United States Department of Agriculture

Forest Service

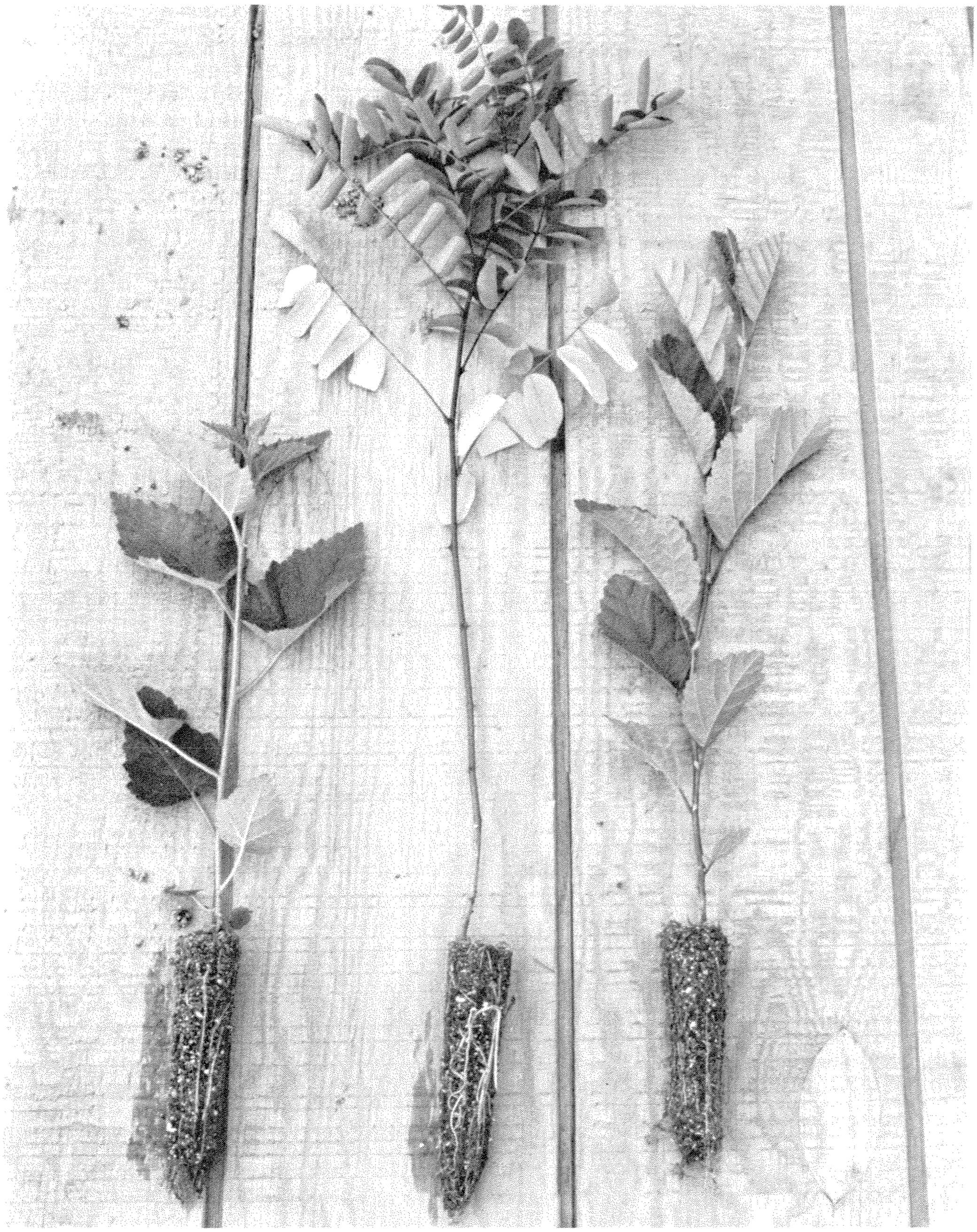
Northeastern Forest Experiment Station

Research Paper NE-500

1982

Economical and Simple Production of Containerized Hardwood Seedlings

Merrill C. Hoyle



The Author

Merrill C. Hoyle is principal plant physiologist at the Forestry Sciences Laboratory, Northeastern Forest Experiment Station, Durham, New Hampshire 03824. He received his B.S. and M.S. degrees from the University of Massachusetts, and his Ph.D. degree from the University of New Hampshire. He conducts research on enzymatic and hormonal mechanisms of growth regulation in trees.

