DEVELOPMENT OF HIGH-CAPACITY PRECISION

SEEDING,LOADING,AND HANDLING EQUIPMENT

FOR CONTAINER NURSERIES [1/]

by

Erling O. Nyborg

and

George Shikaze [2/]

Abstract. This report discusses the design, testing and preproduction development of a high capacity seeding and loading line for container nurseries. Individual components of the line were originally developed at the Agricultural Engineering Department, University of British Columbia under contract from Pacific Forest Research Centre, Canadian Forest Service. Field testing was conducted by the British Columbia Forest Service during their annual container seeding programs. Various models of the precision seeder have been used by B.C. Forest Service to seed their entire container production for the past four years, while the prototype gritter has been used for the past two years. The soil loading machine is in the final stage of development and should be ready for production by spring, 1975.

All of the equipment described in this paper is presently being manufactured by Vancouver Bio-Machine Systems Ltd., Richmond, B.C. Although it was originally designed for use with BC/CFS styroblocks, the equipment has been redesigned so that it will readily accommodate most commonly used types of containers by the interchange of specific components.

Design capacity of the seeding line is one million cavities per eight hour shift although this may be varied to suit the requirements of a specific nursery.

1/Paper presented at North American Containerized Forest Tree Seedling Symposium, Denver, Colorado, August 26-29, 1974.

2/Respectively, Assistant Professor, Agricultural Engineering Department, University of British Columbia, 2075 Wesbrook Place, Vancouver, B.C. V6T-1W5; and President, Vancouver Bio-Machine Systems Ltd., E-284 Olafson Avenue, Richmond, B.C. V6X-2R3.

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INTRODUCTION

The success of container seedling production depends, to a large extent upon the ability of the container loading line to produce consistent cavity fills at economic rates of production. The desired goal is the production of one healthy seedling per cavity with minimum labor input at production rates compatible with the requirements of the specific nursery. Loading equipment must perform within the biological restraints dictated by seedling requirements and specific economic restraints. For example, cavities should be uniformly and consistently loaded with a growing

