Reaping what you sow
Seeds and plant quality

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ABSTRACT

Germination problems in the nursery may lead to a reduction in the quality of the resulting plants and increase the length of the production cycle. Seed dormancy, handling and storage practices before sowing, date of sowing and moisture availability after sowing are probably the most important factors affecting seed germination in the nursery. The results of recent research have shown that dormancy can be broken more effectively in the seeds of many tree species using the target moisture content (TMC) method, which involves maintaining the moisture content (MC) of the seeds at a lower MC than the fully imbibed (FI) state (standard method) during chilling. The TMC seeds can be cold or freezer stored for more than a year with little effect on germination potential or reintroducing dormancy. Short periods of mild freezing or incubation at warm temperatures also may enhance germination in some species. Although the TMC method reduces the sensitivity of seeds to seedbed temperatures, it is preferable to schedule sowing operations to reflect the optimum temperature for germination in each species. Unlike the seeds of most other tree species, oak *(Quercus robur* L. and *0. pelraea* L.) acorns are difficult to store, even over one winter. The results of recent research has revealed that soaking acorns for five days before storage at -3°C improved germination and the yield of usable plants in the nursery compared with acorns that were stored in the standard way. The type or combination of bed coverings used may also influence seedbed temperature and soil moisture availability. Seeds covered with sand followed by grit may germinate better than seeds covered with grit only (standard method for most small-seeded species in Ireland). The use of cloches or mulches may improve germination further. Seedbeds should be irrigated with frequent light (mist) applications (especially alder and birch seeds) of water during dry periods.

INTRODUCTION

Seed factors can have a large effect on the morphological quality of the plants derived from them. Low, slow, uneven and unreliable germination may lead to many of the following problems in the nursery:

- Difficulty in reaching target plant size dimensions
- Understocked or overstocked seedbeds
- Lack of uniformity in plant size
- Longer production cycle.

The end result is that the nursery manager may find it difficult to produce good quality seedlings, or the quality of the plants may not be consistent from year to year. Furthermore, it may be difficult to produce a sufficient number of good quality plants to make the operation economically viable. An example of the result of poor germination is shown in Figure 1.

After addressing soil condition and its suitability for growing a particular species, the next most important step in the production cycle

Figure 1. An example of poor and uneven germination in a seedbed in an Irish nursery.

The term seed is used for convenience throughout the text, although in reality the seed 'unit' may include part of the fruit (e.g. pericarp).

in the nursery is to optimise seed germination. If seed germination is poor, then it is difficult to compensate for this using other cultural measures later in the growing cycle. For example, if the seedlings are small because the seeds germinated slowly or late in the season, additional fertiliser might be applied to compensate for this. Such an approach is unlikely to be successful and it is probably unsustainable in the long term.

Most of the effects of seed germination on plant quality are indirect. For example, too much germination (which might otherwise suggest a 'good' result) reduces quality, mostly through its effect on plant density. Too much germination usually occurs because of difficulties encountered in accurately predicting the exact level of germination (i.e. the implication of the 'field factor'). if germination is variable over several years in the nursery, then it is likely that the sowing rate will be adjusted to reflect this, so there is a risk of overstocking in some years.

Many pre-sowing and post-sowing factors influence seed germination in the nursery. The most important of these are examined in this paper, focussing primarily on the situation for bare-root nurseries. Pre-sowing factors include seed dormancy and seed quality, while post-sowing factors include soil temperature (date of sowing) and moisture availability. Most of the new information presented in this paper is based on the results of research carried out in the COFORD-funded QualiBroad project. Many diseases, insects, birds and other organisms and agents may also reduce germination in the nursery, but these topics arc beyond the scope of this paper.

PRE-SOWING FACTORS

Seed quality and seed dormancy are the most important factors that influence germination in the nursery. Seed quality (as reflected in seed purity, weight, germination potential and vigour) must be accurately assessed so that the correct sowing rate can be calculated. The proportion of empty seeds also influences seed quality. However, since the quality of a seed lot can be assessed prior to sowing, adjustments can be made to the sowing rate to account for differences in quality. A seed lot of lower quality is normally sown more densely than a higher quality lot. However, only high quality lots (i.e. few empty seeds) might be used in a container nursery or for precision sowing operations in a bare-root nursery.

