around the base of the plant for the first 4 or 5 growing seasons is strongly recommended.

The artificial mix used in the container production of holly and other evergreens is as follows:

12 cubic feet sphagnum peat (two 6-cu. ft. bails)

12 cubic feet red wood waste (approx. two 6-cu. ft. bails)

8 cubic feet Turface (or Perlite) (four 2-cu. ft. bags)

4 cubic feet greenhouse potting soil: 1 sand, 1 soil, 1 peat

To this is added approximately 6 cubic feet of well rotted manure, 15 lbs of regular Magamp and 8 lbs of agricultural limestone. The ingredients are thoroughly moistened while being mixed by hand and through a Royer shredder. There appears to be no necessity to allow this mix to age or cure. Often rooted cuttings or transplants are potted in the material on the day of mixing without apparent ill effect.

DEVELOPMENT OF A PRODUCTION CONCEPT FOR HANDLING PRE-GERMINATED SEED

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Abstract. A high degree of utilization is essential when genetically improved seed is used for nursery stock production. This can be achieved in systems which provide improved environmental conditions for germination and early growth. Steps in the development of a pregermination technique are described, utilizing sphagnum moss cigarette plugs for germination and the handling of black spruce germinants. After initial growth in heated greenhouses, seedlings were transplanted into standard nursery beds. Two-year-old transplants were grown, comparable to conventional three to four-year-old bare root nursery stock. Concepts are presented for automating the technique as a possible basis for development of a viable modified stock production system.

A major concern in stock production has been seed efficiency, defined as the proportion of stock shipped from the nursery relative to the number of viable seed sown. For most major reforestation species, i.e. white pine (*Pinus strobus*, L.), red pine (*Pinus resinosa*, Ait.) and white spruce (*Picea glauca* (Moench) Voss), seed efficiency averages about 25%. However, for black spruce (*Picea mariana* (Mill) B.S.P.) this is only 15%. Nature has little concern for seed loss. For example, a mature white spruce in a good seed year should produce 100,000 viable seed, probably repeated 15 to 20 times during a rotation. Yet this tree is replaced by only one or two trees in the natural successional process. Man has embarked on tree improvement programs to increase the potential for growth. Limited quantities of costly high quality seed are produced. The valuable genetically improved seed must be used wisely to regenerate as much area as possible with faster growing trees to meet forecast increases in industrial need.

To achieve a seed efficiency close to the germinative potential, suitable environmental conditions must be provided. Under the optimum conditions defined by Fraser (2) the germinative capacity of most provincial black spruce seed is in excess of 95%, achieved in 8 to 10 days. Under conventional seed bed conditions, especially in northern nurseries, only a small proportion of seed germinates, with emergence extending from spring to early August.

In evaluating modified stock production systems, three major factors must be considered. Quality of stock at time of planting, in terms of top length and stem diameter affect plantation survival and early performance (5). Current information estimates overall mean survival of conventional nursery stock of 58% to 64% across Ontario five years after planting, depending on species (3). Optimum germination conditions, in addition to ensuring a high degree of seed utilization, provide good quality, vigorous germinants which contribute to the uniformly high quality shipping stock necessary to meet competitive situations on outplanting.

Increased needs for planting stock are forecast. Annual planting of 66,000 hectares of the major coniferous species is predicted by 1987 (6). Current planting is reported at 19,300 hectares (1). The black spruce component is expected to rise from 7.6 million (15.8%) of the 48,292 million trees planted in 1977 (1) to 27.4 million (29.8%) of the estimated 92,000,000 trees, bare root and container stock for planting in 1983-84 (Reese, personal communication).[1] Such increases will severely tax labour resources and facilities unless shorter rotations and high speed automation are employed.

