SHORT COMMUNICATION

The collective responsibility for seedling quality

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Abstract

The target seedling concept is based on the idea that seedling stock quality is a predictor of field growth and survival. Good operating practice relating to the production, selection and delivery of good quality seedling stock does not stop at the nursery gate. The potential link between seedling quality and field performance was examined in this study, based on data collected from a nursery trial and under operational field conditions. Guidelines relating to the selection of seedling characteristics best suited to specific sites are also discussed.

Keywords: Seedling quality, field performance, establishment

Introduction

Poor establishment and seedling production techniques can often result in unnecessary replanting and/or post-planting activities, which substantially increase establishment costs and decrease subsequent stand productivity (in this case caused by a delay in the time taken for a stand to reach merchantable size). The national annual costs associated with filling-in (or beating-up) have been estimated to be in the region of €0.22 to 0.75 million per year (Black 2007).

A seedling is considered of high quality ('fitness for purpose', Richie 1984) if it meets the standards of performance at a particular planting site. This implies that both nursery and establishment practices define seedling quality. It is generally recognised that plants of good quality are better able to withstand transplant shock and adverse post-planting climatic conditions, resulting in increased survival and faster early growth. Numerous techniques have been developed to test the quality of nursery stock. However, no individual tests, or combinations thereof, have been developed that fully indicate field growth and survival under operational conditions (see Mattsson 1996). In this paper, we report on the development of a quality index classification system based on a range of morphological and physiological tests. In addition, we suggest that some of these quality measures can be used to pre-select seedling stock best suited to specific site conditions.

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How do we measure good quality?

Morphological assessment

Morphological measurements (physical and structural characteristics) such as shoot height and root collar diameter measurements provide a useful assessment of plant quality. However, shoot height may not always be correlated with field performance because of site or species-specific factors (O'Reilly and Keane 2002). For example, taller seedlings may perform better at sites where there is considerable competition from weeds. Alternatively, shorter seedlings may outperform taller seedlings in exposed sites, where water or nutrients limit performance or where weeds do not pose a problem.

The ratio of shoot to root biomass (S:R) is an excellent indicator of how seedlings may respond when planted under conditions where performance may be limited by water or nutrients. In terms of water stress, S:R provides a measure of the balance between water loss area, via evapotranspiration, and water absorbing area. A useful and more practical surrogate measure for S:R is sturdiness ratio (height (cm)/collar diameter (mm)). However, this is a less robust predictor of seedling performance following out-planting.

Physiological based assessment

There is a wide range of physiological indicators for assessing seedling performance; none, however, are rapid, robust or cheap enough to be used as a routine screening tool. Root electrolyte leakage (REL) is a measure of membrane function and high values indicate that seedlings are either damaged or highly active. Benchmark REL assessments have been developed to provide indicators of dormancy status and for assessing post-storage quality (O'Reilly et al. 2000, 2001, Ritchie 1984, Black 2007).

Photosynthetic performance is a good indicator of plant responses to environmental conditions, since photosynthesis is sensitive to changes in temperature, water availability and nutrient content of leaves. Chlorophyll fluorescence is one of the increasingly used methods for assessing the 'integrity' of the photosynthetic apparatus in conifer seedlings (Perks et al. 2002, Black et al. 2005). For healthy leaves or needles, maximum potential quantum efficiency (Fv/Fm) is usually 0.8. Values below 0.5 usually indicate damage to the photosynthetic apparatus of leaves, which in most cases in non-recoverable (Black et al. 2005). The advantage of the Fv/Fm assessment is that it is non-destructive, quick (30 min) and cheap (once the equipment has been purchased). Another advantage of the fluorescence method is that it can be used to assess the response of seedlings to treatment by herbicides or pesticides.

Development of an integrated quality indicator

An integrated quality index (Q_I) was developed, based on a combination of % REL, Fv/Fm (conifers only) and S:R measurements and threshold values, to categorize the combined physiological and morphological status of seedlings.

$$if \frac{REL\%}{REL\%_{threshold}} > 1, then \rightarrow R_I = \frac{1}{\left(\frac{REL\%}{REL\%_{threshold}}\right)} \times 100 \tag{1}$$

$$if \frac{REL\%}{REL\%_{threshold}} < 1, then \rightarrow R_I = 100\%$$

where R_I is the REL index and $REL\%_{threshold}$ is the published species-specific benchmark REL value (see Black 2007, O'Reilly et al. 2001, Ritchie 1984).

