Edward J. Dimock II
Principal Silviculturist
Pacific Northwest Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture
Olympia, Washington

Influence of Douglas-fir Seedling Height on Browsing by Black-Tailed Deer

Damage by black-tailed deer (*Odocoileus hemionus columbianus*) to Douglas-fir (*Pseudotsuga menziesii*) varies chiefly in response to the tree's acceptability and availability as a browse plant. Reducing palatability of seedlings and saplings by any reasonable means, therefore, may effectively moderate damage. Treating seedlings with chemicals, one route to this end, remains ineffective for controlling damage by deer in forest plantations. Other avenues, such as exploiting inherent qualities of Douglas-fir seedlings themselves, merit detailed study. Naturally occurring variations within the species may include palatability differences that affect use by deer or other animals in the field.

To discover if Douglas-fir seedlings from widely separated provenances might evoke varying feeding responses in deer under controlled conditions, an exploratory trial was made during the winter of 1965-66 with planting stock from five seed sources in western Washington. Preliminary results revealed that feeding preference differed markedly among the races tested. Further testing and analysis showed that preferences were strongly linked to small variations in seedling height—independent of seed origin.

Pen Trials

Testing followed general procedures described by others (Hildreth and Brown, 1955; Cardinell and Hayne, 1947) for assessing repellency of candidate chemical compounds to various lagomorphs—chiefly *Lepus* (hares) and *Sylvilagus* (rabbits). Design, layout, and analysis closely followed methods outlined by Dodge *et al.* (1967) for testing repellents against black-tailed deer and snowshoe hare (*L. americanus*). The U.S. Bureau of Sport Fisheries and Wildlife cooperated in making facilities maintained at Olympia, Washington, available for preference tests with untreated seedlings.

Untreated 2-0 Douglas-fir seedlings were exposed to voluntary feeding by black-tailed deer in two separate trials. The first test compared stock from five geographical races grown at Washington's L. T. "Mike" Webster State Forest Nursery near Olympia. The second test compared stock segregated into height groups from one of the above races. Seedlings were hoe-planted to root-collar depth in a grassy, central part of a 2.5-acre enclosure.

Deer moved freely within the enclosure, and at all times had access to cover, a maintenance diet, and some natural forage. Five animals (one buck, three does, and one fawn), randomly chosen from a herd of 22, were used to test racial effects; seven

animals (two bucks, three does, and two fawns) were later used to test height effects. The race trial began in late November 1965 and was concluded in 23 days. The height trial ran for 20 days beginning in mid-February 1966.

The same randomized block design was common to both tests, and included five treatments replicated in 10 blocks. Treatments within blocks consisted of 10 seedlings each—50 seedlings per block, or 500 seedlings per complete test. Seedlings were randomized within blocks to avoid bias from "row feeding." Spacing was 3 by 3 feet within blocks—each block arranged in five 10-seedling rows.

While exposed to deer, seedlings were checked daily, and the day of earliest browsing was noted for each seedling. Repeated browsing on the same seedlings was neither recorded nor evaluated. Examinations continued until 95 percent or more of all seedlings had been browsed.

Analysis of variance, supplemented by the Q method (Snedecor and Cochran, 1967) for comparing individual treatment means, was the basic statistical tool employed. Two measures of relative preference were used: (1) percent browsing (cumulative) as determined for each day of exposure, and (2) mean exposure in days required for all (95+ percent) seedlings to be browsed. Percentages were analyzed both in the raw form and as transformed to angles by arc sine. Since transformed and untransformed percentages gave similar results, only raw percentages are given.

Race Test

Seedlings selected for trial represented seed sources from a cross section of locations and elevations in western Washington. Racial designations were "Kelso," "Belfair," "Eldon," "Lewis," and "Glenwood" (Table 1). Nursery beds from which representative stock was taken were similar and had received the same regime of nursery culture. All stock was sorted and culled in accord with commercial practice.

TABLE 1. *Race Test.* Statistical description of Douglas-fir seedlings before exposure to browsing by black-tailed deer (100 seedlings per race).

Race	Source elevation	Mean height at planting	Sampling error ($p = 0.05$)	Significant height differences ($p < 0.05$)[1]
	Feet	*Centimeters*	*Centimeters*	
Kelso	800	22.6	±.7	A
Belfair	400	21.4	±.8	A
Eldon	1,000	18.6	±.6	B
Lewis	1,000	16.1	±.7	C
Glenwood	2,500	13.1	±.5	D

[1] Means not followed by a common letter differ significantly based on 10 replicates of 10 seedlings each.

