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Development of Multiple Leaders in Sitka Spruce and Japanese Larch Following Outplanting

INFORMATION NOTE

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SUMMARY

A series of five experiments was initiated to investigate the development of multiple leaders following simulated browsing/ weevil damage to three size classes of Sitka spruce and Japanese larch immediately after planting. The results showed that multiple leaders developed following leader damage and that larch had a much stronger inclination to revert to a single leader than Sitka spruce. The potential loss of sawlog production due to double stems persisting to time of harvest could be between 10.3–28.0% depending upon site and rotation length.

INTRODUCTION

Damage sustained during the early years of tree growth has long been associated with the development of multiple leaders (Baldwin, 1993). Trees that retain multiple leaders from an early age produce smaller dimension timber and also have an unusable section of stem around the fork. The combined effect is to significantly reduce the value of the timber compared to an equivalent single-stem tree.

It is not known how effectively Sitka spruce (SS) or Japanese larch (JL) will self-single after damage to the leader. A series of experiments was set up to determine how these two species recovered from simulated browsing/ weevil damage soon after planting. The experiments also investigated the effects of initial plant size on persistence of multiple leaders and subsequent height growth.

METHODS

Tree seedlings of two species, SS (1u1, Queen Charlotte Island origin) and JL (1u1 stock from UK registered seed stands: JL83(1013) and JL90(4001)) were grown under different nursery regimes (i.e. by manipulating nutrition and sowing date) to produce the maximum size range, using standard nursery practice. Plants were then graded for uniformity into three size classes which were representative of the stock sizes available to forest managers. (Table 1a, b).

Three different restock sites were chosen to represent a typical range of climatic and site conditions (Table 2). All plants were treated with insecticide to protect against weevil attack and the sites were fenced to reduce mammal browsing.

Table 1a Sitka spruce size classes

Size class	Height (cm)	Root collar (mm)
Small	15–25	3.0–3.5
Medium	25–35	4.0–4.5
Large	35–45	>5.0

Table 1b Japanese larch size classes

Size class	Height (cm)	Root collar (mm)
Small	15–25	3.0–4.0
Medium	35–40	4.5–5.5
Large	45–55	>6.0

Experiments were planted out in four replicated, randomised blocks during April 1994. Treatments to simulate leader damage were applied one week after planting to half of the plants. Trees in these simulated damage plots had their leading shoots removed to either 5 cm (SS) or 10 cm (JL) above ground level. Non-damaged trees received no treatment at this time. Tree height, survival and percentage of trees with more than one leading shoot were assessed at one, two, three and six years after planting.

The potential effect of double-stem trees on volume output of sawlogs at the end of rotation was investigated further for SS by assuming a number of allocation categories (i.e. ratios of biomass allocation to persistent double stems). These categories were then applied to trees across three hypothetical sites by varying yield class (YC) and rotation length, for a standard (2 m spacing, no thin) cultural regime: this was thought to be the most likely management regime to allow persistence of double stems.

Table 2 Restock site conditions

Restock site	National grid reference	Elevation (m above sea level)	DAMS (windiness)	Moisture deficit (mm)	Restock description
West of Scotland (Cowal)	985675	76	12	110 (wet and cool)	Planted on mounds with JL and SS
Northeast England (North York Moors)	942928	125	13	160 (dry and cold)	Planted on old ploughing with JL and SS
South Wales (Gwent)	249273	465	14	60 (warm and wet)	Planted on old ploughing after scarification with SS

RESULTS

Initial tree size

Sitka spruce

Height
At every site, for all treatments, the large-sized planting stock retained a significant height advantage over the small stock for the six-year period (Figure 1a).

Survival
Large trees had significantly better survival than the small trees for SS at Cowal (Figure 1b).

Multiple-leaders
Only one site (Cowal SS), had a significant effect of initial plant size on the percentage of multiple leaders remaining at year six: trees from the large-size class had more multi-leaders than the others (data not shown).

