PREGERMINATION: A KEY TO EARLY VIGOR IN ARTIFICIAL SILVICULTURAL SYSTEMS

by

D.A. Skeates [1]

Accelerated growth is an elusive goal, sought after by all foresters throughout the entire rotation of a stand. The first criterion for the geneticist in selection of plus trees is site index, a measure of growth vigour. To the field forester, rapid suppression of competiton is essential for plantation establishment and optimum performance. To the economist, the most important cost factor is time. Vigorous growth, hence reduced rotations, is essential in northern climates which are characterized by short growing seasons, marginal forest sites and long rotations.

Early vigor is critical during the establishment years. Mullin and Svaton (1972) showed strong relationships between stock size at time of planting and subsequent survival and growth of white spruce (*Picea glauca* (Moench) Voss). Scarratt (1974) noted that the "ultimate success of container planting depends on our ability to produce seedlings of a size and quality consistent with maximum field performance. Other considerations are secondary". Early vigor starts with the seed, in the forest, in the nursery, in the greenhouse or in the germination cabinet. Participants in a nurseryman's meeting are more concerned with seed and seed handling influences on stock production. The greatest gains will be made with greenhouse stock products, i.e. accelerated transplants and containers.

In the seed research program of the Ontario Tree Improvement and Forest Biomass Institute a variety of factors that influence germination and early vigor have been studied. One consistent observation has been the strong relationship between early plant vigor and subsequent growth. While this relationship is important in production of multiple year nursery stock products it is of even greater significance in single year container systems where the plant must cope with forest conditions in its second year.

Factors influencing early vigor

Seed Source

Collection of seed is usually beyond the jurisdiction of the nurseryman. The genetic potential of the plantations grown from his stock is irrevocably established the day his seed is collected. Nevertheless the nurseryman must be aware that even through stock production stages, seed source will influence plant vigor. Stock from mixed seed sources can be expected to express greater growth variability than that from individually identified collections.

In Ontario, seed identification and distribution policies have

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[1] Seed Specialist, Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources, Maple, Ontario LOJ 1E0

been debated for many years. Currently the forest district, within ecological site regions (Hills 1960), represents the basic collection unit in northern Ontario (Skeates 1979). Data on nursery performance of white spruce provenances, currently being compiled, indicates significant mean growth differences between stock of seed collected from different stands within such units. The province is moving toward a system of registered stands which will provide source identified seed. This is the first step in improving the quality of seed collections as recognized by the Organization for Economic Cooperation and Development (Piesche and Stevenson 1976). Although this undoubtedly means smaller seed lots and more record keeping for the nurseryman, the policy should contribute to more uniform stock, hence fewer cull trees and reduced culling costs. As our knowledge of stock performance relative to seed source increases, options will become available to ensure more vigorous early plant growth in the future.

Environment

Conditions at time of germination and through the early stages of growth influence subsequent plant vigor. At our Institute, large differences were observed between cotyledonous plants germinated under growth cabinet, greenhouse and laboratory conditions. A survey of 1+0 nursery stock in 1976 across Ontario indicated up to three fold differences in stock dimensions between nurseries or even between compartments of the same nursery for plants from the same registered seed lot. Bunting (1973) related size of seedling stock to bed density of red pine (*Pinus resinosa* Ait), white pine (*Pinus strobus* L.) and white spruce at Ontario's Orono nursery. Similar results were demonstrated on this conference's visit to Lawrencetown nursery. In container stock production Scarratt (1973) identified container diameter as an important factor in seedling growth of white spruce and jack pine (*Pinus banksiana* Lamb). Moisture differences due to minor variation in transplant bed elevations have been observed at Swastika nursery that resulted in about two fold differences in oven dry weight of black spruce (*Picea mariana* (Mill) B.S.P.) accelerated transplants at shipping time (Skeates et al. 1982).