Seedling size, as observed before testing, generally decreased with increasing elevation of seed origin. Since size might influence feeding preference, planted heights of all seedlings were recorded to the nearest centimeter. Minimal size variation within races, evidenced by relatively low sampling errors for planted height, suggested that mean heights between some races might differ significantly. Analysis showed

that only Kelso and Belfair stock, in fact, failed to differ significantly from one another (Table 1). However, the effect of height variation on preference was not clearly apparent until browsing was complete and data were analyzed.

Height Test

Effects of seedling height were also tested independently with Eldon stock. Seedlings were sorted into five height groups (100 seedlings each) with mean planting heights ranging from 10.5 to 22.5 centimeters (Table 2).

TABLE 2. *Height Test.* Statistical description of Douglas-fir seedlings before exposure to browsing by black-tailed deer (Eldon race, 100-seedlings per height group).

Height group	Mean height at planting	Sampling error ($p = 0.05$)	Significant height differences ($p < 0.05$)[1]
	Centimeters	*Centimeters*	
I	22.5	±.4	A
II	19.9	±.4	B
III	16.1	±.6	C
IV	13.3	±.4	D
V	10.5	±.4	E

[1] Means not followed by a common letter differ significantly based on 10 replicates of 10 seedlings each.

Results

Deer discriminated between seedlings from the very start. Preferential browsing was significant by the first day in the race test; by the second day in the height test (Figs. 1 and 2). The preference orders established early were generally maintained with minor variations throughout each trial.

Race Test

Seedlings from lower elevation races (Kelso and Belfair) were clearly preferred over the highest elevation race tested (Glenwood), and the difference was accentuated within the first week (Fig. 1). Maximum separation of means occurred by the 12th day —90 and 89 percent vs. 39 percent, respectively. Thereafter, differences decreased as the less preferred seedlings were eventually browsed. Conclusion of the race test permitted a more concise treatment comparison through analysis of mean exposure time required for all seedlings within a race to be browsed:

Race	Mean seedling height	Mean exposure before browsing
	(Centimeters)	(Days)
Kelso	22.6	7.4 (A)
Belfair	21.4	7.7 (A)
Eldon	18.6	9.3 (A, B)
Lewis	16.1	10.8 (B)
Glenwood	13.1	14.1 (C)

