Role of lammas growth in recovery of Douglas-fir seedlings from deer browsing, as influenced by weed control, fertilization, and seed source[1]

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Abstract: This study examined the effects of weed control, nitrogen fertilization, and seed source on lammas growth (second flushing) in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings. It also assessed the occurrence of deer browsing as related to these silvicultural treatments and examined the role of lammas growth in seedling recovery and escapement from deer browsing. Weed control significantly increased the occurrence of lammas growth, presumably because of greater soil moisture and nutrient availability. Nitrogen fertilization decreased lammas growth significantly, at least in part by favoring weed growth. Lammas growth was not influenced by seed source. The increased lammas growth associated with weed control mediated the effects of deer browse. Although multiple-year browsing occurred more commonly on weeded than unweeded seedlings, after two growing seasons weeded seedlings that were repeatedly browsed were twice as large as nonbrowsed, nonweeded seedlings. On one site, stock of wild origin was more heavily browsed than that from a seed orchard.

Résumé : Cette étude porte sur les effets du contrôle des mauvaises herbes, de la fertilisation azotée et de l'origine des graines sur la pousse d'été de semis de Douglas taxifolié (*Pseudotsuga menziesii* (Mirb.) Franco). Nous avons également évalué l'occurrence du brout par les cerfs en fonction de ces traitements sylvicoles et examiné le rôle que joue la pousse d'été dans la survie des semis suite au brout par les cerfs. Le traitement des mauvaises herbes a augmenté significativement l'occurrence de la pousse d'été, présumément en raison de l'augmentation de l'humidité du sol et de la disponibilité des éléments nutritifs. La fertilisation azotée a causé une diminution significative de la pousse d'été à cause, du moins partiellement, de la croissance accrue des mauvaises herbes. L'origine des graines n'a pas influencé la pousse d'été. L'effet bénéfique du traitement des mauvaises herbes sur la pousse d'été a atténué l'effet du brout par les cerfs. Bien que le brout répété pendant plusieurs années se soit manifesté plus souvent avec les semis traités contre les mauvaises herbes qu'avec les autres semis, les semis traités et sujets à un brout répété étaient deux fois plus grands que les semis non traités et non broutés, après deux saisons de croissance. Dans un des sites, les semis naturels étaient plus broutés que ceux provenant d'un verger à graines.

[Traduit par la Rédaction]

Introduction

Reforestation in the Coast Range of Oregon is hampered not only by intense competition from associated vegetation but also by herbivory by coastal blacktail deer (*Odocoileus hemionus columbianus* Richardson) (Hartwell 1973). Browsing reduces net annual height growth, leaving seedlings susceptible to further browsing and overtopping by weeds (Ruth 1956; Mitchell 1964; Crouch 1969; Dimock 1970; Gourley et al. 1990). Lammas growth, commonly referred to as second flushing, can increase annual height growth and thus may help seedlings of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) recover from or escape the effects of deer browsing (Gourley et al. 1990) and overtopping. Thus, silvicultural treatments that increase lammas growth may accelerate reforestation. This paper describes a 1992–1993 field study that assessed the occurrence of lammas growth and deer browsing as related to weed control, nitrogen fertilization, and seed source selection. Specific study objectives were the following: (*i*) to test for differences in lammas shoot production and deer browsing as related to fertilization, weed control, and seed source selection in all combinations; (*ii*) to identify environmental variables associated with lammas growth and deer browsing; (*iii*) to test for relationships among seedling size, vigor, lammas growth, and deer browsing; and (*vi*) to determine the correlation between lammas and subsequent seedling growth.

Definition of lammas growth

Lammas growth is the secondary midsummer flush of height growth from the newly formed terminal bud. Named