Manuscript received for publication 13 May 1981

Abstract

An automatic mat-watering system for growing hardwood seedlings in containers was designed and tested. The system has only one moving part, and no electrical requirements. There is no need to calculate different watering schedules for different growth phases, different hardwood species, or different evapotranspiration conditions. Results were excellent with mat watering combined with simple, peat-vermiculite mixes, and pelleted, slow-release fertilizers. The system is economical, simple, and physiologically ideal. Mat watering was effective in growth rooms, controlled environment chambers, and greenhouses.

Introduction

Production of container-grown tree seedlings for reforestation has become an increasingly important practice in modern forestry (Tinus et al. 1974). Research has concentrated on the development of specialized containers. Potting mixes, photoperiod, light intensity, temperature regimes, carbon dioxide levels, and fertilizer formulations have been studied also. By comparison, less research has been done to improve the watering system.

Hand watering or various electro-mechanical systems for automatic watering are used generally. The most elaborate automatic system is a moving boom that passes back and forth over the seedlings during irrigation (Tinus and McDonald 1979). Hand watering is a simple system, but it is costly because of wages and is subject to errors in human judgment.

Automated systems have purchasing, installation, and maintenance costs, which can be moderate to high, and are subject to mechanical and electrical breakdown. Overhead watering systems are generally adequate for conifer seedlings, but not for broadleafed hardwood seedlings. Leaves of hardwood seedlings cover the soil surface and prevent wetting from above. Hardwood seedlings wilt and die unless hand watering is used as a back-up system.

In all of these watering systems, the potting soil goes through a wet-up and dry-down cycle. After wet-up by the watering system, dry-down occurs due to evapotranspiration. The problem is to regulate the frequency and duration of watering to prevent wilting and subsequent growth retardation. Because evapotranspiration varies with species grown, day length, ambient air temperature, and relative humidity, watering programs usually require constant monitoring and frequent changes.

Another problem with automatic watering systems is breakdown during nights, weekends, and holidays. Consequently, alarm systems must be installed to cover periods when personnel are absent, and thus, more costs are incurred.

An ideal water system should be:

1. Economical to purchase, install, operate, and maintain.
2. Simple to install, operate, and maintain.
3. Completely automatic.
4. Reliable—that is, no breakdowns.
5. Able to satisfy the plants moisture needs through all stages of growth.

Details for constructing a simple, automatic, mat-watering system that meets all the above criteria are given here. The mat-watering system was used in growth rooms and controlled environment chambers as well as in greenhouses. Also, different potting mixtures and different types of commercial fertilizers were tested for their compatibility with mat watering. Birch was the principal species used in these experiments. Several other hardwood species were tested to verify the results obtained with birch.

Methods and Materials

Bench Setup for Mat Watering

A typical setup for mat watering in a growth room is shown in Figure 1. A bench or table that is level from side to side along its entire length, with a solid top and flat surface, can be used, and the top should be swept clean of particulate matter. A wooden trough about 15 cm wide and 12 cm deep was constructed across one end of each bench. The trough was lined with heavy-duty polyethylene to make it waterproof, and the bench was covered also. The end of the table with the trough was raised with shims to tilt downward 2 degrees.

