LIGHT REDUCTION AND MOISTURE STRESS: EFFECTS ON CONTAINERIZED WESTERN LARCH SEEDLINGS

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ABSTRACT: Morphological and physiological responses of western larch were determined by applying three shade and three moisture stress treatments in late summer to 10-week-old seedlings. Moisture stressing reduced height and diameter of unshaded seedlings. Unshaded and unstressed seedlings had the greatest shoot and root dry weight and the lowest shoot/root ratios. Terminal bud set occurred under a 14-hour photoperiod.

INTRODUCTION

Although its range is restricted to the Columbia Basin, western larch (*Larix occidentalis* Nutt.) is a valuable commercial species. This highly intolerant species grows best under the full sunlight of clearcuts yet suffers high mortality in the seedling stage because of drought (Schmidt and others 1976).

A major goal in rearing conifer seedlings is to produce seedlings morphologically and physiologically suited for withstanding the rigors of planting and harsh site conditions (Tinus and McDonald 1979). Meeting that objective is difficult with western larch because, atypically, it is a deciduous conifer with relatively unstudied physiological requirements. The use of shade and moisture stress to induce dormancy or to stop height growth in larch seedlings is commonly practiced without knowledge of how or if these treatments produce the desired response.

The objective of this study was to see if manipulating the greenhouse environment would produce measurable differences in seedling response. Moisture stressing and shading were applied, and their effects on height, diameter, dry matter accumulation and distribution, and timing of bud set were measured.

MATERIALS AND METHODS

Western larch seed randomly selected from a seed lot of the Montana State Department of Lands were collected in 1980 from about 4,000 ft (1,200 m) elevation and 48°35' latitude and placed in cold storage. All seed were stratified for 23 days, sown in plastic tubes, and grown in the Montana State Nursery greenhouse, Missoula, Montana, during the spring and summer of 1982. The resulting seedlings were grown in a peat-vermiculite medium and under controlled environmental conditions in an operational greenhouse: 85/68°F (30/20°C), 50 to 80 percent RH with a 24-hour photoperiod by supplemental lighting. All seedlings were watered by an overhead sprinkling system and fertilized with a commercial fertilizer (9-45-15 and 20-2020). At the end of July when the seedlings were about 10 weeks old, a set of 15 randomly sampled seedlings was harvested and baseline measurements of height, stem diameter (measured above the root collar), and shoot and root ovendry weight were determined. Supplemental photoperiod lighting was discontinued and further treatments were applied to the remaining seedlings.

Two shade treatments were applied by using commercial shade cloths: one provided 37 percent and the other 27 percent of full sunlight. Each shade shelter covered 600 seedlings (three container trays); another 600 were left uncovered for the treatments with no shade (full greenhouse light, i.e., 70 percent of full sunlight).

After all seedlings were watered to saturation, a subset of 200 seedlings from each light treatment was given one of three moisture stress treatments. One subset was watered at a frequency such that predawn seedling water potential (is) was above -0.4 MPa (unstressed). Water was withheld from another subset until predawn * reached -0.7 to -1.2 MPa (moderate stress), and from a third set until predawn * reached -1.5 to -1.8 MPa (severe stress). Seedling stress development was monitored with a pressure chamber by measuring 0 on sampled seedlings clipped above the root collar (Ritchie and Hinckley 1975). The stress treatments involved two consecutive drying cycles, each taking from 1 to about 2 weeks to complete. During the stress cycling, fertilizer was withheld so as not to confound the effects of the moisture stress treatments. Morphological changes and date of bud set were noted.

At the end of the period (August 16), 15 seedlings from each treatment were harvested and height, diameter, and shoot and root dry weights were measured. The remaining seedlings were subsequently fertilized at weekly intervals with 5-11-26, and greenhouse temperatures were lowered to 77/55°F (25/13°C). The seedlings were moved outside by the end of September, and final data

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were taken the first week in October. Shoot dry weights could not be measured because of extensive needle drop.