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after the Lammas Day harvest festival in England, which takes place during the period when this type of growth occurs (Rudolph 1964), lammas growth was observed as early as the times of Theophrastus (Theophrastus 1916) and in this century has been studied in many northern conifers (Table 1). Lammas growth is a form of "free growth," which as defined by Jablanczy (1971), is the simultaneous initiation and extension of stem units without interruption following "fixed" or predetermined growth. In this paper, lammas growth refers only to free growth that occurs after cessation of predetermined growth, a point at which bud scale formation temporarily halts shoot extension. Lammas growth should not be confused with syllepsis, which is defined by Späth (1912) as the development of a lateral shoot from components not contained previously in a resting bud. Lammas growth is influenced by environmental conditions such as soil moisture, nitrogen fertilization, and physical bending (Büsgen and Münch 1929; Carvell 1956; Sokolev and Artyushenko 1957; Rudolph 1958; Walters and Soos 1961; Smith and Allen 1962; Walters and Kozak 1967; Coutts and Philipson 1976; Newton and Preest 1988, Hallgren and Helms 1992), genetic variation (Thümmler 1958; Rudolph 1961; Walters and Soos 1961; Hallgren and Helms 1992), and tree size, age, and vigor (Walters and Soos 1961; Jablanczy 1971).

Selectivity of browsing: a review

Crouch (1969) states that management practices such as planting, weed control with herbicides, and fertilizing all greatly influence the degree of damage from browsing by deer. In Newton's (1978) study, deer were observed to browse on 93% of western hemlock seedlings in areas cleared of brush by brushblading and burning, but on only 13% of seedlings in uncleared areas; Hyatt (1992) confirmed this finding. Borreceo et al. (1972) found that, although deer usage was greatest in areas where herbaceous vegetation was removed by broadcast application of atrazine, browsing of Douglas-fir seedlings was not significantly greater in these areas. Mitchell (1964), on the other hand, showed that seedlings free of cover were more likely to be browsed by deer than seedlings protected by vegetation or logging slash. In field trials, Oh et al. (1970) and Crouch and Radwan (1981) demonstrated that nitrogen fertilization of Douglas-fir increased both growth rates and the occurrence of deer browse. Presumably the increase in browsing reflects increases in succulent shoots. Radwan et al. (1974) showed that the form of nitrogen used in nursery fertilization had no effect on deer preference upon outplanting.

Dimock et al. (1976) demonstrated substantial differences in deer preference among superior phenotypes within a local race of Douglas-fir. Hahn and Smith (1983) noted that deer preferred larger bare-root Douglas-fir stock two to one over smaller containerized stock, and Dimock (1971) found that under controlled conditions and within the height range of 10.5 to 22.5 cm, taller Douglas-fir seedlings were browsed more readily than shorter ones. However, Newton and Black (1965) found that within the height range of 10 to 115 cm, the chance of deer browse was inversely related to seedling height and that the larger seedlings outperformed the smaller ones in height increment.

Study sites

The three study sites, MacDonald Forest, Dunn Forest, and Summit, are in the Oregon Coast Range below 200 m elevation and within 30 km west to northwest of Corvallis. Soils are clay loams derived from basalt (two sites) and a rapidly weathering siltstone (one site). The siltstone site receives about 1700 mm rainfall, the others 1100–1200 mm, with 87% of the precipitation occurring in the 6 winter months. Growing seasons are warm and dry, and winters are mild, with temperature minima seldom below −12°C. (The lowest temperature locally recorded was −24°C).

Methods

Experimental design

The experimental design was a randomized complete block, 2^3 factorial, with three replicates at each site for a total of nine blocks and 72 plots. The eight treatments created by the factorial design were randomly assigned to experimental units (3.6 × 11.0 m plots containing 14 Douglas-fir seedlings) within each block, with an untreated buffer strip at least 2.0 m wide between adjacent plots. Plots were grouped into blocks in an approximate two by four arrangement. On steep slopes where an environmental gradient was likely, the blocks were oriented perpendicular to the slope and parallel to each other to minimize plot to plot variation within blocks while maximizing variation among blocks (Steel and Torrie 1980).

The three factors in the experiment were weed control (complete (W_1), vs. none (W_0)), nitrogen fertilization (used (F_1) vs. not used (F_0)), and seed source (seed orchard (S_1) vs. wild local source (S_0)).

Seedling sources

The Douglas-fir plug-1 transplants used for this study were grown from two seed sources: genetically improved and wild stock. The genetically improved seed was developed by the Burnt Woods Tree Improvement Cooperative at the J.E. Schroeder seed orchard, near St. Paul, Oregon. This seed was derived from open pollinated crosses among progeny of 161 superior trees located within the same seed zone (252) as the wild stock source. The seed orchard stock was grown at the IFA nursery in Toledo, Washington. The wild local seed was collected from within the local seed zone (252) and did not represent any level of genetic selection. Nursery stock from this seed source was not available from the IFA nursery in Toledo, so the wild stock plug-1 transplants were obtained from the D.L. Phipps State Nursery, near Elkton, Oreg. Hence, there was some confounding between seed source and nursery regime. However, the size ranges of seedlings from both nurseries were similar, averaging 54 cm in height × 6 mm in diameter at 15 cm above ground, so any confounding would be limited to prelifting conditions in the nursery, microflora, and handling or storage.