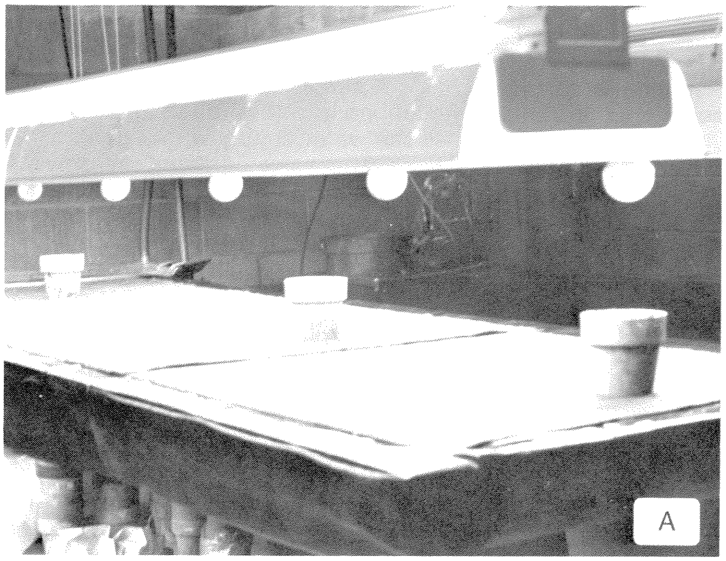
A simple float valve[1] was clamped into the trough and hooked to the water supply with a garden hose. This valve contains the only moving part in the whole system. After prolonged use, the unit may not shut off the water completely. This is easily remedied by replacing the plastic valve (several spares come with each new unit). Water level in the trough was adjusted to about 2.5 cm below the top edge by raising or lowering the float valve.

Mats for capillary watering are generally made of synthetic fibers such as polyester. Large rolls of mat made especially for capillary watering can be purchased from most greenhouse suppliers.[2] A single thickness of this mat on greenhouse benches is recommended. If the bench area is not large, inexpensive polyester blankets from a local department store can be used. Coloring in the blanket is not a problem. Cut to size so the edges of the mat are about 2.5 cm away from edges of the bench top and place on the bench. Small pieces can be used by overlapping. About 10 cm of one end of the mat was draped into the water trough. The rest of the mat was thoroughly wetted and left to equilibrate. At equilibrium, the mat will be saturated, but water will not run off the bench. If water drips off the side, check to see if the bench top is level (side-to-side) and not warped along the long axis. The water trough was covered with black polyethylene to keep debris out and prevent the growth of algae.

---

[1] I used Dare-O-Matic, Farm Tank Float Valves, Battle Creek, Michigan, purchased from a local farm supply store.
The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

[2] I used Troy Flo Thru Moisturing Mat and milled Wisconsin peat moss from Griffin Greenhouse Supplies, Inc., 1619 Main Street, P.O. Box 36, Tewksbury, Massachusetts 01876.



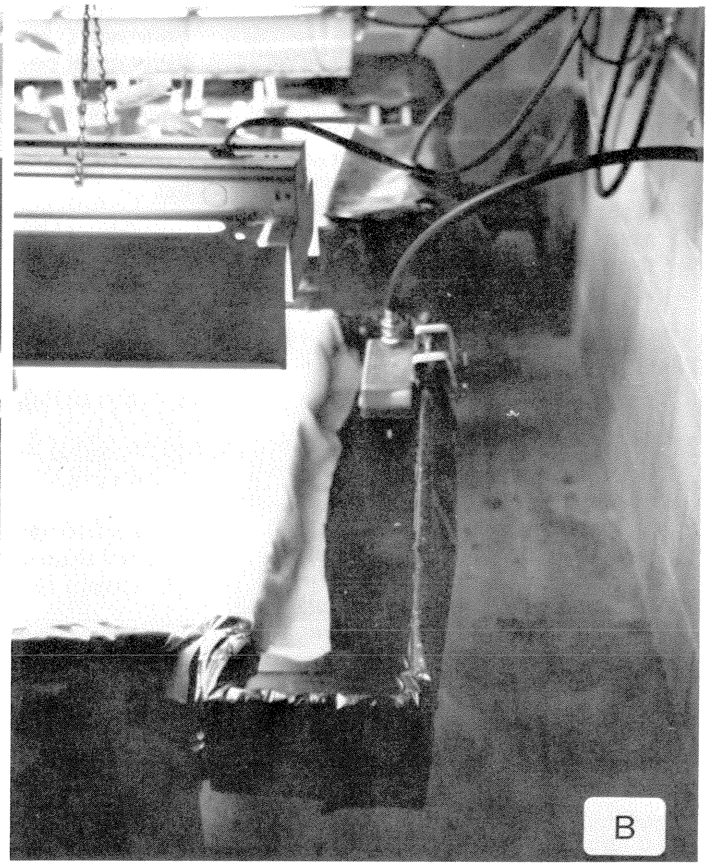


Figure 1.—Components of an automatic mat-watering system in a growth room are: A—wet mat on plastic covered bench, B—water trough with float valve (troughs in background are covered to prevent algae growth), and C—complete setup with potted seedlings and overhead lighting.