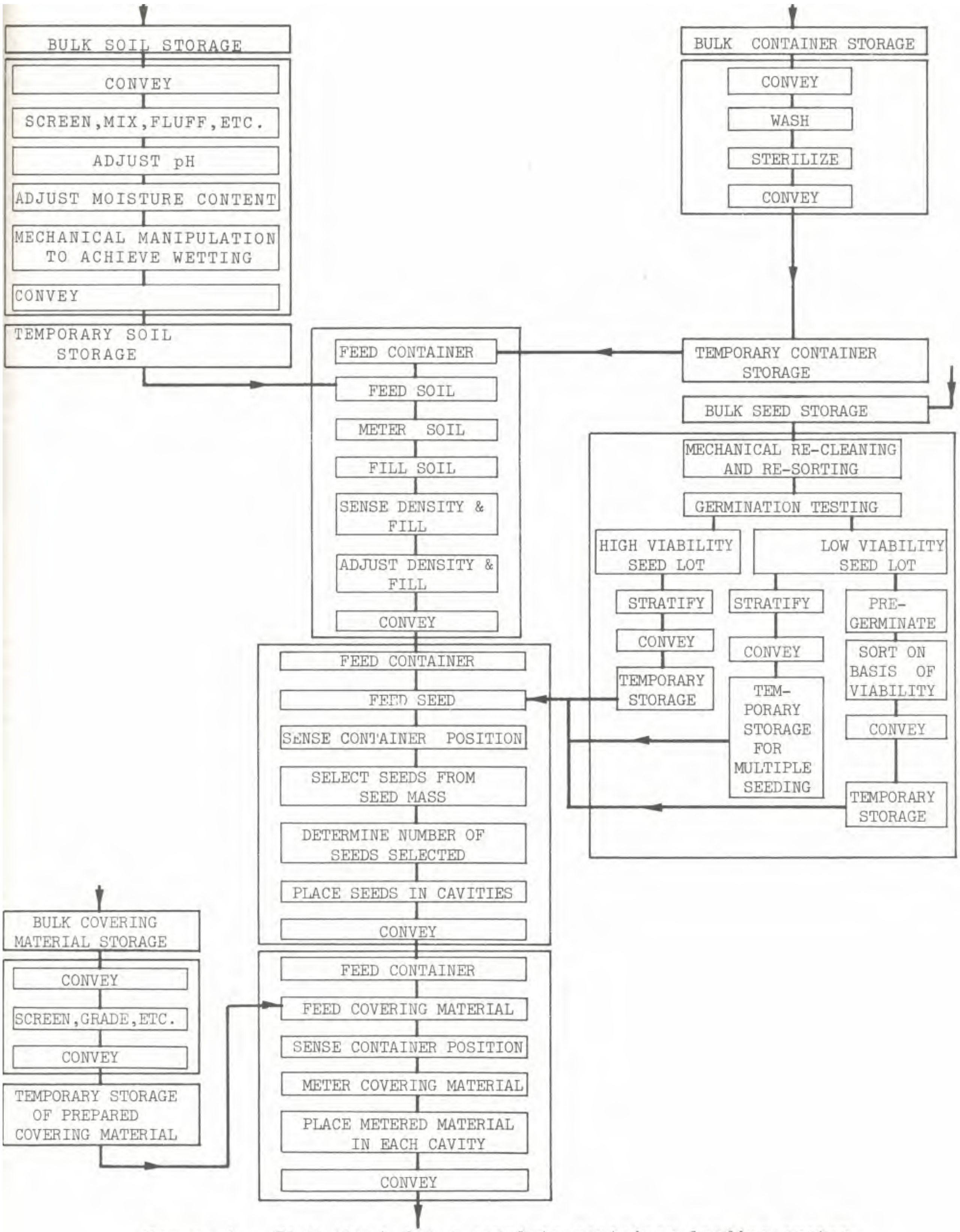

Figure 1.--Flow chart for a complete container loading system.

medium at an optimum density suitable for root development, one viable seed should be placed at a suitable location within each cavity and the seed should be covered with a suitable covering material at a uniform and consistent depth.

Many container types are presently being used for forest seedling production, some experimentally and some for large scale production. Some containers, such as the BC/CFS Styro 2-A and Styro 4 have resulted from many years of trials using various cavity shapes, volumes and spacings to arrive at a suitable balance between a biologically optimum configuration for specific growth and production requirements and specific economic considerations and handling requirements. Some other containers appear to have been developed merely at the whim of a company executive with no concern for the biological needs of the seedling and with no idea of the handling complexities that can be created from poor container design. As is discussed later, container design must first suit the biological needs of the seedling and the economic needs of production. There is however much that can be done during initial container design to simplify and reduce handling requirements and to simplify the equipment required for the container loading line. Before fabrication of expensive tooling for a new container, the designer of the loading and handling equipment should be consulted.

The following report outlines the development of a high capacity precision seeder, a seed covering machine and a soil loading machine for containerized seedling production. The individual machine components are discussed separately. First, however, it is worthwhile to outline the operational requirements of a complete container loading system.

Operational Requirements of a Container Loading Line

The operational requirements of a container loading system for forest seedling nurseries may be summarized as follows:

1. The optimum system will produce one, and only one surviving seedling per container cavity. To achieve this the loading line should place one viable seed at a suitable location in each cavity. The cavities should be filled with growing medium packed at the optimum level and density for root development, and the seed covered to a suitable depth with an acceptable type of covering material. Since in many cases biologically optimum conditions are still unknown, equipment must be designed for operation in a range about the expected optimum. Similarly, design must be compatible with expected future developments. For example, if a system were developed for pregerminating low-viability seed lots and selecting viable seeds, then seeding equipment must be capable of seeding pregerminated seeds.

2. Design capacity must be great enough to suit time limitations and economic considerations of a specific production location. Where containers are grown outside or in minimum cost shelter houses, the short growing season must be used to best advantage and container loading must be completed in a short period.

3. Labor input should be minimal. Aside from economic factors, the more personnel involved in a specific operation, the more chance of human error. Ideally, if one person is required to operate a container loading line, he can be hired as a specialist directly responsible for container production.

4. Equipment should be readily adaptable to a wide variety of container types. Container design is still in an experimental stage and many changes can be expected in the future. Also, nurseries may simultaneously wish to use several container types to suit specific needs.

5. Equipment should be readily adaptable to a wide variety of seed species, growing media and seed covering media.

6. The equipment should be portable as a self contained unit requiring no disassembly for movement within the nursery. Although some container nursery designs incorporate a central loading and preparation

building, other designs are better suited for temporary placement of the filling line within each shelter house or near the outdoor growing location.

A flow chart illustrating the specific functions to be performed by a container loading line is shown in Figure 1. Various portions of this flow chart are described in detail in the following discussion.

DEVELOPMENT OF A HIGH CAPACITY PRECISION SEEDER

Design procedures, detailed laboratory test results on model seeders incorporating various seed selection principles, prototype field test results and operating instructions have previously been reported by Nyborg et al. (3,5,6, 7)3/ The following discussion is abstracted from these references. It has been updated to include recent design changes to facilitate fabrication and to make the seeder adaptable to a wide variety of container types.

Design Procedure

Based on physical properties determinations and seed size measurements of commercially important species grown in British Columbia, a group of seed selection tools incorporating a wide variety of seed selection principles were fabricated and tested. Results indicated that for uniformly shaped and sized seeds possessing some degree of axial symmetry, (such as Pinus contorts) several types of seed selection principles could be used. For irregularly shaped seeds (Pseudotsuga menziesii) however, and for seeds containing pitch on the seed coat (Tsuga heterophylla), a modified vacuum seed selection principle was found most suitable. This seed selection tool, which is described in detail below, was capable of rapid precision selection of individual seeds of all commercially important species.

