, was evaluated with captive white-tailed deer for its repellency in white ash (Fraxinus americana) and black cherry (Prunus serotina) seedlings. Selenium had no effect in reducing browsing of black cherry. However, there was a reduction ($p<0.05$) in the white ash browsing level.

INTRODUCTION

White-tailed deer browsing of advanced regeneration and postharvest natural regeneration interferes with the successful silviculture of valuable eastern hardwoods (Marquis and Brenneman 1981). Several registered, chemical white-tailed deer browse repellents are available. Harris et al. (1983) and Palmer et al. (1983) in Pennsylvania, demonstrated chemical repellents differ in their effectiveness. Palmer et al. (1983) concluded the reduced level of damage provided by currently available repellents does not solve the economic problem of deer damage. Repellents currently available are the contact type that are sprayed or brushed directly on foliage in conjunction with an adhesive. Contact repellents can be washed off, unsprayed foliage is unprotected and during the growing season the repellent must be reapplied to insure protection of new growth (Dietz and Tigner 1968).

Systemic repellents, absorbed by the plant and translocated to the foliage where the repellent has its effect, offer a possible alternative to contact repellents. Systemic repellents are not washed off, and protection of new growth would be insured while the plant is translocating the repellent. Ideally, the compound is absorbed, metabolized, and volatilized by the plant at levels sufficient to repel the target herbivores (Gustafson 1983); the compound would not be phytotoxic at effective levels, nontoxic to the herbivore, and the risk of secondary toxicity or environmental contamination would be low.

Many compounds have been investigated as potential systemic repellents (Eadie 1954), but only the naturally occurring element selenium (Se) has shown potential (Allan et al. 1984). Rediske and Lawrence (1962) first tested the repellent effectiveness of selenium as a systemic repellent for use in reducing clipping of Douglas-fir seedlings by snowshoe hares (Lepus americanus). Using sodium selenate (Na_2SeO_4) formulations, they were unable to demonstrate a repellent effect at subphytotoxic selenium concentrations. Allan et al. (1984) reported a one season reduction in black-tailed deer (Odocoileus hemionus) browsing of Douglas-fir seedlings treated with sodium selenite (Na_2SeO_3) at subphytotoxic levels. There are no reports on the effectiveness of selenium compounds in reducing white-tailed deer browse damage to northeastern hardwoods. The purpose of this study was to determine the effectiveness of systemic selenium in reducing deer browsing of two commercially important northeastern hardwood tree species, white ash and black cherry.

Funding was provided by The School of Forest Resources, The Pennsylvania State University, University Park, PA. We thank G. L. Storm and anonymous readers for reviewing the manuscript. P. J. Wangsness, Head of the Department of Dairy and Animal

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Science, approved the use of the Penn State Deer Research Facility. The Pennsylvania Bureau of Forestry through D. A. Devlin provided the seedlings. We are especially indebted to R. W. Scholz for the use of his laboratory, C. L. Sokol for performing the selenium assays, and R. C. Mothersbaugh, manager of the Penn State Deer Research Facility, for his assistance in handling deer. This paper is authorized as J. Ser. No. 7440 of the Pa. Agric. Exp. Stn.

METHODS

Potted, one-year-old white ash and black cherry seedlings were used for testing the repellent. Selenium treatment levels were based on our results of selenium uptake and phytotoxic concentrations for both seedling species (Angradi and Tzilkowski 1986). Selenium applications were based on a one week selenium uptake period. One week prior to a scheduled repellent trial, 40 seedlings received a high dose of selenium; 40 received a low dose, and 40 received no selenium. A single tree species was used in each trial. For black cherry, 10 mg Se/seedling was the low dose, and 40 mg Se/seedling was the high dose. For white ash, 50 mg Se/seedling was the low dose, and 100 mg Se/seedling was the high dose. Each seedling received a single application directly to the soil surface of sodium selenite (Na_2SeO_3) in 60 ml H_2O.

Repellent trials were conducted in July and August in a 0.25-ha enclosure at The Pennsylvania State University Deer Research Facility located 2.5 km north of the University Park campus in Centre County, Pennsylvania. A 10 x 12-m grid with 1-m spacing was established in the enclosure. Each of 120 grid positions was marked with a steel rod. One potted seedling, from either the high, low or no dose selenium group, was randomly assigned to each grid position. Seedling grid position assignments were randomized to reduce the row feeding effect observed with deer (Dodge et al. 1977). Twelve different female deer (age from 2-10 years) were used in 10 trials with each species of seedling. Food was withheld from deer for 36 h prior to testing. For each trial, a single deer was moved into the enclosure and allowed to browse seedlings in the grid for 24 h. Following each trial, the degree of browsing of each seedling was determined. Seedlings with no missing foliage or buds were classified as unbrowsed; seedlings with only a few leaves or lateral shoots removed were lightly browsed; those with at least half of their foliage or the terminal leader removed were moderately browsed; seedlings stripped of more than half of their foliage and terminal leader were severely browsed. A sample of seedlings from six trials with each species was assayed for selenium by a flourometric procedure (Whetter and Ullrey 1978).

