SPECIFICATIONS FOR A CONTAINER PLANTING MACHINE: A FIELD VIEWPOINT

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Abstract.--Desirable characteristics of a container planting machine suitable for northern Ontario are discussed. A brief description of the working conditions for the hypothetical planter and reasons for its need are presented. Biological and economic constraints on design and ergonomic considerations are used as the basis for the specifications.

Résumé.--On examine les caractéristiques qu'une planteuse de plants en mottes emballées devrait posséder pour son utilisation dans le nord de l'Ontario. On donne une brève description des conditions d'utilisation ainsi que les raisons pour lesquelles on aurait besoin de la planteuse hypothétique. Pour déterminer ses caractéristiques, on s'est basé sur des contraintes biologiques et économiques et sur des considérations ergonomiques.

INTRODUCTION

A container planting machine can be anything from a simple, manually operated dibble to a complex, machine powered, computer controlled, automated machine which site prepares and plants in one operation. The planter we require is one that will do the whole job in a biologically acceptable manner and at a reasonable cost.

The principal factors influencing the choice between the simple and the complex will undoubtedly be related to a number of local conditions. In this paper I will be dealing with those conditions which we find in the Ontario portions of the Canadian Shield, most of which lie in the transition zone between the Great Lakes-St. Lawrence and the Boreal Forest regions. The factors which dictate the design of the machine are i) the species to be planted, ii) the type of container, iii) the labor force available, iv) the terrain and site conditions, v) the scale and duration of the operation, vi) market conditions and available capital. On the basis of these factors, I will attempt to draw up a set of specifications for a hypothetical container planting machine. Unfortunately, my experience is limited mainly to northeastern Ontario.

WORKING CONDITIONS

Northern Ontario is a vast area of mostly forested land (approx. 892,400 km^2), occupied by relatively few people. In the four northern regions of the Ontario Ministry of Natural Resources (OMNR), approximately 42,000 ha of forested land are harvested annually, of which 23,000 ha are replanted. We have a full range of soil conditions from very shallow, coarse tills to deep deposits of sandy outwash to lacustrine silts and clays. Current estimates for the Northeastern Region indicate that of the 5,944 ha planted annually, 3,320 ha will be planted with containerized stock (paperpots). This is approximately 56% of the total area planted. If we were to extrapolate these figures to northern Ontario as a whole, at current rates, approximately 13,000 ha (35 million seedlings) of cutover area would potentially be planted with container-grown stock of one type or another.

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In the Northeastern Region, about 80% of the land area comprises shallow to moderately shallow, gravelly tills. The bulk of the remaining 20% is either lacustrine deposits of finer textured soils which are mostly under agricultural cultivation or deeper outwash deposits of sands and gravel. It is our current opinion that the upland till deposits must be planted by hand, largely because of the stoney, shallow nature of the soil deposits and the generally steep topography. We can visualize the possibilities of using planting machines on up to 10% of the total plantable area over the region. This amounts to 332 ha per year. Again, if we extrapolate this figure to northern Ontario as a whole, it amounts to 1,300 ha of machine-plantable land per year for containerized stock.

The growing season is rather short, averaging about 160-180 days with a possible frost-free period from 10 June to the end of August (80 days). On the basis of outplanting experiments (Scarratt 1974), the maximum recommended period for planting container-grown seedlings is from 1 May to 15 August (107 days). Our current growing regime for containers (FH 408 paperpots) limits the period of shipping, particularly of pines, to a period from 1 May to 15 June for the overwintered crop and from 15 June to 15 July for the spring-grown crop. This limitation is due primarily to the intergrowth of roots from one container to the next. Hence, if we assume that the container to be used for mechanized planting is the paperpot, our planting season would be only about 76 days long.

The labor supply in remote areas of the province tends to be poor. Potential workers demand better social amenities than those offered at "bush camps". These facilities can be found only in the larger towns, at some distance from the planting site. As the planting program lasts only 4-8 weeks, it does not attract highly skilled labor. Generally, OMNR employs unskilled labor for the planting job. Few, if any, of these people are trained in the operation of complex machinery.

The species most commonly planted as containerized stock in the Boreal Forest are jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* [Moench] Voss) and black spruce (*P. mariana* [Mill.] B.S.P.). In the Northeastern Region sizeable quantities of red pine (*P. resinosa* Ait.) and white pine (*P. strobus* L.) are also planted.

