GERMINATION AND SEEDLING QUALITY

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GERMINATION

The germination of seed is the most precarious stage in a tree's life. A seed, encased in a durable outer coat, can endure physical and environmental abuse. As a hardened seedling or mature tree, the level of tolerable abuse is also relatively high. It is only when the embryo resumes growth, the seed coat ruptures and the tender young plant emerges that a tree's survival is problematic. Nurserymen seek to minimize the dangers threatening germinants to ensure a successful crop and to maximize profit.

The first step to successful seed germination is the imbibition of water. The proteins and carbohydrates swell within the integument (seed coat) to such an extent as to rupture it; this permits the escape of the young root (radicle) and the young shoot (composed of cotyledons, epicotyl and hypocotyl). The cotyledons function in the early stages as leaves while the epicotyl is developing into the shoot structure [1].

In the majority of the gymnosperms -and in all the pines - the cotyledons are pushed or pulled out of the ground by the developing hypocotyl; this is epigeous germination. Epigeous germination differs from hypogeous germination (as exhibited by oak and walnut) wherein the cotyledons never come out of the soil (Figure 1).

A number of environmental factors control and influence seed germination; the most obvious being water and temperature. Less obvious, yet still important to germination, are day length, wavelength, oxygen, seedbed characteristics and possibly environmental chemicals [2]

These environmental factors must impinge in a positive way together on the seed before it will break dormancy and begin vegetative growth. The evolutionary reasons for this stringent list of necessities is obvious - if a seed were to germinate during an unusually warm period in late winter, it might succumb to an early spring frost.

Seed physiological changes are drastic following water imbibition. During the peak germination phenomenon, the seed develops the enzyme components and the metabolic systems necessary for growth into the seedling. Specific changes include increased respiration, enzyme turnover, increase in adenosine phosphate and nucleic acids, digestion of stored foods and transport of soluble products to the embryo, and the division, enlargement and differentiation of cells. 2

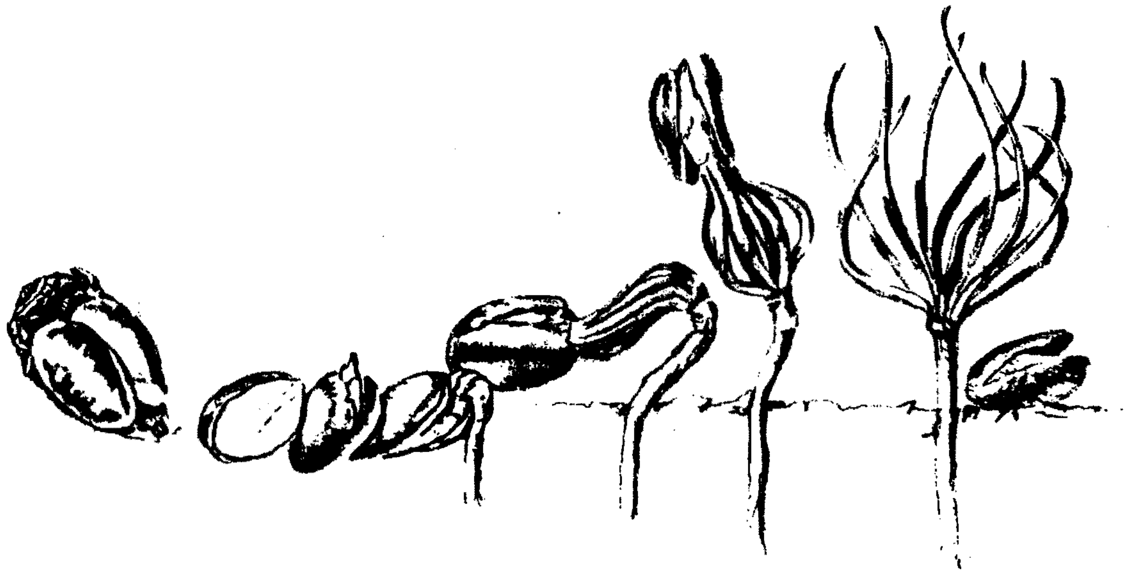

Fig. 1. Germination of pine seed. Figure drawn by Derek Fisher (from Physiology of Woody Plants, P.J.Kramer and T.T. Kozlowski. 1979. Academic Press).

