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Predicted Genetic Gains from Sitka Spruce Production Populations

INFORMATION NOTE

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SUMMARY

Genetically improved planting stock from tested clonal seed orchards and vegetatively propagated family mixtures has been available to forest managers since the early 1990s. Genetic gains vary from 8% height and 2% stem form at 10 years old (early seed orchard) to 20% diameter and 15% stem form at 15 years old (more recent family mixture). Breeding value estimates for wood density of a large number of plus trees are now also available to tree breeders. The General Production Population aims to maximise genetic gains for diameter and stem form whilst preventing a fall in wood density. In order to satisfy the possibly varied demands of forest managers, alternative production populations will be available from spring 2000, which will offer additional gains in wood density and stem form respectively. Gains for stem diameter may be more modest from these alternative sources.

DEFINITIONS

Production populations:

Collections of individuals brought together to inter-mate. This may be through wind-pollination as grafts in a clonal seed orchard, or artificially using controlled pollination to produce family mixtures for vegetative propagation. The component trees have been identified as the very best of the original plus trees which have been re-selected for the breeding population based on the performance of their progeny in comparative trials.

Predicted genetic gains:

These are estimated gains. They have not been measured directly but have been calculated as the mean breeding value of the component trees in the production population. Breeding values are estimated from data collected in progeny tests (Lee, 1992, 1994). Predicted gains for Sitka spruce production populations in Britain which are thought to be of a Queen Charlotte Islands (QCI) origin are usually expressed as a percent deviation from the unimproved QCI control present in every test.

Realised gains:

Gains can only be quoted as actual or realised following trials in which the superiority of the improved material is assessed relative to unimproved controls. Such trials are referred to as Genetic Gain Trials (Lee, 1994).

INTRODUCTION

1. The genetic improvement of Sitka spruce started with the selection of plus trees in 1963. Nearly 1800 plus trees thought to be of QCI origin (containing selections known to be of QCI origin or selections thought to be of QCI origin based on the growth characteristics of their progeny when planted in field trials across Britain) were selected over the next 20 years.

2. More than 200 progeny tests have been established over a 27-year period (1967–1993) in order to estimate the breeding values (or genetic quality) of all these plus trees relative to the unimproved QCI control. A breeding population of 240 of the top-ranked plus trees now exists and is referred to as the General Breeding Population (GBP). Production populations have been selected from the GBP and are described further in this Note. Plus trees thought to be of Washington or Alaskan origins based on the performance of their progeny across sites, which may be re-selected for either a Southern or Northern Breeding Population, are not considered here.

3. It is almost 20 years since the first Sitka spruce clonal seed orchard (SS 10) was established at Slebech near Haverfordwest (South Wales). Predicted gains from this early orchard are modest (8% for height and 2% for stem form) relative to the unimproved QCI control. Since then, a further eight tested clonal seed

orchards have been established with the most recent (SS 18) being planted in 1989/90 at Rogate (West Sussex) offering predicted gains of 18% for height and 7% for stem form.

4. Since the early 1990s there has been a steady increase in the planting of vegetatively propagated Sitka spruce family mixtures. Tree breeders apply a mixture of pollens collected from 20 plus trees to the female flowers of a further 20 unrelated plus trees. All controlled pollinations are carried out on grafted replicates of the original plus trees maintained in clonal archives. Seed from the controlled pollinations are mixed together and sold to the nursery trade. Stock plants are then raised from the seed. Cuttings are taken from the stock plants and inserted in soil under controlled conditions to produce rooted cuttings that are sold to the forest manager (see Mason, 1992).

5. As new progeny test data are collected and breeding values of plus trees are estimated, a new superior plus tree may be identified and included in the GBP for further breeding work. If a new selection qualifies for the production population and exists as a grafted replicate within a clonal archive then it can immediately be included as one of the 40 clones which make up a family mixture. This is the fastest way to get improved genetic gain to the forest manager. The alternative would be to create a new seed orchard involving the same 40 clones. This would lead to a delay of approximately 14 years while grafted replicates of all 40 clones were produced in the nursery, planted in specially selected sites and maintained until they became sufficiently physiologically mature to yield harvestable quantities of seed (Lee, 1992).

6. Predicted genetic gains for vigour and stem form from vegetatively propagated planting stock have increased steadily over the past 10 years. Family mixtures with predicted gains of around 20% for 15-year diameter and 15% for stem form are now available to nursery managers.

7. Table 1 is a list of the various Sitka spruce production populations that have been created to date. There will be approximately 4 years delay between nurseries raising stock plants from family mixtures and rooted cuttings becoming available to forest managers. Only the oldest seed orchards are yielding harvestable quantities of seed; collections are most commonly made in SS12 and SS13.