3/ Numbers in parenthese refer to the Literature Cited, at the end of this Paper.

Modified Vacuum Seed Selection Tool

Individual seed selection tools (Figure 2) are designed as follows: A seed orifice (an aperature with a diameter less than the minimum dimension of a seed) is placed on a drum surface with the central axis of the orifice directed radially. One revolution of the drum is a complete cycle. During this cycle, the air pressure differential across the seed orifice changes three times. The mechanism does this by changing the pressure inside the seed orifice, consequently changing the direction and magnitude of the airflow through the seed orifice. Initially the mechanism introduces a vacuum inside the seed orifice and the resulting airflow is inward. The drum and seed orifice rotate through a shallow line of seeds held at the base of a hopper. The airflow through the seed orifice picks and retains several seeds on the drum surface. The drum continues to rotate, carrying the seeds past an externally applied air blast. This air blast which blows continuously from a nozzle (air brush) is directed

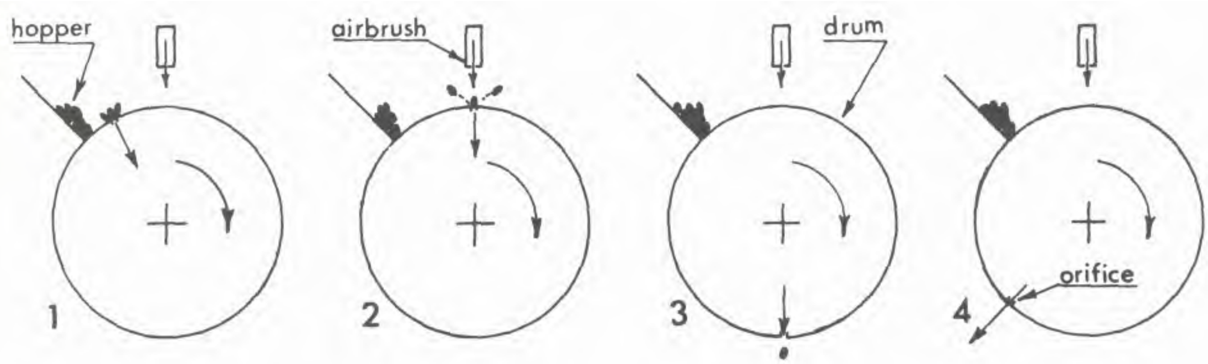

Figure 2.-- Schematic illustration of the phases of operation of the modified vacuum seed selection tool. (Phase 1: pick seed cluster, Phase 2: select single seed, Phase 3: drop seed, Phase 4: scavenge orifice).

inward toward the drum surface at a predetermined angle and removes all but the desired number of seeds from the seed orifice. The air pressure at the nozzle and the vacuum at the seed orifice determine the number of seeds retained on the seed orifice. Thus one seed may be retained for high viability seed lots and two, or more seeds may be retained for low viability seed lots, if hand thinning is to be performed. Seeds are carried by the rotating drum to the position where they are to be released. At this position the mechanism increases the pressure inside the seed orifice creating a light reverse airflow that removes any seeds that may stick to the seed orifice. The drum rotates to a third position where the mechanism further increases the inside pressure so the resulting airflow can clean the seed orifice. The rotating drum then reaches the point of origin and the cycle is repeated.

During initial design, a factorial study of a model seed selection tool was conducted in order to determine the nature of the following functional relationship for various lots of commercial British Columbia seed species:

$$n = f(v,\theta,d,a,b,c,\emptyset,r,\alpha,\beta,h,P_1,P_2,m)$$

where

- n = the number of seeds retained on the seed orifice
- v = peripheral velocity of the seed drum
- θ = slope of the seed hopper base
- d = depth of the seed in the hopper
- a = hopper feedgate opening
- b = hole diameter of orifice root
- c = seed orifice depth
- $\emptyset$ = slope of the seed orifice walls
- r = hole diameter at the air brush root
- α = angle of divergence of the air brush
- β = angle of incidence of the air brush axis on the drum surface
- h = height of the air brush above the drum surface
- P_1 = pressure differential across the seed orifice
- P_2 = pressure differential across the air brush orifice
- m = seed moisture content

Space does not permit presentation of all the factorial study results. Only some of the more important conclusions applying directly to seeder design are reported.

1. A wide range of seed drum speeds is possible. Drum surface velocities ranging from 0 to 450 meters/minute were found satisfactory. Higher velocities were not tested.

2. The seed hopper base angle (slope) should approximately equal the seed angle of repose. An adjustable feed gate in the hopper is necessary to maintain a shallow depth of seed at the drum surface. The position of this feed gate is a function of the seed moisture content and the seed species.

