Clonal Forestry – A View to the Future

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INTRODUCTION

The term clone can be defined as "genetically uniform material derived from a single individual and propagated exclusively by vegetative means" (Hartmann et. al. 1975). While clones may appear to be artificial they in fact do exist in nature. Many herbaceous species that reproduce by bulbs, rhizomes and runners form clones. Clonal varieties of food and ornamental crops have been used in agriculture and horticulture for centuries and today form a significant proportion of all varieties available to farmers and nurserymen. The success of these varieties lies, not only in the characteristics of the products they produce but also, in the ease with which they can be propagated. By contrast, clonal varieties of forest trees have, with a few notable exceptions proven difficult to develop. The main reason being that vegetative propagation, through the rooting of cuttings from mature trees, is problematic and has not presented foresters with the opportunity to develop clonal varieties for specific sites or end uses.

Early attempts at rooting cuttings from old trees that possessed superior characteristics generally resulted in failure or, if successful, the rooted cuttings tended to grow for many years with a plagiotropic or branch like habit. As a result most tree species are grown from seed, the few exceptions are poplars, willows and *Cryptomeria japonica.* These species have been propagated vegetatively for many years and numerous clonal varieties exist today. However, the coniferous and hardwood species that are the mainstay of forestry in the northern hemisphere have proven difficult to propagate vegetatively on a commercial scale. But what was once considered as impossible is now proving to be technically feasible, as a result of two main factors:

- The use of mist propagation units has greatly increased the success of rooting cuttings on a commercial scale.

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- The realisation that it is not necessary to start developing clonal varieties from mature trees but the selection of young individuals from genetically superior populations can overcome the problem of low rooting success experienced with old material.

The Potential Uses of Clones in Forestry

The use of clonal varieties of the major tree species would provide foresters with many new opportunities. Considerable genetic gains could be achieved in traits such as growth rate, adaptability, branching habit, timber quality, insect and disease resistance, to name but a few.

Clonal varieties could be developed for specific end uses for example:

- a variety that could withstand severe exposure.
- one that could combine a high growth rate with acceptable timber density.
- a clonal variety that is more efficient than seedlings in its uptake and use of nutrients.
- a deep rooting clonal variety that would offer increased stability on windy sites.
- a variety with resistance to *Fomes annosus* that could be planted on heavily infested sites.
- clonal varieties suitable for Christmas trees and foliage production.

The opportunities are numerous and are only bounded by the limit of genetic variability that exists in a species. Many studies have been undertaken with tree species to examine the degree of genetic variability that exists in traits that are of economic importance. In many cases this is very substantial, but is often difficult to exploit easily through improved seed due to difficulties in flowering. Also with seed, segregation of genes occurs and it is often not possible to reproduce all individuals with the desired combination of traits.

The use of clones can overcome these problems since vegetative propagation will faithfully copy the individual genotype and is independent of sexual reproduction and its associated problems.

Techniques of Propagation

Clonal forestry by implication means vegetative propagation and consequently requires a different approach to plant production methods than those used for seedling stock. There are several methods of vegetative propagation but at present, rooting cuttings is the only method that can be used to economically produce plants in quantity.

The ease with which rooted cuttings can be produced on a commercial scale depends greatly on the species and the age of the material to be propagated. Among the major commercial conifer species which form the bulk of our forest development programme the spruces and larches are the easiest to root, with the pines and Douglas fir being the most difficult. As a result, the only large scale conifer vegetative propagation programmes underway in Europe are those for spruce. Attempts at producing cuttings of Douglas fir and pine commercially have not met with much success. The only notable exception among the pine species is Monterey pine which is currently being propagated vegetatively on a large scale in New Zealand.

Physiological age can also have a major effect on the ease with which material can be rooted. Generally the younger the material the greater the ease with which it can be propagated. Good rooting percentages are possible with trees aged 10 years or less, but after 10 years rooting success diminishes rapidly. Consequently, considerable effort is being expended in order to maintain selected clonal material in a juvenile and thus easily rootable state.

The spruces are potentially the most important species for clonal forestry in this country. The propagation techniques described below will largely refer to those being employed by the Forest Service to raise rooted cuttings of Sitka spruce.