Treatments

All seedlings were planted within 1 week of each other in February 1992; each plot contained 28 seedlings, 14 of each seed source, at a 0.5 × 1.0 m spacing. Planting was done block by block and site by site. To accomplish complete weed control, 1.37 kg/ha hexazinone (Velpar L®) herbicide was applied, at a volume rate of 92 L/ha, with a hand-held 3.6-m boom powered by a pressurized backpack sprayer. Reinvading herbs in the weeded plots were controlled with directed spot applications of hexazinone at 15 g/L. Nitrogen fertilizer was applied by broadcasting 220 kg/ha urea prill (46:0:0 N–P–K) with a hand-held rotary dispenser in a 3.6-m swath. Fertilizer and

Table 1. Literature referencing multiple flushing in northern conifer species.

Species	Reference
Abies concolor (Gord. & Glend.) Lindl.	Phillips 1911; Walters and Soos 1961; Hallgren and Helms 1992
Abies grandis (Dougl. ex D. Don) Lindl.	Walters and Soos 1961
Abies magnifica A. Murr.	Hallgren and Helms 1992
Picea abies (L.) Karst.	Walters and Soos 1961; Moulalis 1975; Wülisch and Muhs 1986
Picea glauca (Moench) Voss	Watt and McGregor 1963; Nienstaedt 1966; Jablanczy 1971
Picea mariana (Mill.) BSP	Watt and McGregor 1963; Pollard and Logan 1974, 1976; Logan and Pollard 1975
Picea pungens Engelm.	Young and Hanover 1978
Picea sitchensis (Bong.) Carrière	Wood and Lines 1959; Walters and Soos 1961; Coutts and Philipson 1976; Cannell and Johnstone 1978; Millard and Proe 1992
Pinus banksiana Lamb.	Honey 1944; Sokolev and Artyushenko 1957; Thomas 1958; Rudolph 1964
Pinus contorta Dougl.	Thümmler 1958; Thompson 1976
Pinus monticola Dougl. ex D. Don	Walters and Soos 1961
Pinus resinosa Ait.	Kienholz 1933, 1941; Jump 1938*a*, 1938*b*; Honey 1944; Carvell 1956; Littlefield 1956; Thomas 1958; McCabe and Labisky 1959; Watt 1961; Watt and McGregor 1963
Pinus strobus L.	Honey 1944; Paul 1957; McCabe and Labisky 1959; Santamour 1960; Watt 1961; Watt and McGregor 1963; Owston 1968
Pinus sylvestris L.	Downs and Borthwick 1956; Sokolev and Artyushenko 1957; Szczerbinski and Szymanski 1957; Kovalenko 1960; Wright and Bull 1963; Aldén 1971
Pseudotsuga menziesii (Mirb.) Franco	Büsgen and Münch 1929; Walters and Soos 1961; Smith and Allen 1962; Walters and Kozak 1967; Lavender and Cleary 1974; Marcet 1975; Carlson and Preisig 1981; Weber 1983; Newton and Preest 1988; Gourley et al. 1990
Tsuga heterophylla (Raf.) Sarg.	Walters and Soos 1961; Mitchell 1965

Fig. 1. Weed control × fertilization interaction on the occurrence of lammas growth on the three study sites. Vertical bars represent 1 SE of the mean. The same letters within sites denote statistically similar values using Bonferroni's LSD at $p \leq 0.05$.