Changes in technique to achieve these goals must be accomplished in time of economic restraint. For modified germination conditions, facilities such as germination rooms and greenhouses are needed. Full utilization of greenhouses, using only established germinants, and reduced production time help minimize this cost. Only one set of conditions need be maintained in the greenhouse as germination is completed elsewhere. Culling costs relate to uniformity of stock in the nur-

[1] Derived from personal communication with K.R. Reese, Stock Production Specialist, Ontario Ministry of Natural Resources, Toronto.

sery bed. With all greenhouse stock starting from germinants at the same stage of development, and with early culling at time of transplanting, these costs will be minimized.

SYSTEM DEVELOPMENT

A technique has been developed for the production of high quality two-year-old black spruce transplants as an alternative to current three and four-year systems. This involves pregermination of seed, early development under greenhouse conditions and subsequent transplanting and shipping as bare root nursery stock.

Pregermination plugs. The planting of germinants by hand is used in research with valuable seed lots and in developing countries with labour intensive production systems. However, with the high labour costs in Ontario, automation is essential. This necessitates a device for handling the germinant while protecting its delicate radicle.

The use of a small container seems obvious. The Ontario tube was pioneered by the Ministry of Natural Resources for the tubed seedling program (4). The technology developed in that program provided a starting point for smaller containers for germination only. Waxed paper straws were investigated and found to be too difficult to fill and seed. Dental cotton rolls presented an excellent germination medium but proved to be difficult for black spruce root penetration and for maintenance of optimum moisture conditions. Nonetheless this might still be a valuable technique for some horticultural species. A satisfactory solution was found in sphagnum moss. Using a standard hand cigarette roller with 4 cm gauze bandage, peat moss cigarettes were formed and cut into 1.5 cm long germination plugs.

Containers to hold the germination plugs were made by drilling 200 holes in 2.5 cm styrofoam plates, 30 × 15 cm, in a 10 × 20 configuration to facilitate seeding on a standard tubed seedling vacuum seeder (7). Dental cotton rolls were inserted in the bottom of each hole to serve as a base for germination plugs and to act as a wick.

The system, though adequate for small research trials, was not suited for larger projects. A cigarette machine, Molin Mark VI provided by Imperial Tobacco, was assembled at the Ministry of Natural Resources Kemptville provincial nursery. A cleaning tower to eliminate coarse materials from the peat moss was built by Imperial Tobacco staff at Aylmer, Ontario. The research staff of Johnson and Johnson Ltd. provided a gauze type, nonwoven cellulose used in tea bags as a cigarette covering material. Cigarettes, from which germination plugs could be cut, were produced in an afternoon in sufficient quantity to meet research needs over a three year period. Production was about 600 cigarettes per minute, or the equivalent of 3000 germination plugs.

Cigarettes, placed in a hopper which released a single 30 cm long row of cigarettes, side by side, were picked up in a clamp. A second clamp was used to hold the other end of the cigarettes so that they could be cut into 1.5 cm lengths on a paper cutter. A plastic trough (Figure 1) was designed to hold a row of plugs on which seed was sown on a single line vacuum seeder head. A standard tubed seedling tray, 30 cm × 15 cm, held 12 troughs or approximately 450 germination plugs. A germination cabinet with a capacity of 20,000 plugs was used to provide optimum conditions for germination.