Once the seed has successfully emerged from the soil the nurseryman's objective is to culture the optimum seedling. This optimum level is determined by management objectives and operating limitations [4]; that is to say, that one man's optimum seedling may not be another's! The one objective that all woody plant nuserymen share is that of successful outplanting of seedlings- success being measured as survival and growth at acceptable rates.

There are many parameters or gauges of a successful seedling and the following pages will discuss cursorily some of the most obvious and easily interpretible ones.

SEEDLING QUALITY

Morphological Characteristics of a Successful Seedling

Morphology is the biological study of the form and structure of living organisms. When we speak of the morphological characteristics of seedlings we're simply talking about the visually obvious traits of the seedling.

Height

Height seems to be the most impressive attribute to many people with the assumed premise being that bigger is better. This **may or may not be true** depending on other seedling attributes and intensity of field care. Scientific literature supports the premise on many occaisions, citing improved weed competition and faster subsequent growth as the outstanding benefits of a taller seedling (Pawsey, 1972). On the other hand there are instances where smaller seedlings fare as well as or better than their taller counterparts. These conflicting accounts point out the influence and variability exerted by the outplanting site.

For example, a smaller shoot height with a larger root volume may be desirable on a dry site where the shoot will not transpire water faster than the roots can encounter and absorb it. On a site where water and nutrients are not limiting, a taller seedling will usually grow faster than a shorter one, all other factors being equal. So the shoot size of one's seedlings should be matched to the outplanting site conditions if possible.

Root/Shoot Ratio

Another consideration is the amount of seedling root compared to the amount of its shoot; this is commonly called the root/shoot ratio.

The shoot depends on the root to provide water and mineral nutrients, growth regulators and of course anchorage in the soil. The root in turn relies on the shoot to produce the plant's carbohydrates, growth regulators, and organic substances. This relationship illustrates the importance of a balance between the two parts such that each contributes its essential substances in an efficient manner. The 164 ml R-L cell (commonly used at N.M.S.U.'s forestry greenhouses) should support at most a 10-12 inch seedling for irrigated plantings and a 5-8 inch seedling for unirrigated sites. A tall seedling will also be more susceptible to wind throw than a shorter, stockier seedling with a proportionate amount of supporting root.

Diameter

Generally, seedlings with a larger stem diameter tend to do better in the field. Some researchers (Anstey, 1971) found stem diameter alone was a good indicator of field success with Monterey pine; on harsh sites seedling survival increased from 72% for seedlings with 2 mm diameter (2/25 inch) to 98% for seedlings with 6 mm diameter (1/4 inch). Another researcher (Chavesse,.1977) found that stem diameter at the root collar was a better indicator of Douglas-fir seedling quality than shoot height.

Root Characteristics

The health of a seedlings root is at least as important as the shoot and is invariably ignored by inexperienced purchasers of plant material. The rapid expansion of roots from the preformed plug into the surrounding soil is prerequisite for seedling self -sufficiency and subsequent development. The shape of the plug roots will strongly determine the growing habits of the roots in the transplant site soil. Certain easily seen characteristics can give one a good idea of how the roots will do upon outplanting.

The first characteristic to look for is a full plug- i.e. the container medium is fully contained by the seedling root mass. This usually represents an aggressive root and indicates good rearing conditions.

Secondly, there should be no sign of J-rooting or the contorting of roots. A deformed or mal-formed seedling root will usually plague the normal functioning of a tree throughout its lifetime and will often fail to anchor a tree sufficiently. The vertical ribs on the inside of the RL tubes (the white plastic tubes) are designed to prevent just such deformation.

Lastly, white root tips indicate a seedling actively seeking new water and minerals; a good sign of root vigor. These won't be present on all seedlings due to cultural and management decisions (e.g. did the trees need stress before public release), but do indicate a plant capable of rapid takeoff in the field following outplanting.