Japanese larch

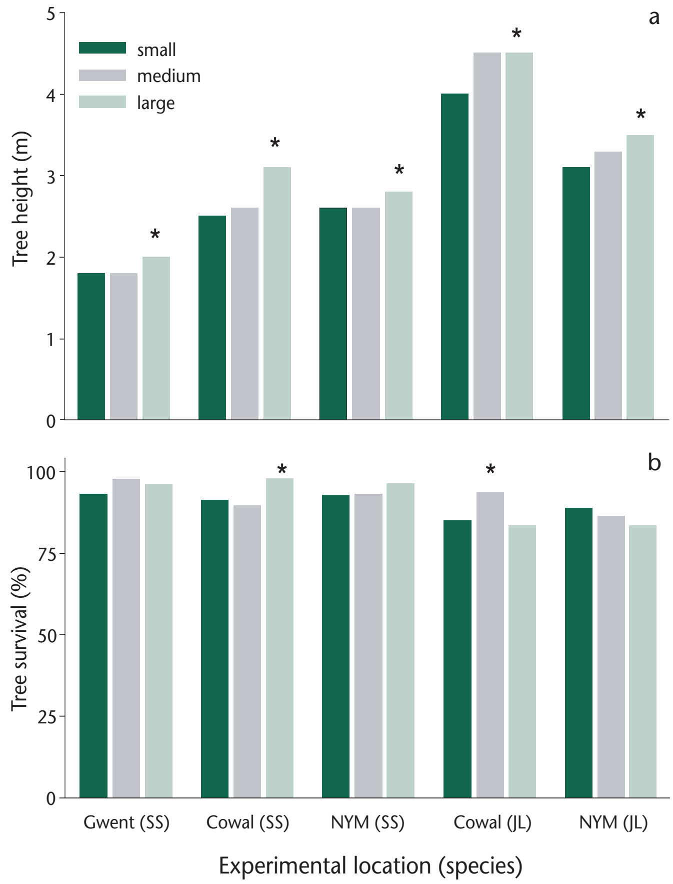
Height
As with SS, the large initial size classes retained a significant height advantage over the small for the six-year period (Figure 1a).

Survival
Medium initial tree size had significantly greater survival at one site (Cowal JL). The large trees had the poorest survival on both sites (Figure 1b) although this was not statistically significant.

Multiple-leaders
There were no significant effects of initial plant size on the percentage of multi-leaders produced (data not shown).

Figure 1

The effect of initial stock size on tree height (a) and survival (b), at year six (* = $P < 0.05$ compared with small stock)



Leader damage

Sitka spruce

Height
All trees subjected to the simulated damage treatment had significantly reduced height growth over the six years compared with the undamaged trees.

Survival
Plant survival at the end of six growing seasons was variable: the only significant result was at Cowal where undamaged trees exhibited improved survival (95% undamaged compared with 88% for damaged stock, irrespective of initial plant size).

Multiple leaders
Not all damage resulted in multiple leaders at the end of the first year though damaged seedlings had significantly greater numbers of multi-leader stems than undamaged trees. The percentage of trees with multiple leaders declined gradually from year one to year three, but then stabilised at between 40–65% through to year six (Figure 2). Between 10–20% of trees in the control treatment developed multiple leaders by year six.

Japanese larch

Height
Undamaged trees had significantly better height growth than damaged trees in both experiments by year six.

Survival
Undamaged trees survived significantly better for JL at Cowal, assessed at year six.

