Moisture Stress and Root Volume Influence Transplant Shock: Preliminary Results[1]

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Abstract--Despite evidence of its economic impact, very little is known about transplant shock. This study was designed to evaluate transplant shock in relation to root volume and soil water content for two year-old Douglas-fir seedlings. Preliminary results found that new growth decreased and days to budbreak increased with higher moisture stress. This effect was most pronounced for high root volume seedlings in the driest soil. Forthcoming results are expected to further implicate moisture stress as an influencing factor in transplant shock.

INTRODUCTION

Transplant shock can be a serious problem to reforestation efforts. A seedling in shock is characterized by "bottle brushing" symptoms (stunted terminal growth with a greater number of needles per unit of leader), browning or loss of needles, cessation of growth, or even death.

This can have quite an economic impact. Mullin (1964) found transplant shock to reduce seedling leader length of white spruce by about 50% in the first year after outplanting. Smith and Walters (1963) found similar results in Douglas-fir. This slow growth, combined with the stressed condition of a seedling in shock, can result in a longer stand rotation age and even plantation failure. Despite the quantitative evidence of its effects, relatively few studies have been published which specifically examine transplant shock. This may be because of the difficulty in assessing such a transient problem.

Although no studies have offered proven causes for transplant shock, most have indicated that the root system's ability to take up water is a most important factor. Following transplanting, a seedling must recover from any damage, reestablish root to soil contact, and resume water and nutrient uptake in a new environment. During this adjustment period, the seedling continues to transpire, resulting in a stressed condition of physiological drought (Rietveld 1989). One study suggests that transplant shock is due primarily to poor root to soil contact after planting when air gaps form at the root-soil interface (Sands 1984). Other studies cite damage to the root system during lifting and handling procedures as a significant factor (Mullin 1963; Stoneham and Thoday 1985). Soil drought further contributes to the stressed condition of the seedling. Kaufmann (1977) found that dry soils significantly reduced growth of Monterey pine (_Pinus radiata_) seedlings.

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Nursery cultural practices such as fertilization, packing and irrigation have also been examined as possible factors in seedling field performance (Darbyshire 1984; Jopson and Paul 1984; Mellor et al. 1970). However, even seedlings grown under optimum cultural practices commonly go into shock.

A few experiments have been done to attempt to increase drought resistance in planted seedlings by pre-conditioning (Kaushal and Aussenac 1989; Unterscheutz 1974). Although these studies found that drought pre-conditioned seedlings had lower transpiration rates, transplanted seedlings still had reduced terminal shoot growth. Other studies have indicated that cold storage may reduce transplant shock. Jenkinson and Nelson (1984) found that survival potential, growth capacity, and field performance of seedlings stressed after storage approximated that of unstressed seedlings. Blake (1983) found that cold stored seedlings appear better able to avoid transplant shock and early drought despite delayed root growth.

It is unlikely that transplant shock can be entirely eliminated. However, it would be useful to target specific seedling characteristics which are correlated with minimum transplant shock symptoms. These targeted characteristics could be used to supplement current seedling grading criteria. Burdett (1983) and Sutton (1979) both emphasize the importance of a quality grading system which ensures that stock is best adapted to the planting site.

The objective of our current research is to induce transplant shock in 2+0 Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco.) seedlings by applying moisture stress treatments in a controlled greenhouse environment. The data will be used to better understand the causes of transplant shock and to establish relationships among initial seedling morphological parameters, (specifically root volume), moisture stress, and transplant shock. These relationships could be applied to nursery grading standards in order to select seedlings which are least likely to go into transplant shock following transplanting to a specific site. This paper is a report of our preliminary results and future plans.

PROCEDURES

Plant material

Two year-old (2+0) Douglas-fir seedlings from a BLM northwestern Oregon provenance (seedlot 261-20-01, Western Forest Tree Seed Council, State of Oregon Tree Seed Zone) were grown under standard nursery cultural practices at International Paper's Kellogg Nursery located in western Oregon approximately 10 km south of Elkton. A live tree count before lifting, on January 18, 1990, gave a count of 25 seedlings per square foot.

Following lifting, seedlings were graded to operational specifications. Each tree was measured for height (cm) from bud scar to base of terminal bud, caliper (mm) just below the bud scar, root volume (cm^3) measured by water displacement, and total fresh weight (g).

Treatment

Following measurement, seedlings were divided into four root volume categories (table 1). These categories were determined from the root volume distribution shown in figure 1. Each seedling was then randomly assigned to a moisture stress treatment (table 2) and experimental block.