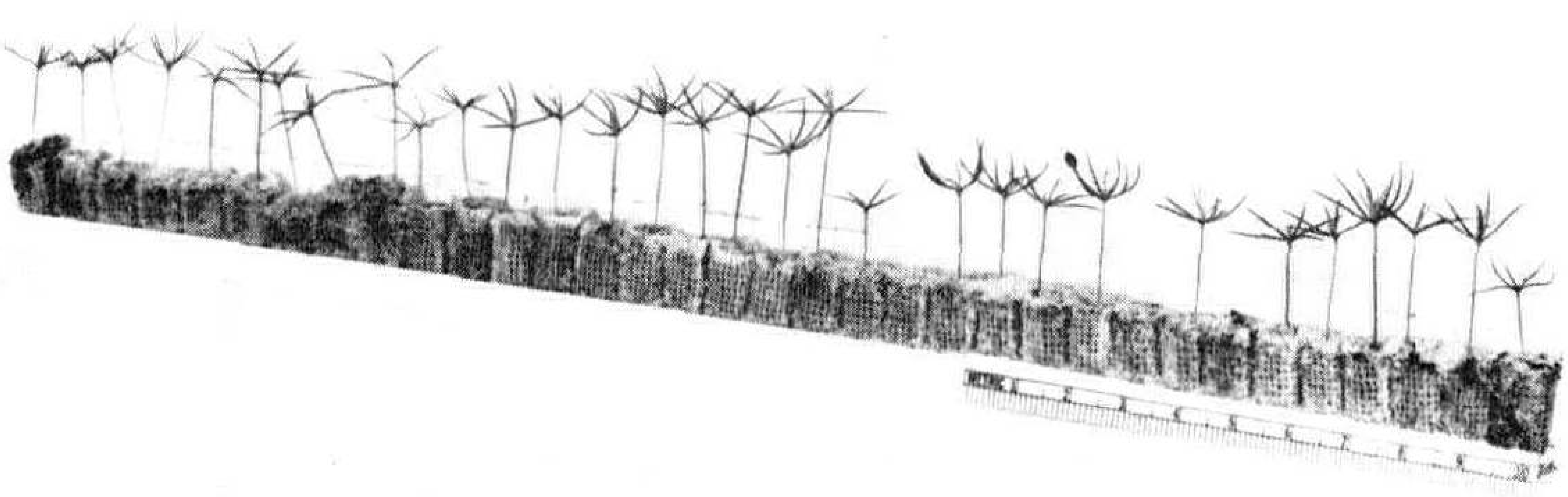

Figure 1. A trough of germination plugs with germinants.

Soil Blocks. A system was required in which the germinants could develop further in the greenhouse to a size sufficient for transplanting into the nursery. A soil block making machine was used to produce 2.5 cm cubes or a line of 12 across a continuous 30 cm conveyor belt (Figure 2). This machine appeared to have potential for production of either "containerless" containers or greenhouse transplants. The machine was modified so as to provide a hole in each cube to accommodate a germination plug. The holes replaced the shallow depressions normally provided for seeding. To overcome the difficulty of cubes breaking across the dibble holes, further modifications were made to recut the original fault lines between cubes.

Various soil media were tried. Muck, so successful in the production of vegetables in Holland Marsh, was of poor structure and its pH was too high for production of coniferous seedlings. Screened organic peat from a bog in Dunmore Township in northern Ontario and commercial peat moss with additions of 10% sand and 5% clay worked well on the machine.