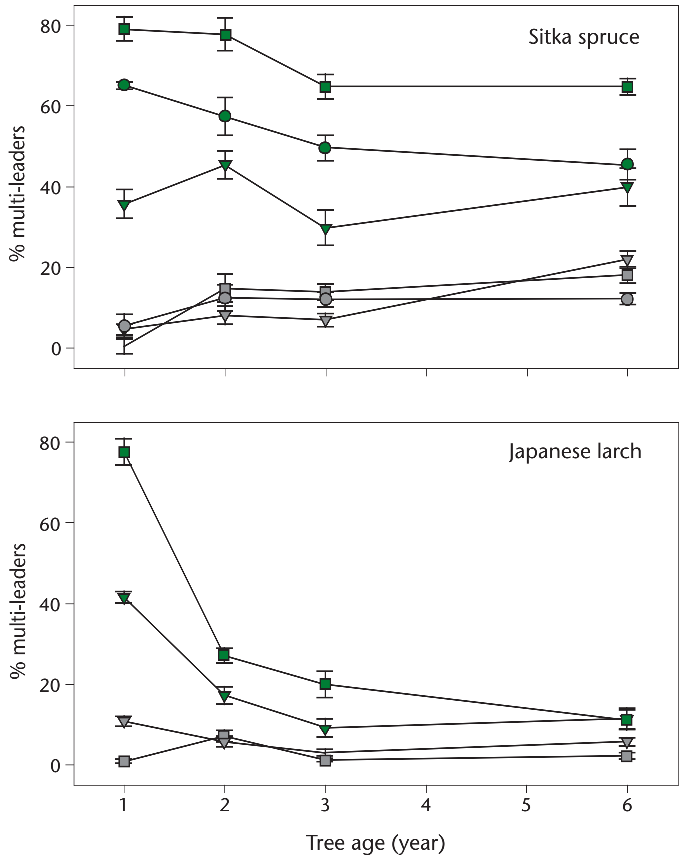
Multiple leaders
Initially a significantly greater number of multi-leader trees were present in the simulated damage plots compared with the control plots (*P* <0.01). The percentage of multiple leaders reduced dramatically from year one to year three, and then continued to decline to year six in JL at North York Moors. At Cowal there was a slight increase in multiple leadering in both control and damaged trees between years three and six. A significant treatment difference was still evident at year six (Figure 2, *P* <0.05).

Full-rotation analysis

The potential effect of persistent double stems upon sawlog production for SS over typical rotations was analysed. In Figure 3 we represent the biomass allocation between two persisting stems and compare this with a single stem 'mean tree'. The mean tree is derived from three yield class scenarios based on the published yield models and assortment tables (Edwards and Christie, 1981). The effect of a double stem for three different situations was calculated: a) 50:50 allocation, where biomass is divided equally between the two stems; b) as a), but with a processing loss of 1 m from the bottom of the stems; and c) 25:75 allocation, where one stem achieves partial dominance. There is an assumption that biomass partitioning to the stem(s) remains constant across different yield class and growth conditions. The simulations are all calculated for an unthinned stand at 2 m spacing, i.e. where double stems are not removed during the rotation.

Figure 2

The percentage of multi-leader trees over time for Sitka spruce, and Japanese larch. Treatments are denoted by: green symbols (damaged) and grey symbols (control). Sites are: Gwent ●, Cowal ▼ and North York Moors ■. Error bars are ±1 S.E.



Under all the scenarios tested there was a reduction in sawlog outturn, on a per tree basis (Figure 3). Analysis of sawlog production per hectare shows that the effect of persistent double leaders is more serious when shorter rotations and/or smaller tree sizes are considered (Table 2). For levels of multi-stems reported in Scotland (Gill *et al*., 2000) in a YC14 stand, sawlog outturn is reduced by 23% in both of the double stem allocations. By contrast, on a YC18 site and a longer rotation, the sawlog outturn is reduced by 9.8–12.3%, depending on the biomass allocation between the double stems. Such differences do not allow for any increase in the incidence of compression wood within multi-stem trees.

Figure 3

The effect of various double stem scenarios, assumed to persist to harvest, upon 'mean tree' sawlog volume in unthinned Sitka spruce grown at 2 m spacing. A range of yield classes is compared. This produces three (notional) 'mean tree' volume scenarios. See text for further details.

