The importance of plant size for successful forest plantation establishment

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- Bare-root stock is grown in nursery beds, then lifted and shipped bare of soil. After one or two years in seedbeds, the seedlings may be transplanted into another bed at lower density to produce larger stock (transplants). Undercutting and wrenching is usually used to improve root development in non-transplanted stock, but these treatments are sometimes used also on transplants.
- Container seedlings are produced in greenhouses, sometimes with additional light and heat. Plug (roots normally bind the medium into firm plug) seedlings are grown in rigid-walled containers and are removed from the containers before planting. Alternatively, degradable soft-walled containers which can be penetrated by roots, are planted with the seedling in the field.
- Choice of stock type depends on factors such as species, availability, planting method and cost. Whatever the stock type, seedlings should be of the best quality, uniform and healthy.
- **Shoot** characteristics such as plant height and stem diameter are easy to measure and describe.
- **Root** characteristics such as volume, length, area of root system, mass, and fibrosity, are more important but more difficult to measure.
- The shoot:root ratio should not exceed 3:1 (dry weight basis) for most species, and is a useful indirect measure of the balance between the transpiration area versus water-absorbing area.

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Introduction

The size of the planting programme in Ireland is still relatively large (*ca.* 22,000 ha in 2001), despite the decline in planting in recent years. Furthermore, there has been a large decrease in the proportion of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) being planted, with a consequent increase in the planting of 'diverse' species. However, these alternative species are generally more difficult to establish than Sitka spruce. Post-planting maintenance (e.g. weed control) may also be high if seedlings that survive grow slowly after planting. The quality of the planting stock used may be contributing to these problems. A brief overview of the potential impact of the morphological (visual) quality of planting stock on post-planting field performance (survival and early height growth) of seedlings is given in this note. The effects of physiological (non-visual) attributes on plant quality are addressed in COFORD Connects, Reproductive Material Note No. 6 (O'Reilly and Keane 2002).

Figure 1: *One year-old seedlings in a bare-root nursery.*

Production systems and stock types

Seedlings planted in the forests or on farmland are produced in nurseries. Most seedlings planted in Ireland are produced as bare-root stock; that is, the stock is lifted from the nursery bed and shipped bare of soil (Figures 1-3). Container seedlings are produced in greenhouses (Figure 4), sometimes using additional light and heat. Occasionally seedlings are raised for a few weeks in a greenhouse and then transplanted into a bare-root nursery. Bare-root stock may be more

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Figure 2: *(left and below) Three year-old transplanted conifer seedlings in a bare-root nursery.*

Figure 3: *Two year-old (non-transplanted) broadleaved seedlings in seedbed in a bare-root nursery.*

Figure 4: *(Right) Containerised Sitka spruce seedlings.*

(Below) Greenhouse used to grow container stock.

sensitive to handling stresses than container stock because their roots are less well protected. Planting stock can be described by its age and method of nursery culture.

Bare-root stock

Bare-root seedlings are grown in nursery beds for two to four years, depending on species and size required, and then dispatched for field planting (Figure 5). The stock may remain in the same seedbed throughout the nursery cycle of production (usually about two years) (Figure 1), or after one or two years in the seedbed it may be transplanted into another bed at a lower growing density to produce larger stock (Figure 2). Some species (such as pines and most broadleaved species) are not transplanted (Figure 3) because the development of the taproot may be distorted (frequently resulting in 'J' shaped roots). Non-transplanted stock is sometimes grown under a regime of frequent root undercutting/wrenching (in which the roots are severed) to encourage root development. However, the quality of the root system of 'undercuts' is likely to vary greatly depending on the intensity of the undercutting/wrenching regime used. Undercutting/wrenching is also sometimes used to further improve the quality of the root system of transplanted stock.

Bare-root stock type is usually described by a two-part code separated by a plus sign (e.g. 1+1, 1½ +1½ , 2+1, 2+2). The first part of the code refers to the number of years (or growing seasons) that the plant was grown in the seedbed (Figure 1), while the second part refers to the number of years spent in the transplant bed (Figure 2). The second part of the code is a zero (e.g. 2+0) if the stock has not been transplanted. However, undercut stock is frequently referred to using the letter 'u' in the code (e.g. 1u1 instead of 2+0). Container seedlings (usually 'miniplugs') that have been transplanted into a bare-root nursery have a letter in the first part of the code, such as 'P' for plug (P+1) or 'MP' for miniplug (e.g. MP+1), or just 'G' for greenhouse (e.g. G+1).

Container stock

There are two main container categories. The most common category is the rigid-walled container. The seedlings are removed from the containers before shipment or planting. The roots bind the medium into a firm mass or 'plug' (Figure 6). The second category is a soft-walled container that is planted with the seedling (e.g. Japanese paperpot, Finnpot) (Figure 6). The roots can penetrate the container walls and the containers degrade after planting. There is a large variety of container types within each category. The size/type of container used depends on species, cost and other considerations (e.g. ease of planting). Container seedlings can be described by their size, container system and container size, but a code is generally not used.