An additional fluorescence index was used for scoring conifer seedlings:

$$F_I = \frac{Fv/Fm}{0.83} \times 100 \tag{2}$$

where F_I is the fluorescence index, 0.83 is the maximum Fv/Fm and Fv/Fm is the measured value. The F_I of needles with measured Fv/Fm values below 0.5 are scored as 0%.

A shoot to root index (S:RI) score was also included:

$$if \frac{S:R}{S:R_{threshold}} > 1, then \rightarrow S:R_I = \frac{1}{\left(\frac{S:R}{S:R_{threshold}}\right)} \times 100$$

$$if \frac{S:R}{S:R_{threshold}} < 1, then \rightarrow S:R_I = 100\% \tag{3}$$

The following a priori $S:R_{threshold}$ values were selected as a benchmark:

a) all spruces < 3,
b) other conifers (excluding larch) < 5,
c) oak and ash < 1,
d) other broadleaves (and larch) < 2.

Additional morphological penalty scores (MPS) were deducted from the combined quality index, where 5% was deducted from the physiological indices for bud break, broken leaders or needle yellowing, and 2% for storage mould or poor form.

Quality indices for all conifers excluding larch (QIC) and broadleaves including larch (QIB) were calculated as:

$$Q_{IC} = \frac{R_I + F_I + SR_I}{3} - MPS \tag{4}$$

$$Q_{IB} = \frac{R_I + SR_I}{2} - MPS \tag{5}$$

How does QI relate to field performance?

Nursery plot experiments

Bareroot seedlings from a total of 1378 sample bags were obtained at regular intervals from the two main Irish nurseries and some European nurseries over the period December 2005 to May 2007. An average of 15 sample trees per bag were assessed for shoot:root ratio, root electrolyte leakage and chlorophyll fluorescence (conifers only). QI values were then calculated as described.

A sub-sample of tested Sitka spruce seedling batches (42 in total) were planted out in a nursery trial at Ballintemple Nursery, Co Carlow. Seedling batches, from cold storage with a varying Q_{IC} (55 to 100%) were planted out at different times of the year to determine the influence of climatic conditions and Q_{IC} on seedling survival.

Potential soil water deficit was measured at Ballintemple to see if it had an effect on seedling survival in a demonstration nursery plot. Potential soil water deficit provides a measure of available water in the soil, based on precipitation and potential evapotranspiration. When soil water deficits (precipitation - evapotranspiration) are negative, the soil moisture content decreases. This could decline beyond permanent wilting point once the 10-day deficit reaches ~ 40 mm, depending on soil type.

The effect of planting poor quality nursery stock under ideal conditions

Poor field performance of good quality stock can be due to unsuitable weather following out-planting. The dry conditions of May/June 2006 provided a good opportunity to test the impact of such weather on field performance.

The results from this trial demonstrated poor field performance of good quality nursery stock (Q_{IC} > 85%) when planted in dry conditions. It was also evident from the nursery trial that bareroot Sitka spruce seedlings should not be out-planted when soil moisture deficits exceed -25mm (Figure 1), which had occurred by the end of May 2006 and April 2007 at Ballintemple nursery.

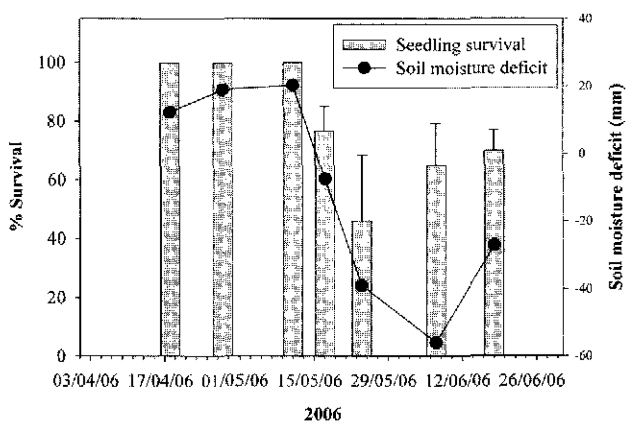

Figure 1: The effect of out-planting date and soil moisture deficit on seedling survival in a demonstration plot at Ballintemple in 2006. (All seedlings were cold-stored prior to quality assessments and out-planting).

The effect of planting poor quality stock under ideal conditions

In a separate analysis we attempted to asses how survival was related to quality (Q_{IC}) under ideal conditions for seedling establishment following good practice planting procedures. A sub-sample of tested Sitka spruce batches (Q_{IC} of 55 to 100 %) were out-planted when there was a low likelihood of subsequent water deficit (> -20 mm). Batches of 20 seedlings were planted in single rows 0.5 m apart. Seedling performance was monitored and survival was assessed after 1 year. There was a significant correlation between Q_I and survival following out planting (Figure 2). The result suggests that the survival of seedlings declines to below 50 % if the Q_I is below 70%.