The setup for automatic mat watering in controlled environment growth chambers (Fig. 2) and greenhouses (Fig. 11) was essentially the same.

Container Setup

Almost any rigid container is compatible with mat watering. I have used plastic pots from 7.5 cm to 20 cm in diameter and different size Styroblocks. One or more holes are needed in the bottom for inserting wicks. Wicks can be cut from pieces of mat and inserted with tweezers (Fig. 3). Ten-cm plastic pots with three wicks in the bottom of each were used in all the experiments described in this paper. In unreported tests based on the results of these experiments, a variety of other containers were tested with different hardwood species.

Potting Mixes and Fertilizers

Different potting mixes containing peat with perlite, and/or vermiculite were tested. The different combinations were mixed when dry then wetted with tap water. Fertilizers were added next. Pots containing wicks were filled with the different combinations of mix and fertilizer and placed on a wet mat. Equilibrium between water in the mat and water in the soil mix was obtained when all free water drained from the soil mix and only capillary water remained. This was usually accomplished within a half hour.

Seedling Establishment

Paper birch (*Betula papyrifera*) was the primary test species used in these experiments. Some experiments also used yellow birch (*Betula alleghaniensis*). Birch seeds were germinated in shallow trays of potting mix under lights and transplanted into pots or germinated in the pots. In the latter case, Oil Sorb (composed of kaolinite clay) was sprinkled over the birch seed and all pots were covered with plastic until the seed germinated. Two weeks after germination, seedlings were thinned to the most vigorous seedling per pot. Two true leaves were

Figure 2.—Mat watering setup in a controlled environment growth chamber.

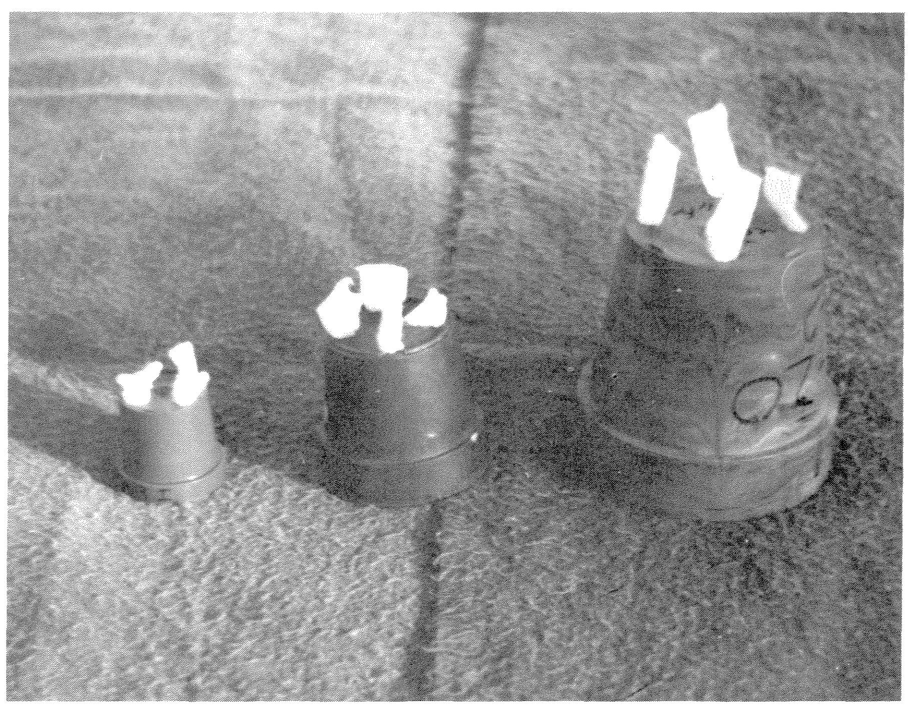


Figure 3.—Plastic containers with wicks in place. Wicks are most easily inserted with tweezers.

usually present. Seedlings were grown for 8 more weeks in all experiments. Height measurements were taken weekly. All other measurements were taken at the end of this 8-week-growth period.