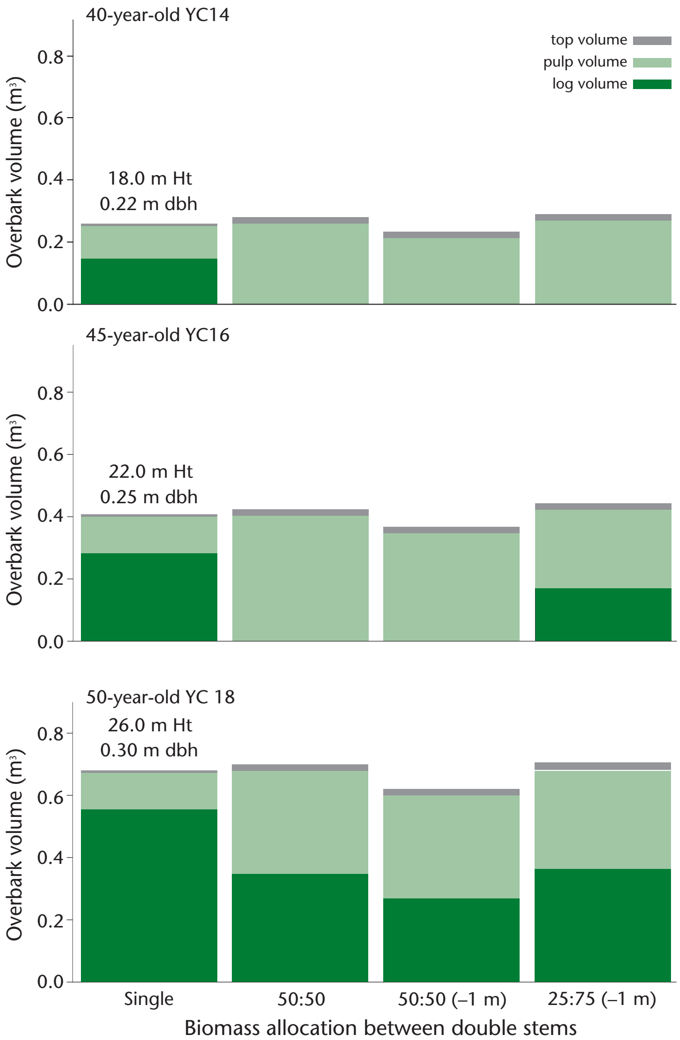


Table 2

Loss in sawlog outturn for Sitka spruce estimated for levels at which multi-stems have been reported in Scotland.

Site yield class scenario	Volume loss in sawlog outturn [volume gain in pulp] (%)	
	Biomass allocation between double stems	
	50:50 (–1 m)*	25:75 (–1 m)*
YC14 40 years old	28.0 [36.0]	28.0 [39.0]
YC16 45 years old	25.5 [53.0]	12.3 [26.0]
YC18 50 years old	12.7 [42.0]	10.3 [31.0]

*as previously noted: calculated to account for a processing loss of 1 m from the bottom of the stems.

DISCUSSION

Initial stock size

These studies corroborate earlier studies in showing that large stock sizes will maintain height advantage over smaller initial size planting stock up to year six (Nelson, 1990; South and Mason, 1993). This appears not only to be the case for SS on new planting sites, as previously reported, but is also evident in JL and across the studied range of climatic and site types.

Large (class) initial plant size did appear to have a small negative effect on JL survival, while SS of large initial size tended to exhibit higher survival rates. It therefore appears that the manipulation of nutrition to produce the larger size class continued to provide a growth benefit at year six. However this finding should be interpreted with caution, regarding the benefits which might be attained by using large stock of an older age class, where root:shoot ratio is likely to be reduced.

In general, initial tree size did not affect the production of multi-leaders in either the damaged or control treatments. Welch *et al.* (1992) studied the interaction between initial tree height and the incidence of physical (deer) damage after planting on leader growth in SS. They recommended that trees of >30 cm (preferably >40 cm) were used as these produced the greatest compensatory regrowth after damage, therefore spending less time exposed to further browsing. Repeat browsing has also been reported to occur preferentially (Welch *et al.*, 1991).

The main implication for forest managers is that larger planting stock of both SS and JL will retain a height advantage over smaller initial stock for at least a period of six years. There should not be any detrimental effect on survival with SS assuming good planting practice is followed. However, use of large size JL planting stock does appear to have some negative effect on survival.

A definitive recommendation for initial stock size cannot, however, be made as seedling establishment success and survival is often poorly related to morphological attributes alone (e.g. Mason, 1991). Secondly, initial planting stock size must take into account site-specific climatic constraints such as exposure and frost risk (Tabbush, 1988). Furthermore, second rotation sites are likely to incur heavy *Hylobius* infestations and, under these circumstances, will benefit from planting stock with large root collar diameters.

Leader damage

Several factors are known to cause damage to leaders, either in nurseries or after planting. These include deep planting, insect damage (particularly by *Hylobius*), mammal browsing, frost damage and physical breaks by high winds or snow (Gross, 1983). Simulated leader damage reduced SS and JL height growth at all sites over the six years studied. Damage reduced survival for both species at Cowal but not elsewhere. Basal sweep was also noted in JL at Cowal, most likely due to the exposure of the site.