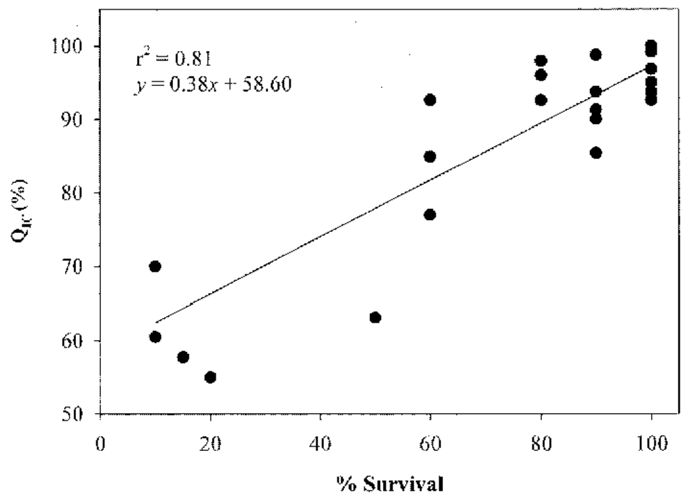

Figure 2: Correlation between quality index Q_{IC} and Sitka spruce seedling survival following out-planting under ideal climatic conditions. (All seedlings were cold- stored prior to quality assessments and out-planting).

Field performance

Field trial evidence for the detrimental effect of planting poor quality stock was hindered by the simultaneous reduction in post plant survival and vigour due to combined effects of adverse climatic conditions, variable seedling QIC and weevil damage. In April 2006, seedling survival of good quality bare root Sitka spruce stock (Q_{IC} > 85%) was 88 ± 3%, based on an analysis of 24 sites (81 plots). Survival declined to 72 ± 8%, when planted out in June when water deficits were higher. However, it is important to note that the ability of seedlings to survive weevil damage or dry conditions increased when:

a) seedling quality was good, particularly a balanced shoot to root ratio and a low sturdiness value;
b) bareroot stock were not planted under dry conditions or on exposed sites after April or May 2006.

Conclusions and recommendations

The implementation of a routine seedling quality testing service in nurseries and screening of stock, using an integrated Q_I system, prior to dispatch, can, if screening avoids poor stock going to the field, improve field performance and thereby reduce overall establishment costs. However, we estimated that fewer than 4% of the 1378 bare root stock batches sampled over the 2005/6 and 2006/7 were not suitable for out-planting (Black 2007). In addition, most of these batches were withdrawn before dispatch to the field. This highlights the importance of the implementation of a third-party seedling screening service for bare root nurseries. This should be seen as an added value service to nursery managers, as the information can be used as a marketing and quality assurance tool, providing a competitive advantage. Test results can also be used in quality control and in evaluating the effects of cultural practices (e.g. the effect of treating seedlings with insecticide to protect against pine weevil damage).

The low frequency of poor quality stock in nurseries does, however, suggest that seedling handling, planting quality, climate and selection of seedlings suitable for specific sites may also be an important issue in securing high survival and initial growth rates. This supports the concept of collective responsibility for seedling quality. Based on the evidence presented here, it is clear that field performance following out-planting is influenced by both nursery stock quality and establishment procedures/timing. We have demonstrated that field performance of good quality nursery stock is reduced when out-planted when soil moisture deficit is high.

It has been suggested that global climate change will result in more erratic climate and drier summers in Ireland, particularly in the south and east (Ray et al. 2007). Therefore, it is possible that periods of extended soil moisture deficit may occur earlier than April or May and more frequently in the future. This may result in a shorter planting season and highlights the need for selecting fit for purpose seedlings, specific to individual sites, soils or climatic regions. The use of seedlings with a low S:R for planting on freely drained soils, particularly in the south and east of the country could be a prerequisite in the future.

In conclusion, establishment systems have traditionally been a one-way system where seedlings are simply passed on to establishment teams. A key component of an integrated establishment system is the target seedling concept (Landis and Dumroese 2005). Quality assurance systems, such as quality index assessments presented here, can facilitate the definition and selection of fit-for-purpose seedlings for specific site and environmental conditions. This should lead to well defined standard operating practices along the chain from nursery to plantation establishment.

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