Jack pine can be grown in paperpots under a 14-week growing regime, on a two-crop-per-year basis. The spruces should be produced under a greenhouse regime of at least 18 weeks' duration, starting in late February or early March, to be grown on outside during the frost-free summer period and overwintered. They should be planted the following spring or early summer.

Red pine and white pine are best grown as summer crops in the greenhouse, beginning in early June, for overwintering until the following spring. They should be planted prior to 15 June.

The hard pines (jack and red) are perhaps better suited to container planting than to bare-root planting, largely because of their rooting habit. These species do not put out adventitious roots and therefore are extremely prone to deformities resulting from poor planting practices. The use of containerized seedlings can reduce, to some degree, the severe deformities found in planted bare-root stock (Heikurinen and Wilson 1980).

The spruces are capable of adventitious root development; consequently, the deformation of the original root system is not as critical as that of the hard pines. However, factors which affect root regeneration potential, such as planting depth, planting microsite, and moisture stress in the tree, seem to be more critical for spruces than for pines. The containerized seedling can, if handled properly, alleviate some of these potential problems.

THE NEED

Do we need a mechanized planter? The answer to this question undoubtedly depends on whether the planter helps to resolve some of our regeneration problems.

Some of the problems we face in Ontario are related directly to shortages in the labor force in remote areas. The arduous and highly seasonal nature of the planting program will not attract workers from the more populated areas. One of the greatest concerns of our field staff relative to the doubling of our planting program by 1984 (Scott 1975) is the question of who will plant the trees. Existing labor is thought to be barely sufficient for the current program. One of the answers to this problem could be greater use of containerized planting stock, together with a mechanized planter capable of greater rates of planting than would otherwise be achieved with manual labor.

Machines will consistently duplicate a task with very little variation. If a machine can be made to plant a seedling well, it should do this consistently. We are plagued with the problem of planting error in our hand planting operation. Poorly planted trees account for at least 50% of the mortality in our plantations. A machine planter might aid in this respect, by providing a better working environment and at the same time increasing the worker's capability. However, mechanization will undoubtedly involve some loss of capability in terms of microsite selection in order to achieve consistency and speed of operation.

SPECIFICATIONS

I will now attempt to elucidate a set of general machine specifications based on the working conditions outlined in Table 1. These specifications are intended solely as guidelines for designing a machine which will plant containerized stock in northern Ontario.

Biological Considerations

The planting machine must be capable of delivering the tree, without mechanical or physiological damage, into the soil, in as natural a position as possible.

To prevent physiological damage, the tree should be held in a suitable receptacle until placed in the soil so as to protect the roots from exposure to air. The vibration and bouncing of the machine must not loosen soil, as this might lead to loss of growing medium from the container or plug. The integrity of the container must be protected throughout the planting process.

The machine should be designed to permit the maintenance of adequate moisture conditions in the growing medium within the container during the planting operation. This generally will mean a watering capability if more than a 4-hour supply of seedlings is carried on the machine. For shorter periods, protection from direct sunlight and moving air must be provided.

Table 1. Factors to be considered in the design of a container planting machine.

Species	- jack pine, red pine, white pine, black spruce and white spruce.
Size of stock	- 10 to 15 cm top with a 1 to 3 mm root collar diameter, and weighing 250 to 1,500 mg.
Container	- any biodegradable, flexible paper container or plug ranging in size from 3 cm to 6 cm in diameter and 8 cm to 12 cm in depth.
Site conditions	
Soils	- Lacustrine deposits of silts and clays.
	- Fluvial deposits of fine to coarse sands with varying degrees of gravel.
	- Aeolian deposits of very fine to fine sands.
Stoniness	- ranging from nil to plentiful, but not excessive. Mostly pebbles and cobbles with few boulders.
Soil depths	- minimum depth of 30 cm.
Slash	- less than 9 m^3/ha (about 25 tonnes/ha) well distributed, ranging up to 7 cm in diameter.
Stumps	- 750/ha, with average diameter of 40 cm and maximum height of 50 cm.
Slopes	- less than 15% on a sustained slope.
Job duration	- 1 May to 15 July.
Job size	- varies from 10 to 200 ha per location.
Market size	- enough machines to plant 1,300 ha in Ontario (3.5 million seedlings).

The temperature of the stock should be kept above 5°C and below 33°C during the planting process. The trees should be protected from exhaust fumes, oil drips, and other toxic elements which are normally present during machine operations.