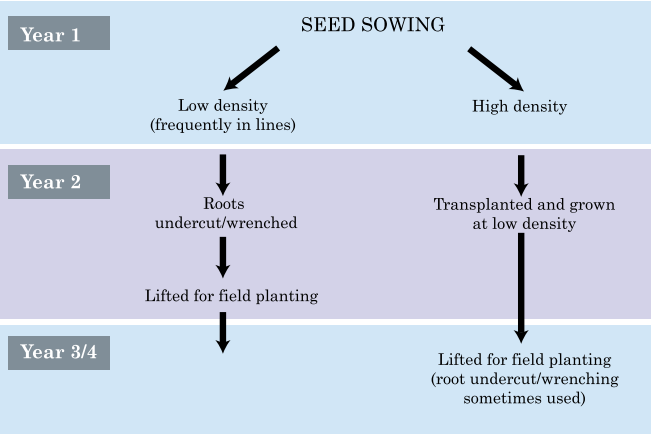

Figure 5: *Schematic representation of main phases of culture from sowing to lifting in a bare-root nursery.*

Figure 6: *Typical examples of some container stock types used in Ireland. The plants shown were grown in rigid plastic container (left) and in Finnpots (right).*

Choice of stock type

There are advantages and disadvantages to using either bare-root or container stock. However container plants are currently more expensive to produce than bare-root stock in Ireland. It is also easier (and probably cheaper) to grow large plants in bare-root nurseries. The advantages of using container stock include reduced land requirements for production, ability to mechanise, more flexible growing and planting schedules (including the ability to extend the planting season), more efficient use of seed, more control over seedling characteristics, shorter production cycle (making it easier to match supply with demand). Container stock is also used with most current reforestation planting machines (Figure 7). There can be disadvantages to using container stock as animals or insects may more easily kill them, if the plants are not protected.

Figure 7: *Machines used for planting container stock.*

Morphological characteristics

The choice of stock type (bare-root or container) used may depend on species, local availability, planting method preferred or cost. It is important that the seedlings should be of the highest quality possible, regardless of stock type used. It is important that differences in plant size are small (plant uniformity), particularly for stock used in mechanical planting. The seedlings should be healthy: leaf and stem colours are often characteristic for a species and damage should be easily identified because parts eaten by insects or infected by fungi are frequently discoloured.

Bare-root stock

Most morphological characteristics are relatively easy to describe or measure, and the most commonly used are plant height and diameter (usually measured near the root collar). Plant height is a useful measure of quality, but it is not consistently correlated with survival and growth after planting (both survival and growth are collectively referred to by the term 'field performance'). While tall seedlings usually out-perform shorter seedlings, the response may be site- or species-specific. Short seedlings may outperform tall seedlings on an exposed site that has little weed competition, but this may vary with stock type and species. The results of research carried out by Coillte in Ireland (Thompson and Lowe 1999b) indicate that Sitka spruce, greater than 40 cm in height, generally performs better after planting than smaller seedlings, but initial height has little effect in Japanese larch (*Larix kaempferi* Carr.) or Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). However, more recent research

(unpublished) has indicated that where site preparation treatment is sub-optimal, taller Sitka spruce plants might perform better than shorter plants. Stem diameter is generally considered a better indicator of quality than height, and it usually correlates better with field performance. Large diameter plants also tend to have bigger root masses, although this may not always be so

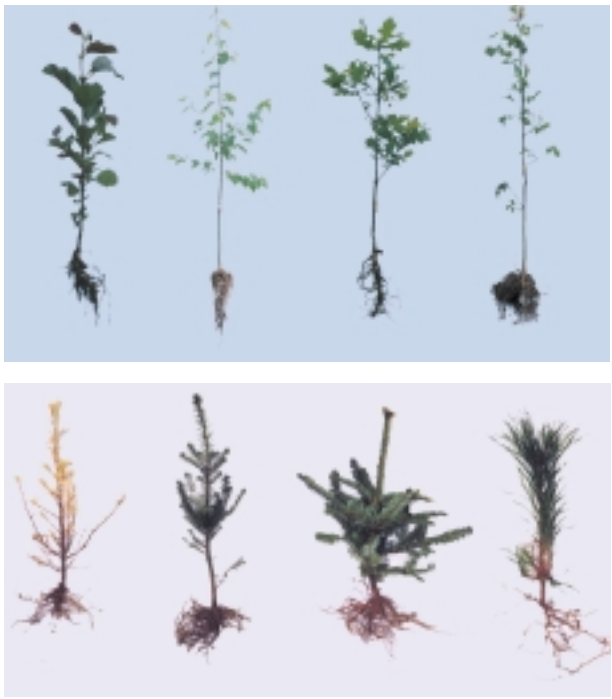

Figure 8: *Typical examples of good quality bare-root planting stock used in Ireland (relative sizes of examples not to scale nor representative). Above: (left to right): alder (Alnus glutinosa), birch (Betula pendula), oak (Quercus robur), ash (Fraxinus excelsior). Below: (left to right): larch (Larix kaempferi), Sitka spruce (Picea sitchensis), noble fir (Abies procera), Scots pine (Pinus sylvestris).*