In order to achieve a consistent and repeatable high rooting success with spruce cuttings it is necessary to provide an optimum set of environmental conditions namely:

1. A humid environment – when cuttings are detached from the donor plant they continue to respire, therefore, to minimise water loss during the vulnerable period when roots are being formed they must be placed in a very humid environment. This is usually achieved by placing them under intermittent mist in a glasshouse or polyethene tunnel.

2. Rooting medium – generally a good rooting medium must:
- be able to keep cuttings in a vertical position
- have good drainage but at the same time have sufficient water content
- have good aeration

Spruce can be rooted in a wide range of rooting media. Those most commonly used consist of either pure fine gravel or a mixture of drainage such as gravel, sand or perlite with a

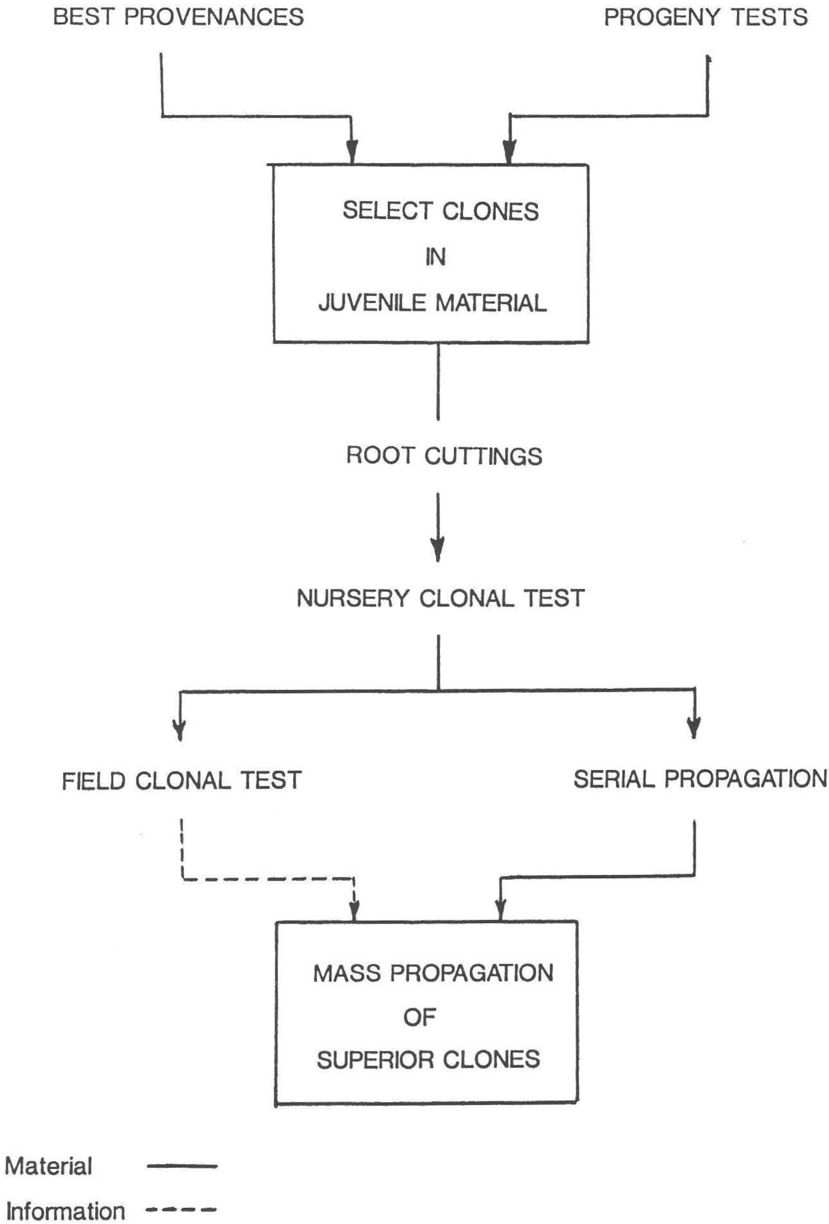

Figure 1 Outline of Sitka spruce clonal testing programme.

moisture retaining material such as sphagnum peat. The ratio of drainage material to peat depends on individual preference but a medium consisting of 20% peat is recommended when propagating under mist (Mason 1984).

