Plant quality: what you see is not always what you get

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- Forest seedlings should only be lifted when they are sufficiently dormant to resist the stresses of lifting, handling and storing.
- The root growth potential (RGP), or natural ability of seedlings to grow new roots quickly after planting, is important for most species. High RGP may not be realised if seedlings are damaged during handling or storage.
- Seedlings are sometimes placed in cold storage to prolong dormancy and then dispatched for field planting when required.
- Physiological tests such as root electrolyte leakage (REL) can be used to evaluate seedling quality before planting and indicate the potential field performance of stock.
- Planting quality and site cultivation treatments also influence the success of establishment.

Introduction

Although the morphological (visual) characteristics of seedlings are important (see COFORD Connects Reproductive Material No. 5 [O'Reilly *et al.* 2002]), it is often their physiological (non-visual) attributes that have the greatest effect on survival and growth after planting. The visual appearance of stock may be deceiving, particularly if quality has deteriorated due to adverse handling or poor storage practices after lifting in the nursery. Handling rarely influences morphological quality, although severe shocks can damage roots and other plant parts. Forest seedlings should not be lifted unless they are sufficiently 'dormant' and therefore likely to be more resistant to the stresses of lifting, handling and storing. Most freshly lifted bare-root stock in Ireland is planted during the dormant period, which extends from about November to March or April. In addition to reducing survival and growth, poor seedling quality and/or planting at the wrong time of year may lead to shoot dieback and poor stem form, especially in species such as oak (*Quercus* spp.) and sycamore (*Acer pseudoplatanus* L.). Additional post-planting care (e.g. weed control) will be required if seedlings grow slowly, while formative shaping may be needed if the shoots die back. On reforestation sites, seedlings that do not grow vigorously may be prone to attack by the large pine weevil (*Hylobius abietis*).

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Physiological status of planting stock

Dormancy and stress resistance

Dormancy status varies seasonally in tree seedlings in response to changes in day length, temperatures and other factors. Since weather conditions vary from year to year, differences in dormancy status between years may be considerable, particularly early or late in the lifting season. Such differences are usually small from about late December to

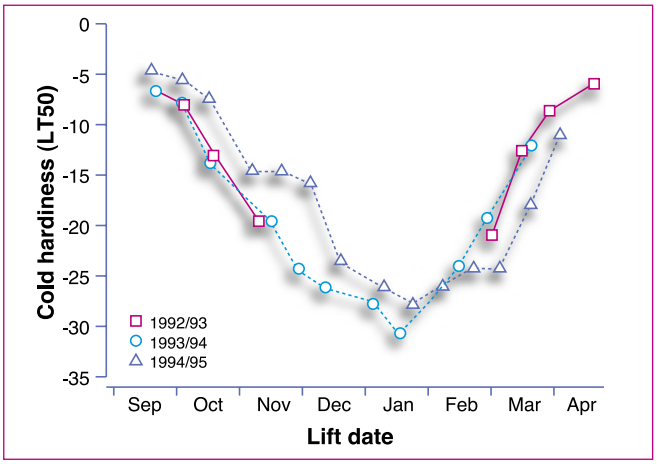

Figure 1: *Seasonal changes in cold hardiness in Douglas fir shoots in Ireland. Y-axis indicates temperature that caused 50% needle mortality (LT50). Equipment used in 1992/93 could not be used to assess hardiness< -20°C. Note that shoots were up to 10°C hardier in late November 1993 than in late November 1994. Seedlings were ready for lifting about one month later in 1994 than in 1993.*

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early February. The resistance of plants to stresses closely parallel changes in dormancy; plants are most resistant when highly dormant. Cold hardiness of shoots (Figure 1) can be used to assess dormancy and stress resistance levels indirectly, although other methods can also be employed. The optimum time to lift for immediate planting has been determined for several species in Ireland based on physiological and field performance assessments (O'Reilly *et al.* 2001).

Root growth potential (RGP)

The natural ability of seedlings to grow new roots quickly after planting (or RGP) is important for most species, although the less efficient, existing root system may be adequate initially for some species. Some tree species have a relatively high RGP over a large proportion of the dormant period, whereas the period is quite narrow in other species (including many broadleaves). A good RGP may be particularly important for evergreen conifers because they have a large transpiring leaf surface area during the dormant period. Sitka spruce (*Picea sitchensis* (Bong.) Carr.) has a relatively high RGP over much of the dormant period, which might explain its ability to establish relatively easily after planting. However, Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) has a generally lower RGP than Sitka spruce, and RGP is low late in the lifting season (March/April) (Figure 2). Larch (*Larix* spp.) has a good RGP early (usually October) and late (March/early April) in the lifting season. RGP is high in most broadleaves late in the lifting season (late February to early April, the exact period depending on year and species). High RGP may not be realised if seedlings are damaged during handling or storage, or due to post-planting conditions (see below). There may be a high risk that RGP will not be realised for seedlings lifted after about mid-March because the plants might be damaged during handling or storage (exact period will vary with species and year).

