A SYSTEMS APPROACH TO FOREST TREE SEEDLING PRODUCTION A NEW CONCEPT

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Abstract.-- A concept of an integrated systems approach to sowing and harvesting 50-foot-wide forest seedling nursery beds is presented. Basic nursery operations of bed preparation, sowing, bed tending, seedling care, and harvesting use a moveable carriage that operates on cogged tracks. The systems concept is based on a goal of harvesting 36 million seedlings within 10 work days. Time sharing of the harvesting equipment should be possible on a weather cline with a resultant large scale operating cost savings for forest industries.

Additional keywords: Nursery development, nursery production, nursery mechanization.

Forest tree seedling nurseries in the South are similar in operation and production techniques to those utilized 60 to 70 years ago. In most of the nurseries the seedlings are grown in 4-foot-wide mounded beds with 6-inch spacing between rows.

The 4-foot-wide bed poses a problem since only 8 rows of seedlings can be lifted simultaneously. In order to decrease harvest time, more machines must be used or machinery operation speed must be increased. However, it may not be possible to significantly increase the tractor speed down the nursery beds without damaging seedlings. Moreover, the 4-foot-wide bed is a limiting factor in that there is not enough room behind the lifter to handle the large volume of seedlings lifted. Consequently, seedlings are lifted en masse and transported to packing sheds where they are hand sorted, graded, and packed. In essence, the current harvesting and packing process is labor intensive and bottlenecks develop at various points in the system. A significant amount of soil is also removed in the process which must be returned to the nursery.

Aside from these problems, one of the major complaints against 4-foot-wide nursery beds is that only 67 percent of the available area is cultivated, with the remaining area used for tractor wheel paths and waterlines. Although there is talk of developing equipment to operate on 6-foot-wide nursery beds, this will not: (1) significantly increase bed cultivation space per acre; (2) increase the speed of harvesting operations; or (3) lower costs.

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The problem is technological, but it appears that technological improvements of the current system result in smaller and smaller margins of productivity. Faced with the prospect of diminishing returns from increased mechanization efforts of the existing system, there is a need to radically redesign forest tree seedling operations so that improvements can be engineered over the next generation. This means that the next design in nursery operations should embody a concept that will permit large gains in productivity as new and more efficient machinery is developed. The overall objective is to develop not only a highly mechanized nursery system, but one which utilizes a low degree of complexity in equipment design. This is the basic concept of the proposed approach to nursery production.

Basic System Concept

The focal point of the new approach to nursery production described here is that all of the sowing, cultural harvesting, grading, and packing operations are done over the nursery beds. The key to the success of this new system is the operation of a wide span carriage on fixed, cogged rails. The carriage will provide sufficient work area so that the entire nursery operation, phase by phase, can be done directly over the seedling beds. Mechanical lifting, grading, and packing systems will be designed to lower operating costs.

The chart in figure 1 outlines the present stepwise process of nursery operations. These steps and a conceptual design for the equipment necessary to integrate them are discussed below.

Bed Preparation

Traditional nursery bed preparation practices include plowing, disking, harrowing, and mounding in addition to the application of fertilizers, fumigation, and herbicides. All of the processes are done on 4-foot-wide beds with standard equipment pulled by tractors.

In the proposed system, nursery bed preparation operations will be done from a carriage riding down fixed tracks. With fixed tracks, positive traction is the guiding force of the system. Thus, the entire operation can be done over a 50-foot and perhaps eventually a 200-foot-wide bed, cog by measured cog. Such a system can be speed graduated for any operation using synchromeshed electric motors on each wheel or each pair of wheels, or perhaps by a stationary diesel motor at the end of the bed with a cable hook-up to pull the carriage. Separate power sources for carriage movement and cultural operations will be employed.