Through control of environmental factors at time of germination and during early plant development, the nurseryman can accelerate early growth. Williamson (1977) designed insulated plastic seed bed shelters which added growth degree days early in the season while providing protection from late spring frosts. Because of early germination and more vigorous early growth, 50% gains were recorded in oven dry weight of 1+0 jack pine and white pine seedlings at Swastika and Kemptville nurseries respectively. At Dryden nursery gains ranged from 40% for red pine, 65% for jack pine and black spruce, 100% for white pine and 200% for white spruce.

Similarly small seed drill shelters, ten and fifteen cm high were tested. The principle is adapted from the inverted open-topped plastic cups used for direct seeding of pregerminated Scots pine (*Pinus sylvestris* L.) seed in Sweden (Hagner and de Jong 1981). Gains of 12 and 30% were observed in 1+0 white and black spruce in Thunder Bay, 40 to 100% in red pine and 90% in white pine at Orono.

As part of a black spruce accelerated transplant development project, pregerminated seed was sown May 1, 1980 in peat cubes formed by the Dewa block process at Swastika nursery. Trays of cubes were placed in a seed bed shelter for two months. The containerized seedlings were conditioned during July by removal of roof sections and transplanted the first of August. The early start resulted in 0.2 g one-year-old transplants, which was roughly five times the dry weight of 1+0 seedlings. At two years of age these produced 3.5 g transplants compared to 0.8 g field growth 1.5 + .5 transplants.

Environmental factors have affected results of various container and container transplant projects. Location in the greenhouse relative to ventilation and side walls provided a growth gradient in one study. In another, trays placed on a deep gravel floor in a heated greenhouse in February experienced a chilling effect from frost in the ground below. Difficulties with the irrigation boom adversely affected parts of another study. In a container/media study variation in compaction, hence aeration in the rooting zone, resulted in a two fold variation in growth. Even minor variation in environmental conditions during the critical stages of germination and epicotyl elongation have had a strong and continuing influence on first year growth.

It is clear from the above that environmental factors can greatly influence early seedling performance, thereby possibly masking influences due to genetics or seed quality. It is equally apparent that environmental factors can be manipulated to take advantage of gains achieved through tree improvement.

Seed Characteristics

The terms seed size, seed density and seed weight have been used interchangeably in literature creating a confused picture in this subject. Seed studies at our Institute have indicated that seed size and seed density are components of seed weight in jack pine, black and white spruce (Skeates 1972). The influence of either size or density of seed disappeared gradually while strong correlations were achieved between plant dry weight and seed weight. Differences tended to increase with time and the correlations remained strong over the duration of the study.

Thus seed weight may influence plant vigor for several years. Perry (1976) noted that Pinus taeda progeny at four years were closely correlated with seed weight. Bunting (1969) achieved 55% shippable 2+0 white spruce with large seed but only 15% with small seed.

Mean seed weight is a term with various meanings depending on authors. It has been used as a measure of seed from an individual tree or of seed of different stands or provenances. In a white spruce seed production plantation at Orono, Ontario, weights of individual seeds from single trees have been shown to vary up to two fold. For this whole plantation, individual seed weights varied from 1.2 to 4.3 mg. The strongest growth/mean seed weight relationships have been shown by authors using individual seed weights or seed weight classes as the independent variable.

Numerous trials of seed size and seed weight in Ontario nurseries have shown that seed characteristics significantly affect size of bare root transplants at time of shipping. Early vigor, however, is far more cost effective in production systems involving expensive facilities and short rotations, i.e. container and accelerated transplant stock.

Time of Sowing

Growth progressions have been published for jack pine container stock production (Scarratt and Reese 1976) and similar growth progressions have been prepared by the Ontario Ministry of Natural Resources for other species grown in Ontario nurseries*. These indicate that the length of growing period will differ relative to time of sowing to reach comparable shippable standards. Hallett (1982) presented curves of total oven-dry weight of black spruce containerized seedlings based on weekly measurements. These indicated comparable growth patterns for February and May/June sowings but reduced early vigor exhibited by seedlings from October, November and December sowings. One study in our greenhouses, indicated reduced vigor from successive sowings of black spruce from February through to June. Pregermination of seed is a technology designed to exploit the advantages observed by the studies noted above.