Seeds are normally stored from the time of harvesting until the time of sowing in the nursery, so their physiological quality may deteriorate during this period. Nevertheless, seeds of most tree species can be stored at cold temperatures for long periods, provided the moisture content (MC) of the seeds is kept below about 12%. Seeds that have such characteristics are known as 'orthodox' seeds. Such seed is normally highly dormant during storage (Gordon 1992b), so it must be pretreated to release dormancy before sowing. The type of pretreatment used, as well as its timing and duration, should be carefully determined for different species, to maximise seedling yields.

The seeds of some species are difficult to store and are classified as 'recalcitrant'. These include seed of *Aesculus*, *Araucaria, Castanea* and *Quercus* species. The nuts of common beech *(Fagus sylvatica* L.) are usually characterised as orthodox, although considered by some as intermediate (Gordon 1992b). Pedunculate *(Quercus robur* L.) and sessile *(Quercus petraea* L.) oak are the only species with recalcitrant storage characteristics that are of importance to Irish forestry.

The effects of the most important pre-sowing factors on germination potential are described separately for seeds that have orthodox and recalcitrant characteristics.

Orthodox species

It is important to ensure that seeds are handled, processed, and stored under close to ideal conditions so that quality is not compromised at any stage. Seed dormancy is the most important pre-sowing factor affecting germination potential and vigour. Furthermore, seeds that are fully released from dormancy are vulnerable to damage during handling and sowing operations (Tanaka 1984). Therefore, dormancy is also important because it affects the potential resistance of seeds to handling stresses.

Seed dormancy

Seed dormancy is defined as the ability of a seed to germinate under favourable environmental conditions. However, the seeds of many tree species also display conditional dormancy, which means that they do not germinate or they germinate poorly under certain environmental conditions. For example, alder *(Alnus glutinosa (L.)* Gaertn.) and downy birch *(Betula pubescens* Ehrh.) seed germinated readily at both low (15°C) and high (20/30°C) temperatures after been prechilled, but seeds that received short periods of chilling germinated poorly at the low temperature (Figure 2).

Seed dormancy is a complex mechanism in many tree species, especially in the broadleaves. It may be expressed through morphological or physiological mechanisms, or more commonly a combination of both. The hard outer seed coat (or surrounding tissues) is the most common (morphological) mechanism of seed dormancy, which restricts water uptake and gas exchange (Suszka et al. 1996b). Seed of most species can be readily softened in cold water, but more extreme measures may be required in others. Acids, hot water, 'hot wire' and various mechanical treatments may be used to soften the seed coat and/or surrounding tissues (Bonner 1987). Some species require warm temperature, or warm temperature alternating with cold temperature, to release dormancy (Suszka et al. 1996b). For example, seed of common ash *(Fraxinus* exelsior L.) (and some other species) requires a warm phase followed by a cold phase to break dormancy (Suszka et al. 1996b). Nevertheless, most tree species require some form of moist prechilling (sometimes called stratification) to release dormancy. The seed coat is usually softened during pretreatment.

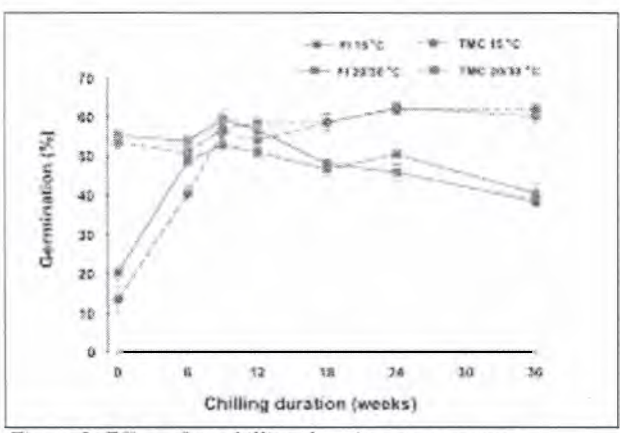

Figure 2. Effect of prechilling duration on percentage germination of alder seeds at 15°C or 20/30°C. The seeds were fully imbibed (FI) or adjusted to a target moisture content (TMC) level before chilling.