Bed preparation and sowing would be integrated as follows. If necessary, at the leading edge of the carriage, rototillers would chop the soil. Immediately behind the rototiller (perhaps at 10 feet) a harrow operation follows. At the back edge of the carriage the bed would be sown

BED PREPARATION

1. Plowing, disking
2. Fumigation
3. Mounding
4. Pre-emergence herbicide

SOWING

1. Plant seed
2. Mulching
3. Post emergence herbicide
4. Fertilizers

BED TENDING

1. Insecticides
2. Herbicides/weeding
3. Watering
4. Fertilizers

SEEDLING CARE

1. Top pruning
2. Wrenching
3. Lateral pruning

HARVESTING OPERATIONS

1. Lifting
2. Grading
3. Packing

Figure 1.--Basic operations of a forest tree seedling nursery program.

and the drills covered by trailing rollers. All of the bed preparation equipment would be designed in 25-foot segments to fit exactly onto the carriage and to be operated by a single size power source. The development of tillers, harrows, and seeders for this phase of operation is not necessary. All that is needed is a technology transfer from existing equipment and an efficient connection to a power source.

Soil management techniques have been studied for years at the USDA National Tillage Laboratory in Auburn, Alabama, and operational procedures are well defined for raising crops in the soil bins of the type proposed. Cultivation of seedlings in bins, such as developed at the National Tillage Laboratory, would result in huge labor and energy savings since plowing, disking, and bed forming operations would not be done, making it unnecessary to purchase equipment for these operations. Since all of the operations are done from the carriage on the tracks, soil compaction will not be a problem. Consequently, because there is no soil compaction, tillage equipment, time, and energy requirements will be minimal. For example, after seedling harvest the only operation required to prepare the soil for sowing the next crop is to level the soil with a harrow.

The Carriage

The carriage would be designed to be lightweight in structure and form. The entire structure would be a lattice work with tubular metal used wherever possible. A sketch of the carriage design is shown in figure 2. The only purpose of the carriage is to hold equipment and people; it is a passive unit and is not subject to breakdown. Some of the cultural equipment such as the harrow, sprayer, and root pruners are passive and no breakdown is expected. Other equipment such as the beltlifters have moving parts and are subject to breakdown. This will require the development of highly reliable equipment.

Construction of Nursery Beds

A major concern of nurserymen is the condition of the nursery soil. Drainage and aeration are two of many important aspects of nursery soil management and are fully capable of being manipulated to specification. However, water management techniques in current forest tree nurseries are still primitive, consisting basically of aboveground delivery and runoff. Little can be done to improve aeration of the existing beds as long as heavy machinery operate in the nursery.

To achieve better soil and water management, about 30 inches of topsoil could be removed and replaced with a sand:perlite:loam mixture with a known drainage and aeration capacity. Since massive soil excavation and rearrangement is commonplace in nurseries now being constructed, an additional stage of mixing to known proportions should not be uneconomical considering the expected benefits.