Pregermination of Seed

Pregermination of seed is a means of optimizing gains in early vigor. The nurseryman can benefit from the use of heavy seed from the most suitable source, germinated under optimum conditions early in the growing season. This benefit can be magnified several fold by pregerminating seed before the growing season. One-year-old seedlings from pregerminated seed or early initiated mini-container systems appear more like two-year-old nursery stock when compared to those developed from naked seed through the normal growing season.

The word pregermination is used here in a broad sense to include a range of techniques from germinants with emerging radicles to cotyledonous seedlings and mini-container seedlings up to 8-10 weeks of age. The latter may be intended as a pre-growing component of container and container transplant systems, which may in itself utilize germinants instead of naked seed. There are potential gains to be made through use of pregerminated seed to replace naked seed in any silvicultural system.

The following is a brief description of pregermination systems which are presently under consideration or development in Ontario (Table 1).

Fluid Drilling

This is an operational technique in which seed is germinated in

* Personal communication, V. Sadreika, Forest Resources Branch, Ontario Ministry of Natural Resources, Queen's Park, Toronto, Ontario

a temperature controlled aerated water bath. Germinants with emerging radicles are separated from non-germinated seed in sugar solutions of varying specific gravities depending on species. Germinants are either sown from a water bath with a vacuum pick-up into containers or into nursery beds using a gel delivery system.

This equipment is adaptable to any container system and has been used in Ontario for planting germinants into peat cubes. The equipment that was demonstrated at Lawrencetown during this nurseryman's meeting was custom designed to operate with a Dewa block soil-forming machine that is currently being used experimentally at Swastika in our accelerated transplant program. The germinants must be sown before the radicle exceeds 2 mm.

Savings in time and space are particularly valuable for species with low germinative capacity and slow germination energy. With seed lots of good germinative characteristics, savings in greenhouse operating time are not great, nor is stocking a major problem. We have experienced problems of aeration in bags of seed in the germinator as well as in the logistics of identification of seed lot fractions that had to be separated daily for the duration of the germination period. To achieve almost 100% stocking in containers, a considerable base load of germinated seed must be maintained in the seeder. This base load is wasted at the end of the run.

This technique is considered to have its greatest potential in container transplant production and for sowing into seed beds. In the nursery the greatest benefit would be with species with irregular and unreliable germination and emergence.

Floatation Germination

This is an operational technique developed in Sweden (Hagner 1981). Seeds are germinated while floating on water supported by surface tension. As seeds germinate they up-end, break the surface tension and sink to the bottom where they can be picked up by an underwater vacuum. Seeds with 1-2 mm radicles are cold stored to arrest further development until the complete seed lot is ready to sow.

It would appear to be difficult to handle numerous seed lots at a time, as a separate bath would be required for each. The logistics of collecting the germinated portions of each seed lot each day might also present some problems in handling.

Seed pregerminated by this system has been used in Sweden for production of Scots pine container stock and direct seeding in the forest. For Ontario conditions any system using seed in the early stages of development would appear of greatest value for accelerated transplant production or gel sowing into seed beds.

Germination Plugs

Seed is sown in 1.5 cm long peat moss cigarettes which provide a germination medium and a means of handling germinants. The cotyledonous seedlings (Fig. 1) are planted into containers when the seed coats have dropped. To date the containers used have been 2.5 cm peat cubes formed by a Dewa block machine (Skeates and Williamson 1979a). Though not operational as yet, concepts for mechanization have been published (Skeates and Williamson 1979b).

The system would appear applicable in production of accelerated transplants. It has the advantage of saving two or three weeks of greenhouse time over the previous two systems, using seed which has developed into cotyledonous plants. Through culling at time of planting, full stocking in the greenhouse is achieved at a more advanced stage of plant development.