Prechilling to break dormancy

Provided seed is sown in the autumn or winter, dormancy can be broken naturally in the seedbed in response to natural chilling after sowing (Gordon 1992a). The response of seeds to natural fluctuating conditions varies, especially due to genetic factors, leading to huge variation in the time and level of germination. Although this might maximise the survival potential of a species in the wild, it may lead to poor, uneven and/or unreliable germination in the nursery. Losses due to vermin, diseases and other agents over the winter may exacerbate the problem. In addition, it is sometimes difficult to sow during the autumn and winter due to other constraints (e.g. adverse weather conditions or availability of seedbed space).

Seed of most species is chilled (usually 2-4°C) in the fully imbibed (FI) state for various periods to release dormancy, depending on the species and seed lot (Gordon 1992a). While dormancy will be broken more evenly using controlled, constant chilling temperatures, than under natural conditions, there will still be considerable variation in the response of seeds to chilling. Furthermore, seeds are prone to germinate prematurely or deteriorate if the period of chilling is extended. Adverse weather conditions and other factors frequently delay sowing in the nursery. Prematurely germinating seeds are also prone to damage during sowing operations, as discussed earlier. An alternative method is to use a lower or 'target' MC (TMC) level during chilling. Seeds are usually adjusted to TMC levels of 3-8 percentage points below the Fl state, but it may be much lower than this in some species. Seed dormancy in many species is broken much more effectively using this method, but there are other important advantages. Seed adjusted to TMC levels can be held at chilling temperatures for lengthy periods without the risk of premature germination (Jensen 1996, De Atrip and O'Reilly 2005). The only potential disadvantage in using the TMC method is that the duration of the chilling period required to release dormancy is usually longer than for the standard Fl method (thus increasing the length of the lead-in period needed for treatment).

The main findings of recent research on the use of the TMC method compared with

Table 1. Effect of standard fully imbibed (FI) versus TMC seed prechilling treatments on alder and birch seedling emergence (number m^{-2}) in Ballintemple Nursery.

Species	FI	TMC
Alder	827	865
Birch	183	500

the standard Fl method in alder and birch are shown in Figure 2. Germination potential declined in the Fl seeds as the period of prechilling was extended beyond about 8 weeks in alder and 12 weeks in birch. The results from a field experiment in birch confirmed that the TMC method resulted in better germination than the standard Fl method (Table 1), but sowing was delayed, leading to a decline in the quality of the FI seeds during the extended chilling period. Germination varied less in alder, but a similar result might have been expected if sowing had been delayed also. Therefore, the TMC method is likely to deliver consistently reliable results in the nursery. Similar results have been reported for several other species (Downie et al. 1993, Jinks and Jones 1996, Poulsen 1996, Jensen 1997).

<u>Temporary storage of prechilled seeds</u>

While 'orthodox' seeds can be safely stored at normal refrigeration temperatures for long periods in the 'dry' (low seed MC) state, fully moist seeds may germinate prematurely or deteriorate quickly once dormancy has been released. Sowing delays, which frequently occur due to adverse weather or other reasons, may cause such problems. Many nurseries, including Coillte Nurseries, routinely use mild freezing temperatures (ca -3°C) to arrest germination and slow the rate of deterioration in Fl seeds. Recent research on alder and birch seed confirmed the benefits of mild freezing (De Atrip and O'Reilly 2006a), as shown for alder in Figure 3. After prechilling, alder seeds were held at -3°C for up to 60 weeks in the moist or dry (re-dried to <12% MC before storage) state. All seed stored for up to 12 weeks with little impact on germination potential (compared with values at time of storage). The moist FI seed deteriorated after about 12 weeks at -3°C. There was a larger decline in germination in the redried seeds, but this was mainly due to a re-introduction of dormancy rather than a decline in quality (De

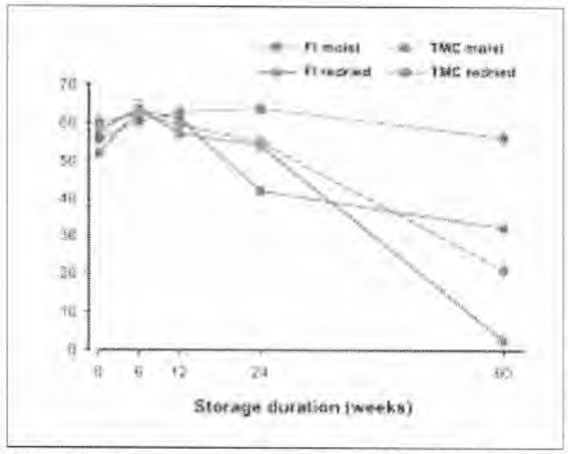

Figure 3. Percentage germination at 15°C of alder seeds after storage at -3°C for up to 60 weeks. Seeds were prechilled at fully imbibed (FI) or target moisture content (TMC) levels, after which they were stored moist or redried to <12% MC. Vertical bars are one standard error.