3. Seed orifice design is critical. Some seed orifice configurations that satisfied operational requirements are schematically illustrated in Figure 3. Two orifice root diameters are suitable for all British Columbia species; 0.50 mm for Pinus contorta, Tsuga heterophylla, Picea glauca, and Picea sitchensis and 0.75 mm for Pseudotsuga menziesii. Types (a), (b), and (c) orifices operate in a range from 98% to 102% single seeds, while type (d) orifice may be adjusted for a consistent 100% delivery of single seeds. Type (d) orifice is suitable only for seeds possessing some degree of axial symmetry such as pine, spruce and hemlock. Orifice type and depth must suit the particular seed species. Orifice types (e), (f), and (g) may all be used for multiple seeding of low viability seed lots. Proper selection of orifice diameter, and proper adjustment of orifice vacuum, airbrush pressure and inclination permits a single orifice (type (e)) to be used for quite consistent delivery of a desired number of seeds per orifice. Multiple orifices (types (f) and (g)) may also be used for precision delivery of multiple numbers of seeds per cavity.

4. Clean seed is essential for satisfactory orifice performance. For this reason, pre-cleaning of seed lots to be used for container production is recommended. The use of an air column, such as a Dakota blower, to remove wing and seed coat particles is quite

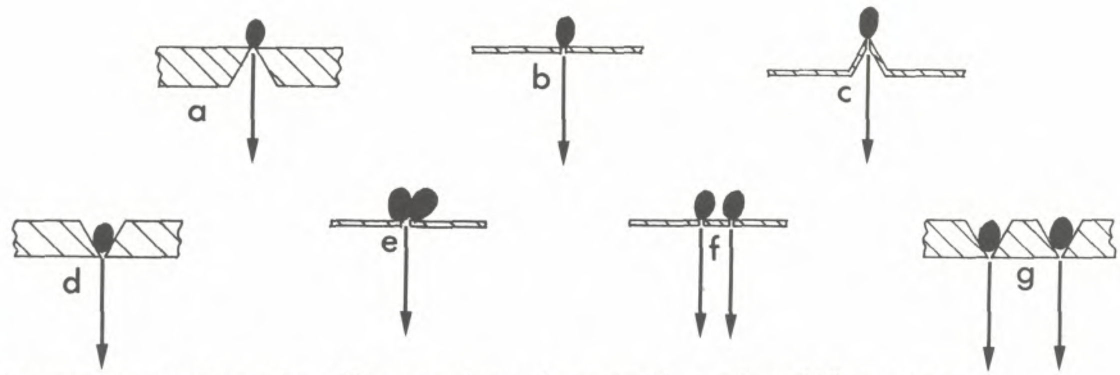

Figure 3.--Schematic illustration of several seed orifice types.

successful. A properly designed sump at the base of the seed hopper to accumulate seed coat particles is also useful, especially when seeding large lots of Pseudotsuga menziesii.

5. Airbrush characteristics are critical for proper performance of types (a), (b), (c), (e) and (f) seed orifices. Airbrush characteristics are less critical for type (d) and (g) orifices. A specially designed diverging airbrush nozzle was suitable for all seed species. The angle of incidence of the brush on the seed drum and brush height must be adjusted during calibration for each seed species, seed orifice type and rate of seeding.

6. The required pressure differentials across the seed orifices and at the airbrush nozzles depend upon the seed species, the seed orifice type and the rate of seeding. They must be adjusted during calibration.

7. The seed selection model performed well with wet and dry seeds of all species as well as with pregerminated seed.

8. Seed orifice plugging was completely eliminated using the air scavenge cycle. An air scavenge gauge pressure of approximately 200KPa was suitable for all the seed orifice types.

Design of a Container Seeding System

The following is a detailed description of a precision seeder, incorporating the modified vacuum seed selection tools, which performs all of the seeding functions outlined in Figure 1.

Seed orifices are machined into a thin walled steel sleeve covering the seed drum. (Although brass and aluminum were used for seed orifices on some early prototypes, steel was found to be necessary to eliminate wear problems and to reduce the possibility of orifice damage by inexperienced nursery personnel). Seed orifices are placed on the drum surface, with lateral spacing coinciding with cavity spacing of a specific seedling container. A number of rows are placed about the circumference of the seed drum to coincide with rows of cavities in a container. The circumferential spacing of orifice rows is determined by the type of container and by the desired number of revolutions of the seed drum to traverse a container. Thus, a specific seed drum is required for each container type and for each seed orifice type to be used with this container. Figure 4 shows seed drums fabricated to suit stroblock 2, 2-A and 4 containers.

An air passage beneath each row of seed orifices connects the orifices to a valve plate at one end of the seed drum. A stationary pressure-vacuum manifold attaches over the valve plate, serving as a bearing, air seal and rotary valve. The air brush (Figure 5) contains air nozzles which align laterally with the seed orifices. Hence, a specific airbrush is also required for each container type.