Data were subjected to an ANOVA. Significant differences in treatment effects were determined by Duncan's multiple range test.

RESULTS AND

DISCUSSION Growth and

Morphology

Mean heights of the seedlings harvested on August 16 and on October 15, 1982, are presented in table 1. Because of the variability within treatments, the effects of light reduction on height were not statistically significant at the 0.05 level of confidence. Rehfeldt (1982) found height variability within genetic populations and attributed it to the exogenous nature of shoot growth in western larch. In the present study, however, statistically significant differences in height were detected among moisture-stressed seedlings receiving the most intense light treatment.

Although bud formation was visible before August 16, there was measurable height growth of about 0.8 in. (2 cm) among the unstressed seedlings between August 16 and October 5 (fig. 1). This growth may have been due to the continual or "free growth" habit of western larch (Rehfeldt 1982; Owens and Molder 1979) and to the late seasonal growth characteristic of Larix species (Ledig and Botkin 1974). However, height growth almost ceased in the stressed seedlings.

Light reduction significantly decreased mean diameter of seedlings harvested October 5

A fungus, Botrytis cinerea, infected seedlings in September, causing considerable needle drop. Therefore, shoot dry weights were determined only on seedlings harvested August 16. Among severely stressed seedlings, dry weight differed significantly between those shaded and unshaded (table 1).

Root dry weight was significantly greater among unshaded seedlings than among shaded ones, regardless of moisture stress (table 1). The relative increase in allocation of dry matter to roots by October was greatest in unstressed seedlings grown under full light (fig. 1). The increase in root dry weight with increasing light intensity was linearly correlated (r^2 - 0.68, n - 135). This relationship has also been found in other coniferous species by Fairbairn and Neustein (1970) and Logan (1966).

Shoot/root ratios were calculated from seedlings harvested August 16 (table 1). Within the unstressed and moderately stressed treatments, shoot/root ratio was significantly greater for seedlings grown under 27 percent light than for those in the other two light treatments; however, there was no difference as a result of moisture stressing. The unshaded treatment with no moisture stress resulted in seedlings with the highest mean total weight (0.642 g) and the lowest mean shoot/root ratio (1.74).

Dormancy Induction

Terminal buds first appeared on August 13 when daylength was approximately 14 hours. Vaartaja (1959) found that in 1-year-old eastern larch seedlings from as far south as 46° latitude, critical daylength for terminal dormancy was also 14 hours. In the present study, no significant differences in time of terminal bud set were

Table 1.— Morphology and dry matter accumulation and distribution in the test seedlings, by harvest date, moisture stress, and light treatment.

Harvest date & moisture stress	Height (cm) according to % full light			Diameter (cm) according to % full light			Shoot dry weight (g) according to % full light			Root dry weight (g) according to % full light			Shoot/root ratio according to % full light		
	70	37	27	70	37	27	70	37	27	70	37	27	70	37	27
August 16															
None	13.6a	12.8a	12.7a	.20a	.18b	.17b	.405a	.345a	.352a	.237a	.182b	.171b	1.7a	1.9ab	2.1b
Moderate	12.4a	12.8a	12.5a	.17a	.18a	.17a	.357a	.354a	.321a	.203a	.162b	.132b	1.8a	2.2b	2.4b
Severe	12.5a	12.5a	12.6a	.19a	.16a	.15a	.387a	.322b	.291b	.209a	.161b	.139b	1.9a	2.0a	2.1a
October 5															
None	15.8a	15.1a	14.9a	.25a	.21b	.20b	—	—	—	.559a	.355b	.285c	—	—	—
Moderate	12.7a	13.7a	13.8a	.24a	.21b	.19b	—	—	—	.537a	.343b	.267c	—	—	—
Severe	13.2a	14.1a	13.9a	.23a	.20b	.20b	—	—	—	.509a	.343b	.241c	—	—	—

Note: Values connected by vertical brackets in a column (moisture treatments) and values followed by the same letter within a row (light treatments) are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test. Values for moisture treatments are discrete by date, and those for light treatments are discrete by seedling parameter.