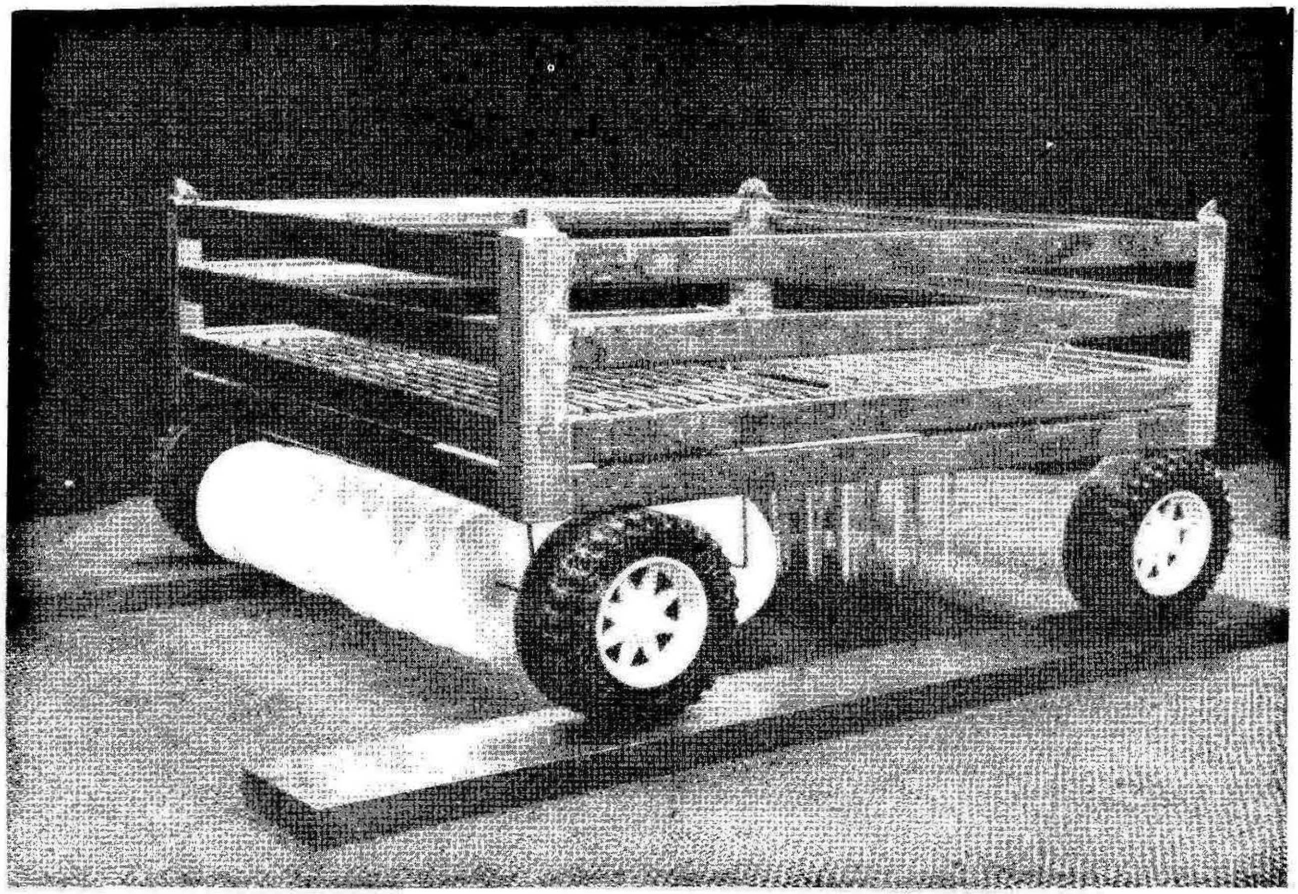


Figure 2.--Wide span nursery carriage. The carriage will travel over fixed tracks. All of the equipment needed for cultivation, sowing and harvesting will be accommodated on or under the carriage. In this view, disks and harrow operations are shown.

In the new generation nursery bed, the bottom and sides of the nursery pit could conceivably be lined with clay to hold water. Electronically operated moisture sensors and valves would monitor the level of moisture within the nursery pit to drain the pit if necessary. Among other benefits, this scheme would permit flushing of salts if necessary to avoid toxicity from salt imbalances.

Seedling Care

Another group of functions that could be integrated would involve insecticide, herbicide, and fertilizer application. Pesticides are currently applied with overhead sprayers which saturate the soil or foliage. This is wasteful in that tractor paths and waterlines are also sprayed. Precision sprayers are available which permit a directed application of pesticides to the target area if controlled tracking is used. The proposed system would result in very precise row spacing. Of even more importance, because of the fixed track nature of carriage travel, it is easy to adjust the spray nozzles either for precise, uniform application or for random application patterns. With precision application and a guaranteed repeatability it will be possible to reduce pesticide application rates by at least 60 percent and maybe more. Figure 3 illustrates the type of sprayers that would operate from the carriage. Little innovation would be required to position and adjust the sprayer angle, type of spray, and rate of delivery to reduce current costs. An alternate method is to lay a tape impregnated with fertilizers or pesticides between the seedling rows.