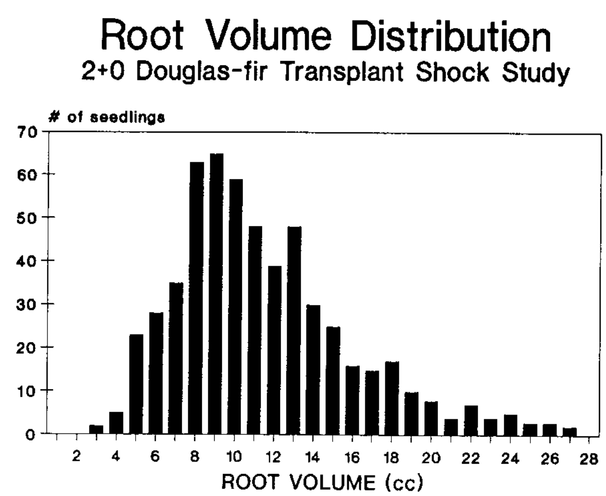


Figure 1.--Root volume distribution of 2+0 Douglas-fir seedlings in transplant shock study.

Table l.--The four root volume categories used in this transplant shock study.

CATEGORY	ROOT VOLUME (CC)
1	5-8
2	9-10
3	11-13
4	14-20

Table 2.--Moisture stress treatments applied to seedlings in terms of soil water content (%) and soil water potential (MPa).

TREATMENT	WATER CONTENT (%)	WATER POTENTIAL (MPa)
1	6	-1.60
2	12	-0.80
3	18	-0.10
4	24	-0.01

(Field capacity = 42 %)

Seedlings were transplanted into 15 liter plastic pots (five seedlings per pot). The same weight of sterilized soil mix was put in each pot. All pots were thoroughly watered after planting and placed in a controlled greenhouse environment. Fans were used daily for 6 hours to lower greenhouse humidity, encourage normal seedling transpiration, and better simulate a true transplant environment.

Moisture stress treatments consisted of watering all pots to field capacity and letting them dry down to a predetermined soil moisture content and then rewatering to field capacity over a period of 120 days. Moisture stress treatments were selected based on earlier trials and represent a wide range of soil water potentials (table 2).

Soil water content was monitored by weighing the pots and using the following equation:

$$TW = (WC * DS) + DS + P$$

where

TW = Total weight (soil + water + pot)
WC = Water content of desired treatment.
DS = Average weight of dry soil in each pot
P = Weight of pot

(Weight of seedlings was considered negligible)

Pots were weighed two to three times per week to assess water content and were rewatered once they had dried down to their specified water content. sixty days after transplanting, new terminal length (cm) and lateral length were measured. Days to terminal and lateral budbreak were also monitored.

PRELIMINARY RESULTS AND DISCUSSION

Growth

New terminal and lateral length depended on soil moisture content (fig. 2). Under more moist conditions (18-24% water content), terminal length stayed relatively constant over all root volume categories. On the other hand, with the drier soils (6-12% water content), leader length tended to decline as root volume increased. The effect was most pronounced for the driest soil treatment where seedlings had the greatest reduction in growth at high root volume (fig. 3).

It was not surprising to find that under well-irrigated treatments, root volume had little effect on growth. However, we hypothesized that the highest root volume should have the greatest growth in drier soils because of higher root growth potential and greater absorption capacity (Carlson and Miller 1990). We found the exact opposite.

This apparent inconsistency may be explained by the fact that seedlings with higher root volumes were observed to have a greater number of branches. Therefore, selecting for higher root volume may also be selecting for higher leaf area and hence greater surface area for transpiration. Pots with higher root volumes needed to be watered more often indicating relatively higher water uptake (roots) and demand (leaves). We speculate that demand exceeds uptake by a greater margin in the higher root volume trees resulting in reduced growth.