Photoperiod

Twenty-hour photoperiods were used in these experiments with birch and in all subsequent tests with other species in the greenhouse. Hardwood species in New England are long-day plants requiring a minimum photoperiod of 14 to 16 hours. For commercial production in greenhouses, long photoperiods are achieved most economically by interrupting the dark period for an hour.

Germination of Other Species Tested

European black alder (*Alnus glutinosa*) seed was collected locally and germinated directly in the containers. Black locust (*Robinia pseudoacacia*) seed was collected locally, taken from the pods, treated with concentrated sulfuric acid, and germinated in the containers. An inoculum made from crushed root nodules that were dug from under wild trees was given once after germination. Red maple (*Acer rubrum*) and silver maple (*Acer saccharinum*) were collected locally and germinated in the containers. Sugar maple (*Acer saccharum*) and northern red oak (*Quercus rubra*) were collected locally, germinated in the cold at 3.5°C, and planted when radicals were 2.5 cm long. Pin cherry (*Prunus pennsylvanica*) and black cherry (*Prunus serotina*) were stratified with moist forest humus in the cold at 3.5°C and planted after germination at room temperature. Sweet gum (*Liquidambar styraciflua*) collected in Pennsylvania was germinated in the containers at ambient temperatures.

Results

Birch Experiments

Experiment 1. Comparisons of yellow birch growth were made between two potting mixes (peat-vermiculite—PV and peat perlite—PP), two types of fertilizer (Osmocote—solid and Rapid-Gro—liquid), and two methods of watering (automatic mat watering and hand watering in trays under each pot). Pelleted Osmocote (18-6-12) was mixed in at the rate of 6 g/pot. A solution of Rapid-Gro (25 g/10 l) was used to wet the mix initially, and 25 ml/pot was added each week thereafter.

For height growth, mat watering was better than hand watering, PV was better than PP, and Osmocote was better than Rapid-Gro with PV but not PP (Table 1). The tallest seedlings averaged 40 cm 8 weeks after appearance of the first true leaf. The best treatment combination—PV with a one-time application of pelleted, slow-release fertilizer and automatic mat watering—was also the most convenient and the most economical.

Dry matter production (Fig. 4) of leaves, stems, and roots was best with the same combination of factors. However, with PV, Rapid-Gro was equal to Osmocote in dry matter production with mat watering, but not with hand watering. The cause of this reduction in growth associated with hand watering was not determined.

Further comparisons were made between yellow-birch growth in the mixes described above and the peatlite mixes developed at Cornell University (Boodley and Sheldrake 1967). The Cornell peatlite A is a 1 : 1 mixture of peat and vermiculite, and peatlite B is a 1 : 1 mixture of peat and perlite. Both peatlite mixes are fortified with ground limestone, superphosphate (20%), 5-10-5 fertilizer, borax, chelated iron, and a surfactant. In general, peatlite B produced greater height and dry weight than peatlite A (Table 2), but both Cornell mixes were inferior to the growth obtained with the PV mix and Osmocote.

Experiment 2. Because of the excellent results with mat watering in the first experiment, only mat watering was used in this and all subsequent experiments. Pelleted Osmocote was tested against solutions of Rapid-Gro and Universal. OSMOCOTE (18-6-12) was added at the rate of 6 g/pot. Rapid-Gro (20-20-20) and Universal (23-19-17) solutions of 5 g/10 l were added initially and 15 ml/pot were added each week. Trace elements were also tested by additions to Osmocote and Rapid-Gro (Universal, 23-19-17,

Table 1.—Effect of watering technique, type of potting mix, and type of fertilizer on height growth (cm) of yellow birch seedlings.