Atrip and O'Reilly 2006a). However, the moist (not redried) TMC seeds could be safely stored for up to 60 weeks at -3°C (Figure 3). This gives additional flexibility in nursery operations, allowing TMC seed to be sown the following spring with no adverse effect on seed quality or risk of re-introducing dormancy.

Recalcitrant species

This section addresses storage and germination of penduncalate and sessile oak.

It is difficult to store acorns safely over more than one winter, so they are often sown in the autumn and allowed to break dormancy naturally in the seedbed (Gordon 1992a). Nevertheless, significant losses can occur over the winter (Aldous and Mason 1994), and it is often difficult to sow in the autumn due to poor weather conditions. Although dormancy is relatively weak in oak acorns (Suszka et al. 1996b), they are likely to germinate unevenly after autumn sowing. Therefore, it is usually necessary, and perhaps preferable, to store acorns for sowing in the late winter or spring.

The results of several studies have shown that the critical MC for storage of acorns is about 40%, below which viability declines rapidly (Suszka and Tylkowski 1980, Gosling 1989, Poulsen 1992). The usual method of short-term storage (over one winter) of oak acorns is to mix the seed in a medium (such as dry peat or sawdust) and place them in containers or sacks at ca 2-4°C (Gordon 1992b). Acorns can also be kept in cold-storage in containers (e.g. plastic bags) without a medium (Gosling 1989). However, Suszka (1996b) reported that oak acorns can be stored at -3°C for up to three years with only a modest decline in viability if they are maintained in a modified environment (high CO_2 and low 02 concentrations). However, this method of storage is difficult to implement in practice, so it is not used widely. Furthermore, acorns should be treated (usually using hot water) prior to storage to reduce the risk of fungal damage (Suszka and Tylkowski 1980; Suszka et al. 1996b), but the risk may be low for acorns stored at freezing temperatures (Ozbingol and O'Reilly 2005). In Ireland, oak acorns (about 38-43% MC) arc sown in the autumn or stored in Hessian bags at -3°C over one winter.

The results of recent research in the QualiBroad project revealed that acorn storability could be improved by soaking for five days before storage at -3°C, compared with standard method. Acorns that had the highest MC performed best in laboratory tests (Figure 4). The results of field experiments in 2004 confirmed that this method of seed pretreatment/storage improved germination and the yield of saleable plant in the nursery bed (Table 2).

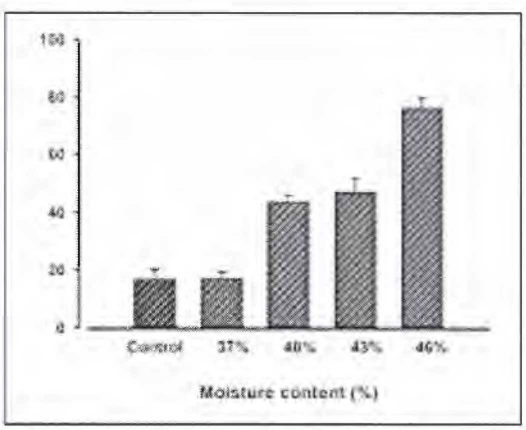

Figure 4. Effect of freezing storage for six months on the germination of oak acorns adjusted to different moisture levels prior to storage. Acorns were soaked and then redried to the moisture contents shown, except for the control (40-42% moisture content) which was not soaked. Vertical bars are one standard error. Note: The germination test was six weeks long, which may not be sufficent time for all acorns to germinate.

Table 2. Effect of acorn pretreatment on emergence and seedling growth in Ballintemple Nursery in 2004.