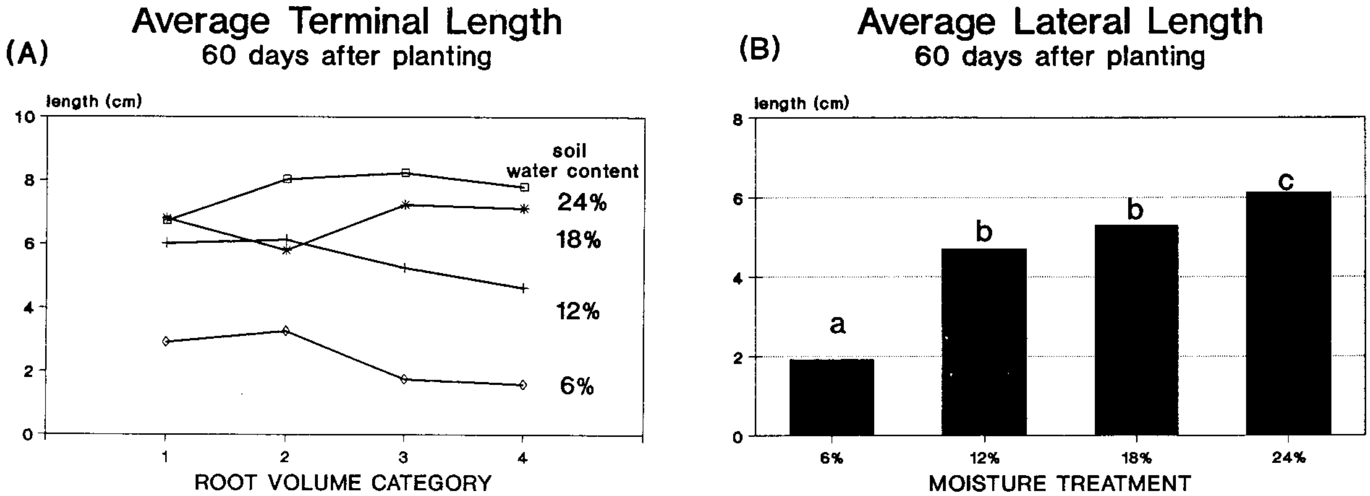


Figure 2.--Growth of seedlings 60 days after planting depended on soil water content: (A) terminal length decreased with higher moisture stress especially for high root volume seedlings; (B) lateral length also decreased with stress, however, there was no root volume interaction.

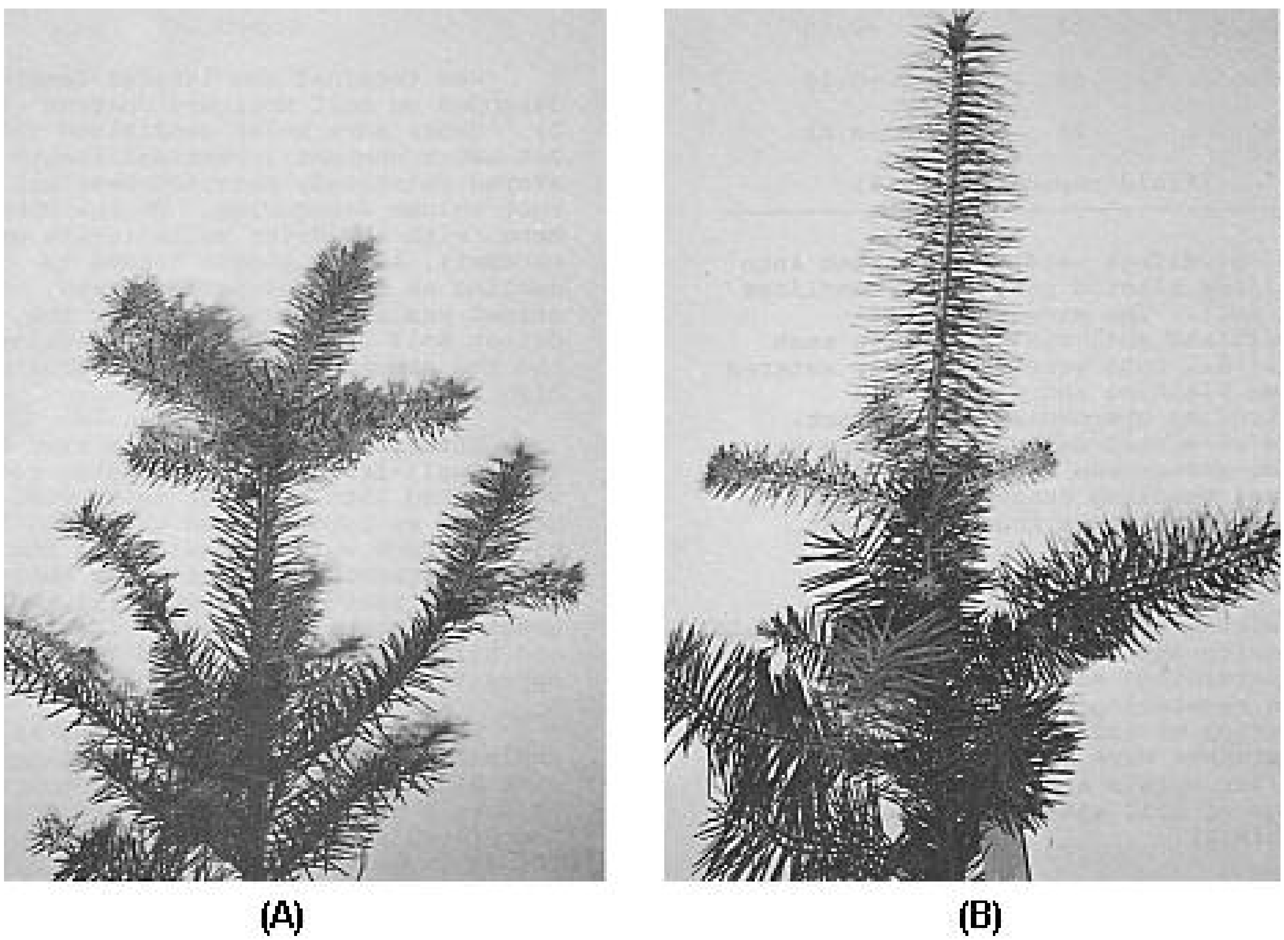
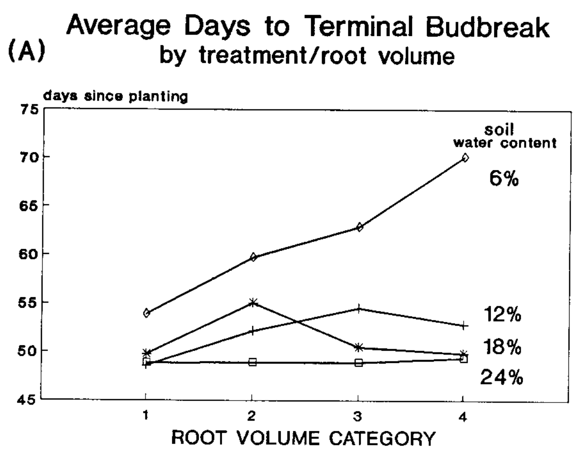