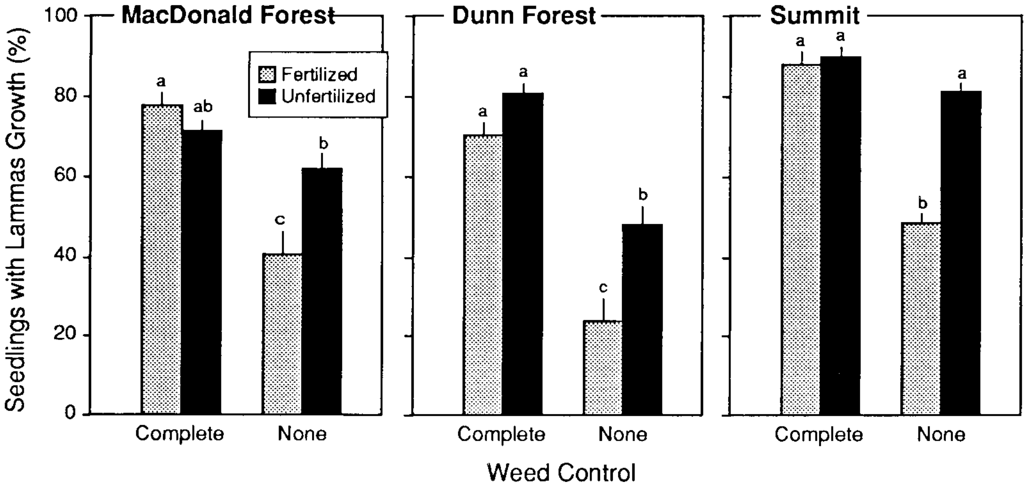


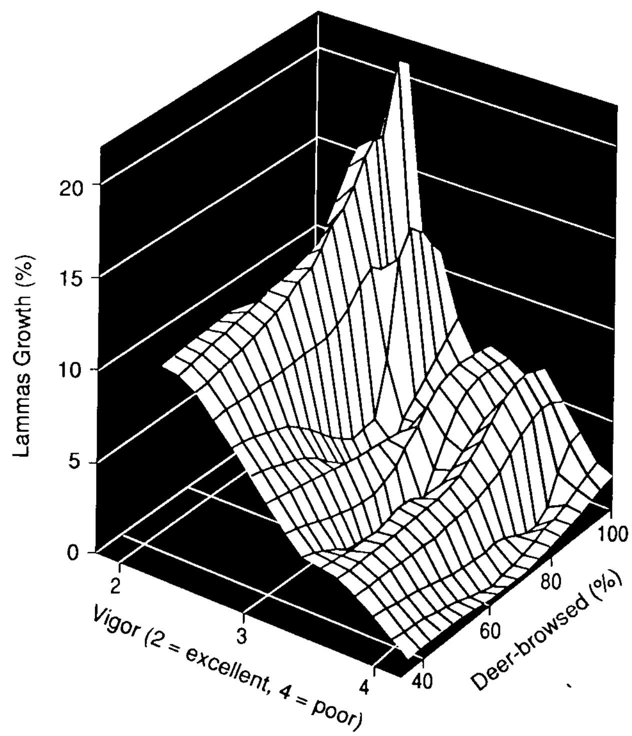
Table 2. ANOVA table for terminal lammas shoot length in the second growing season.

Source*	df	Mean square	p
L	2	3 294.9	0.0001
B(L)	6	499.4	0.0007
W	1	15 981.7	0.0001
F	1	1 126.2	0.0018
W×F	1	230.3	0.1395
S	1	119.3	0.2845
W×S	1	24.6	0.6248
F×S	1	6.3	0.8051
W×F×S	1	7.9	0.7815
L×W	2	1 081.7	0.0002
L×F	2	289.1	0.0692
L×W×F	2	107.4	0.3562
L×S	2	52.7	0.5987
L×W×S	2	302.7	0.0615
L×F×S	2	51.7	0.6045
L×W×F×S	2	44.0	0.6509
Error	42	101.5	

Note: Data are based on plot means weighted by number of surviving seedlings.

*L, site; B, block; W, weed control; F, fertilization; S, seed source.

Fig. 2. Response surface of lammas growth versus vigor and browse in year 1, calculated on a plot basis.



weeding treatments were performed on March 18, 1992, and again on March 25, 1993. On each site, an electrically charged 18-gauge wire, suspended 1.0 m off the ground with fiberglass poles, was wound among all plots to discourage deer from entering. The wires were electrified during May and June of each year with a Jolt electric fence controller (model 4000B, IAAB U.S.A., Inc., Bellevue, Wash.). To prevent wire short circuiting, vegetation growing beneath the wire was controlled with a single directed application of glyphosate in the spring of each year. Care was taken to avoid treating nonweeded plot vegetation in this process.

