Effects of Rough Handling on Early Performance of White Pine and White Spruce Seedlings

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This study examined the effect on seedling health of dropping standard plastic-lined kraft tree bags containing 3+0 white pine (Pinus strobus *L.*) *and white spruce* (Picea glauca *(Moench) Voss) seedlings from various heights; timing of irrigation after planting was also tested for its effect on seedling vigor. Treatments were evaluated by measuring root growth potential (RGP), and bud flush was assessed at the end of a 3-week period to evaluate its use in predicting stress on seedling performance. White pine seedlings showed a decrease in RGP at every treatment height, but white spruce showed a decrease in RGP at 2 m (the greatest drop distance) only. Irrigating did not increase RGP for either species, although white spruce seedlings exhibited higher RGP than white pine after irrigation. Although irrigation did not affect bud flush in white pine when dropped from 2 m, the percentage of buds that broke dormancy was significantly decreased ($P < 0.05$). For white spruce seedlings, a downward trend was evident with increasing drop heights, but there was no significant difference at 2 m.* Tree Planters' Notes 45(4):142-146; 1994.

The Canadian forest industry harvested 162 million m^3 (211.7 million yd^3) of wood in 1993 (Anon 1993), but only 500,000 ha (1,235,000 acres) were replanted. The need to maximize survival of outplanted seedlings is underscored by these figures. To increase seedling survival, individual seedlings must be healthy and robust prior to planting. Historical studies have investigated obvious factors affecting seedling health (such as lifting date, Rietveld 1989; or soil temperature, Tabbush 1986), but only a few studies have dealt with damage during seedling transport. These studies (McKay and others 1993, Tabbush 1986, Ritchie 1986, Sharpe and others 1990) suggest that careless handling may have a detrimental effect on seedling growth. McKay and others (1993) studied the effect of dropping seedlings 135 times from heights of 0.1 m (0.3 ft), 1 m (3.3 ft), and 3 m (9.8 ft). Results showed that Sitka spruce *(Picea stitchensis* (Bong.) Carr.) seedlings had lower survival rates as dropping distance increased. Tabbush (1986) reported that dropping Sitka spruce and Douglas-fir *(Pseudotsuga menziesii* (Mirb.)) seedlings from 3 m was as damaging to their health as such deleterious influences as desiccation or extreme temperature. Ritchie (1986) found that placing seedlings in a large metal tumbler to simulate rough handling led to lower initial growth. Many studies have also examined the effect of drought on seedling performance (Coutts 1980, Sands and Nambiar 1984, Deans and others 1990). In a drought, most newly planted seedlings suffer from shock and water stress. Once shoots begin to elongate, an intense water demand is placed on roots. Water uptake can be greatly inhibited by poor root-to-soil contact (Kauppi 1984), which may develop if even a thin layer of air exists around roots. Instead of relying on rainfall, managers can improve survival by irrigating right after planting, because irrigation fills air spaces, establishing a bridge favorable to root growth. This research was designed to

- Examine the vigor of white spruce *(Picea glauca* (Moench.) Voss) and white pine *(Pinus strobus L.)* seedlings after rough handling during shipping from nursery to planting site.
- Study the effect of irrigation in overcoming damage to newly stressed seedlings.
- Evaluate the possibility of using bud flush as a reliable predictor of stress on seedling performance.

Materials and Methods

Plant material. The tree species chosen for investigation were white spruce and white pine, both currently planted and harvested commercially in Ontario. A recent study (Maki 1993) has suggested that white pine is especially sensitive to rough handling and that white spruce is relatively tolerant. Three-year-old bareroot seedlings (3+0) lifted in late fall of 1993 used in this study were acquired from the Ontario Ministry of Natural Resources Nursery in Orono, Ontario.

Stress treatments. Seedlings were placed in a room at 4 ºC (39 ºF) for 1 week after being shipped.