Figure 3.--Photographic comparison of moisture treatment effect on high root volume seedlings (14-20 cm3): (A) treatment 1 (6% water content) exhibiting transplant shock symptoms; (B) treatment 4 (24% water content) showing no evidence of shock.

Budbreak

Similar to the growth measurements, days to terminal and lateral budbreak depended on soil water content (fig. 4). At relatively high water content (18-24%), days to budbreak was generally constant, irrespective of root volume. However, at the drier water content (6-12%), days to budbreak tended to increase with increasing root volume. Once again, the effect was most pronounced with the driest soil (6%), where days to budbreak increased about 30% from root volume category 1 (5-8 cm^3) to category 4 (14-20 cm^3)



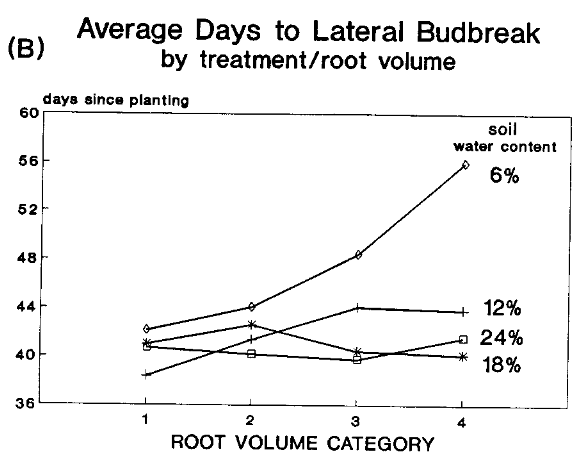


Figure 4.--Average days to budbreak increased with increasing moisture stress, particularly for seedlings in the high root volume category, for both (A) terminal budbreak and (B) lateral budbreak.

Delayed budbreak with increasing water stress has been found in another ongoing study with the Nursery Technology Cooperative (unpublished data) and was expected in this study. Seedlings with large root volumes were expected to be most vigorous (i.e. initiate rapid budburst). However, this was not the case, especially in the driest treatment. As with growth, we speculate that the high root volume seedlings may actually be under greater transpirational stress, despite a high capacity for water uptake.

FURTHER PLANS

Seedlings were harvested in late May, 1990 and measured for transplant shock symptoms such as new terminal and lateral growth, needle length, needles per centimeter on the terminal, and dry weights. Although the data have not been analyzed yet, it appears that both root volume and moisture treatments are significant influences on transplant shock. It is expected that moisture stress will be further implicated as an important causal factor of transplant shock and that the relationship between initial root volume and transplant shock will be better defined.

This study is being repeated with seedlings from the same seedlot which were cold stored for 120 days following lifting. Since this second study is being conducted at a different time, it cannot be statistically compared to the study with unstored seedlings. However, observational differences will be noted. It is expected that the moisture stress or root volume effects may differ between the two studies since the stored seedlings flushed much earlier in the experiment before soil dried to treatment levels.

A complete report of these studies will be prepared for publication in 1991.

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