Measurements

Douglas-fir and cover measurements

Seedlings were measured shortly after planting (spring 1992) and at the end of each growing season (fall 1992, 1993). Measurements included seedling height (nearest cm), diameter at 15 cm (nearest mm), and vigor. Vigor, a qualitative measure, was quantified on a five-point scale based on seedling color and general appearance. The rating scale was as follows: 1, tree with long foliage, lammas growth; 2, healthy, green tree with no

Table 3. Stem volume of surviving seedlings after two growing seasons by weed control treatment and number of years lammas growth occurred, averaging across seed source and fertilization.

	Complete weed control		No weed control	
Lammas growth	No. of seedlings	Avg. stem vol. (cm^3)	No. of seedlings	Avg. stem vol. (cm^3)
Neither year	146 (10.1)	44.1*c*	270 (18.7)	20.0*e*
One year	534 (37.1)	64.0*b*	334 (23.2)	29.1*d*
Both years	135 (9.4)	74.2*a*	21 (1.5)	26.5*de*

Note: The number of seedlings is out of a total of 1440 surviving seedlings. Percentages of total surviving seedlings are in parentheses. For average stem volume, values followed by the same letters are not significantly different using Bonferroni's adjusted LSD.

Table 4. Stem volume of surviving seedlings after the second growing season by weed control treatment and number of years browsed, averaging across seed source and fertilization.

	Complete weed control		No weed control	
Years browsed	No. of seedlings	Avg. stem vol. (cm^3)	No. of seedlings	Avg. stem vol. (cm^3)
Neither year	231 (16.0)	74.0*a*	237 (16.5)	27.2*c*
One year	263 (18.3)	68.1*a*	241 (16.7)	23.2*c*
Both years	321 (22.3)	48.7*b*	147 (10.2)	24.7*c*

Note: The number of seedlings is out of a total of 1440 surviving seedlings. Percentages of total surviving seedlings are in parentheses. For average stem volume, values followed by the same letters are not significantly different using Bonferroni's adjusted LSD.

more than minor discoloration; 3, tree stunted, severe yellowing, up to 50% defoliation; 4, loss of terminal and severe defoliation (>50%); 5, dead. From the height and diameter measurements, relative stem volume was estimated by using the universal formula for a cone, i.e., volume = $\pi d^2(h/12)$, for which our measurements were d, diameter at 15 cm, and h, total height. Volume, diameter, and height increments were calculated at the end of each growing season from yearly differences in seedling dimensions. Occurrences of deer browsing, lammas growth, and herbicide damage were also noted in the fall of each year.

Percent cover by herbaceous forbs and grasses was estimated on a 0.5-m around each seedling in the fall of 1992; in the fall of 1993, because of the relative homogeneity of the vegetation within the plots, it was estimated as a percentage of total plot area. Percent overtopping was calculated with the cone occlusion method described by Howard and Newton (1984).

Xylem water potential and soil moisture

Predawn and midday xylem water potentials were measured using a Scholander pressure chamber (Waring and Cleary 1967, Ritchie and Hinckley 1975) from current-year shoots of three randomly selected seedlings per plot. These measurements were made in mid-July 1992 and mid-August 1993 to obtain maximum contrast in water regimes between weeded and unweeded treatments. In 1992, plot soil moisture was measured gravimetrically at the time of the xylem water potential measurements; soil moisture was not measured in 1993 because of an abnormally wet summer.

Nutrient content

A baseline analysis of mineral soil nitrogen and phosphorus was done for each site at the time of planting (February 1992) using a composite of six subsamples taken from the top 30 cm of mineral soil at each site. Total foliage nitrogen and phosphorus were based on foliage samples taken from each treatment and site at the end of the second growing season (October 1993). Foliage samples were taken from the current year's growth of an upper whorl lateral, excluding any lammas shoots, on the southeast side of each surviving seedling. Samples were bulked by treatment across blocks on each site for a total of 24 samples. Total nitrogen and phosphorus were determined with a standard micro-Kjeldahl digestion method and atomic absorption spectrophotometer, with nutrient concentrations calculated on a dry weight basis (Lavender 1970). This was done to determine whether nitrogen fertilization resulted in dilution of at least one other macronutrient.