Figure 1—*Dropping a bag of seedlings from 2 meters.*

Sixty seedlings from each species were then randomly selected from the same tree bag. For each treatment, 5 seedlings with roots and shoots that did not appear to be damaged were randomly chosen from the lot of 60 and placed horizontally at the bottom of a standard plastic-lined kraft tree bag. Approximately 20 kg (44.1 lb) of additional seedlings were placed on top, to simulate a full bag of seedlings. A separate bag was then dropped 10 times from each of three treatment heights (figure 1)-1 m (3.3 ft), 1.5 m (4.9 ft), and 2 m (6.6 ft). A control treatment was similarly prepared but not dropped. After treatment, each seedling was planted in a 6-L (6.3-qt) pot using Promix as soil medium and then placed in a greenhouse for 3 weeks.

Irrigation treatments. To study irrigation effects, 50% of the treated seedlings from each species were watered within 4 hours of potting. Because the number of seedlings was uneven, 3 of 5 seedlings per treatment were irrigated within 4 hours of treatment for two blocks, and 2 of 5 seedlings in the third block were irrigated. Remaining seedlings were watered 48 to 52 hours after potting.

Evaluation. Two methods were used to evaluate treatment effects on seedling performance: root growth potential (RGP) and bud break. RGP was quantified by counting the number of new roots produced over the 3-week period, as described by Ritchie (1985). A classification system developed by Burdett (1979) was used, based on number of new roots more than 1 cm long. There were six scores: 0 (no new roots), 1 (new roots less than 1 cm long), 2 (1 to 3 roots more than 1 cm long), 3 (4 to 10 roots more than 1 cm long), 4 (11 to 30 roots more than 1 cm long), and 5 (more than 30 roots more than 1 cm long). Seedlings with high RGP's were judged to have high vigor and performance potential.

Bud break was scored as positive if any new foliage was evident or if buds had expanded and new needle color was apparent. Seedlings were assessed for both bud break and RGP 3 weeks after potting.

Statistical analysis. Data on number of new roots produced and percentage of trees exhibiting bud flush after 3 weeks were analyzed as a three-factor random incomplete block design. The three factors were distance dropped, time of irrigation, and species type. There were three replicates of 16 treatments (2 species x 4 drop heights x 2 irrigation times), with a total of 40 plants per block. All statistical analyses were performed using PC-SAS (SAS 1989).

Results

Stress treatments. Root growth potential for both species declined with increasing distance dropped (table 1), although for spruce the decline was inconsistent. The number of buds that broke dormancy over the 3-week period similarly declined with increasing distance dropped (table 2). However, significant differences in number of trees with bud flush occurred only in white pine. The mean number of new roots produced 3 weeks after dropping was significantly ($P < 0.05$) and substantially less for white pine seedlings dropped from both 1.5 and 2 m; for spruce, no significant ($P < 0.05$) difference was noted among drop heights (table 3).

Table 1—*Median root growth potential of white pine and white spruce seedlings, by height dropped and irrigation treatment*

	Root growth potential			
	White pine		White spruce	
Height dropped (m)	Irrigated within 4 hr.	Irrigated within 48 hr.	Irrigated within 4 hr.	Irrigated within 48 hr.
0	4	3	4	3
1.0	3.5	0	3.5	4
1.5	1.5	0	4	3
2.0	0	1	3	0

Note: 0 = no new roots; 1 = new roots less than 1 cm long; 2 = 1 to 3 roots more than 1 cm long; 3 = 4 to 10 roots more than 1 cm long; 4 = 11 to 30 roots more than 1 cm long; and 5 = more than 30 roots more than 1 cm long.

Table 2—*Rate of bud flush on white pine and white spruce seedlings, by height dropped*

	Bud flush (%)	
Height dropped (m)	White pine	White spruce
0	86 a	53 a
1.0	44 ab	53 a
1.5	36 b	33 a
2.0	44 ab	27 a

Note: Values within columns followed by the same letter are not significantly ($P < 0.05$) different.

Irrigation treatments. Both species exhibited a trend towards general reduction in RGP, number of buds breaking dormancy (table 4), and new root production (table 5) as the interval between time of planting and watering increased. However, these differences were not significant ($P < 0.05$).

Table 3—*Mean number of new roots produced on white pine and white spruce seedlings, by height dropped*

Height dropped	Mean no. new roots	
(m)	White pine	White spruce
0	16a	22a
1.0	8ab	18a
1.5	5b	18a
2.0	2b	12a

Note: Values within columns followed by the same letter are not significantly ($P < 0.05$) different.