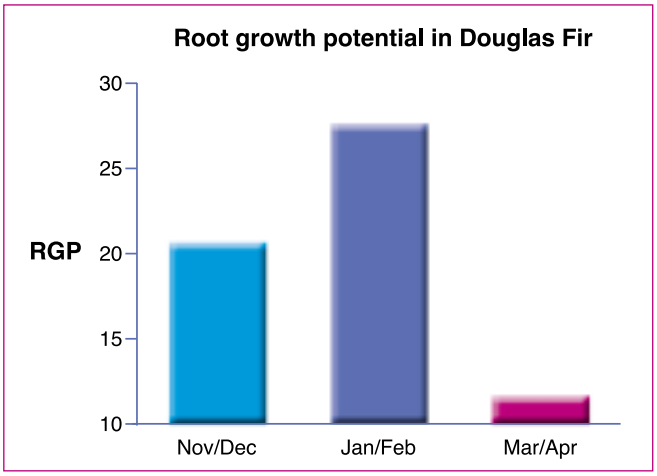

Figure 2: *Average root growth potential (RGP) during the lifting season in Douglas fir. RGP is the natural ability of seedlings to produce new roots in an ideal environment.*

Plant handling and temporary storage

Drying out, rough handling, depletion of food reserves or heating may adversely affect plant quality during the period after lifting until the time of planting. Forest planting stock is most resistant to these stresses when dormant. Roots are particularly vulnerable to damage caused by drying, especially if they are exposed during windy conditions.

In Ireland, stock is commonly held outside, usually in co-extruded polythene bags, for some time before planting (Figure 3). If heat generated inside the bag during seedling respiration is not dissipated, it may lead directly to heat damage, especially if the bags are packed too tightly together. The bags should be kept upright to help reduce likelihood of soil water contaminating the shoots (perhaps leading to disease problems). Seedling food reserves also will be depleted quickly if the temperature inside the bags increases, which may be exacerbated further if the weather is warm and/or where bags are in direct sunlight. Foliage diseases, and other diseases, are also likely to spread quickly during these conditions. Rough handling, such as dropping the bags during loading or unloading, may cause both physical and physiological damage to plants. Crushing and abrasion may cause similar damage. While one stress factor might have a small effect on quality, a combination of stresses commonly leads to greater deterioration than might be expected. Containerised seedlings are also at risk from handling damage, and most species perform best after planting when handled at the times recommended for bare-root stock. In particular, the succulent new shoots are readily damaged if the plants are handled when the shoots are active (even carefully handled plants are easily damaged at this stage).

Figure 3: *Seedlings in co-extruded bags held in temporary storage after lifting in the nursery.*

Figure 4: *Cold store containing planting stock ready for dispatch.*

Cold storage

Seedlings are sometimes placed in cold storage (Figure 4) to maintain the stock in a dormant state, and then dispatched for field planting when required. The advantages of cold storage are that the seedlings can be lifted when conditions in the nursery are favourable and used to extend the planting season when the planting of freshly lifted (non-dormant) stock is not advised. However, seedlings may deteriorate in cold storage, especially if lifted for storage at the wrong time or due to desiccation damage in the store (especially if storage bags are not properly sealed or have holes). Prolonged cold storage may also cause deterioration due to the depletion of food reserves. Some species, such as Douglas fir, noble fir (*Abies procera* Rehd.), beech (*Fagus sylvatica* L.) and sycamore, are more sensitive to storage than others. Although cold storage may cause damage, sometimes killing the plants, the stock usually looks normal. The consequences of this damage will appear soon after planting. Physiological tests can be used to evaluate quality before planting (see below).

While it is preferable to use cold stored stock rather than freshly lifted stock for planting late in season (about mid-March to June), there are some drawbacks to planting at this time. Although usually dormant at the time of removal from cold storage, the plants will be released quickly from dormancy since ambient temperatures are likely to be higher then than earlier in the season. There may also be a higher probability of post-planting failures due to drought just after planting (dry weather frequently occurs during the April to June period). Newly planted stock may not have had sufficient time to initiate new roots (which absorb most water required) before the advent of the dry weather. Finally, since cold stored stock is normally planted late in the season, this reduces the length of the growing season that the seedlings can exploit. Cold storage reduces first-year height growth in the field in larch more than in other species.