Color

Different species will obviously have different predominant hues of green or even different colors (e.g. blue spruce or the yellowish type of arborivitae) The only instances where color alone can be used as a criterion for determining health occur when one knows his particular trees well enough to be cognizant of subtle color changes. Discoloration (i.e. deviation from normal healthy color) may be for positive reasons like cold acclimation or for negative reasons like frost damage, nutrient shortages, or pathogen infestation.

Cold temperatures usually induce dormancy in seedlings and this is often characterized by a dulling of the standard coloration of a seedling; oftentimes a little yellowing or purpling will follow. This is normal. In fact, eastern redcedar (*Juniperis virginiana*) turns a brownish maroon in winter as a natural and healthy response to cold weather.

Excessively cold temperatures impact an improperly hardened seedling with deleterious or fatal results which may be characterized by an exaggerated form of discoloration followed by necrosis (browning) - a sure sign of tissue death. This necrosis may occur only on the needle tips, in which case the seedling has a good chance of convalecsing, or may occur throughout the seedling. Toss this one!

Discoloration due to nutrient shortage is rare in our nursery - we fertilize the trees every time we water. You may see this color change occur at outplanting depending on the soil fertility, physical status of the planting site, and cultural practices.

Bud Characteristics

A bud is a much compressed embryonic shoot. A well developed bud usually indicates seedling cold hardiness and promises faster stem elongation come spring. Species that set bud (e.g. ponderosa pine, the firs and spruces) need a certain amount of exposure to cold (chilling requirement) and increased daylength to resume growth following bud set. Species like afghan pine and arizona cypress don't normally set bud the first year and so can grow whenever climatic conditions allow.

Physiological Characteristics of a Successful Seedling

In general, these characteristics will be impossible to measure without special equipment and training; they are included in this paper merely to add to a seedling buyer's knowledge and allow him greater appreciation for the multiplicity of factors involved in a good seedling.

Nutrient Status - newly planted seedlings must rely on the nutrients present in the plug medium and its internal reserves until new roots establish themselves and can explore the surrounding soil. A seedling with optimum nutrient levels will therefore have an easier time in getting established and initiating growth. This status is measured by chemical tissue analysis; of course, handling conditions and outplanting site conditions will influence the interpretation of these results.

Water Relations - a seedling must rapidly establish normal water uptake patterns with its new environment. An aggressive seedling root system and good moisture conditions at the outplanting site will be conducive to the reestablishment of the normal water use patterns of a seedling.

Dormancy Status - a seedling must be dormant to ensure that vegetative shoot growth will not ensue during a time when frost damage is still possible. This proper dormancy status may be assured with proper hardening-off techniques in the nursery.

Root Growth Potential- After outplanting, the rapid regeneration and expansion of roots out of the container plug and into the surrounding soil is closely linked to a seedling's ability to avoid water stress. A seedling's capacity to regenerate new roots in a given time is termed root growth potential and is presumed to be closely linked to metabolic carbohydrate content.

Species Adaptability - selection of seed sources and seedling genotypes will have a major impact on survival and succes of seedlings in a given area. Species and even provenance selection may determine whether a seedling will survive in a given region or if it will grow at an acceptable speed and with acceptable appearance.

Germination information is referenced and treated more exhaustively in 'Physiology of Woody Plants'. 1979. Paul Kramer and Theodore Kozlowski. Academic Press.

1. Botany: A functional approach. 1979. W. Muller. Macmillan Publishing.

2. Physiology of Woody Plants. 1979. Paul Kramer and Theodore Kozlowski. Academic Press.

3. Plant Growth and Development. 1975. A.C. Leopold and P.E. Kriedemann. McGraw-Hill Book Co.

4. Growing the "best" seedling for reforestation success. 1984. David South and John Mexal. Forestry departmental series no.12, Auburn Univ. Alabama Ag. Exp. Station.

5. Evaluating seedling quality: principles, procedure and predictive abilities of major tests. 1984. Workshop proceedings, Oct. 16-18. Oregon State U.

6. Seedling Physiology and Reforestation Success. 1983. Mary Duryea and Gregory Brown (eds.). Martinus Nijhoff/Dr. W. Junk Publishers.

7. Survival and early development of Pinus radiata as influenced by size of planting stock. C.K. Pawsey. Aust. For. Res. 1972 5(4) 13-24.