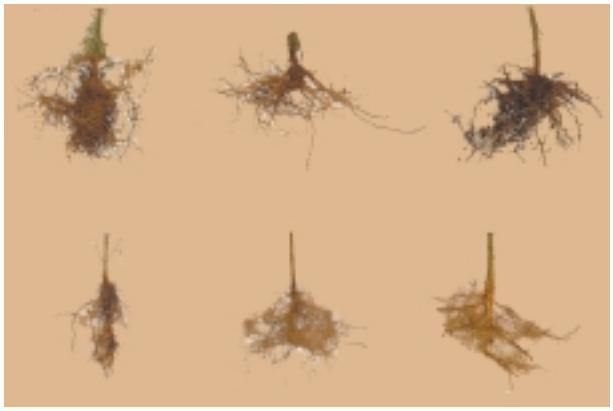

Figure 9: *Close-up of root systems of transplanted (top) and non-transplanted (bottom) bare-root planting stock. The non-transplanted seedlings have a distinct taproot. All plants have a good fibrous root system, but this varies with species (relative sizes of examples not to scale nor representative).*

(e.g. the roots may have been removed during undercutting in the nursery bed or they may have been pruned after lifting). Research by Coillte (Thompson and Lowe 1999a) revealed that ash seedlings (*Fraxinus excelsior* L.) with a root collar diameter of less than 7 mm had poorer survival than those with larger diameters. Similar trends have been observed with Sitka spruce (Thompson and Lowe 1999a). The shoot height (cm): root collar diameter (mm) ratio, or "sturdiness", gives an indication of the balance between seedling height and diameter. This is a useful value, although there are few data from field studies to support this claim. Many other above-ground characteristics can be used to assess quality, including shoot biomass or weight (usually dry weight basis), bud size, foliage colour, needle size and density (Figure 8).

Although the characteristics of the shoot system are important, the quality of the root system is probably far more important. However, it is generally more difficult to measure/describe the root system. The mass, volume, length, or area of the root system can give good information on the quality of the root system. Root mass (usually dry weight basis) is the preferred value, mainly because the others are currently difficult and tedious to determine. Root fibrosity (presence of large proportion of 'fine' roots) (Figure 9) is an important characteristic for many trees species, but root mass measurements may not reflect this if there is a high proportion of woody roots. Fine roots are important because they usually absorb most of the water and nutrients just after planting, and most new roots are initiated from these after planting. However, root fibrosity may be less important for some species (e.g. *Quercus* sp.). The shoot:root (S:R) ratio (usually determined on dry weight basis) is a useful measure of balance between the transpiration area versus water absorbing area. The S:R ratio should not exceed 3:1 for most species. Transplants tend to have a more fibrous root system, larger stem diameter, and lower S:R ratio than non-transplanted bare-root stock of the same age. However, some 'undercut' stock may have similar or superior characteristics to transplants of the same age. The quality of undercuts tends to vary more than the quality of transplants.

Container stock

Container stock can be described using the same morphological characteristics as outlined for bare-root seedlings. Root mass measurements may be a little harder to determine because of the difficulty in extracting roots from the growing medium. The root system should adequately fill the container (Figure 6), holding the medium intact under normal handling procedures (this is especially important for mechanical planting). However,

root 'spiralling', which usually occurs if the plants remain in the container for too long, is also a sign of poor root form. Severe spiralling may lead to root 'strangulation', toppling or the death of the seedling after planting. A higher S:R ratio (*ca*. 4:1) may be acceptable for container stock, perhaps reflecting the higher efficiency of the more protected and less woody root system.

Planting stock sold in Ireland

Nursery stock cannot be sold for forestry purposes in Ireland unless it meets Irish and/or EU standards. The Forest Service has published guidelines on quality limits for transplants of various species. In addition, some companies have their own morphological specifications to augment these guidelines. Most bare-root stock is sold by height category, but a minimum root collar diameter is stipulated for each category. Since the quality of the root system is so important, it is recommended that buyers should inspect the plants, especially the roots, before agreeing to purchase stock.

Conclusions and recommendations

The quality of the plants should be uniformly good, regardless of seedling size or stock type used. The shoot and root systems of the stock must be large enough and in balance so that the seedlings have a good probability of establishing and competing successfully in the field. A good fibrous root system is desirable for most species. Seedlings should be free from defects, such as 'J' roots, and diseases, and appear healthy. If possible, inspect the stock in the nursery before purchasing. In particular, check the quality of the roots system. It is important to be satisfied that the plants conform to Forest Service/EU regulations on quality.

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