Fertilizer treatment	Peat-vermiculite		Peat-perlite	
	Mat	Tray	Mat	Tray
None	12.0	10.0	9.0	9.5
Osmocote	41.0	37.5	29.0	26.5
Rapid-Gro	40.0	27.5	31.0	31.5

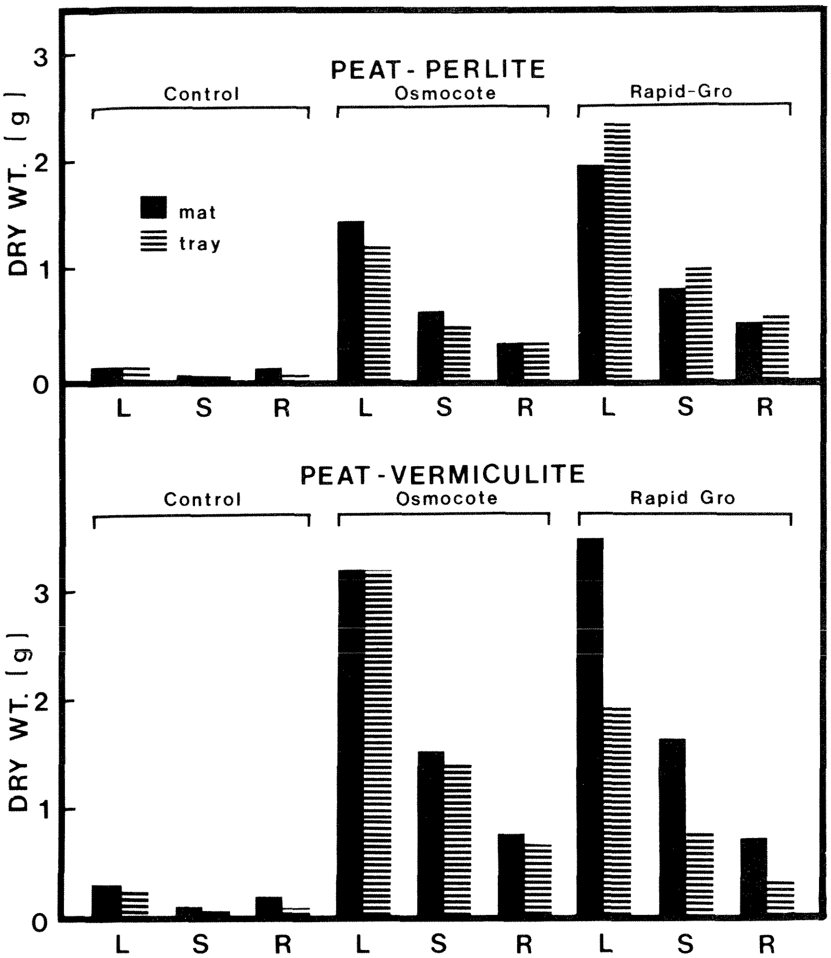


Figure 4.—Effect of watering technique, type of potting mix, and type of fertilizer on dry matter production of yellow birch seedlings. L—leaves, S—stems, R—roots.

Table 2.—Effect of Cornell mixes with mat or tray watering on height (cm) and dry weight (g) of yellow birch seedlings.

Growth measurement	Peatlite A		Peatlite B	
	Mat	Tray	Mat	Tray
Stem height	16.5	17.7	24.3	26.5
Leaf weight	0.8	0.8	1.1	1.1
Stem weight	0.2	0.3	0.5	0.5
Root weight	0.3	0.5	0.3	0.5

was already fortified with trace elements). Solutions of Universal Soluble Trace Element Mix (1 g/10 l) containing Fe, Mn, Zn, Cu, B, and Mo were added initially and 15 ml/pot were added each week. Paper birch was the test species. Total height, diameter at 1 cm, and dry weights were measured at termination.

Osmocote produced the largest seedlings among the three fertilizers tested without additional nutrient supplements (Table 3). Universal was more effective than Rapid-Gro when both were used at equal concentrations. Comparable treatments for yellow birch in Experiment 1 with Osmocote and Rapid-Gro (Fig. 4) showed greater dry weights of leaves and stems. Solution concentrations used in this study were made to give 100 ppm of N. The manufacturers have recommended this level of N to give adequate growth and still not burn the foliage. The addition of trace elements to Osmocote and Rapid-Gro gave additional increases in all growth measurements. The best treatment was Osmocote with supplemental trace elements. These birch seedlings were about 40 cm tall with sturdy stems and good leaf and root development.