Cigarette Micro-containers

This is the same system as above using 4.5 cm cigarettes can produce plants eight to ten weeks old at 8600 per sq m. In a preliminary trial at the Institute this spring nine week old black spruce seedlings 10.6 mg oven dry weight, 2.2 cm high were transplanted in two nurseries.

The potential application is seen as high density greenhouse production of plants for container systems. The delicate seedlings are handled by the cigarette for insertion into a dibble hole in the soil of the container. A formed peat cube is seen as being the container system with the greatest potential application since the dibble hole could be part of the mold forming the cube. A second dibbling operation would be needed for prefilled containers. The system also has possible application in direct sowing, as a low stock production cost planting system.

Wiesinger's Micro-containers

This unique technology is in developmental stages (Wiesinger 1982). One million jack pine were grown for the Ontario Ministry of Natural Resources container program in Kenora in the summer of 1982. Seed is sown in strips of Coroplast, an insulated cardboard-like plastic, at 27,500 per sq m. The tiny cavities are open on one side so that the back of each strip forms the fourth side of the previous strip. Black spruce seedlings were grown at the Institute this spring and assessed at nine weeks (Fig. 2). At 7.3 mg these seedlings were not as heavy as those grown in cigarette plugs indicating that container size or density of plants had limited growth by this age.

The seedlings are transplanted into Wiesinger's container system and he feels confident he can develop the technology to automate planting into any container system.

Blackmore Waffle Sheets

The tobacco industry **in** Ontario has used the waffle sheets for starting their plants. Seed is germinated in small shallow pockets of soil. The bottom of each cavity is slit in a cross. Transfer of containerized pregerminated seed is accomplished by a plunger which pushes plant and soil through into Speedling trays or other containers below. Varying the position of the sheet allows for direct transfer from close spacing in small containers to the wider spacing in the trays.

The system is operational in many agricultural endeavours across Canada and the United States. The Yarmouth N.S. Farm Focus of June 9, 1982 had an interesting description of this system for producing bedding plants in Saint John, N.B. In Ontario the Kemptville nursery has used the technique for production of hardwood plants but it was felt that the upright habit of cotyledonous conifers would result in damage to the plant when transferred into trays. The shallow pockets are not considered suitable for the rooting habit of conifers. However the system appears to have potential for planting germinated hardwood seed into containers.

Blackmore Mini-containers

Kemptville nursery has progressed from the waffle to the Blackmore 400 series containers. These are thimble shaped cavities in a plastic tray similar in design to a small scale multipot tray. These are used as medium density container transplants for hardwoods. Plugs of soil are pushed up from below or pulled from above for transplanting into nursery beds. It is particularly useful with pregerminated seed of certain hardwoods of low germinative capacity.

Discussion

The nurseryman has many choices of technology available to him in achieving the necessary quality of stock for each species and stock product required by his clients. The range in techniques form a continuum from which he can mix and match to achieve his goals. He must be aware however that factors affecting germination and early plant development will have a strong bearing on first year vigor. The quality of the first year plant will strongly influence second year vigor, either in the nursery in the case of greenhouse transplants or in establishment and growth of outplanted container stock.

Pregermination systems contribute to a rapid early start for the plant. To date in Ontario the concept has been tested primarily with accelerated transplants. Advantages include reduction in greenhouse operating time and full stocking in expensive facilities. Uniformity of stock, all started at the same time, reduces culling costs especially for species such as white spruce which germinate over a period of several days. Reduction in growing time facilitates the planning of silvicultural operations. The ultimate goal in greenhouse transplants will be 1.5 and 1 year production schedules. In container systems the goal could be production and planting in single year schedules.

The major cost of greenhouse production systems after the capital outlay for construction will be the ever increased cost of energy. In current systems, economic and biological factors are mutually compromised by reducing container size for cost reasons yet trying to increase plant size to ensure reasonable outplanting success. A high density pregermination system would dramatically minimize greenhouse requirements. Planting into larger containers for further development under less costly conditions would allow improved growth of containerized plants. Pregermination systems reduce operating time in greenhouses for accelerated transplant production. Finally the potential for automation of operations through to shipment of containers or transplanting of greenhouse stock makes the various pregermination systems a viable option in stock production systems.