The following adjustments are provided to control the performance of the seed drum: seed hopper feed gate opening, seed orifice vacuum, airbrush pressure, airbrush position and angular

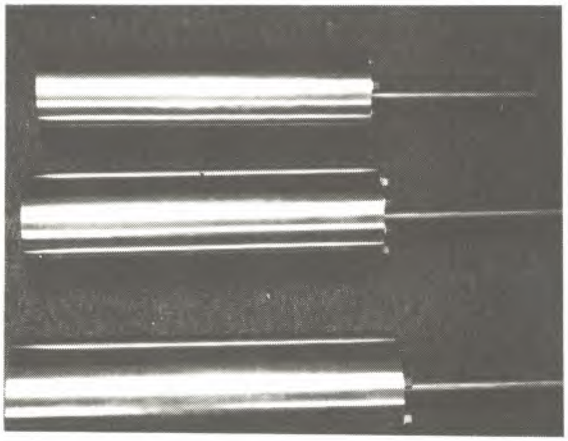

Figure 4.--Seed drums to suit styroblock 2, 2-A, and 4 containers.

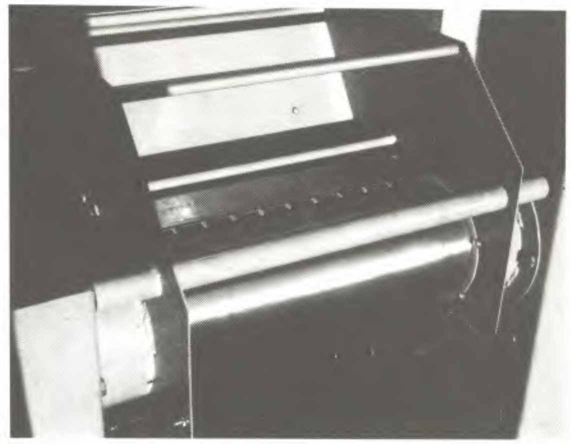

Figure 5.--View of seed drum and air brush.

orientation, seed drop pressure and seed orifice scavenging pressure. The control console is shown in Figure 6.

The seeder is designed to be fed from an inclined dead-roll conveyor. Soil filled containers, butted end-to-end are gravity fed onto the powered seeder conveyor. The two stage seeder conveyor automatically spaces containers to permit accurate position sensing.

When the leading edge of a container reaches a predetermined position under the seed drum, a limit switch energizes the seed drum drive, causing the seed drum to rotate above the moving container. As the seed drum rotates, each of the seed orifice rows successively passes through the four phases of operation shown in Figure 2. Seeds are dropped, one row at a time, into the corresponding row of cavities in the container. Once the container has passed by the seed drum, a sensing circuit stops the drum in its original position.

The design capacity of present production, when using styroblock 2-A containers, is seeding of one million cavities per eight hour shift. This may be increased or decreased to suit specific requirements.

An industrial vacuum pump delivering approximately 10 dm^3/s at 80 KPa is used as the vacuum source and is suitable for seeding all the species. In addition, an air compressor, rated at approximately 5 dm^3/s at 700 KPa gauge is required to operate the pressure components.

The Value of Multiple Seeding

The principle of multiple seeding of low viability seed lots is practiced by many nurseries in an attempt to obtain better cavity fill. Although the seeder may be adjusted to place more than one seed per cavity, the whole concept of multiple seeding of low viability seed lots may be of questionable benefit. A list of probability tables, outlining the possible successes of multiple seeding for seed lots of various viabilities has previously been reported by Nyborg (7). Space does not permit the duplication of these tables, however, one example will be used to illustrate a point:

Let us assume that a certain seed lot of 20% viability is in short supply and must be used for seedling production. Assume that the seeder operator decides to place five seeds per cavity to increase the number of productive cavities and to conserve greenhouse space. From probability techniques it may be seen that 33% of the cavities will produce no seedlings 41% will produce one seedling, 20% will produce two seedlings, 5% will produce three seedlings, and 1% will produce four seedlings. On this basis, 960 seeds will be placed in a styroblock to produce 129 productive cavities.

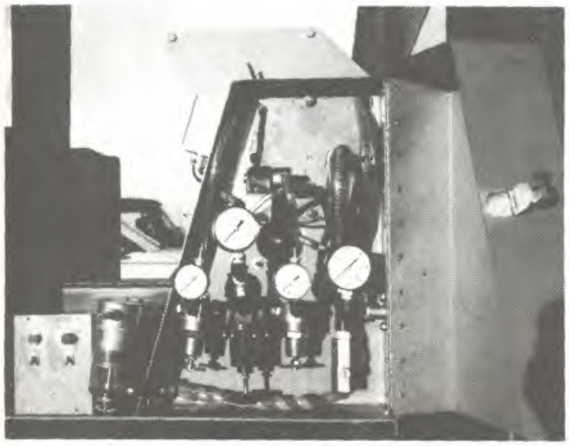

Figure 6.--View of seeder control console.