Parameter	Standard	Soaked
Emergence (number/m^2)	113	147
Plant height >30 cm (number/m^2)	59	67
Plant height >40 cm (number/m^2)	34	40
Mean root dry weight (g)	6.86	7.31

Other pretreatments

The principal other approaches used (mainly in addition to prechilling) to improve germination potential include: priming or invigoration, freezing and IDS (incubation, drying, separation) methods.

Priming

Priming involves incubating seed in a warm (usually 15-20°C) environment for a short period before sowing (Downie and Bergsten 1991). It appears that priming stimulates metabolic activity which prepares seed for germination (Fujikura et al. 1993, Pill 1995). Primed seed can generally tolerate post-sowing environmental stresses better than non-primed seed (Schmidt 2000). Priming might be expected to result in higher germination and/or a faster rates of germination (Heydecker and Coolbear 1977, Coolbear et al. 1980, Bergsten 1993). Although seeds can be primed in the Fl state, a lower (e.g. TMC) seed MC level will reduce the risk of premature germination and/or deterioration. Priming at either 15 or 20°C enhanced germination and speed of germination in the seed of Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco) and noble fir *(Abies proceru* Rehd.) (Doody and O'Reilly 2005), loblolly pine *(Pinus tueda L.)*, and shortleaf pine *(Pinus echinuta* Mill.) (Hang= 1989). A short period (ca 2 days) of incubation at room temperature (ca 20°C) also slightly improved germination in alder and birch seeds (De Atrip 2005), but the method was most effective for the standard FI seeds (but there is a risk that the FI seeds will germinate prematurely if sowing is delayed).

Freezing

There are few reports on the possible beneficial effects of freezing temperatures on the germination response in tree seed. Freezing at -3°C for up to 12 weeks increased germination potential in alder and birch seed (Figure 5).

There was also evidence that oak acorns responded positively to freezing (Figure 4) (Ozbingol and O'Reilly 2005a). Suszka et al. (1996a) have reported that freezing improved germination in common alder, red oak *(Quercus rubra* L.) and Norway maple *(Acer platanoides* L). Freezing might provide additional chilling, thus helping to release dormancy further, but the nature of the response to freezing may differ from that provided by conventional non-freezing chilling.

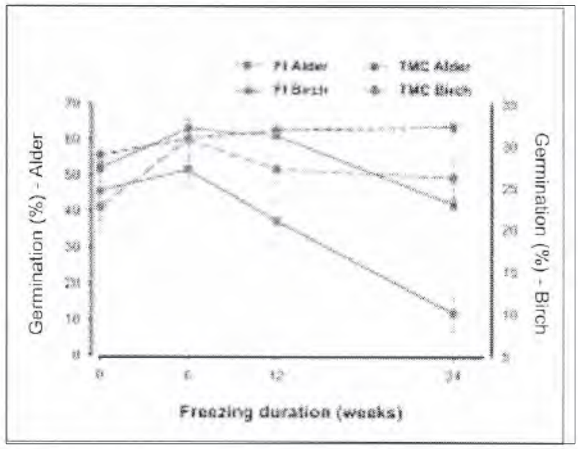

Figure 5. The effect of freezing (-3°C) *duration on subsequent percentage germination at 15°C in alder and birch seed. Seed was prechilled in full y imbibed (Fl) state or target moisture content* (MC) *level before freezing. Vertical bars are one standard error*

DS treatment

The incubation, drying, separation (IDS) method involves the use of a combination of priming and seed processing procedures (Downie et al. 1993, Downie 1999). Some steps can be skipped, depending on the characteristics of the species or seed lot. The method is particularly useful for separating non-viable from viable seed. Seed of some species (e.g. noble fir) contain a high proportion that are non-viable, but these may be difficult to separate if they are similar in size and weight. Using the I DS approach, separation is based on the principle that viable seeds lose water more quickly when dried after incubation than non-viable seeds, thus then allowing separation using conventional seed processing equipment (e.g. gravity tables). The period of incubation used may be short, when the method is used primarily to separate viable from non-viable seed. Longer periods of incubation can be used to invigorate low vigour lots. Furthermore, the last phase (separation) may not be used to treat a lot that is known to contain few non-viable seed. The IDS method is particularly useful where high seed viability is needed, such as in container nurseries and for precision sowing in a bare-root nursery. Most seeds are broadcast or drill sown in bare-root nurseries in Ireland, so there may be fewer advantages to using the IDS method.