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Table 1. Application of pregermination systems under consideration in Ontario.

System	Direct Seeding	Seedling Prod'n	Accel. Trans-plants	Con-tainers	Hardwood Accel. Trans-plants	Hardwood Con-tainers
Fluid Drilling		Op.	Op.			
Floatation		Op.	Op.			
Germ. plugs			Dev.			
Cigarette mini-cont.	Dev.			Dev.		
Wiesinger's mini-cont.				Dev.		
Blackmore waffle						Op.
Blackmore 400 series					Op.	

Op. - Operational system

Dev. - System being developed

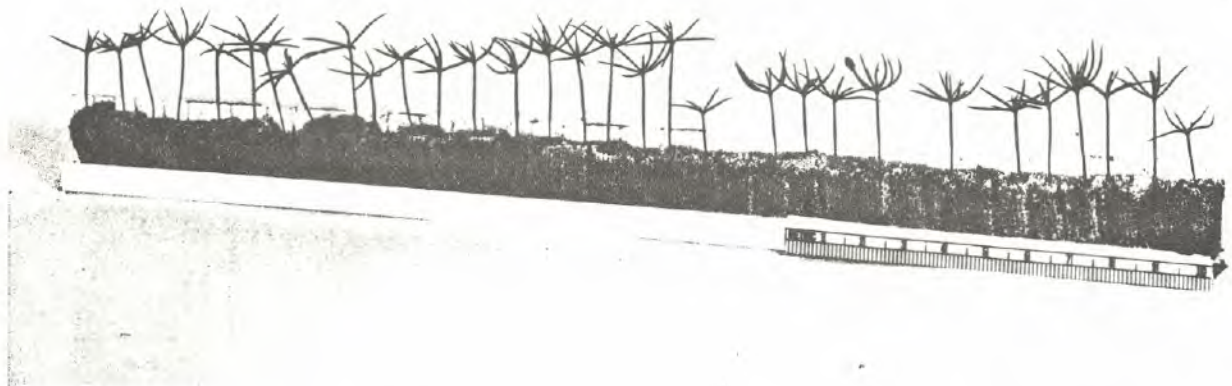

Fig. 1. Cotyledonous white spruce seedlings in germination plugs of commercial peat (Skeates and Williamson 1979a).

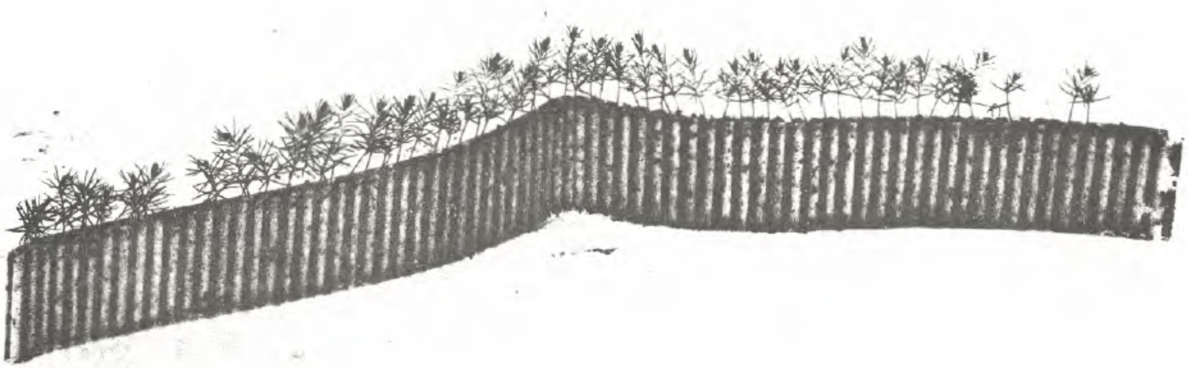

Fig. 2. Black spruce growing in micro containers designed by Wiesinger (1982).