3. Temperature of rooting medium and the air.
A temperature at the base of the cuttings of 18°-20° is the optimum for callus formation and will speed rooting over lower temperatures. Air temperature around the cuttings can be lower to lessen transpiration. This is not absolutely necessary and providing temperatures do not rise above 35°C for prolonged periods and humidity in the rooting house is high, a wide range of temperatures is tolerable.

4. Adequate light levels.
Light is necessary for photosynthesis and also for a good rooting response. Excessive shading can have an adverse effect on rooting as can high light intensities. However, normal light intensities experienced during the growing season are adequate for practical purposes but a light shading is often necessary to reduce the effects of sun scorch on cuttings.

The cheapest and most commonly used propagation structures for the rooting of cuttings are polyethene tunnels equipped with heated propagation beds and mist irrigation (Fig. 1). The propagating beds which contain the rooting medium, either loose or in trays, can be heated by hot water pipes or electrically heated cables. Heating is not essential but does speed up rooting significantly at these latitudes, particularly when dealing with older material. It also minimises the effects of seasonal variation in temperatures and provides constant favourable rooting temperatures. The use of heat allows cuttings to be lined out early in the year and thus achieve a good sized plant at the end of the propagation period. However, young material that is 2-3 years from seed roots very easily and generally does not require heat, thus reducing considerably the cost of production.

Spruce cuttings will root throughout the year but to achieve a high rooting success they are best taken when the levels of endogenous root promoting substances are high. This occurs in spring and again in autumn. Cuttings of 8–10cm are taken from donor plants and inserted into the rooting medium without stripping basal needles. Cuttings are usually treated with a fungicide to prevent fungus attack during the rooting period. They can be treated with auxins if so desired. However, these root promoting substances are not essential when rooting young

Figure 2 Rooting of Sitka spruce cutting under mist.

Figure 3 Clonal differences appearing in 3 year old cuttings of Sitka spruce.

material but are beneficial when dealing with older material (Girounard 1974).

The time taken to root cuttings depends very much on the physiological age of the material and also the environmental conditions, but young material taken in mid March should be rooted, hardened off and ready for transplanting by the beginning of July i.e. a period of 12 to 14 weeks.

The Development of Clonal Varieties

Unlike many of the very early clonal varieties of food and ornamental crops, which were discovered rather than created, clonal varieties of commercial forest trees are largely the result of a planned breeding effort. Large clonal propagation programmes already exist in many of the European spruce growing countries and the common link between them is the fact that they are all closely connected with breeding programmes, the reason being that further improvements in a clone are not possible. It is therefore necessary to have a breeding scheme where traits of economic importance can be improved over time. As these improvements are made new clones can be selected from a breeding population, tested and then mass produced. This is a continuous process and new improved clones can replace those that are aged and less productive.

An outline of the strategy being adopted by the Forest Service to develop clonal varieties of Sitka spruce is shown in Figure 2. This type of scheme is common to many programmes and it involves the selection of superior individuals in the best juvenile genetic material available at the time of selection.

Superior transplants are selected from the nursery stage of progeny tests and also initially from adapted provenances growing in bare root nurseries. The initial selection of plants from the commercial nurseries is usually the best plant out of 1,000-2,000 depending on the material available. A lower selection intensity is used on the material from the progeny tests since it is limited and has already gone through a process of rigorous selection. The cuttings are taken from the plants and rooted to form clones.

The clones are evaluated for growth rate and habit at the end of the second growing season by which time they are fit for transplanting in the field. The best 30-40% of clones are retained, the rest rejected. Plants of the selected clones are divided into two parts. One part is used to establish field trials to test the performance of the clones, the other, to provide cuttings for the second cycle of propagation.

During the field testing stage plants of the selected clones are retained in the nursery and are repropagated every 2 years (serial propagation) to maintain them in a juvenile and hence easily rootable state. At each propagation cycle the numbers of cuttings per clone increases and by the time superior clones are identified from the field tests (at 6 years outplanted) several hundred plants will have been propagated for each clone. Cuttings can then be collected from plants of the superior clones retained in the nursery, mass propagated and used for operational plantings.