Physical or mechanical damage to seedlings must be minimized in the handling and planting process. During machine loading operations, the original growing tray should be used for handling or, alternatively, the containers should be transferred carefully to a cassette or tray from which the container can be transferred to the planting head. It is important to minimize handling of the individual container, to avoid loss of growing medium. At no time should the seedling shoot be used as a handle in the moving process. Generally, the seedling is not sturdy enough to support the relatively heavy root ball. The container should always be firmly supported, yet not squeezed or otherwise mutilated. In the case of paperpots, separation of containers should be delayed as long as possible and should never be done more than 4 hours in advance. The paperpot must always be soaked thoroughly prior to separation; otherwise, damage in the form of torn pots, loss of growing medium, etc., will result.

During the planting process, a planting hole should be made similar in size to the container. The container should be planted slightly below the surface of the soil. In the case of paper containers, the paper should be buried to a depth of about 0.5 cm. Root disturbance should be minimized by placing the container in the hole gently. The impact of the container falling to the bottom of the hole should be no greater than that of the container falling from a height of 60 cm down a tube, with a cross-sectional area not greater than 125% of the cross-sectional area of the container. At no time should the container be injected into the hole by pneumatics or other means, or with anything greater than gravitational force. Pneumatic injection may cause loss of growing medium or enlargement of the hole to the extent that compaction may be hindered.

Roots protruding from the container side walls or the bottom, to the extent that they will be swept upward during the planting process, should be pruned mechanically. Both live and dead roots have a tendency to catch on the side of the planting hole, and turn up. In hard pines, this will result in the worst possible type of deformity, i.e., deep vertical roots will not develop. For hard pines, rapid development of vertical roots is required for growth on the driest sites on which these species are prescribed for planting (Fayle 1978).

In the process of creating the planting hole, minimal compaction of the walls of the hole is sought. A blunt dibble should never be used for this purpose. An auger or a punch which removes the material from the hole is the preferred tool. Something similar to the jaws of a Pottiputki, which forms an appropriate hole configuration by splitting the ground and compacting two sides of the planting hole, is acceptable. A continuous shoe or an intermittent shoe which creates a slit is not desirable.

Compaction of the earth around the container after planting should not be excessive. The compaction process should not bend, flatten or otherwise mutilate the container or the tree. Light tamping around the tree is preferred to compacting wheels which tamp on two sides only. Never use heavy pressure from one side of the container.

Operational Considerations

The planting machine must be both efficient and effective from an operational point of view.

In the first place, it must be cost-efficient. The cost per unit planted is a function of the operating cost, the cost of the machine, its planting rate capability and its availability.

At the risk of oversimplification, I have attempted to estimate the cost of such a machine by assuming that the total cost of planting with the machine should not exceed that of manual planting. A current estimate of the cost of manual planting is $125.00 per 1,000 seedlings, including direct and indirect costs. In a machine planting operation, the prime mover will cost $50.00/hr, including operator. The cost of labor to service and operate a planting machine is about $30.00/hr (based on a requirement of two operators and one service person at $10.00/hr each). In most projects of this nature, overhead costs constitute up to 25% of the total cost. I have assumed $20.00/hr; therefore, the total cost, excluding the planting machine, is $100.00/hr. In Table I, I have outlined the allowable cost of the machine for three assumed planting rates.

On the basis of this example, a machine planting 1,000 seedlings/hr can have an operating cost of $25/hr while a machine with triple the productivity at 3000/hr can have an hourly cost 11 times that of the slower machine. Conversely, a machine that is expensive to own and operate must have high production rates.

The cost of "downtime" will offset some of the advantages of the high production/high cost models over the low production/low cost models. Trees not planted will not produce much wood fibre, despite the cost of planting. Therefore, the planting machine must be very reliable and not be prone to breakdown. In the more remote parts of northern Ontario, skilled mechanics and supplies of spare parts are few and far between. The day to day maintenance and repairs quite often must be carried out by local staff. Even simple machine parts must often by shipped from Toronto or other large centres. It is very important that machines be durable and as simple as possible to operate and maintain, and that parts used in the construction of the machine be readily available. Sophisticated electronic and hydraulic components are generally prone to failure because of the rugged environment and are difficult to replace. Such components should be minimized or totally eliminated.