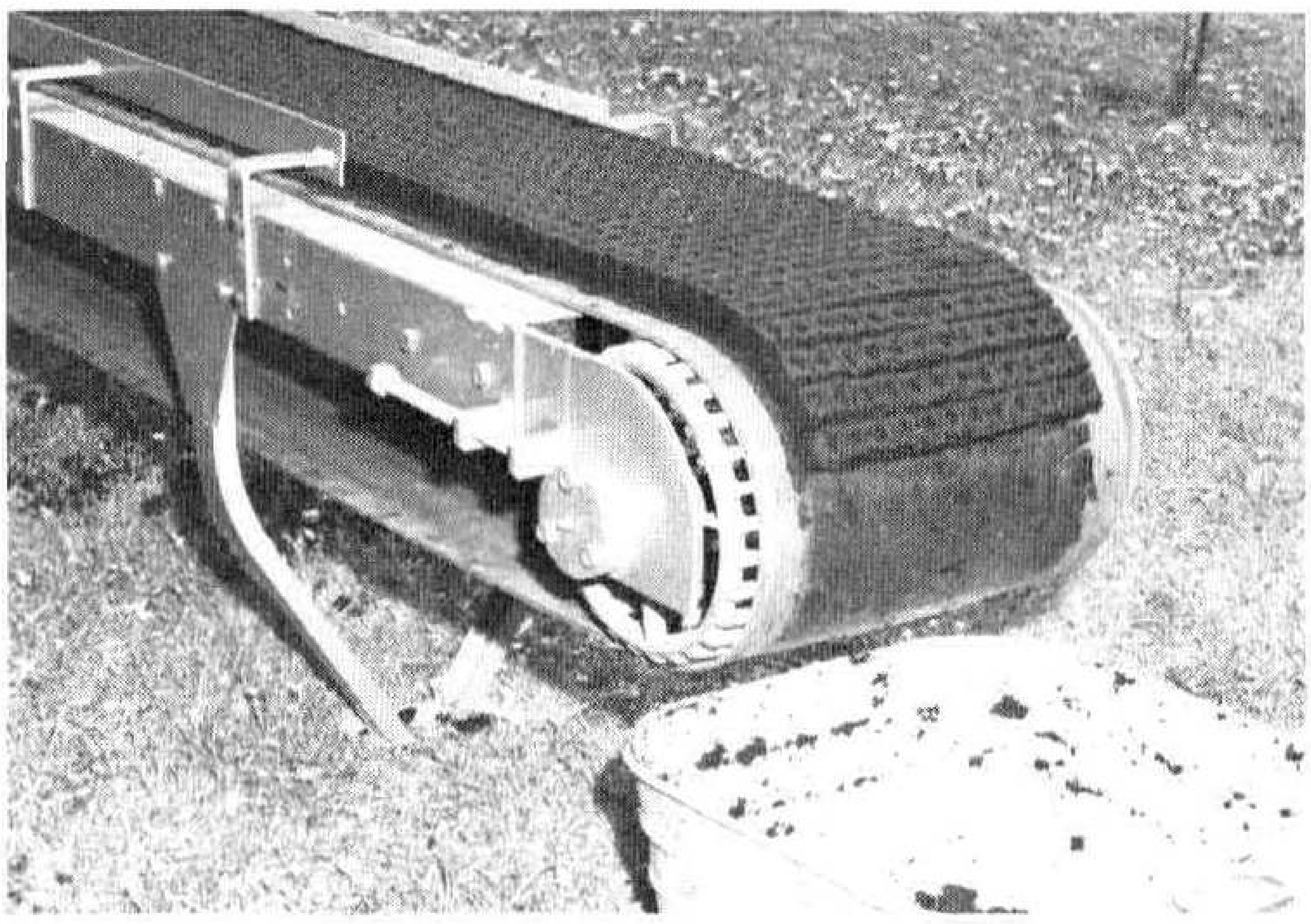

Figure 2. Dewa soil block machine delivering cubes of organic peat.

FIELD TRIALS

Orono Nursery 1975. A study of time of sowing was initiated at the Ontario Forest Research Centre at Maple and seedlings transplanted manually at the Ministry of Natural Resources nursery, Orono, Ontario. Plugs were sown at approximate monthly intervals from mid-February to early June. Germinants were planted in cubes as soon as cotyledons were fully formed and seed coats had dropped. Planting was by hand, using forceps to handle the plugs. The results are in process of publication by the authors.

Plants, sown in February and sampled after the second season in the nursery bed attained an average height of 27 cm and a dry weight of 5.3 g. Ministry shipping standards of 15 cm and 2.5 g plants were achieved by sowings up to May 1st though with considerable variability between plants. Shoot/root ratios, based on dry weight, were about 2:1, indicating a well balanced plant.

Swastika Nursery 1976. A pilot operation was conducted at Swastika, a northern Ministry of Natural Resources nursery near Kirkland Lake, Ontario. Seed was sown April 1st and planted into cubes April 20th. Seedlings were grown in a heated greenhouse for eight weeks, moved to a shaded area and finally transplanted July 5th to a standard nursery bed.

A subjective assessment by the nursery superintendent indicated stock could be shipped without culling. Mean height of 28 cm and 7 g dry weight far exceeded the minimum Ministry shipping standards. Shoot/root ratios of 2.7:1 were satisfactory. Trees grown in cubes of peat from Dunmore Township consistently outperformed those grown in cubes of commercial peat.

