Forestry Commission

Research Note

Benefits of improved Sitka spruce: volume and quality of timber

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The increase in timber volume gained from planting improved Sitka spruce stock has been estimated to be between 21% and 29% at the end of a rotation. This Research Note presents the results of new research designed to investigate the impact of improved Sitka spruce stock on quality characteristics which determine the quantity of green sawlogs in the forest and construction-grade timber in the sawmill. The study was carried out using trees close to rotation age from a trial of improved Sitka spruce at Kershope Forest in Cumbria. A number of characteristics relating to growth rate and timber quality were assessed on the standing trees in the forest and the sawn timber obtained from the trees after felling. The volume of green sawlogs and sawn timber meeting the strength classes C16 and C24 was calculated. Three improved lots with respectively the highest wood density, fastest growth rate and best stem form were compared with a control of unimproved Sitka spruce of Queen Charlotte Island (QCI) origin. The results at both the individual tree and per hectare level showed increased sawn timber volumes from improved planting stock without deterioration in construction grade strength requirements. In the best progeny, increases of up to 130% in both green sawlog volume and sawn timber volumes per hectare were predicted with equivalent mechanical properties to the QCI stock.

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Introduction

Improved Sitka spruce (*Picea sitchensis* (Bong.) Carr) planting stock has been available to forest managers in Britain since the early 1990s. Stock can be obtained as either seedlings – grown from seed collected in progeny-tested clonal seed orchards – or rooted cuttings, taken from stock plants raised from seed produced by controlled pollination between progeny-tested parents. Predicted gains in growth rate (expressed as diameter at breast height (DBH)), stem straightness and wood density, relative to unimproved planting stock of Queen Charlotte Islands (QCI) origin, are published for all the planting stock available to the nursery trade (www.forestresearch.gov.uk/treeimprovement).

Lee and Matthews (2004) estimated the volume gain from planting improved stock should be between 21% and 29% at the end of a rotation. To date, there have been no end of rotation data published on the possible gains in quality traits such as stem straightness, the number and size of branches (and therefore knots) and wood density from planting improved stock. These characteristics will affect the proportion of good quality or 'green' sawlogs (Forestry Commission, 1993) produced in the forest, the construction-grade timber produced from these sawlogs, and thus ultimately the economic viability of the investment.

Many different characteristics are known to influence the mechanical properties of timber which is finally determined at the sawmill by a calibrated strength-grading machine. The objective of tree breeders through the first generation of selection and testing of Sitka spruce has been to maximise growth rate and stem straightness whilst minimising the loss of wood density. This has not been an easy task given the generally strong negative correlation between diameter and wood density in Sitka spruce (Lee, 2001). However, Maun (1992) found that, provided branch surface area (and therefore the related knot area and grain deviation) is decreased by 10%, wood density can decrease by as much as 10% before the proportion of timber lengths satisfying construction timber requirements starts to decrease.

This research was designed to further investigate the suitability of improved Sitka spruce planting stock for construction grade timber. In 2004, the opportunity arose to fell trees in an old tree breeding trial which contained sufficient numbers of mature trees to represent a range of individual treatments. A number of characteristics were measured on the mature trees in the different treatments before and after they were felled. A sawmill study was then set up to investigate the variation in timber properties of the improved Sitka spruce. The strength classes of lengths of timber were monitored as they passed through the sawmill to compare the strength of timber from the treatments representing improved Sitka spruce relative to unimproved QCI material.

Methods

The breeding trial used in this study was originally designed to investigate the optimum plot size for future genetic tests. It was planted in Kershope Forest, Cumbria (NY473773) in 1968. The site is at an elevation of 200 m on former grazing land with a peaty-gley soil, annual rainfall of 1400 mm, moisture deficit of 112 mm and 1262 accumulated degree days (>5°C). The trial consisted of trees raised from open-pollinated seed collected from seven different plus-trees, and an unimproved QCI seed lot as a standard control. Despite a variation in plot size, there was a standard square spacing of 1.83 m (6 feet) and there were three complete replications of all treatments across the site. The experiment had never been thinned.