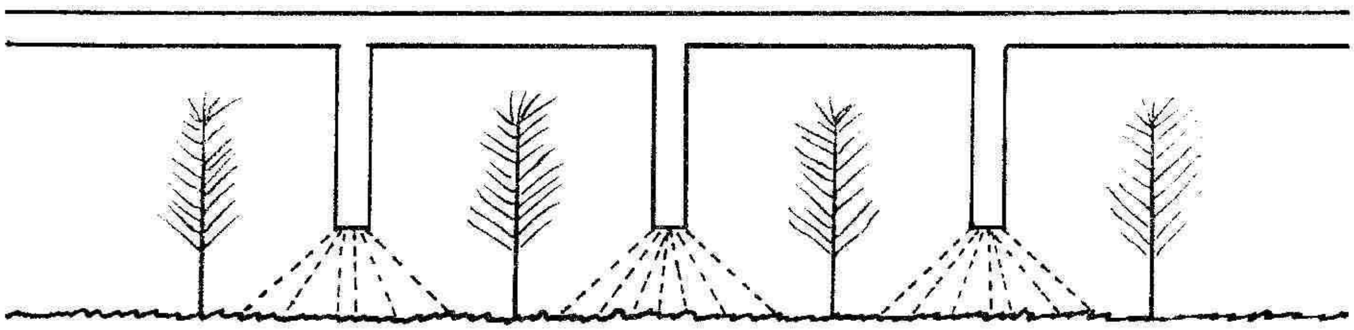
An additional benefit is that existing top pruning and lateral root pruning equipment can be easily adapted to operate on the carriage.

Lifting Operations

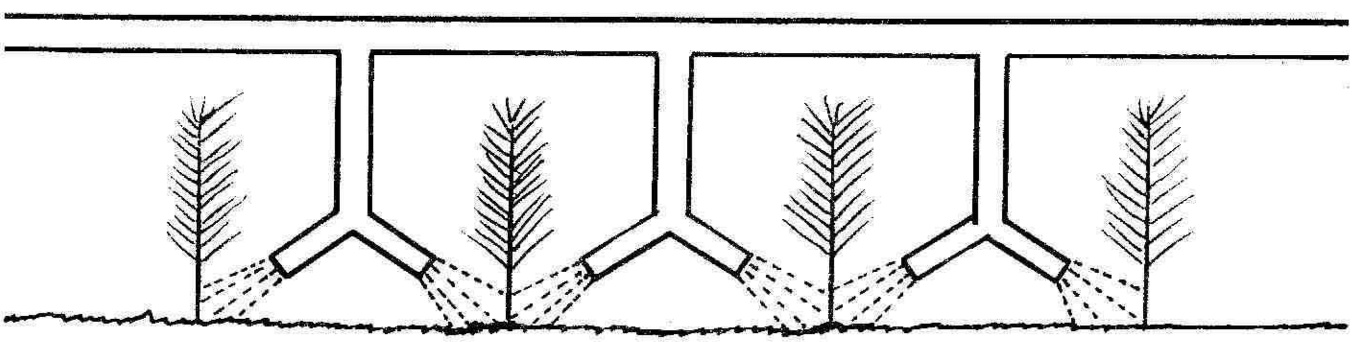
With the new method, lifting operations can be synchronized over the wide bed because the seedling beds have been sown with precision, the beds are level, and the rows perfectly spaced. In this integrated approach to nursery production, the most radical departure from existing technology will occur in the harvesting phase. A whole new method will be developed with the end result of total mechanization of the lifting, grading, and packing processes.