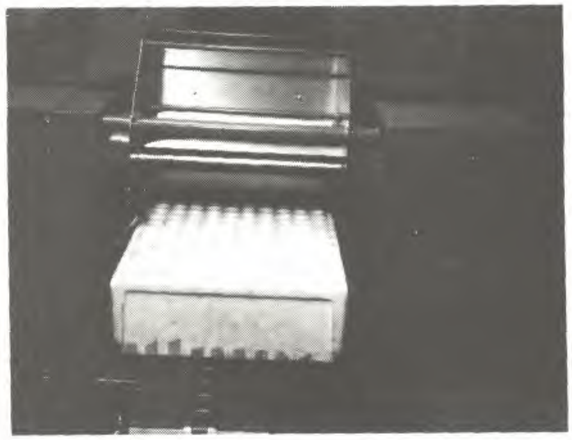

Figure 7.--View of seeder and conveyor assembly.

Furthermore, 68 viable seeds will have to be discarded from each container in the hand thinning process. This means that 35% of the viable seeds in the seed lot will be wasted in order to obtain a cavity fill of 67%. Only if seed cost, seed availability, greenhouse storage costs and hand thinning costs are known, is it possible to determine if any benefit may arise from multiple seeding.

The ultimate goal must be the development of equipment for proper sorting of low viability seed lots before seeding. It is reported that a system for pregermination and sorting of low viability seed lots has been developed by Hagner (1). This would allow precision seeding of single viable seeds into each cavity.

DESIGN OF A SEED COVERING MACHINE

Various types of seed covering media are used in different container nurseries. The type of covering material used depends upon the specific function it is to serve. In British Columbia, screened granite grit is used as a seed covering material for all containers. Its main purposes are to reduce the growth of mosses and liverworts on the cavity surfaces, to prevent seed losses due to migratory birds when containers are grown outdoors, and to reduce evaporation losses on the cavity surfaces in the initial growing stages. The grit is also heavy enough to prevent seed and grit loss due to wind, rain and irrigation water during the initial growth stages.

In Scandinavia, styrofoam pellets are used as a seed covering material in most container nurseries. Although they serve most of the functions listed above, they also serve as a reflective material, increasing the radiant energy received by the seedlings. Hulten (2) indicates that this may significantly increase the initial growth of seedlings. One severe drawback with styrofoam pellets, however, is that they are readily susceptible to loss due to wind, rain or irrigation water.

Since the type of covering material used and the quantity of material placed in each cavity will vary depending upon specific requirements, a seed covering machine should have the capability of working with a wide variety of covering materials. It should also be capable of metering specified amounts of the covering material into each cavity.

Design Considerations

The operational requirements considered in design of the seed covering machine were: It should be capable of metering and delivering an adjustable quantity of covering medium into each cavity, it should perform successfully with a wide variety of covering media, it should be readily adjustable to accommodate different container types and its capacity should at least equal seeder capacity to permit continuous on-line production.

A schematic illustration of a metering and feeding tool, which meets these operational requirements, is shown in Figure 8. Cylindrical indents, placed tangentially, in the surface of a steel covered rotating drum serve as metering tools. The quantity of covering media retained by each indent is determined by the level of material on the rear drum surface. Since material level is adjustable by means of a feedgate, the quantity of material delivered by each indent may be varied to suit specific requirements. A specially designed feeder is used for distribution of the metered material into individual container cavities.

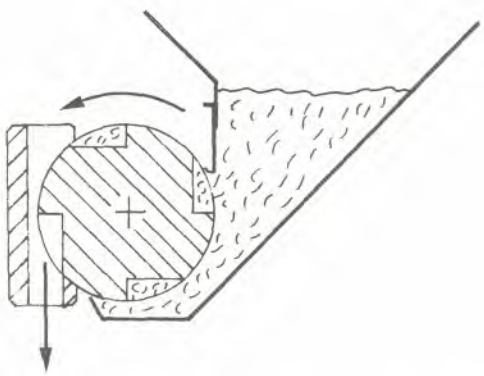

Figure 8.--Schematic illustration of metering and feeding tool for seed covering.

Indents are placed in rows on the drum surface, withlateral spacing corresponding to lateral spacing of cavities in a seedling container. The number of rows of indents on a drum depend upon the number of revolutions of drum travel

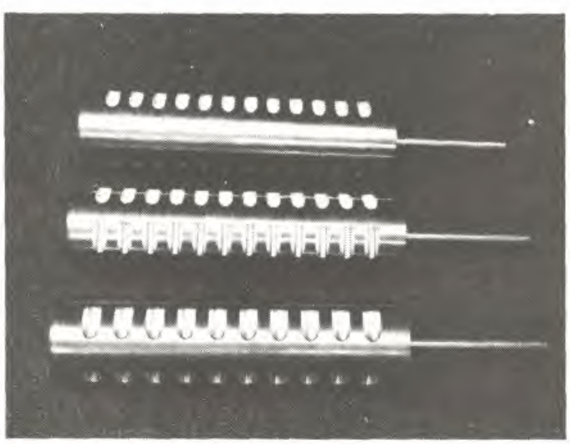

Figure 9.--Grit drums for styroblock 2, 2-A, and 4 containers.