Analysis

Differences in tree stem growth, lammas growth, and level of deer browsing were detected by analysis of covariance (ANCOVA) for main and interaction effects according to the model below, based on plot averages weighted by the number of surviving seedlings in each plot (Steel and Torrie 1980):

$$Y_{ijklm} = \mu + L_i + B(\mathrm{L})_{ij} + W_k + F_l + WF_{kl} + S_m + WS_{km} + FS_{lm}\, WFS_{klm} + LW_{ik} + LF_{il} + LWF_{ikl} + LS_{im} + LWS_{ikm} + LFS_{ilm} + \beta(X_{ijklm} - \chi..) + LWFS_{iklm}$$

where

L is site (i = 1,2,3)

B is block (j = 1,2,3)

$B(L)$ is error a (blocks within sites)

W is weed control (k = 0,1)

F is fertilizer (l = 0,1)

S is seed source (m = 0,1)

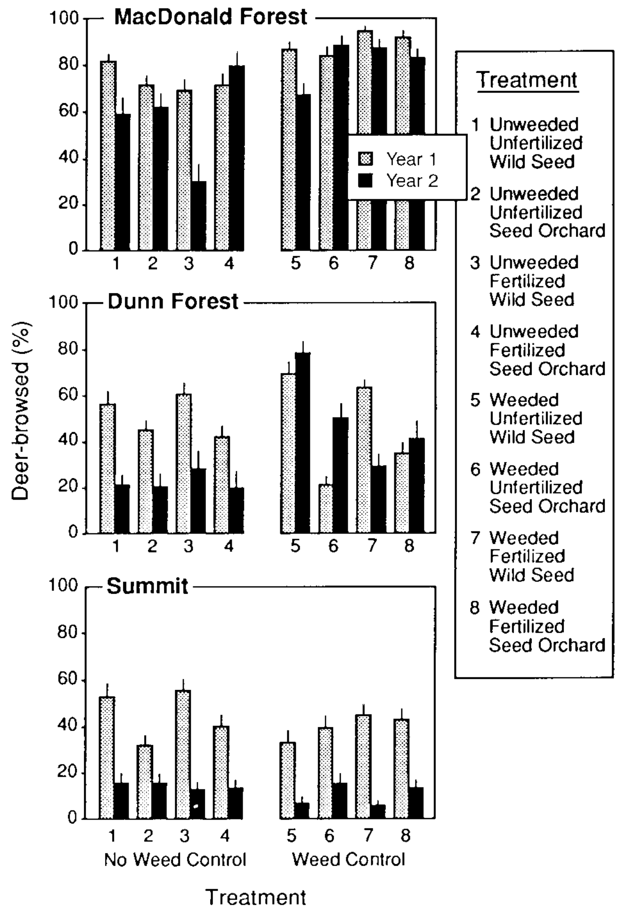
$\beta(X_{ijklm} - \chi..)$ is covariate denoted by X

LWFS is error b

Site terms were tested against error a and all remaining terms were tested against error b. Covariates tested included initial seedling size and surrounding cover. When a significant covariate was not found, the covariate term was left out of the model. Several seedlings at the Summit and Dunn Forest sites showed signs of herbicide damage in the second growing season and were eliminated from the analysis.

Frequency of occurrence of browsing and of lammas growth within plots were transformed by arcsine – square root transformation. This satisfactorily normalized distributions for ANOVA testing (Sabin and Stafford 1990). Height increment was not transformed. Significant differences between means were determined by using Bonferroni's protected least significant difference (LSD) procedure (Milliken and Johnson 1984). Multiple linear regression models were developed, based on weighted means from individual plots, to relate lammas shoot production and probability of deer browse to the various levels of weed control, fertilization, and initial seedling dimensions represented by the various treatments. The models explaining the most variance were chosen with the stepwise selection procedure (Neter et al. 1989).

Fig. 3. Percentages of deer browse during two growing seasons by site and silvicultural treatment. Vertical bars represent 1 SE of the mean.