If we are to replace people with machines, then machine productivity must be higher. If we assume that a planting machine requires four people to operate it, then what must be its productivity? One person can plant on an average about 1,350 containerized seedlings in one 8-hr day, i.e., 168.75 seedlings/man hour. To break even on labor requirements, a machine must average 675 seedlings/machine hour. An acceptable machine availability is 80%. Hence, during the available time, the machine must be capable of planting 843.75 seedlings/hr. If we include °the lost time such as coffee breaks, travelling time, etc., it would appear that a reasonable minimum rate of production to break even on the labor requirements would be 1,000 seedlings/hr. As determined in Table 2, the maximum operating cost of this machine should be $25/hr or less. In order to achieve average production rates of 1,000 seedlings/hr, and planting at 2 m intervals, a single row machine would have to travel at a calculated average speed of 2 km/hr. To increase production capacity to the point at which the planting machine would be of benefit, i.e., 2,000 seedlings/hr or better, rates of travel would have to be 4 km/hr or greater. Average speeds of this nature are not feasible in the Ontario cutover. Hence, it would seem that a single row planter would be of little or no use on a large-scale planting operation. A two- or three-row machine is necessary.

Spacing in forest stands is important for optimizing wood production. Therefore, the machine should be capable of spacing plants within and between rows with only minimal variation. To do this, we have found that crawler tractors are most suitable as prime movers. Conventional wheeled tractors have not proven successful in the past, primarily because of their inability to maintain constant speeds. If wheeled prime movers are contemplated, then the planting mechanism must be designed so that it is not dependant on constant forward rates of travel. A wide variety of prime movers are used in Ontario forests: no standard machine is available. The planting machine must, therefore, be highly adaptable to a variety of makes and models or must be self-propelled. The terrain, even in the better soil conditions, is very often uneven, hummocky and littered with stones and debris. Many unsuitable microsites are encountered in unpredictable locations. The planting machine must be able to sense whether or not to plant in a specific location in order to avoid planting on stumps, rocks, or slash piles. If a planting chance is missed, the machine must be able to recycle quickly and pick out the next plantable location without loss of average spacing.

Prior to designing a machine, the designers must have a thorough understanding of the site conditions the machine will traverse. It is our experience that service factors in current use in the design of ma-

Table 2. Allowable machine cost relative to production rates

Planting rate	Cost (excluding planting machine)		Allowable cost of planting machine		Total cost	
1,000s/hr	Cost/hr	Cost/1000	Cost/hr	Cost/1000	Cost/hr	Cost/1000
1.0	$100.00	$100.00	$ 25.00	$ 25.00	$125.00	$125.00
2.0	100.00	50.00	150.00	75.00	250.00	125.00
3.0	100.00	33.33	275.00	91.67	375.00	125.00

chinery do not adequately reflect the harsh conditions found in the forest.

SAFETY

The effect on human comfort and safety of problems created by the harsh site conditions in our forests, particularly when planting machines are being operated, cannot be overstressed. In order to function efficiently, the machine must be operated efficiently. The operator must be adequately protected from the hazards of the site and at the same time be free to do the task at hand. The person feeding stock into the machine should be placed well away from the operating planting head because of the hazards created by moving machine parts and the difficulty of providing personal protection from flying debris. The feed to the planting head should be done by mechanical components.

Since the terrain tends to be rough, the machines often rock severely. This movement hampers the operator's ability to work. Either the tossing about of the operator must be greatly reduced or the task at hand must be simplified to allow for the movement of the machine. The bouncing or tossing action may be minimized by using modern, low pressure tires which engulf obstacles. The task of loading container seedlings could be semi-automated so that the operator loads the seedling into some type of cassette rather than directly into the ground or the planting head. The cassette would also allow for the irregular loading rates which result from unsteady working conditions.

The operator must also be protected from undue machine noise and from sharp machine components. If possible, he should be protected from wind, heat, rain and pests such as mosquitos and blackflies. A totally enclosed, climate controlled cab may become necessary for a high speed machine that requires a high degree of efficiency from the operator.

SUMMARY

The design of a container planting machine must be such that it will successfully transport and plant a container-grown seedling without damage, at an affordable cost.

The conditions under which it must operate dictate that the machine be simple to operate and maintain, be built from standard and rugged machine components and yet be cheap enough to operate on a three-to-four-months-per-year basis. The scale of operations shows a potential need for six to ten machines in northern Ontario.

The need for a planting machine can be justified only if it will solve one or all of the problems associated with labor shortages, poor planting quality, and high planting costs.

How complex or how simple the machine will be is left to the designers and manufacturers. Ultimately, they must decide on the configuration of the machine we use on the basis of sales and profits resulting from its manufacture.

The designers of the machine are urged to become very familiar with the ground and terrain conditions and related engineering service factors prior to design.

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