Figure 4 contrasts the structure of a traditional nursery bed with that of the new method. Lifting equipment on the proposed carriage will be sequential as follows: About 12 inches in front of each row lifter, a small trencher will operate. The function of this is to dig a trench between the seedling rows. Each trench will be about 2 inches wide and 7 inches deep. The seedlings will be left in 4-inch-wide mounds. Six inches behind the trencher, in a single row, a side to side reciprocating blade will undercut and guide each row of seedlings into the lifter belt where they will be transported up onto the carriage and enter into the root dipping trough and the mechanical grader. The advantage of having a lateral trencher

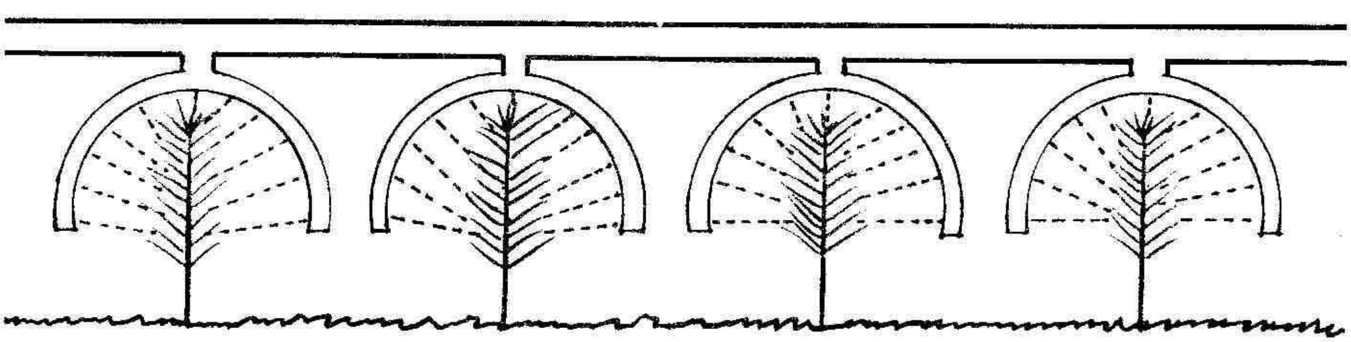
Figure 3.--Three types of precision sprayers for use in the proposed nursery system. Each of the sprayers in a), b), and c) are designed for directional application and to deliver either a mist/fog or a droplet/drench depending upon the required treatment.



a) Between row sprayer



b) Root collar or within row sprayer



c) Foliage sprayer

Figure 4a: Traditional seedling bed without trenches between the seedling rows. The lifting blade has a drag force along its entire width and has to be heavily built to avoid bowing along its front edge.

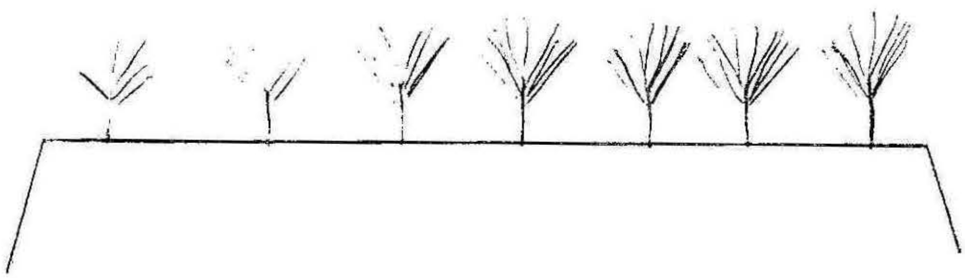
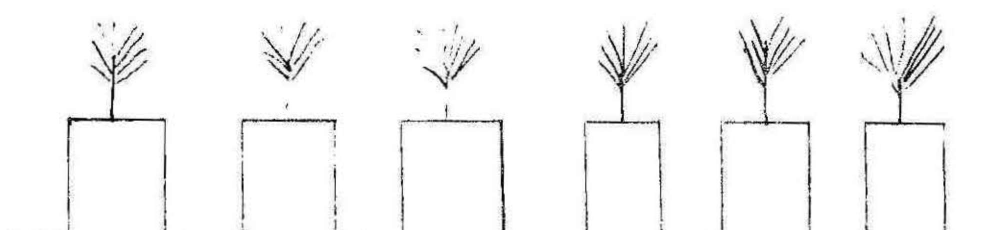