Results

Lammas growth

Weed control significantly increased lammas shoot growth ($p < 0.0001$), presumably through increased soil moisture (Table 2). Weeding alone accounted for about two-thirds of all explained variation in lammas growth. Fertilization with urea increased competitive cover and reduced lammas growth on unweeded plots at all sites ($p < 0.0018$). Fertilization had little effect when there was no competition (Fig. 1). Seed source had negligible effect on lammas shoot production. Frequency of lammas growth in the two growing seasons affected stem volume response to weed control (Table 3). Table 3 also shows total surviving trees out of the 1004 trees of each source. Survival in the weeded plots was 81.1 versus 62.3% in the nonweeded plots, reflecting the occurrence of lethal water stress in nonweeded plots. This level of stress would likely explain a lower frequency of late-season growth.

Regression analysis of 2nd-year plot averages, weighted by number of surviving seedlings, showed 2nd-year lammas growth to be negatively related to the current season's predawn xylem tension and positively related to the previous year's vigor. The effect of vigor is a reflection of the previous year's water stress and is shown in Fig. 2.

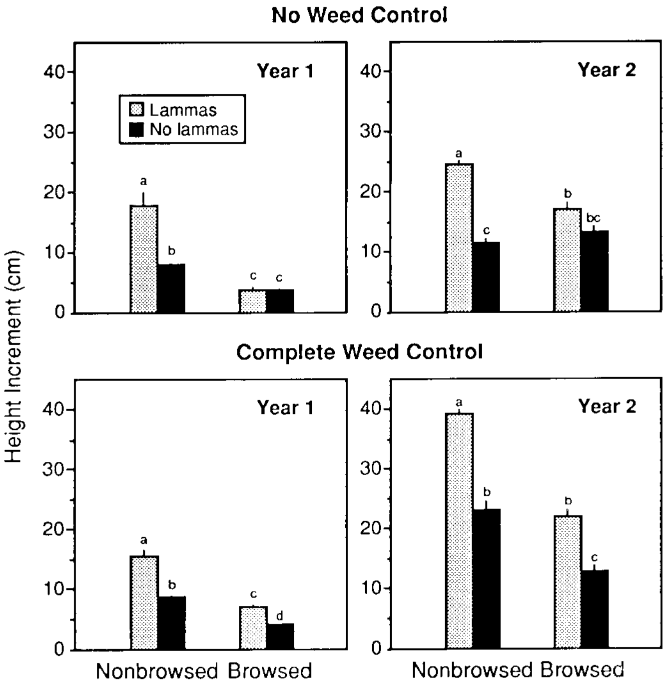
Deer browsing

Browsing by deer was highly variable among years, treatments, and sites (Fig. 2); most, however, occurred during the first flush of growth, within 3 weeks of bud break. Second-year browsing was negatively related to the amount of surrounding herbaceous cover and positively related to the occurrence of browsing the previous year. The single-strand electric fence functioned through the period of maximum browsing activity but failed to keep the deer out. We are uncertain whether fencing influenced the level of damage.

Frequency of browsing by deer influenced stem volume by reducing net height increment. Of the surviving seedlings that were browsed twice, those in weeded plots were twice as large as those in nonweeded plots. Among seedlings browsed only once, those in weeded plots were close to three times the size of nonweeded seedlings (Table 4). Whereas there was a tendency for two-time browsing to increase in completely weeded plots and for browsing to cause more loss in weeded than nonweeded plantings, the net increase in growth in weeded plots versus nonweeded was always significant ($p < 0.05$) despite browsing. Indeed, under competition, growth was poor enough so that degree of browsing made little difference in 2 years.

Although autocorrelation between browse, lammas growth, and seedling size and vigor prevents complete

Fig. 4. Height increment of browsed and unbrowsed seedlings by year, lammas growth, and weed control treatment. Vertical bars represent 1 SE of the mean. The same letters within graphs denote statistically similar values using Bonferroni's LSD at $p \leq 0.05$.



separation of these effects from each other when comparing treatments, several trends were apparent in this study. Deer preferentially browsed wild-type seedlings on the Dunn Forest site ($p < 0.0001$) during the first growing season, but the pattern was not repeated for other sites or in the 2nd year (Fig. 3). There was a significant interaction between deer browse and lammas growth. During the first growing season, lammas growth following browse tended to occur most frequently on the most vigorous seedlings (Fig. 2). For seedlings in weeded plots, lammas growth following browse compensated for lost height growth due to the browsing, to the extent that at the end of the 2nd year, browsed seedlings with lammas growth were as large as nonbrowsed seedlings without lammas shoots (Fig. 4).