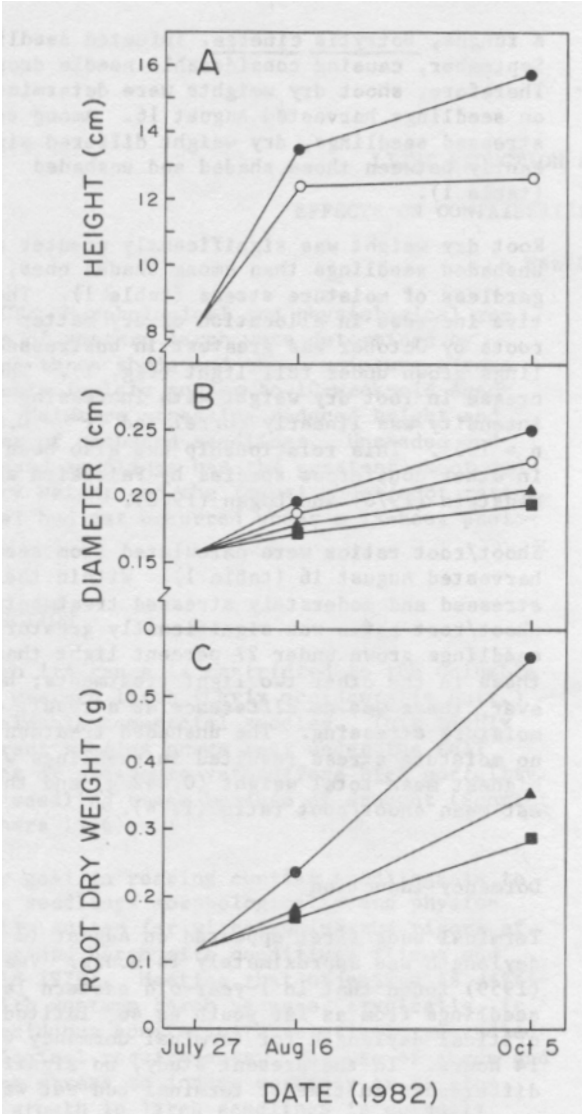

Figure 1.--(A) Change in height of unstressed (●) and stressed (○) western larch seedlings under 70 percent of full sunlight; (B) change in diameter of unstressed and stressed seedlings under 70 percent of full sunlight and of unstressed seedlings under 37 percent (▲) and 27 percent (■) of full sunlight; and (C) change in root dry weight of unstressed seedlings under all light treatments. Each point is the mean of 15 measurements.

detected among the various treatments: terminal buds were visible on virtually all seedlings within 72 hours. Although buds in greenhouse-grown western larch seedlings often rebreak, these were the final resting buds of the season. Photoperiod was a more critical factor than light intensity or moisture stress in inducing a final resting bud and dormancy under the environmental conditions of this study.

CONCLUSIONS

The variability in height among the test seedlings suggests that this parameter is not predictable for western larch and that less emphasis should be placed on it as an attribute of seedling quality. Nevertheless, seedling height growth decreased as moisture stress became more severe. If seedlings are not stressed, height growth may continue after bud set. The direct relationship of root dry weight to light intensity and the dramatic increase in root dry weight late in the growing season under relatively intense light suggests that shading larch after bud set is not desirable. In general, the most intense light produced the heaviest seedlings with the lowest shoot/root ratios, but not necessarily with the greatest height.

Onset of bud set was not influenced by moisture stressing or by reduction of light intensity but by the 14-hour photoperiod. This relationship suggests that while moisture stressing may induce a temporarily resting bud in larch, truly dormant buds could best be induced by photoperiod control.

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