POST-SOWING FACTORS

Many factors affect seed germination after sowing, but the most important are soil temperature and moisture availability. Although environmental factors (especially temperatures) cannot be controlled readily in a bare-root nursery, it is possible to take steps to minimise adverse effects. Since most bare-root nurseries in Ireland now have irrigation systems, soil moisture availability may be a less serious problem for germination now than in the past.

Soil temperature

The date of sowing has a large effect on its success, mainly due to the effect of soil temperature. Soil temperature is often too low or sub-optimal for germination, particularly for seed sown early in the season. For instance, if seed is sown too early in a cold spring, germination is likely to be slow, and although the seedlings may grow to an acceptable size by the end of the season, seedling yields may be low and variable. If seed is sown too late in a dry spring, germination may be lower than expected. Generally, seed should be sown as early as possible in spring after the soil temperature at the 10 cm depth exceeds 10°C (Thompson 1984), but this criterion may be less useful for seed of species that is sown at a shallow depth (e.g. grit covered). The temperature of the soil near the bed surface may provide the most useful information on the best time to sow small-seeded species that are sown at a shallow depth. The temperature at this depth may be 5-6°C higher than the daily maximum air temperature, while the lowest temperature may differ little from the minimum air temperature. Air temperature, therefore, is not a useful guide for the best time to sow. The optimum temperature for germination for each species should also be considered when deciding on the best time to sow.

Seed of most species will germinate better at warm than at cold temperatures. The level of dormancy present in the seeds (see above) may influence the response to seedbed temperature, which is likely also to vary with species and seed lot. This conclusion is supported by controlled laboratory tests conducted on Douglas fir and noble fir in Ireland (Doody and O'Reilly 2005). Douglas fir seeds germinated better at relatively high temperatures, whereas noble fir showed the opposite trend (Table 3). Germination also varied in alder and birch seed in response to temperature (De Atrip and O'Reilly, in prep). The optimum temperature for germination was 20°C in alder and 15°C in birch. Other species may show a similar response to germination temperature. Therefore, sowing operations should be scheduled to optimise the likely response to soil temperature.

There is evidence that seed pretreatment may reduce the sensitivity of seeds to temperature. In Douglas fir for example, seeds prechilled using the TMC method germinated well at both low and high germination temperature, whereas seeds given the standard Fl treatment germinated poorly, especially at the low temperature (Table 4). Similarly, alder seeds that received the TMC pretreatment germinated well over a wide range of temperatures, whereas there was a clear optimal for those given the standard Fl pretreatment (De Atrip and O'Reilly, in prep).

Seed coverings (including grit, sand, mulches and other materials) and cloches also potentially influence seedbed temperature. In Ireland, grit is the most commonly used material to cover conifer seed and small-seeded broadleaf species. The colour of the grit may influence germination: dark grits may become hot and damage seeds or newly germinating seedlings (Mason 1994). Other coverings, usually used in addition to grit, may influence temperature much more. Air temperatures up to 20°C above ambient have been recorded inside clear polythene cloches, but increases of 8-16°C are more usual (Thompson and Biggin 1980, Mason 1994). There is a risk that temperature may become too high inside a cloche, potentially inducing seed dormancy, but the risk is probably low for seed sown early in season. Plastic mulches might result in a similar response, although temperatures probably do not get as high under these coverings as under a cloche. However, these coverings also affect moisture availability, as discussed below.

Table 3. Effect of germination temperature on laboratory percentage germination of Douglas fir and noble fir seeds given the standard fully imbibed (FI) prechilling treatment.

Temperature	Douglas fir	Noble fir
20 (dark)/30 (light)°C	87.5	16.3
15°C constant	69.1	52.1

Table 4. Effect of standard fully imbibed (FI) versus TMC seed prechilling treatment on laboratory percentage germination at differernt temperature in Douglas fir.