Table 1 Predicted gains from Sitka spruce family mixtures and seed orchards

Seed orchard or family mixture	Predicted gain
M0055 M0054 M0052 M0051	22% diameter, >15% stem form
M0046 M0043	22% diameter, 10% stem form
M0038 M0037 M0034 M0030	20% height, 6–11% stem form
SS 18 (Rogate) M0021	18% height, 7–10% stem form
SS 17 (Marches) SS 15 (Tentsmuir) SS 14 (Shobdon) SS 13 (Ledmore) M0014 M0013	15% height, 5% stem form
SS 12 (Ledmore) SS 11 (Slebech)	15% height, 2% stem form
SS 10 (Slebech)	8% height, 2% stem form
Seed stands	2–5% height, unknown stem form
Direct import QCI	Datum. No gain

Note: Figures are given to allow managers to make comparisons across seed sources. All figures are predicted, based on measurements of progeny in replicated tests leading to estimated breeding values of the parent trees relative to unimproved QCI. Gain figures cannot be realised or confirmed until a Genetic Gain Trial has been carried out (Lee, 1994). Gain figures for growth rate were previously quoted in terms of 10-year height, but this was changed to 15-year diameter in 1993; there is however a good correlation between height and diameter at this early age. Stem form is assessed on a 1 (good) to 6 (poor) subjective scale at the individual tree level (see Lee, 1992) and then a mean calculated for that family. If, for example, QCI has a mean score of 3.5, and a family has a mean score of 3.0, this represents a percentage gain of 1-(3/3.5)*100% = 14.3%. Orchard location is given in brackets, e.g. SS 10 is located at Slebech in South Wales.
Forest managers should always contact the nurseries offering genetically improved planting stock and ask for details regarding predicted genetic gains.

MULTI-TRAIT SELECTION

8. All the clonal seed orchards, and the very first family mixtures produced by controlled pollinations for vegetative propagation, were created without any data on estimated plus tree breeding values for wood density. This is because the trees in tests at that time were considered too young to give reliable estimates. Since the mid-1980s all progeny greater than 15 years from planting have been assessed for wood density as

well as 15-year diameter and stem form. From 1992 to the present (1999), final selections for the GBP and production populations, considered suitable for areas where QCI origin material can be planted, have been based on a combination of all three characters using multi-trait selection index techniques (Lee, 1997).

9. The industry requires fast growing, straight trees with high wood density. The strong negative genetic correlation between trees selected for stem diameter and wood density (r = -0.7; Lee, 1997) makes the concurrent improvement of these two characters difficult, but not impossible. Stem form, however, has a neutral correlation with both stem diameter and wood density making concurrent selection for either of these trait combinations relatively straightforward (Lee, 1995).

10. Multi-trait selection of Sitka spruce has been directed at selecting parent trees which, when mated together, maximise the predicted gain for 15-year diameter and stem form whilst preventing a fall in wood density. Such production population are referred to as the General Production Population (GPP). All Sitka spruce family mixtures sold to commerce since January 1994 have been in accordance with these objectives.

ALTERNATIVE PRODUCTION POPULATIONS

11. Whilst tree breeders can speculate on what constitutes the best combination of traits for production populations required to satisfy future construction markets, this may not agree with the expectations or aims of all forest managers. In order to satisfy the possible range of customer requirements the Tree Improvement Branch of Forest Research will produce a choice of alternative production populations by altering the weighting placed on stem form and wood density within the breeding population. Family mixtures designed to show additional increases in (i) stem form and (ii) wood density relative to the GPP will be made available to nursery managers from spring 2000.

12. Table 2 gives the theoretical maximum predicted gains that should be available from controlled pollinations carried out in clonal archives assuming all the re-selected plus trees in the respective production populations exist as flowering grafts or pollen in store.

Table 2 Theoretical maximum predicted gains from alternative production populations

Production population	Diameter	Stem form	Wood density
General Production Population	22%	16%	0%
High stem form	15%	20%	0%
High density	10–15%	15%	9%

Maximum gains in the High Stem Form and High Density production populations will not be available until after all the first generation of progeny tests have been evaluated for all three traits (approx. 2005) and physiologically mature grafts of subsequent selections are available in clonal archives (approx. 2010). In the meantime controlled pollinations will still be carried out with the best available material to produce family mixtures for the nursery trade, although predicted gains for the favoured traits will be more modest.

13. Relative to predicted gains quoted for existing family mixtures, the scope for further improvement in the GPP is limited; only stem form is expected to increase slightly. Further gains will have to await the introduction of superior pair-matings. Progeny tests to identify particularly good pair-matings have been planted and the best ones should make their way into the GPP in about 5 years time (Lee, 1997).

CONCLUSION

14. Genetically improved Sitka spruce planting stock derived from seed harvested in seed orchards or rooted cuttings from family mixtures is now widely available.

15. Since 1994 production populations have been selected to maximise stem diameter and stem form whilst preventing a fall in wood density. Such production populations are referred to as the General Production Population.

16. Tree breeders are now selecting alternative production populations of parent trees to improve gains for either stem form or wood density at the expense of a slight decrease in gains for stem diameter.

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