Experiment 3. Experiments 1 and 2 showed that a simple PV mix incorporating pelleted fertilizer was entirely compatible with automated mat watering for producing fast growing, healthy birch seedlings. The quantity of nutrients in the tap water used in experiments 1 and 2 was not known. Therefore, we made additional experiments to compare tap water with deionized water. Also, long-term release Osmocote (18-6-12, 8 to 9 months) was compared with the short-term release Osmocote (14-14-14, 3 to 4 months). Both types were at the rate of 6 g/pot. Height and dry weight of paper birch seedlings were measured at termination.

Table 3.—Effect of solid and liquid fertilizers with microelements on height (cm), diameter (mm), and dry weight (g) of paper birch seedlings using automatic mat watering.

Fertilizer treatment	Height	Diameter	Dry weight		
			Leaves	Stem	Roots
Rapid-Gro	22.8	3.7	1.2	0.3	0.2
Rapid-Gro + micro	31.1	4.2	1.5	0.5	0.5
Osmocote	39.5	4.4	2.4	0.8	0.5
Osmocote + micro	41.3	5.4	3.0	1.1	0.7
Universal	29.3	4.4	1.6	0.5	0.6

Table 4.—Effect of different formulations of Osmocote, using tap or deionized water for automatic mat watering, on height growth (cm) and dry weight (g) of paper birch seedlings.

Treatment	Height	Dry weight		
		Leaves	Stem	Roots
Deionized/14-14-14	38.2	2.7	1.0	0.5
Deionized/18-6-12	39.4	3.2	1.2	0.6
Tap/14-14-14	44.4	2.9	1.1	0.6
Tap/18-6-12	44.3	2.9	1.2	0.6

Height of birch seedlings was slightly greater with tap water than with deionized water (Table 4). Otherwise, there were no differences in height growth or dry weight due to type of water or type of Osmocote used.

Experiment 4. In this experiment, a commercial preparation of PV known as Jiffy-Mix was tested with three levels (0, 3, and 6 g/pot) of Osmocote (14-14-14). Jiffy-Mix contains small amounts of added nutrients, so some growth would be expected without Osmocote. Mat watering with deionized water and paper birch seedlings completed the setup.

The maximum rate of height growth was about 2 cm/day for all seedlings with Osmocote, and less than 1 cm/day for seedlings without Osmocote (Fig. 5). Three g of Osmocote/10-cm pot produced the tallest seedlings and greatest dry weight (Fig. 6) of leaves and stems. In addition, this treatment produced greater dry weights than had been achieved in all previous experiments (compare Fig. 6 with Tables 3 and 4). The highest level of Osmocote produced the shortest seedlings that were lowest in root weight and intermediate in stem and leaf weight.

Experiment 5. Compacted bales of Canadian peat moss were used in all previous experiments when preparing PV mixes. Considerable time and effort were required to break up and sieve the compact peat moss before it could be mixed with vermiculite. In this experiment, milled (ground), loose Wisconsin peat moss[2] was used in the PV mix. The loose moss was used without further sieving. Osmocote was applied at 5 g/10-cm pot. Mats were watered with tap water. Heights, diameters, and dry weights of paper birch seedlings measured at termination were:

Height — 54.4 cm

Diameter — 6.2 mm

Leaves — 4.8 g

Stem — 2.1 g

Roots — 1.1 g

In general, the growth obtained with Wisconsin peat moss was greater than growth with Canadian peat moss (Table 3 and 4), but comparable to results obtained with Jiffy-Mix and 3 g Osmocote/10-cm pot (Figs. 5 and 6).

Experiment 6. Osmocote (14-14-14) was tested at seven different levels, both in growth room and greenhouse (additional lighting was used in the latter to give a 20-hour photoperiod). Ten-cm pots of PV mix with Wisconsin peat moss were made up with 0, 1, 2, 3, 4, 5, or 6 g Osmocote/pot. Height growth in the different treatments were measured weekly, the diameters and dry weights were measured after the usual 8-week period.

In general, sharp optima for height, diameter, and dry-weight growth were not indicated (Figs. 7 to 10). Best growth in all tests occurred between 4 and 5 g Osmocote/10-cm pot. One and two g Osmocote levels definitely were deficient for best growth. Five g of Osmocote ensures maximum growth and avoids waste.