Temperature	FI	TMC
20 (dark)/30 (light)°C	87.5	94.7
15°C constant	69.1	83.6

Moisture availability

Despite the use of irrigation in many nurseries in Ireland, low moisture availability is probably the most important post-sowing factor reducing germination of small-seeded species. Species with large seeds (e.g. oak, beech) may be less prone to desiccation damage, but they are still susceptible to it. Lack of sufficient moisture, even for a very short period, may greatly reduce germination. If dry conditions occur for a short period soon after sowing, the seed may dry back and become dormant, then germinate later when conditions are more favourable. Irrigation can be used to minimise the risk of drought damage, but it may be wise also to use other measures to help protect seed from damage (Mason 1994). Although late and uneven germination is a common symptom of drought effects, more severe drying may result in poor to no germination. Irrigation water may evaporate very quickly, especially during warm, dry, windy weather. Furthermore, the irrigation water may not be distributed evenly. Therefore, it may be difficult to keep the seedbeds moist enough to maximise seed germination.

Proper irrigation requires considerable skill to maintain appropriate moisture levels for germination. The type of nozzles used influence its efficacy. Those that deliver a very fine mist at frequent intervals are best. Nozzles used to irrigate growing plants, which normally generate large droplets are not suitable, as they may disturb and therefore damage small seeds. Furthermore, such irrigation may lead to overly wet conditions.

Although grit is effective in retaining moisture, it may be necessary to consider using other seedbed coverings. Sand, commonly used to cover seeds in nurseries in other countries (e.g. the US) (Tanaka 1984), may be more effective than grit in retaining soil moisture (De Atrip and O'Reilly 2006b), although it may not always do so (Gordon 1992a). However, the exact proportion of fine material (such as sand) in the grit may have a large effect on seed germination (Gordon 1992a, Lally and O'Reilly 1998). Sand is not suitable for use on its own in Irish nurseries because of a high risk that it will be blown away. Nevertheless, sand in combination with grit (2 mm covering of sand topped by 2 mm grit) resulted in better germination in alder in an experiment conducted at Ballintemple Nursery (Table 5). In addition to the judicious use of irrigation, this covering type might deliver better germination results than using grit alone for small-seeded species.

The depth of grit, gravel and sand used is also important. As a general rule, the depth of covering (including soil) should slightly exceed the length of the longest axis of the seed (Mason 1994), but unfortunately this is sometimes exceeded, resulting in poor germination.

Other seedbed coverings, such as cloches and mulches, can be used to improve the moisture regime for germination (they may also help to provide more favourable temperatures for germination, as mentioned above). For example, a fleece mulch is routinely used to cover birch-sown seedbeds in one Irish nursery, with generally favourable results. Most plastic mulches and some plastic cloches must maintain a seal to be effective. The sealed covering helps to retain moisture in the soil, so irrigation is not normally required. if the seal is not maintained, most of the moisture will evaporate. Rain or irrigation is not likely to penetrate these coverings effectively. Cloches are also prone to damage by wind, so maintaining a seal may be difficult to achieve under Irish conditions. Although perforated cloches can also be used, they may not maintain enough moisture in the soil. These coverings may greatly reduce the amount water that reaches the ground through rainfall and irrigation. Therefore if not used correctly, many of these coverings might also result in low germination.

Table 5. Effect of seed covering type on seedling emergence in alder in Ballintemple Nursery.

Standard grit (4 mm)	Sand (2mm) topped with grit (2 mm)
124	201

There is also evidence that exposure affects germination (especially in ash). Exposed seedbeds are likely to lose moisture more quickly than sheltered ones. It is also likely that a higher proportion of the resulting seedlings might die soon after germination, probably as a result of drought stress. (New germinants would have a shallow root system which might make them prone to drought stress.)

RECOMMENDATIONS

The following steps should be taken to maximise germination in the nursery:

Pre-sowing phase

- Use the optimal (preferably the TMC) method to prechill the seeds of most tree species.
- Plan sowing operations so that there is sufficient time to use the optimal treatment.
- Pretreated seeds are fragile so they must be handled carefully.
- Store pretreated seeds at -3°C until the time of sowing.
- Consider using other methods to improve germination (e.g. priming or freezing treatments).
- Soak oak acorns for 5 days before storing at -3°C until time of sowing.

Sowing and post-sowing phase

- Schedule sowing operations to suit the temperature requirement of each species/seed lot.
- Use seed coverings which minimise moisture losses.
- Make sure that the optimal depth of covering is used.
- Use frequent, light (mist) water applications (especially for small seeds) to irrigate seedbeds after sowing.

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