Lammas growth in the previous growing season did not significantly reduce current-year height growth for any of the sites, in either weeded or unweeded plots (Fig. 5). To prevent confounding of these data due to multiple-year browsing, seedlings not browsed in year 1 and browsed seedlings in year 2 were excluded from this analysis.

Discussion

Weed control

Weed control was the single most influential factor in lammas and total seedling growth, explaining over 10 times the variation contributed by the next most important factor. In western Oregon, where summer drought is common, the soil moisture conserved through weed control is enough to trigger lammas growth (Newton and Overton 1973); nitrogen fertilization in addition to weeding is unnecessary. Because weeding increases lammas growth, it also counteracts the problem of deer browse (Gourley et al. 1990). Although weeding may increase browsing through greater seedling exposure (McDonald and Radosevich 1992), vigorous weed-free seedlings have a higher propensity for lammas and total growth and thus greater recovery and net growth potential than nonweeded seedlings. Also, because lammas shoots are rarely browsed by deer, the second-flushing mechanism that weeding appears to encourage allows seedlings an escape from the reach of browsing deer and recovering vegetation.

Fertilization

Nitrogen fertilization had no positive effect on lammas growth, probably because nitrogen was not a limiting nutrient in our study sites. Fertilization did, however, spur the growth of associated vegetation. Thus, in soil conditions that require nitrogen fertilization, it should be done in conjunction with weed control. Ordinarily, weed control increases nitrogen availability; hence, fertilization at this time may be redundant or even toxic.

Seed source

Although the seed orchard seed source grew significantly faster in diameter than the wild local seed source, seed source had no effect on lammas growth occurrence. Apparently, for these two populations of low-elevation Douglas-fir, field environmental conditions play a much larger role than genetics with regard to lammas and total growth. Because the relative contribution of seed source decreased in the 2nd year, we cannot predict a longer term effect.

To summarize, because lammas growth in the 1st year did not reduce growth the following season and actually restored height losses from deer browse in the same season, our findings suggest that the ability to second flush may be a desirable trait in juvenile Douglas-fir provided the lammas shoots harden off before fall frosts. In early stages of stand development, the limited losses resulting from defects in stem form (i.e., multiple tops) due to lammas growth will be offset by the increased seedling growth rate associated with second flushing. Intensive weed control is much more effective than fertilization or genetic selection in obtaining the benefits of Douglas-fir lammas growth.

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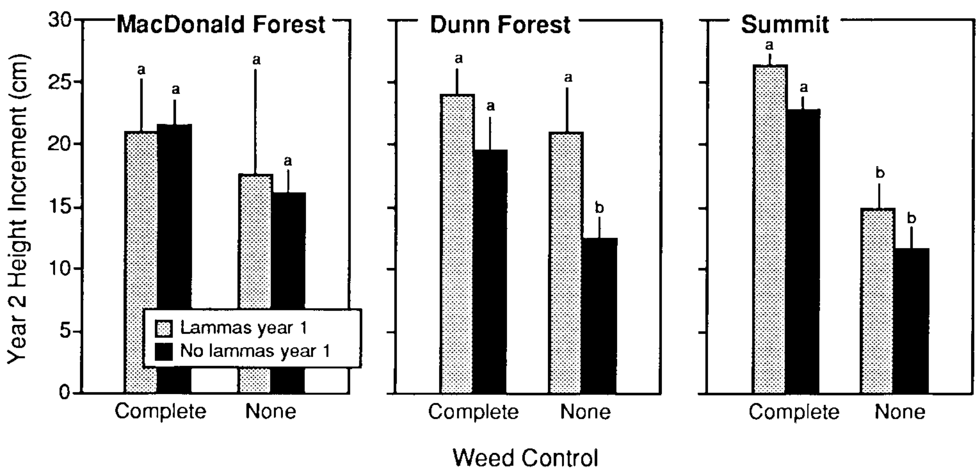
Fig. 5. Effect of year 1 lammas growth on year 2 height increment by site and weed control treatment. Unbrowsed year 1 seedlings and browsed year 2 seedlings were excluded from the sample. Vertical bars represent 1 SE of the mean. The same letters within graphs denote statistically similar means at a 95% significance level using Bonferroni's LSD.



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