Planting date, post-planting conditions and planting quality

Seedlings always suffer some degree of stress (often called 'planting shock') during handling, storing and planting. Bare-root stock is particularly vulnerable since the intimate contact between the roots and the soil is disturbed. Assuming that these stresses have been minimised, further steps should be taken to maximise the likelihood of success after planting. The best time to lift in the nursery (i.e. when dormant and stress resistant) may not always be the best time to plant, although there is a good association for most species. However, there is evidence that some species, such as Douglas fir, require relatively warm soil temperatures to encourage root growth soon after planting so that it can successfully establish. Douglas fir performs best if planted early in the lifting season (November to mid-December) when stress resistance levels for handling are moderately high, root growth potential is adequate and the soil is usually still fairly warm. Although Douglas fir may have similar levels of stress resistance late in the lifting season, and soil temperatures are relatively warm at this time, it is unlikely to perform well after planting because RGP is generally very low then. Therefore, the recommended time to plant should reflect considerations such as those outlined for Douglas fir. The optimum time to lift and plant several species, based upon research carried over several years in Ireland is described in O'Reilly *et al.* (2001). In particular, this research revealed that freshly lifted seedlings planted late in the season (after about mid-March) often performed poorly after planting; severe shoot dieback was a common response in some species (especially in oak and sycamore).

Planting quality is also important in ensuring good establishment success. The ability of the roots to grow and supply water and nutrients may be seriously impeded if planting quality is poor (e.g. roots coiled around each other with little soil contact). Site cultivation treatment may also influence the probability of success. These treatments should improve the microenvironment for the seedlings, for example by reducing weed competition, improving drainage (particularly crucial for successful larch establishment) and increasing soil temperatures. Since all stock suffers some stress during handling and planting, the probability of post-planting success is enhanced, including the probability of recovery from damage, if post-planting conditions are favourable. The need for post-planting care is most important for sensitive species such as Douglas fir and Norway spruce (*Picea abies* Karst).

Guidelines on the best time to lift and plant in Ireland (O'Reilly *et al.* 2001) should be interpreted carefully. These recommendations reflect the 'average' conditions that tend to prevail in Ireland. Climatic and site differences within Ireland are not currently reflected in these guidelines, so local experience should also be considered. However, the reader is advised not to rely too heavily on local anecdotal evidence. Sometimes growers may be lucky and have relatively good success after planting a particular batch of seedlings at the 'wrong' time, but it is more likely that they will experience losses. If the recommended guidelines are followed, post-planting success is likely to be consistently good.

Plant testing

The quality of nursery stock can be tested or monitored by the nursery or forest manager/grower. The nursery manager is likely to use physiological tests to determine when the stock is ready for lifting/storage, whereas the forest manager/grower may be interested more in quality just prior to planting (thus also assessing effects of handling and temporary storage). The most valuable tests used to determine physiological quality for both managers are root electrolyte leakage (REL), water status, and chlorophyll fluorescence (indicates integrity of photosynthetic functioning) measurements, although these tests may be of more limited value for the broadleaves (see O'Reilly *et al.* 2001). The REL test is perhaps the most useful one, especially since it takes only 48 hours to complete (Figure 5). High leakage rates indicate that the roots may have been damaged. The test is most useful for evaluating the quality of stock after cold storage.

The ability of seedlings to initiate roots (RGP) in a controlled environment can provide useful information, but the duration of the test (2 to 6 weeks) is a drawback from an operational perspective.

There are a number of benefits to plant testing:

- Test results give information that can be used in quality control and in evaluating the effects of cultural practices on quality.
- The information can be used as a marketing tool.
- Testing greatly increases awareness of the role of quality, and staff are more likely to handle plants carefully when they know that quality is being monitored.
- The results of the tests can also be used to prioritise and plan, e.g. a batch of plants that has a relatively high REL reading (but within acceptable limits) might be planted before one that has a lower reading.

It is important to bear in mind that the results of the tests only give an indication of the potential field performance of stock - actual performance cannot be predicted from the results. Nevertheless, while good quality stock may not perform well after planting, perhaps due to poor post-planting conditions, it is unlikely that poor quality stock will perform well, regardless of post-planting conditions.

A plant testing service is currently offered at the Department of Crop Science, Horticulture and Forestry at UCD (contact Conor O'Reilly for further information).

Figure 5: *Testing root electrolyte leakage (REL) and equipment used.(Inset) to read after equipment used.*

Conclusions and recommendations

A number of steps can be taken to maintain/improve quality of forest planting stock:

- Order plants to be delivered just in time for planting to avoid having to temporarily store them at the planting site for long periods.
- Decide on a lifting/planting schedule that takes account of biological constraints. If it is required that planting takes place late in the season, consider using cold stored or containerised stock. Keep records of lifting and planting dates.
- Handle/store the plants carefully and plant them as soon as possible. Keep bags containing seedlings upright and out of direct sunlight; make sure the bags are sealed; inspect quality regularly (roots should be moist); and, if possible, monitor temperatures in the bags. Keep container stock moist and, if possible, under cover.
- Make sure that the quality of the planting is good.
- Site preparation treatments should be adequate to help favour establishment – this is especially important for sensitive species. Small, containerised stock may require a higher standard of site cultivation than larger bare-root stock.

References

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