Table 4—*Rate of bud flush on white pine and white spruce seedlings, by irrigation treatment*

	Bud flush (%)	
Irrigation	White pine	White spruce
Within 4 hours	57	49
Within 48 hours	49	35

Note: There are no significant ($P < 0.05$) differences between values within columns.

Stress–irrigation interaction. No significant interaction between drop treatment and timing of irrigation was observed ($P < 0.05$). However, early irrigation may ameliorate damage from rough handling, at least in white pine (table 1). For spruce, greatest reduction in RGP occurred when seedlings were dropped from 2 m (6.6 ft) and irrigation was delayed for 48 hours.

Discussion

Dropping seedlings reduced RGP in both species, although white pine appeared to be more sensitive to rough handling than white spruce. However, this difference in root growth may be a function of an unequal number of initial roots (lateral and fine roots) between the two species or a difference in physiological response rather than a response to environmental factors: white pine may have appeared more sensitive because its RGP was lower to begin with than that of white spruce. Moreover, the seedlings in this experiment, taken as they were from the bottom of the dropped bags, would likely have been most severely impacted. Other seedlings in the bag may not have sustained as much damage.

In his studies, Tabbush (1986) found that Douglas-fir began with a lower RGP than Sitka spruce. He also confirmed that peak RGP for Douglas-fir was in midwinter, whereas the RGP peak for Sitka spruce was in late summer. Sharpe and others (1990) observed a

Table 5—*Mean number of new roots produced, by irrigation treatment*

	Mean no. of new roots	
Irrigation	White pine	White spruce
Within 4 hours	11	21
Within 48 hours	4	14

Note: There are no significant ($P < 0.05$) differences between values within columns.

similar disparity in RGP between species under the same treatment. In all treatments, Sitka spruce had at least 5 times more roots than Douglas-fir.

The negative relationship of RGP to increasing drop heights observed in this study was expected. Observations made by Maki (1993) working with black spruce (Picea mariana (Mill.) B.S.P.) seedlings at the Ontario Forest Research Institute (Saint Ste. Marie, Ontario) dropped at the same frequency and height range support our results. Maki reported mean RGP's of 4.6, 4.9, and 3.9 for black spruce seedlings dropped 10 times from heights of 0 m, 0.5 m (1.6 ft), and 2 m (6.6 ft), respectively. A study by Deans and others (1990), in which the seedling was struck with the toe of a boot to knock off dirt after lifting, also showed a decrease in RGP. In that study, the RGP of roughly handled Sitka spruce seedlings was only 15% of the RGP found in control seedlings.

Because there was no apparent mechanical damage to roots or shoots from the treatment in the present study, reduction in RGP may be due to cytological damage. Jaffe (1980) measured ethylene production of vascular plants that had undergone mechanical stimuli and observed a change in the permeability of the cell membrane and an increase in ethylene production. Because ethylene plays a role in producing phytoalexin-like stress metabolites that reduce growth (Takahashi and Jaffe 1984), it is likely that mechanical stress increases ethylene production and subsequently inhibits growth.

A study by McKay and others (1993) reported an increase in electrolyte leakage and respiration levels in Sitka spruce seedlings subjected to several (1, 5, or 15) drops from 10 cm (3.9 in), 100 cm (39 in), and 300 cm (390 in). This suggests that cell membranes were damaged, resulting in impaired transmembrane electrolyte transport.

Irrigating planted seedlings after stress may have a mitigating effect, especially for white pine, and further tests should be carried out to define this effect. RGP was less in plants irrigated 48 hours after being dropped than in those irrigated 4 hours after dropping (table 1), which may be of ecological significance, even though statistical testing was not done on this class data.

Water is obviously important to plants under stress, especially when seedlings are newly transplanted (Rietveld 1989, Coutts 1980). Stressed seedlings show decreased transpiration rates and a partial closure of the stomata (Coutts 1980), and these effects may last for a day or longer, depending on severity of root disturbance.

Spruce needles are shorter and have a thicker waxy layer than pine needles. This provides spruce with a higher water stress resistance, indirectly seen in the results: irrigation of white spruce resulted in no significant difference in RGP between 4-hour and 48-hour treatments (unlike irrigation of white pine).