Separate analysis was conducted for each seedling species. Log-linear techniques (BMDP-P4F, Brown 1981) were used to obtain the Chi-square statistic and related p-value for each trial. The null hypothesis that there was no relationship between treatment and browsing was tested using Fisher's method for combining independent probabilities (Kinnism 1985:105). If the null hypothesis was rejected, a method proposed by Goodman (1979:537) for describing the association within a two-way table having ordered classifications was used to analyze the association between browse intensity and treatment level. The FORTRAN program ANOAS (C. C. Clogg, pers. commun.) was used to fit the null association-independence and treatment effects models.

RESULTS AND DISCUSSION

For both species, the majority of the seedlings were not browsed (Table 1). Of the 271 (22.5%) black cherry seedlings browsed, 133 (49%) were moderately browsed. Of the 346 white ash seedlings browsed, 170 (49%) were moderately browsed. The preponderance of moderately browsed seedling was accounted for by the typical browsing

Table 1. Observed browse frequencies for all trials (n=10) with black cherry and white ash seedlings.

Applied Se (mg)	Browse Intensity: None	Light	Moderate	Severe	Total
		BLACK CHERRY			
0	309	24	46	21	400
10	309	17	55	19	400
40	311	18	32	39	400
Total	929	59	133	79	1200
		WHITE ASH			
0	267	28	65	40	400
50	295	19	50	36	400
100	292	24	55	29	400
Total	854	71	170	105	1200

behavior of the deer. Deer usually took a single bite from a seedling. A mouthful included considerable foliage and, usually, several lateral branches. One bite was enough to cause moderate browse damage.

Mean percentage of untreated, treated (10 mg Se), and treated (40 mg Se) black cherry seedlings browsed was 22.75%, 22.75%, and 22.25%, respectively. No relationship existed between selenium treatment (treated vs. untreated) and browsing (browsed vs. unbrowsed) for black cherry ($P > 0.975$) (Table 2). Selenium treatment had an effect ($P < 0.05$) on frequency of deer browsing white ash seedlings (Table 2). Likelihood ratio G^2-values of 7.25 (df=6) and 2.64 (df=4) were obtained for the null association-independence and treatment effects models, respectively. The best fit was obtained for the treatment effects model ($P > 0.50$), indicating browsing intensity in white ash was associated with selenium application level.

Our results indicated systemic selenium was a deterrent to deer browsing of white ash seedlings, and was ineffective in reducing browsing of black cherry seedlings. Angradi and Tzilkowski (1986) reported white ash seedlings absorbed more applied selenium than black cherry and were more tolerant of elevated levels of foliar selenium concentration. In this study, white ash seedlings assayed for selenium had higher foliar selenium concentrations than black cherry seedlings (Table 3). We attribute these differences in repellency between species to differences in uptake of selenium.

Selenium may be an essential micronutrient for white-tailed deer (Ullrey et al. 1981). There is no documentation of free-ranging, unstressed, wild deer not meeting their selenium requirements (Ullrey et al. 1981). Kare and Beauchamp (1977:117) concluded wild animals, when compared to domestic animals, were "more responsive to nutritional and physiological consequences of their diet than to the sensory qualities." In the northeastern United States where forages are low in selenium (Kubota et al. 1967) deer may be attracted to forages containing artificially high levels of selenium. Additional study is needed to

Table 2. Number of treated and untreated black cherry and white ash seedlings browsed in each trial, and the P-value for Fisher's test for each trial. For each trial: treated seedlings (n=80), and untreated seedlings (n=40).

	Seedlings Browsed		
Trial	Treated	Untreated	P-value
	BLACK CHERRY		
1	15	15	0.0253
2	32	9	0.0627
3	3	6	0.0283
4	8	3	0.7317
5	7	3	0.8953
6	4	2	0.9032
7	28	17	0.4196
8	10	4	0.7522
9	52	25	0.7759
10	21	7	0.3119
	WHITE ASH		
1	4	1	0.6472
2	18	16	0.0442
3	5	9	0.0093
4	20	10	0.9712
5	32	26	0.0105
6	9	6	0.5237
7	12	5	0.7666
8	74	37	0.9224
9	32	15	0.8044
10	7	8	0.0762

Table 3. Means (n=6 for all values) and standard deviations of foliar selenium concentrations (parts per million, dry weight basis) in black cherry and white ash seedlings harvested during repellent testing. All seedlings harvested one week after selenium application.

Applied Se (mg)	$\bar{X}$	SD
	BLACK CHERRY	
0	1.77	1.41
10	2.15	1.75
40	8.02	7.97
	WHITE ASH	
0	1.92	1.47
50	16.17	8.34
100	56.38	56.98

evaluate the repellent effectiveness of systemic selenium with free-ranging wild deer.

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