Swastika Nursery 1977. A second pilot operation, sampled in October, 1978, showed considerably more variation among plants. Germination was slow and irregular due to inability to maintain optimum germination conditions in the early weeks of opening the greenhouse in February. Mean height of 25 cm and dry weight of 6.5 g were still well above the minimum criteria. However it was estimated that 15-20% of the trees would not be shippable after two growing seasons. Shoot/root ratios averaged 2.3:1.

PRODUCTION CONCEPTS

The feasibility of growing two-year-old greenhouse transplants of acceptable shipping standards has been demonstrated. Some of the production steps have been worked out, but to date most developments have been to facilitate a manual operation. With automation, the number of steps can be reduced. The stage has now been reached where it is necessary to visualize the overall system in an operational setting.

Production and Handling of Germination Plugs. The Molin Mark VI cigarette machine is fully mechanized. By removing the indexed cutter, the cigarette machine will produce a continuous cigarette rope which can be stored on large reels.

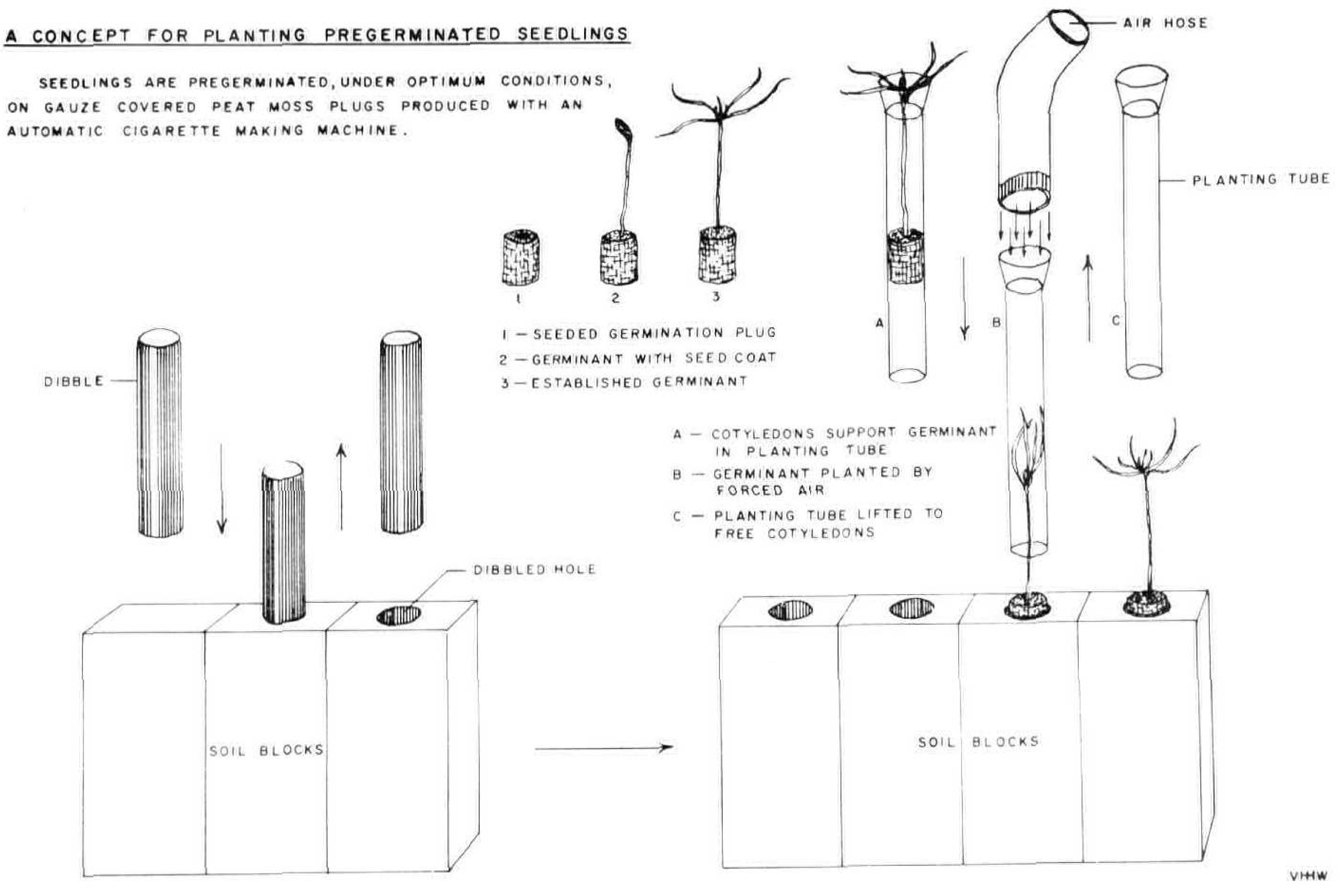

Figure 3. Assembly concept for production and handling plugs.

Through a series of guides, wheels and an indexed cutter, plugs can be produced and placed vertically in a line between horizontal guide rails (Figure 3). The line will move forward by means of a conveyor wheel onto a feeder conveyor into handling troughs. Once in the troughs, they will be moved into trays where other steps such as seeding, moistening and germinating can easily be automated on a production scale.

Planting in Soil Blocks. Some modifications to the soil block machine are complete. The cylindrical dibbles open a cavity adequate to hold the germination plug. A germinant planting device is currently being designed.

A culling step will be in place to allow selection of fully developed germinants between the germination and planting stages. This will be in a transfer system, where lines of germinating plugs will be scanned and accepted germinants of adequate height will be gathered into units of 12 for delivery to the planting system.

A system delivering 12 stocked germination plugs into the seeding tubes (Figure 4) will be installed on the soil block machine. Plugs drop easily into the tubes but are stopped by the cotyledons, holding the germinant suspended at the top of the tube. A pressure release at the appropriate time for a short period of time will send the plug and germinant down the tube into the dibble hole in the cube.