In 2004 when the trees were 37 years old from planting, all surviving trees in some of the larger plots (4 × 4, 5 × 5 and 6 × 6 trees) were measured for DBH. Analysis of these data found no difference or interaction between the different plot sizes and diameter allowing all the trees within these plots to represent a treatment within a replication. Additional assessments of stem straightness (according to Macdonald *et al.*, 2001), an indirect measure of wood density using the Pilodyn gun (see for example Lee, 2001) and grain angle at 1.3 m height (average of values measured on north and south of tree using a scribe and protractor after removal of bark) were carried out on all living trees in the selected block plots.

Resources did not allow all seven families from each plus tree to be felled and processed at the sawmill so the QCI control and three representative families were selected (Figure 1).

Figure 1 Trees selected for felling and more detailed analysis within one of the chosen treatments.

These were:

- Family 2
  The treatment with the straightest stems. Also faster growth rate but with lower wood density than the QCI control.

- Family 3
  The treatment with the largest DBH. Also slightly straighter but with lower wood density than the QCI control.

- Family 4
  The treatment with the highest wood density. Also slower growth rate but straighter stem than the QCI control.

The yield class of each of the selected families was estimated from the height of the seven largest diameter trees in each treatment area (0.07 ha) according to Matthews and Mackie (2006). Twelve trees of 18 cm DBH or greater were randomly selected across each replicate to represent potential sawlog trees making a total of 36 trees felled per treatment. The selected trees were felled and measured for diameter at a number of points along the length of the bole (Matthews and Mackie, 2006) to allow estimation of stem volume (Figure 2). Each felled tree was visually assessed for optimum green log volume (Figure 3) according to Forestry Commission guidance (Forestry Commission, 1993) prior to cutting to a standard log size of 3.1 m. The number and diameter of each branch on the outer surface of the log was measured to allow the knot to surface area ratio (KAR) to be estimated.

Figure 2 Measuring the diameter of a selected tree. This was done at a number of points along the length of the stem to calculate volume.

Figure 3 Assessing the straightness of one of the standard logs (3.1 m).

All logs were transported to a sawmill for processing (Figure 4), where they were cut into standard timber lengths known as battens (50 mm × 100 mm × 3 m lengths). The battens were randomly divided into two samples: one was tested at strength class C16 and one at C24. Timber graded as C16 is used for general construction work and partial load-bearing end uses such as wall studs or framework. Timber graded as C24 is a higher structural grade for higher specification structural applications. Assessment at C16 or C24 was carried out on a standard strength grading machine calibrated according to EN338:2003 (CEN, 2003).

Figure 4 A truck takes the various standard logs off to the mill for processing. The four treatments investigated in this study were colour coded with either blue, green, red or yellow paint.

Results

In general terms of site productivity, the trial at Kershope Forest was on a good quality site. The QCI Control and Family 4 (highest wood density but slowest rate of growth) were predicted to be growing at Yield Class (YC) 22, and the faster growing Families 2 and 3 were predicted to be growing at YC24.

Results are presented both for the trees selected for processing (Table 1) and at a stand level for each family (Table 2). The mean diameters of the processed trees were similar but in some cases the mean green log volume obtained per tree varied significantly. Family 2 (the straightest family) had 42% additional green log volume whilst Family 3 (the fastest growing family) had 29% extra green log volume relative to the QCI control. This additional log volume translates to an additional sawn timber volume recovery per tree of 41% (Family 2) and 20% (Family 3). In contrast, Family 4 (the highest wood density family) had a slightly reduced green log volume (4%) and almost identical sawn timber volume compared to the QCI Control although the differences were not significant. The KARs for the improved progeny were all lower than the QCI Control.

When the random selection of battens from each family were tested against the C16/reject grading criteria all of the lengths from all four families passed and none were rejected (Table 1).

When the second random sample of lengths from each family were tested against the C24/reject grading criteria there was a lower overall pass rate varying from 62% in Family 4 (the highest wood density family) to 74% in Family 2 (the straightest family) with the QCI Control having a pass rate of 70%. However, the differences between families were not statistically significant.