Figure 10.--Seed covering machine hopper assembly.

required to traverse a specific container while the size of the indents is governed by the maximum amount of covering material desired per container cavity. A special drum and feeder assembly is therefore required for each type of seedling container used. Figure 9 shows grit drums designed for styroblock 2, 2-A and 4 containers while Figure 10 is a view of the assembled hopper and drum.

The seed covering machine is placed over the same conveyor assembly which feeds the seeder (Figure 11) and is mounted on the same undercarriage. A sensing circuit, similar to that on the seeder, is used for drum activation.

Figure 11.--View of seeder, gritter, conveyor and support frame assembly.

DESIGN OF A SOIL LOADING MACHINE

Several different types of soilmedia are used for containerized forest seedling production. Although the majority of container nurseries use straight sphagnum peat moss, some nurseries use mixtures of sphagnum peat moss and vermiculite, while others also add sand or bark mulch. Experience has shown that in most cases a more durable seedling plug can be produced by the use of straight sphagnum peat moss or a mixture of peat moss and vermiculate. The granular plug structure resulting from the addition of sand, and the coarse plug structure resulting from the use of bark mulch may produce seedling plugs which deteriorate readily during extraction, packaging, transporting and planting, A second advantage of peat moss, as a growing medium, is that it is sterile due to high drying temperatures during processing.

The soil serves two contradictory purposes in seedling production. It physically supports the seedling during growth and must act as a binding agent for formation of a durable plug. It also must act as a storage reservoir for water and dissolved nutrients. Some compromise, therefore, must be made between low cavity fill densities which may be suitable for optimum moisture storage and root development and high cavity fill densities which may be more suitable for good plug durability. It has been reported by McLeod et al. (4) that factory dry sphagnum peat moss in its uncompressed state has pore space occupying over 90% of its volume. Uncompressed peat at particle saturation moisture content has a density of approximately 0.087 gm/cm^3 while individual peat particles have an approximate density of 1.6 gm/cm^3. Hence, it is physically possible to load containers at cavity fill densities up to 20 times greater than that of uncompressed peat.

Since the optimum cavity fill density for optimum seedling growth and the importance of cavity fill density variations within and among cavities is unknown, initial development work on a soil loading machine had to be directed toward determination of the effect of cavity fill density on seedling growth and plug durability. Results of this study will reveal suitable design parameters for cavity loading equipment. Similarly, since the physical properties of commercial sphagnum peat moss, such as flow characteristics, and wetting characteristics are also unreported, physical properties determinations were also necessary. Although these studies are reported in detail by McLeod et al. (4), they may briefly be summarized as follows:

Pertinent Physical Properties of Commercial Sphagnum Peat Moss.

The following data apply to sphagnum peat moss mined from the Burns Bog area of British Columbia and commercially dried and prepared. Although much variation may be expected depending upon the location of the peat bog, the data give some general parameters to be considered in design of loading equipment.

(1) Commercial peat preparation plants dry peat moss to approximately 74% moisture content d.b. (dry basis). This moisture content is approximately at the fibre saturation point level, corresponding to the transition point between constant rate drying and falling rate drying.

(2) Prepared peat mechanically meters most satisfactorily at or below the fibre saturation point moisture level, although, using proper techniques, satisfactory metering may be obtained at moisture contents up to 200% d.b.

(3) Peat at moisture contents below the fibre saturation point is nonwettable and will not accept water without proper mechanical manipulation. It is possible, by proper mixing techniques to achieve good wetting characteristics within the moisture content range at which satisfactory metering occurs.

(4) The wetting characteristics of commercially prepared peat are dependent upon drying temperatures and exposure times at the processing plant. Drying temperatures below 95°C are preferable as the particle saturation level is approached. Packaging peat at a moisture content slightly above 74% d.b. would also improve initial wetting characteristics.

Design of a Model Peat Loading System for Growth Studies.