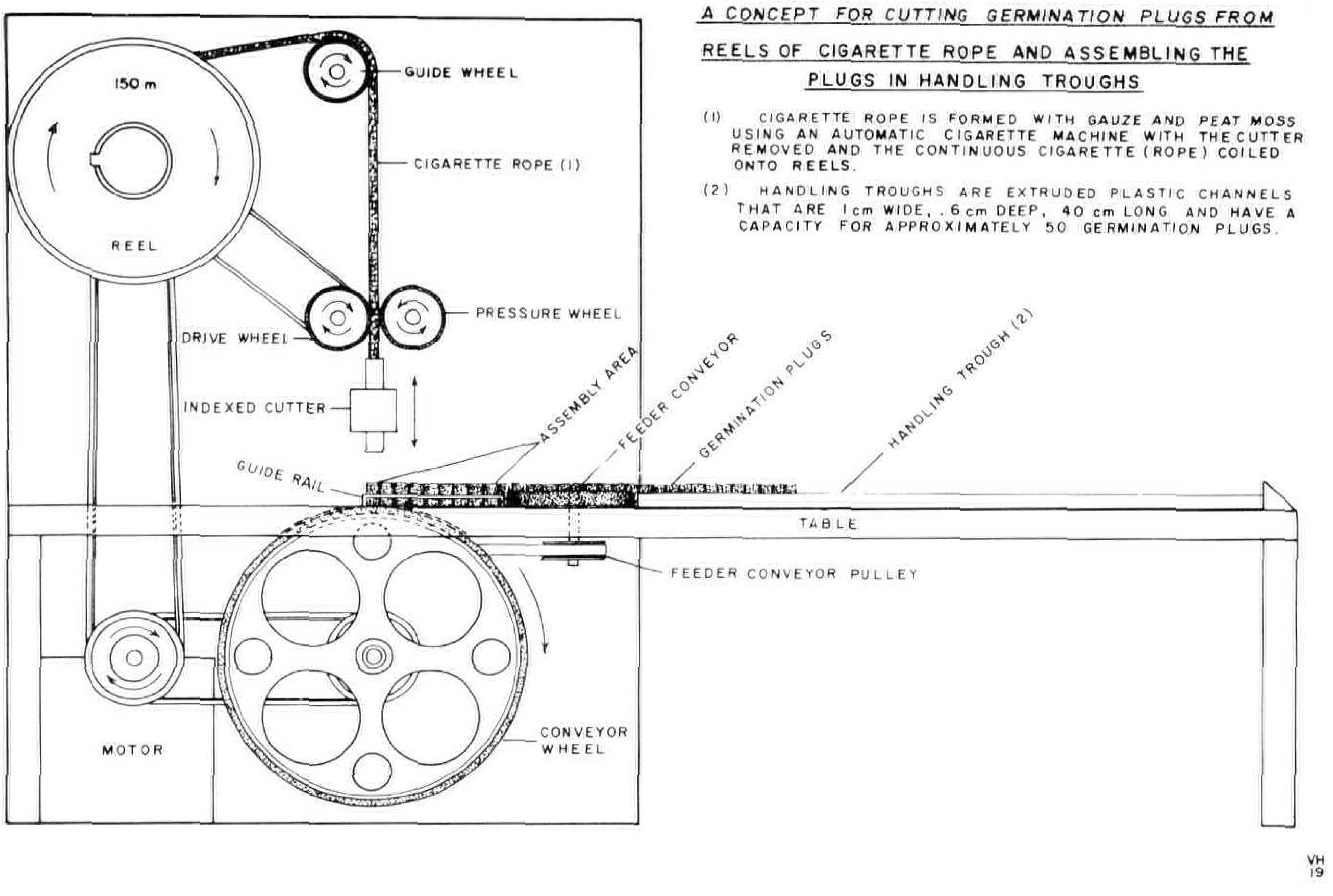

Figure 4. Assembly concept for planting pregerminated seedlings.

Transport of Cubes with Germinants to Greenhouse. Continuous lines of cubes from the conveyor belt will be fed directly into pallets (Figure 5). The pallets will be moved to the greenhouse by forklift whenever transfer is necessary.