Figure 4b: The proposed bed with trenches between seedling rows. The lifting blade need only be about 6 inches wide to lift the 4-inch-wide columns with seedlings. The individual lifters could be lighter in design strength.



proceed the lifting operation is that the single row blade undercutter can be designed so that it is smaller, requiring less operating energy than a blade continuous across the entire bed. The open trench on each side of the seedling row will let the lifter operate freely. Only about 4 inches of drag will be placed on each lifter. The mechanics of a multiple row lifter working simultaneously with a lifter having a 4-inch drag will be simple; however, an estimate of the overall power required to operate the carriage forward during this process is not known. A prong about 12 inches long, parallel to the ground and about 2 inches wide, immediately proceeds the lifter. This will prevent the seedlings from falling over and guide them into the lifter.

The mechanics of developing a seedling lifter capable of simultaneous harvesting 50 to 200 feet of nursery bed should not be difficult. The hydraulic belt lifter currently used requires 1 hp to lift the 4-foot-wide bed. With slight modification this lifter unit would be mounted side by side on the carriage and run in series. The units would be small enough so that if one unit breaks down it could be removed and replaced by a spare. The damaged unit would be serviced off the carriage.

Seedlings from individual rows will be lifted by belt lifters and carried up about 6 inches into a trough full of water which runs parallel and then perpendicular to the seedling rows. As the individual seedling is carried along this trough its roots will be washed free of soil and the mud returned to the nursery bed. Somewhere along the path an electronic grader will react to each seedling and either cull it or let it pass to another trough containing clay slurry where the roots will be coated. The seedlings will then be packed and loaded into refrigerated trailers at the end of each bed. Culled seedlings will be transported to a central hopper on the carriage where they will be chopped and their remains blown back over the nursery bed.

The entire design for lifting, grading, and packing must be scaled to fit the carriage. Thus, a division of space must be allocated and developed into a workable model. Two important factors favor the development of a totally mechanized system: (1) the carriage has abundant space to work over the nursery beds, and (2) the slow rate of carriage travel over the bed. If need be, the carriage length can be expanded to the length necessary to accommodate the harvesting equipment.

The key to the success and flexibility of this concept is the rate of travel of the carriage. For example, a lifter designed to operate on a 4-foot-wide bed would have to lift 50, 4-foot-wide beds to cover the same area as the carriage lifting over the 200-foot-wide bed. With today's level of technology, the 200-foot-wide carriage only has to travel at 1/50 of the forward speed of a 4-foot-wide lifter to cover the same area. A slow forward speed would permit synchronized mechanical lifting and grading operations. The first designs will undoubtedly be relatively simple and slow, but as technology improves, lifting and grading speeds could be increased. Theoretically, if the forward speed of the carriage can be increased to 1/25 of the speed of a 4-foot-wide lifter, then the total time of lifting will be cut by 1/2. This ratio of forward speed of the carriage to total lifting time is the key to the long term viability of this nursery design. Improvements in lifting operations will result in direct reduction of labor costs. A totally mechanized nursery system such as described should not need over 3 to 5 people to operate it during the sowing and bed tending season. During the lifting season it would be necessary to employ between 10 to 15 people.

Time Sharing

With a concentrated effort the proposed nursery system could be workable within 3 to 5 years. Another notable feature of the system is that it may be possible for nurseries to cooperate or share equipment. For example, a crew could lift seedlings at one nursery for a 15-day period, dismantle the carriage harvesting equipment, and move it to another nursery where it would be installed on another carriage to lift seedlings at that site. This process could be repeated about 7 to 8 times on a north to south to north weather cline. Contract lifting could thus reduce substantially the carriage equipment capital investment for each nursery. The concept of shared use of the lifting equipment would easily fit into the framework of a large corporation that has several nurseries on such a weather cline. The corporation would purchase the carriage equipment but contract the operation to operators or assign a group of technicians to operate it during the lifting season.