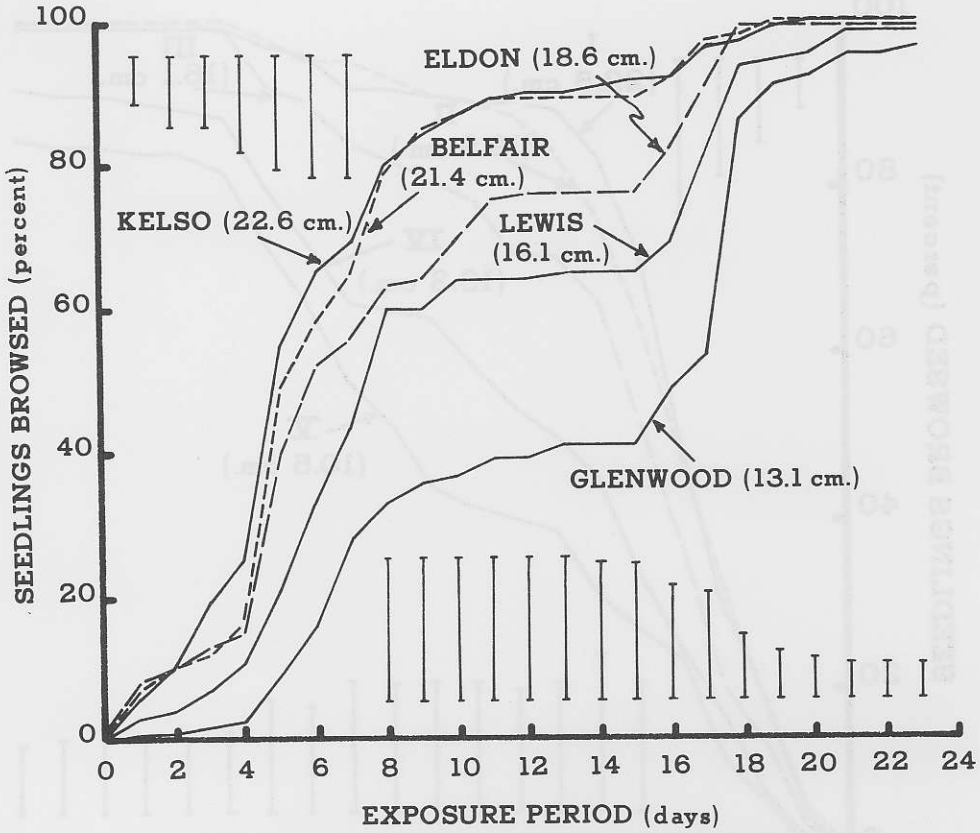

Figure 1. Browsing preference by black-tailed deer for Douglas-fir seedlings from five western Washington races. (Differences exceeding bar lengths are significant at $p < 0.05$.)

Glenwood seedlings required nearly twice as much time to be browsed as Kelso and Belfair seedlings (days not followed by a common letter significantly differ at $p < 0.05$).

The obvious correlation between seedling height and preference by deer, as measured by mean exposure before browsing, is highly significant ($r = -0.792$ with 48 df) and suggests that most of the apparent preference for certain races might be caused by the greater attractiveness of taller seedlings. Adjustment by covariance analysis of mean exposure times to an average seedling height for all races (18.4 cm) shows that height, indeed, had a powerful impact:

Race	Mean exposure before browsing adjusted to mean height
	(Days)
Lewis	9.0
Eldon	9.6
Belfair	10.0
Kelso	10.3
Glenwood	10.4

None of the differences between adjusted means was significant.