As was previously mentioned, optimum design parameters for a soil loading machine were unknown at the initiation of this study. Hence a model soil loading machine was designed and fabricated to load styroblock 2 cavities at uniform densities throughout the cavities. The machine also has the capability of producing a wide range of uniform cavity fill densities. This model (Figure 12) incorporates mechanical metering and pneumatic injection in order to load predeter-

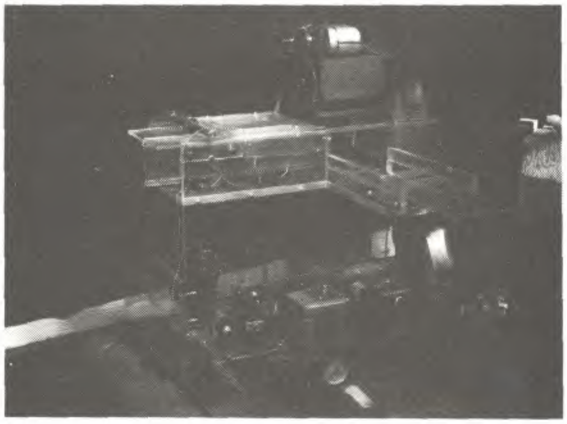

Figure 12.--Model pneumatic peat loading machine.

mined quantities of peat at desired cavity fill densities. A group of styroblocks were loaded in March,1974 at a wide range of cavity fill densities. These blocks are presently being grown at the Burnside laboratory of Pacific Forest Research Centre. Seedling growth rates, root development and plug durability are presently being assessed in order to determine the effect of cavity fill density. The outcome of this study will determine the necessary type of soil loading equipment. If cavity fill density is an important factor, sophisticated equipment may be required, while if wide variations in density may be tolerated, simple equipment may be suitable.

Cavity size arid shape may create special soil loading problems. For example, straight walled containers with cavity diameters greater than 2.5 cm may be loaded with simple techniques. Such containers, however, may biologically not be the most suitable container and may lead to problems such as root spiralling. On the other hand, small diameter, tapered and ribbed cavities, which are designed for good root development and plug handling characteristics may create special soil loading problems due to bridging.

CLOSING REMARKS

This paper has briefly summarized the operational requirements of a rest seedling container preparation line and has described some component suitable for a nursery preparation line utilizing a wide variety of container types. In observing the many types of seedling containers which have been developed in the past few years, it is apparent that people often forget some of the basic requirements of a seedling container, in their haste to develop a new container type. Since proper container design can greatly simplify design of a loading line, it is worthwhile, in closing, to list some of the basic requirements of a seedling container.

1. The biological needs of a specific species for a specific growing regime determine factors such as cavity size, cavity shape and cavity spacing. These can only be determined by repeated growth trials and by reference to the previous successes and failures of others. The ultimate goal is the minimum cost production of a seedling which survives in the environment in which it is to be ultimately planted. It is important to remember that cavity shape may possibly produce effects which do not show themselves until many years after planting. For example, there is concern by some researchers that excessive root spiralling within a cavity and improper root pruning may lead to the failure of development of a tap root in Pinus contorta. This may ultimately lead to toppling as trees approach maturity.

2. A suitable balance between biological requirements and economic requirements may require some deviation from the design selected on a purely biological basis.

3. The material used in container design will largely depend upon material costs, raw material availability and expected container life, if recycling is anticipated. The material must also be biologically compatible with the specific species being grown. For example, root penetration in porous or poorly bonded material may prevent plug extraction. If the container, or a portion of the container is to be used for transport to the planting site, field planting trials are essential to ensure acceptance of the technique by planting crews.

4. From a mechanical handling point of view, the following criteria are important:

   (a) The container should possess sufficient strength and rigidity so that when loaded with soil and moisture to field capacity it can withstand handling loads without undue deformation or breakage.

(b) If plug extraction and repackaging are anticipated at the nursery level, cavity drain holes should be of uniform size and shape and of predetermined spacing.

(c) Some portion of the container (preferably a leading edge) should consistently be spaced at a uniform distance from the rows of cavity holes to permit accurate position sensing.

(d) Cavity spacing should be consistent and should not vary during handling. (One of the severe disadvantages of paper pots is that cavity size and the spacing of cavity rows is a function of how the paper pot is unfolded. At least two container nurseries in Sweden have developed an elaborate prestretching machine for paper pots in an attempt to achieve uniform cavity spacing so that seeding equipment spacing matches cavity spacing).

(e) The number of rows of cavities in a specific container is critical for ease in machine design. The number of cavity rows should be an even multiple of some of the smaller integers. This allows any rotating feeding device to make an even number of revolutions per container and to reset automatically for the next container. For example, 20 rows of cavities permits the use of 1, 2, 4, and 5 revolution devices for seeding and filling, whereas 19 rows of cavities permit the use of only single-revolution devices. This principle has been overlooked in the design of one recently developed container which has 13 rows of cavities.

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Question: How often do vacuum holes have to be cleaned of chaff or pitch?

Nyborg: They are cleaned by compressed air during each rotation of the cylinder. The purge pressure I mentioned is somewhere around 30 lb/square inch. The first model of the machine did not have the purge feature; when we used high pressure to drop the seed, it went all over the place. This is why we use the low-pressure seed drop and the high-pressure scavenge.

Question: Is the seed treated with talc, starch, or dye?

Nyborg: Sometimes seed is coated with talc.