Scale of Economy

Five basic phases of a typical bare-root nursery operation are outlined in figure 1. Current nursery operations are labor intensive for the bed preparation and harvesting operations, thus the greatest labor saving costs can be achieved by mechanizing these operations. Sowing, bed tending, and seedling care operations are less labor intensive and there is little room for lowering expenses by increased mechanization. The systems approach outlined in this paper suggests potentially large labor cost savings in the bed preparation and harvesting operation phases.

Data accumulated at the USDA National Tillage Laboratory in Auburn, Alabama, emphasize the potential of lowering labor costs by operating equipment on controlled traffic paths (Taylor 1981). Controlled traffic tillage has proven economic benefits; these are: less tillage energy required, improved tractive efficiency, and timeliness of operations. A controlled track system would eliminate the problems associated with soil compaction resulting from bed preparation, sowing, and tending operations. The major benefit would be a better soil structure resulting in increased air and water infiltration, decreased erosion by water runoff, decreased need for nitrogen fertilizer, and better root development.

The potential savings on nursery manual labor wages for the harvesting phase are substantial. The average southern nursery employs about 50 lifters, graders, and packers. If these work an average of 48 hours at $4.50 per hour (a typical wage in the South) then the weekly payroll is $10,800. In a 42-day lifting period the payroll is $75,600. Each year (using constant dollars) 100 nurseries will pay out $7,560,000 and in 10 years $75,600,000. Under the proposed system, one harvesting crew will be able to work in several nurseries. If the average wage for the more skilled labor needed is $9.00 per hour, the labor cost for the nursery harvest phase would be: 48-hour work week x 2 lifting weeks x 15 employees x $9.00/hour = $12,960, a savings of $62,640 per year. The total cost of harvesting for 100 nurseries is $1,296,000. Thus 100 nurseries could save $6,264,000 per year. Over 10 years this would represent a savings of $62,640,000.

Similar economics would result from a reduced need for total nursery tillage area. The average nursery utilizes approximately 5 acres for the packing shed, machine shed, etc. and about 41 acres to produce 36 million seedlings at 30 seedlings/ft^2 in 4-foot beds. In the proposed system, 36 million seedlings could be produced on 27.6 acres and less than 1 acre would be required for accessory area, since only an office and a small machinery building would be needed. Additional land for rotational/fallow schemes would follow the same ratio.

Additional savings would be realized from reduced costs by more precise, and consequently less, application of pesticides, fungicides and herbicides. It can be estimated that the rate of application of fungicides can be reduced by 80 percent and that of pesticides and herbicides by 60 percent. Currently, 70 southern nurseries spend approximately $3 million each year for herbicides and fungicides. Consequently, there would be a yearly combined savings of about $1.8 million for these nurseries or $25,700 per nursery and about $18 million over 10 years.

Very large savings would be realized from basic machine inventory costs. A modern nursery can easily carry an inventory of tractors, wagons, combines, etc. worth more than $300 thousand. A machinery pool of this magnitude has a high yearly repair and maintenance expenditure, plus, it is depreciated at about 10 percent per year. Thus 100 nurseries collectively have about $30 million worth of machinery and a yearly replacement cost of about $3 million.

Development of the System

The nursery system described in this paper requires two radical changes from the traditional nursery operation. The first is the fixed track and soil bin. The technology of this system has been developed for 35-foot-wide bins at the National Tillage Laboratory. The second change is to develop a carriage to hold the sowing, tending, and harvesting equipment. The different equipment for different operations would be mounted on the carriage when needed. For example, when the seeder was not in use it would be removed and stored. The development of the carriage and power source to move it on a rail system is not a complex problem.

LITERATURE CITED

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