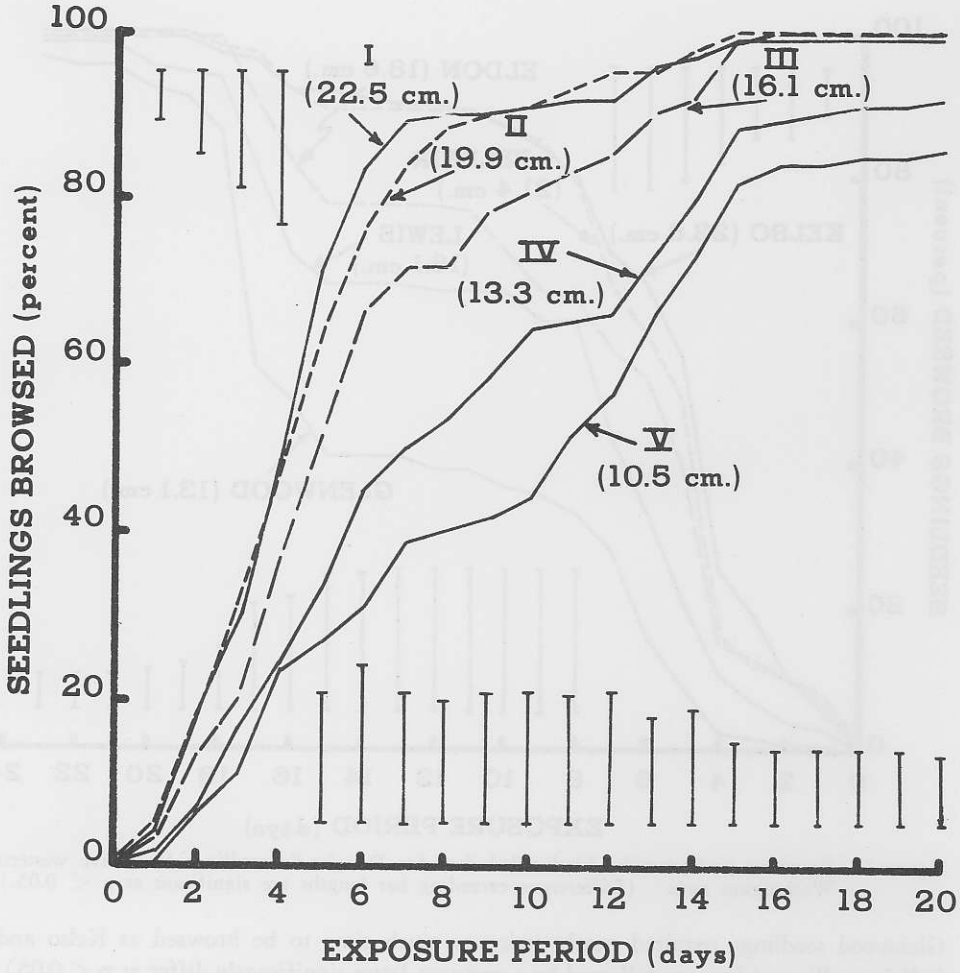

Figure 2. Browsing preference by black-tailed deer for Douglas-fir seedlings from one western Washington race (Eldon) segregated into five height groups. (Differences exceeding bar lengths are significant at $p < 0.05$.)

Height Test

The height test with Eldon stock (Fig. 2) corroborated the independent effect of height variation on deer preference within the 12-centimeter range between group means:

Height group	Mean seedling height	Mean exposure before browsing
	(Centimeters)	(Days)
I	22.5	5.2 (A)
II	19.9	5.2 (A)
III	16.1	6.6 (A)
IV	13.3	9.1 (B)
V	10.5	10.8 (C)

Again, seedlings in the two tallest groups were browsed twice as readily as those in the shortest group (days not followed by a common letter significantly differ at $p < 0.05$).

Discussion and Conclusions

Despite failure of the race trial to show clear feeding preferences by deer for seedlings from different provenances, the testing methods used appear suitable for further study of animal preference among tree seedlings of the same species. Since test animals must discriminate seedling by seedling in selecting or rejecting different genotypes, the likelihood of results having applicability under field conditions is enhanced. Also, simultaneous use of several deer in testing serves to smooth out varying feeding responses between individual animals to provide a more representative result. Further, the preceding demonstration of significant preferences between seedlings differing by less than 3 cm in height attests to the adequacy of the design.

In pen tests of short duration, the measure of preference through mean time of exposure before browsing seems at least equally suited to analysis and interpretation as browsing intensity in percent. It better reflects mean preferences shown throughout the entire exposure period. Since every seedling provides a measured value (time), rather than a binomial occurrence (browsed or unbrowsed), data transformation is unnecessary. Also, the point of peak sensitivity for analysis cannot be accidentally bypassed.

Ascribing demonstrated preferences solely to height is probably an oversimplification. The close correlation between source-related seedling heights and preferences shown does not preclude the possibility that qualitative variations also affected deer browsing. Similarly, even the independent height test with Eldon stock may have masked qualitative, height-correlated differences—*i.e.*, the taller, faster-grown seedlings may have been more palatable as well as more conveniently available. The case is convincing, however, that height at planting functions independently as a determinant of feeding preference by deer among seedlings less than 25 cm tall.

Precautions to minimize effects of height variation seem mandatory in pen testing seedlings for susceptibility to deer browsing. Though height variation may be accounted for statistically, the use of similar-sized seedlings would seem simpler and surer. In short-term pen tests this may be accomplished by deeper planting of tall seedlings to approximate the heights of shortest seedlings being tested.

The same precautions would apply to assessing field comparisons of planting stock classes that differed in size. Recent field work by the author (Dimock, 1970) has shown that 12-year-old Douglas-fir saplings growing in dense western bracken (*Pteridium aquilinum* var. *pubescens*) were browsed less frequently as their heights decreased below 4 feet. Field tests of qualitative preference by deer for seedlings of different origin or pretreatment should probably be short term. Otherwise, differences in growth rates might well make results uninterpretable.

Literature Cited

Cardinell, H. A., and D. W. Hayne. 1947. Pen tests of rabbit repellents. Mich. Agr. Exp. Sta. Quart. Bull. 29: 303-315.

Dimock, E. J., II. 1970. Ten-year height growth of Douglas-fir damaged by hare and deer. J. Forest. 68: 285-288, illus.

Dodge, W. E., C. M. Loveless, and N. B. Kverno. 1967. Design and analysis of forest-mammal repellent tests. Forest Sci. 13: 333-336.
Hildreth, A. C., and G. B. Brown. 1955. Repellents to protect trees and shrubs from damage by rabbits. U.S. Dep. Agr. Tech. Bull. 1134, 31 p., illus.
Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. (6th ed.) Iowa State Univ. Press, Ames, Iowa. 593 p., illus.

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