The biggest differences between families occur when variations are compared for all trees at a per hectare level (Table 2). The values on a per hectare basis were calculated by scaling up the figures from Table 1 (based on an equal number of 12 trees per treatment and replication) to reflect the actual number of trees per plot with a DBH greater than 18 cm. As expected, Family 4 had the highest wood density as measured using the Pilodyn gun (i.e. less pin penetration) and Family 2 had the lowest wood density (more pin penetration). The QCI trees and Family 3 had similar wood density which was significantly higher than Family 2 but lower than Family 4. The grain angle measured on the outside of the stem was slightly better (lower value) for Families 2 and 4. All three of the improved families were on average straighter than the QCI.

The number of surviving trees per hectare was similar for the improved families and these were all higher than the unimproved QCI. The increased mortality in the QCI material together with smaller average DBH resulted in a lower basal area.

Table 1 Results for processed trees (36 trees >18cm DBH for each family).

Treatment	Mean DBH of selected trees (cm)	Mean green log volume (m^3)	Green log volume against QCI (%)	Mean batten volume (m^3)	Batten volume against QCI (%)	Average log KAR%	C16 pass rate (%)	C24 pass rate (%)
QCI	23.6	0.229[a]	100	0.102[a]	100	0.22	100[a]	70[a]
Family 2	24.4	0.325[b]	142	0.145[b]	141	0.16	100[a]	74[a]
Family 3	25.3	0.294[a,b]	129	0.119[a,b]	120	0.18	100[a]	67[a]
Family 4	22.0	0.220[a]	96	0.103[a]	101	0.15	100[a]	62[a]

Table 2 Results at stand level (based on all living trees).

Treatment	Yield class	Mean DBH (cm)	Pilodyn penetration (mm)	Grain angle (°)	Mean straightness score	Trees/ha	Basal area/ha (m^2)	Predicted green log volume/ha (m^3)	Predicted green log volume/ha against QCI (%)	Predicted batten volume/ha (m^3)	Predicted batten volume/ha against QCI (%)
QCI	22	20.7[a]	17.1[b]	1.9	3.9	1559	56	219	100	98	100
Family 2	24	22.2[b]	18.5[c]	1.7	4.5	2097	84	515	235	229	234
Family 3	24	22.2[b]	17.2[b]	1.9	4.3	1913	79	401	183	163	166
Family 4	22	19.9[a]	14.9[a]	1.5	4.7	2012	66	296	135	139	142

a, b, c figures with different superscripts are significantly different; those with the same superscripts show no significantly difference; P=0.05.
No superscripts indicates significance tests either not carried out or not possible.

The consequence is that differences in the green log and sawn timber volumes available from the improved planting stock are much higher on a per hectare basis than on an individual tree basis. The result is that for Family 2 there is a prediction of an extra 135% in both green log volume and batten volume per hectare compared to the QCI control. The figures for Family 3 were predicted as 83% more green log volume and 66% more batten volume. Even the slower growing, higher wood density family (Family 4) had a predicted increase in green log volume of 35% and batten volume of 42% compared with the QCI control, at a per hectare level.

Discussion

The results of this study indicate that improved Sitka spruce can produce increased volumes of sawlogs and sawn timber with no decrease in the pass rate at C16 or C24 strength classes. Increases of green log volume of up to 42% at an individual tree level and 135% on a per hectare basis were measured for the straightest, fast growing family despite an (indirect) assessment of a significant reduction in wood density relative to the QCI control. The volume increases on a per hectare basis should be treated with some caution because the small size of the plots may have led to higher than usual mortality in the QCI trees if they were overshadowed by faster growing neighbours. However, comparing the QCI mortality with standard yield tables (Edwards and Christie, 1981) suggests that it is very close to what would be expected. The reasons for the large increase in sawn timber from green logs on a per hectare basis is a combination of increased green log volume from individual trees because they are straighter, a lower mortality in the improved families and a larger average tree diameter so that a greater percentage of trees are able to potentially produce sawn timber (i.e. DBH>18 cm).