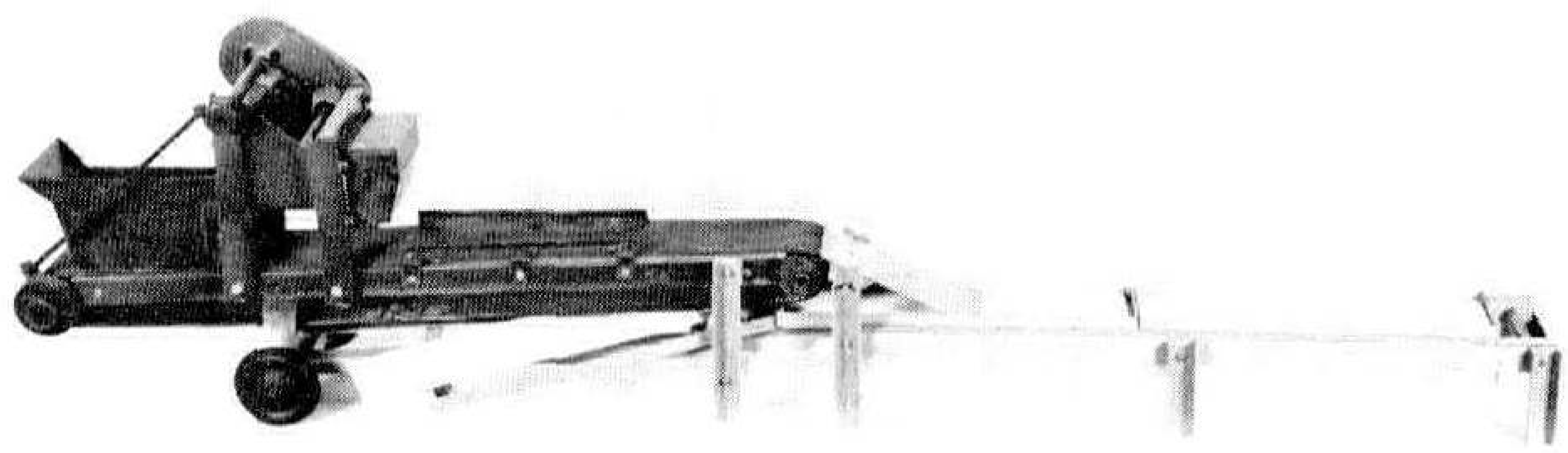

Figure 5. Model of soil block machine.

Transport of Cubes with Seedlings to Nursery. Pallets of seedlings will be moved to holding areas for hardening off before transplanting. Subsequently they will be transported to nursery compartments and transferred to a transplanting vehicle (Figure 6). A device on the vehicle will remove the pallet frame and the cubes will be moved forward by a conveyor. At the end of the conveyor, pallet bottoms will be separated from the cubes. The cubes will then pass through rolling coulters and be guided in lines into the nursery bed at whatever desired configuration.

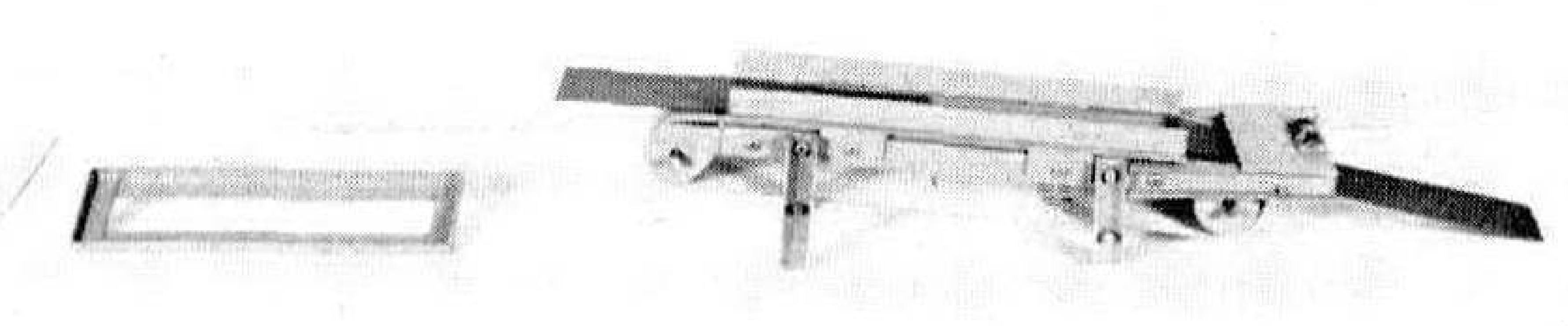

Figure 6. Model of transplanting vehicle.

CONCLUSION

A system has been developed for growing a crop of coniferous seedlings using germination plugs, peat cubes and various handling devices. Most of these developments have facilitated manual operations though some highly mechanized steps have been completed. The goals in terms of growth objectives have been shown to be feasible.

A need remains to produce optimum schedules for greenhouse growth and to produce the necessary germination facilities in order to improve quality of stock. The concepts presented here form a basis for automating the mechanical operations from pregerminated seed to production of bare root nursery transplants.

Acknowledgement. Photographs were taken by Miss Jean Robinson, Ontario Forest Research Centre, Maple, Ontario.

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BILL FLEMER: Why not sow directly on the soil blocks instead of on the cigarette process first?

VICK WILLIAMSON: We find that by growing on the cigarette process first, we can germinate under optimum conditions. We are able to get the root radicle down into the medium with the least expense of energy. After it starts to produce its own food it can branch out into the soil.

VOICE: How do you get each individual seed into the cigarette plugs?

VICK WILLIAMSON: We use a vacuum seeder.