Juvenility

The success of the scheme described depends very much on the ability to maintain the clones in a juvenile state. As clones become physiologically mature they become more difficult to root. At present there are no methods available to rejuvenate old clones and reliance must be placed on the ability to arrest the ageing process while the performance of the clones is being tested. Currently two methods are favoured. One is serial propagation already described, the other is hedging, that is the maintenance of low hedges of each clone. These have the advantage over serial propagation of being able to produce considerable quantities of cutting material but their management is more difficult. Inferior clones can be easily dropped from serial propagation but the expense of repropagating clones every 2 years can be considerable. Trials testing both systems have not been in existence long enough to come to firm conclusions although indications are that serial propagation is being favoured (St. Clair et. al. 1985).

Bulking Up

One of the great technical difficulties in propagating selected clones is achieving the situation where a superior clone can be bulked up from a single plant to many thousands available for planting. Conventional cutting propagation described will result in a slow build up of numbers at each cycle of propagation. In the future, however, biotechnology may provide a means of rapidly increasing numbers of plants per clone through tissue culture. John (1986) estimates that a multiplication rate of 0.5 million plants of a single clone can be achieved over a 7 year period. In contrast only 2,500 plants would be available from serial propagation. If, or maybe when, this technology becomes available it will enable tested clones to be rapidly moved into commercial production.

Deployment of Clones

There are risks associated with clonal forestry that at first seem overwhelming because we have such little experience in managing this type of forest. However the risks of clonal forestry can be counterbalanced with the resulting gains. These risks primarily arise from restricting the genetic diversity of plantations when reducing the number of clones from many, to one, or a very few (Thompson 1984). Examples of disasters from growing large areas of unsuitable single clones have been well documented for poplars and *Crytomeria*. In Ireland, the monoclonal biomass plantations of *Salix aquatica gigantia* have been repeatedly attacked by the rust species *Malampsora*. However, the genetic diversity of a clonal plantation is directly under the control of the forester to make it as wide or narrow as he desires. There are two deployment strategies being frequently debated and these are:

- wide spread intimately mixed plantations versus
- mosaics of monoclonal stands.

Early in a clonal programme it is probably prudent to deploy large numbers of clones in intimate mixtures to plantations. The mixture will provide a better safeguard against pest attack and spread and this provides some measure of insurance for success of the plantings. However, several factors argue for mixtures of relatively few clones. These include:

- the possibility of mixing highly selected well known complementary clones to increase unit area productivity
- easier and more efficient nursery management, and
- the possibility of reducing cross adaptation of narrowly-adapted pests following colonisation.

A safe number of clones depends on the rotation size, intensity of management, genetic variability of the species, genetic diversity of clones and the acceptable risk and loss levels of a particular situation. Theoretical evidence suggests that from 7 to 30 clones would be safe for use in a "typical" clonal plantation Liddy (1982).

Concern over the number of clones necessary to make a clonal plantation safe has led to the establishment of government regulations for clonal forestry in some European countries. In Germany, since 1977 clonal plantations must consist of mixtures of tested clones in specified proportions. Sweden has developed similar regulations that allow for fewer clones as more information on clonal preference becomes available (Thompson 1984). At present no unified EC rules on clonal forestry have been established. However, it is probably only a matter of time before these are introduced.

Cost of Production

It has been estimated that the cost of production of vegetatively propagated plants will be 1.5-2.0 times that of seedling transplants (Mason and Harper 1987, Pfeifer 1988). The extra cost arises mainly from the increased labour requirement in the production of cuttings. The collection, preparation and setting of cuttings amounts to approximately a 50% increase in labour over seedling stock. The automation of these operations would greatly reduce costs but machinery has not yet been developed that is capable of doing this task.

While rooted cuttings may initially seem expensive, the extra cost of their production is more than offset by the increased quality and productivity of the crops that they form. Data on genetic gains achievable from clonal varieties of Sitka spruce are limited since little work has been done in this area. However, information from Norway spruce breeding programmes has shown that a 15-20% gain in vigour is achievable over unimproved stock (Kleinschmit et. al. 1977) and indications are that similar gains can be expected with Sitka spruce. Gains of this magnitude when translated into production figures mean a rise of one yield class. The economic effect of this is shown in table 1 when the returns from increasing the mid range of yield classes for Sitka spruce by one unit are presented. A 4% discount rate, the 1974-86 timber price size curve and current establishment costs were assumed.

Table 1: The effect of planting genetically improved planting stock on Net Discounted Revenue (NDR).

Increasing Yield Class From To	Net Profit (NDR) 1987 £/ha assuming cuttings at £200/1000
12 - 14	435
14 - 16	520
16 - 18	600

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