The breeding programme has made general improvements in the straightness of the trees and the grain angle of the wood, both of which will be beneficial in reducing distortion following kiln drying. Increased straightness and volume growth in Families 2 and 3 resulted in greater green log volume recovery at an individual tree level. Although there was increased straightness in Family 4, there was a decrease in average growth rate (probably due to selection for increased wood density) and this meant that total green log production for this family was very similar to the QCI control at the individual tree level.

Wood density as measured by the Pilodyn appeared to have no effect on the pass rate of the sawn timber despite a measured decrease in density in Family 2 approaching 10%. In fact Family 4 which had the highest density also had the lowest pass rate at C24 (62%) although the differences between the families were not significant. It appears that the improved straightness and lighter branching (lower KAR) in Family 2 compensated for the reduced wood density resulting in the highest pass rate (74%), as Maun (1992) had predicted.

The material studied here was open-pollinated trees collected from a small sub-selection of plus trees. The genetic gains and between-tree variation for size and quality should be typical of planted stock raised from seed collected in a tested clonal seed orchard or cuttings raised from a bulked family mixture. A more recent source of improved material is the full-sibling family which is a single-pair mating between a known mother and father; both of tested genetic superiority. These full-sibling families will have less variability between individuals and potentially an even greater production of green logs than measured here (Lee, 2006).

Conclusions

This study has demonstrated that improved Sitka spruce can offer substantial increases in the volume of green logs and sawn timber produced at an individual tree level, but particularly at a per hectare level, at close to rotation age – relative to unimproved QCI material. This increase in volume is obtained with no significant differences in strength-grading pass rate at the sawmill meaning the improved material is at least comparable to unimproved QCI in terms of suitability for construction grades.

The study has confirmed the findings of Maun (1992), that trees selected for a relatively fast rate of growth and consequent small decrease in wood density, but with well above average stem straightness and reduced knot:surface area ratio, will show no significant decrease in construction grade pass rates at the sawmill. The volume per hectare of battens satisfying the various construction strength classes will however be substantially increased as a result of the selection pressures imposed by the tree breeders.

This study was based on trees harvested from a single site. Caution is required before extrapolating these figures to the whole of Britain where improved Sitka spruce could potentially be grown. However, it is clear that tree breeders can select for Sitka spruce parents (plus trees) which will produce faster growing, straighter trees. Forest managers can also be confident that a small decrease in wood density will not result in a decrease of the proportion of battens meeting the C16 and C24 machine strength-grading criteria at a sawmill.

References

CEN (2003).
Structural timber – strength classes. EN 338:2003. European Committee for Standardization, Brussels.

EDWARDS, P. N., CHRISTIE, J. M. (1981).
Yield models for forest management. Forestry Commission Booklet 48. Forestry Commission, Edinburgh.

FORESTRY COMMISSION (1993).
Classification and presentation of softwood sawlogs. Forestry Commission Field Book 9. HMSO, London.

LEE, S.J. (2001).
Selection of parents for the Sitka spruce breeding population and the strategy for the next breeding cycle. *Forestry* 74, 129–143.

LEE, S. J. (2006).
'It's a family affair' *Forestry and British Timber*, December, 14–16.

LEE, S.J. and MATTHEWS, R. (2004).
An indication of the likely volume gains from improved planting Sitka spruce stock. Forestry Commission Information Note 55. Forestry Commission, Edinburgh.

MACDONALD, E., MOCHAN, S. and CONNOLLY, T. (2001).
Protocol for stem straightness assessment in Sitka spruce. Forestry Commission Information Note 39. Forestry Commission, Edinburgh.

MATTHEWS, R and MACKIE, E. (2006).
Forest mensuration: a handbook for practitioners. Forestry Commission, Edinburgh.

MAUN, K.W. (1992).
Sitka spruce for construction timber: the relationship between wood growth characteristics and machine grade yields of Sitka spruce. Research Information Note 212. Forestry Commission Research Division, Farnham.

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