JL exhibited the ability to rapidly self-single and, by year six, the percentage of JL trees with multi-leaders had fallen to 11% at both sites. SS did not show the same ability as JL to self-single, with only a slight reduction in the number of multiple leaders from year one to year six.

Implications of multiple leaders

The presence of multiple leaders may not be of primary importance in young trees, and if the species were able to self-single within a few years then the implications (at harvest) for volume outturn would be minor. However this study suggests that, for SS, multiple leaders may persist for many years leading to a reduction in timber quantity and quality.

It is clear that, even without allowing for wastage at the fork, the volume of sawlog material is always reduced when multiple stems are present. The amount of loss depends on tree size and the proportion of biomass allocated to each stem. Where double stems persist and reach log size, there will be an increased occurrence of compression wood formation and likelihood of eccentric pith. Thus the resulting timber is less suitable for conversion into battens. Apart from the loss in sawlog production, we conservatively estimate whole product outturn loss of 0.27–13.3% ha^{-1} across the range of simulated age–yield classes analysed. This corroborates estimated product outturn losses reported by Gill *et al.* (2000) in the range 0.8–7.1% ha^{-1} (for 40-year-old YC12 and 60-year-old YC16 SS).

The benefits of singling a young SS crop should be considered in relation to the cost of the operation and the likely benefits in value at the end of the rotation. Costs for singling operations between years three and five can vary between £35 and £150 ha^{-1} depending upon the prevalence of multiple leaders and the size/age of the trees. Given the much higher proportion of multi-stems persisting in SS, singling is more likely to provide an economic return than in larch. For larch, persistent multi-stems (assuming observed levels of 11% at year six) are likely to be removed during thinning, therefore early singling operations are unnecessary. Results presented by Welch *et al.* (1995) suggest that SS may self-single more effectively in thicket and pole stage than in pre-thicket crops, but postponed intervention will result in a continued reduction in timber quality and an increased operational cost which makes later interventions (after 5 years) prohibitively expensive.

Using knowledge of the operational cost of singling, it is possible to compare the (discounted) cost of double stems at product outturn with singling operations early in the life of the crop. By application of this method it is possible to obtain guidance on the time at which it becomes uneconomic to single a particular crop. A knowledge of the following factors is required:

- cost of singling operation (dependent on prevalence of multi-stems and age of crop at the time of intervention).
- site yield class and rotation length.
- knowledge of likely persistence of multi-stems and/or effect upon product outturn (e.g. Table 3).

Table 3

Predicted loss in value for Sitka spruce, estimated for multi-stem levels in Scotland, assuming persistent double stems with biomass allocation 25:75(–1 m)*.

Site yield class	Economic loss in product outturn (% value using 3% discount rate)		
	Rotation length (years)		
	40	45	50
YC16	6.6	2.7	1.9
YC18	5.5	1.8	1.6

*as previously noted: calculated to account for a processing loss of 1 m from the bottom of the stems.

It should be noted that the estimates in Table 3 do not account for reduced value due to increases in the incidence of compression wood which are likely with multi-stem trees.

Preliminary evaluation using costs from Cowal and Trossachs Forest District showed that singling was generally most cost-effective on higher quality sites and with shorter rotations. Singling should therefore be considered for SS stands grown with the primary objective of attaining high-quality timber and for improved genotypes.

CONCLUSIONS

Sitka spruce shows a much poorer ability to self-single compared with Japanese larch, which appears capable of effective self-singling within six years of damage.

The presence of multiple stems, particularly when persisting from early in the rotation, can have a major effect on the quantity and quality of sawlog material at harvesting.

For multi-stem levels reported in Scotland, potential whole product losses for SS are estimated at 0.27–13.3% ha^{-1}, with losses in sawlog outturn at 10.3–28.0% ha^{-1}.

Singling of young crops of SS is likely to be most cost-effective on higher quality sites and with shorter rotations. A knowledge of singling costs (dependent on level of multi-stems and crop age at intervention), site yield class and rotation length and the likely effect upon product out-turn value (Table 3) will allow managers to identify where cost-effective returns are likely from singling operations.

Economic analysis of singling should be considered for SS stands grown with the primary objective of attaining high-quality timber and for improved genotypes.

Multi-leaders in JL are likely to be effectively removed by thinning.

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