Conclusions

Results confirm that rough handling can have a negative effect on seedling growth. White pine seedlings showed a decrease in RGP after drops of 1 m (3.3 ft) or more, and white spruce seedlings showed a similar decrease at 2 m (6.6 ft). The mean number of new roots produced 3 weeks after dropping also declined in both species, although the decline was significant ($P < 0.05$) only in white pine. Results underscore the need for careful handling of seedlings during transport from nursery to planting site.

The greater sensitivity of white pine than white spruce to rough handling can be used in practice to develop different handling procedures for the two species. For example, irrigation of white pine seedlings may be useful in offsetting handling stress and improving survival.

Although RGP has been widely accepted as a sensitive measure of seedling vigor, it can be timeconsuming and requires destructive sampling. Bud flush provides a quick, nondestructive method of assessing seedling vigor. It has the advantage over methods such as dormancy release index (DRI, or the number of days after planting before bud flush) of requiring only one visit per plant. Evaluating bud flush might be an excellent method if it could be used to assess the vigor of outplanted seedlings. However, further evaluation of bud breakage in relation to mechanical stress and relative to the length of time required for flushing in individual species is required to refine the technique.

Results pertain only to seedlings taken from the bottom of tree bags. Further research is needed to evaluate the impact of rough handling on the "average" seedling not found at the bottom of the bag.

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Literature Cited

Anon. 1993. State of Canada's forests. Ottawa, ON: Canada Ministry of Supply. p 110.

Burdett, AN. 1979. New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. Canadian Journal of Forest Research 9:63-67.

Coutts M. 1980. Control of water loss by actively growing Sitka spruce seedlings after transplanting. Journal of Experimental Botany 31(125):1587-1597.

Deans JD, Lundberg C, Tabbush PM, Cannell MGR, Sheppard JH, Murray MB. 1990. The influence of desiccation, rough handling, and cold storage on the quality and establishment of Sitka spruce planting stock. Forestry 63 (2):129-141,

Jaffe MJ. 1980. Morphogenetic responses of plants to mechanical stimuli of stress, BioScience 30(4):239-241.

Kauppi P. 1984. Stress, strain, and injury: Scots pine transplants from lifting to acclimation on the planting site. Acta Forestalia Fennica 185:1-49.

Maki D. 1993. Effects of rough handling on black spruce. Sault Ste. Marie, ON: Ontario Forest Research Institute. Unpublished research.

McKay HM, Gardiner BA, Mason WL, Nelson DG, Hollingsworth MK. 1993. The gravitational forces generated by dropping plants and the response of Sitka spruce seedlings to dropping. Canadian Journal of Forest Research 23:24432451.

Rietveld WJ. 1989. Transplanting stress in bareroot conifer seedlings: its development and progression to establishment. Northern Journal of Applied Forestry 6:99-107.

Ritchie GA. 1985. Root growth potential: principles, procedures and predictive ability. In: Duryea ML, ed. Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. Proceedings of a workshop; October 16-18, 1984. Corvallis, OR: Forest Research Laboratory, Oregon State University. p 93-104.

Ritchie GA. 1986, Relationship among bud dormancy status, cold hardiness, and stress resistance in 2+0 Douglas-fir. New Forests 1:29-42.

Sands R, Nambiar EKS.1984. Water relations of *Pinns radiata* in competition with weeds. Canadian Forest Research 14:233-237.

SAS. 1989. STATS /SAS guide for personal computers. Vol. 6. Cary, NC: SAS Institute Inc. 378 p.

Sharpe AL, Howes REJ, Mason WL. 1990_ Early forest performance of roughly handled Sitka spruce and Douglas-fir of different plant types. Scottish Forestry 44:257-265.

Tabbush PM. 1986. Rough handling, soil temperature and root development in outplanted Sitka spruce and Douglas-fir. Canadian Journal of Forest Research 16:1385-1388.

Takahashi H, Jaffe MI. 1984. Thigmomorphogenesis: the relationship of mechanical and perturbation to elicitor-like activity and ethylene production. Physiologia Plantarum 61:405-411.