Cool night temperatures in the greenhouse probably caused the slower germination and longer time to reach maximum rate of height growth (usually 1.5 cm/day) in this group. Dry-weight increments for

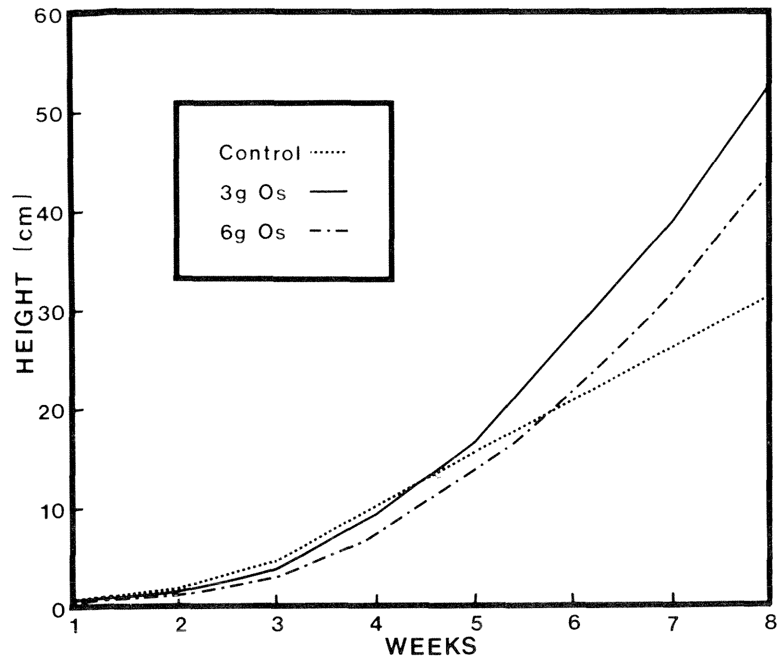


Figure 5.—Effect of Osmocote levels on height growth of paper birch seedlings grown in Jiffy-Mix with automatic mat watering.

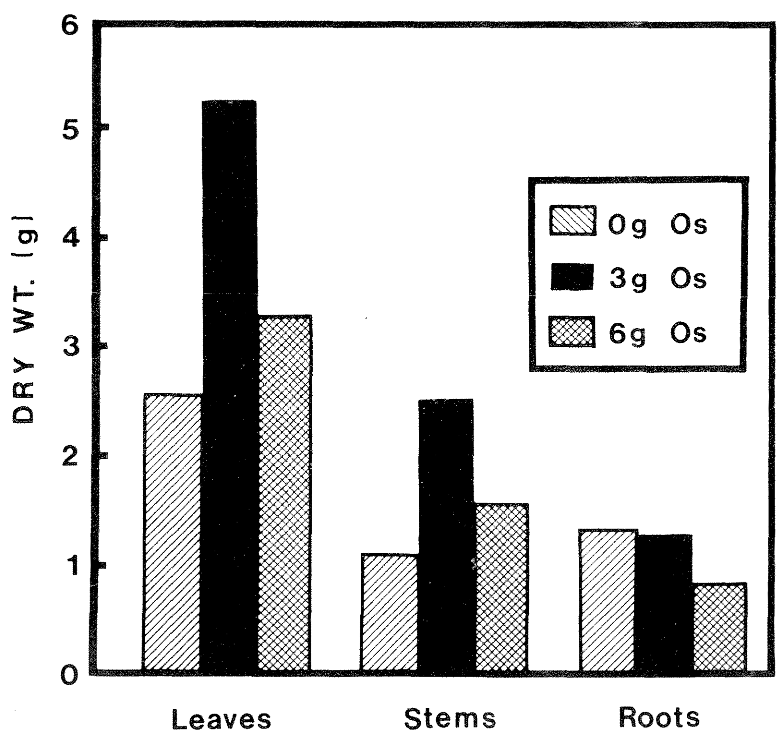


Figure 6.—Effect of Osmocote levels on dry matter production of paper birch seedlings grown in Jiffy-Mix with automatic mat watering.

the growing period were less for greenhouse than for growth room seedlings for the same reasons.

Greenhouse Tests with Mat Watering

Greenhouse benches were set-up (Fig. 11) for mat watering in the same manner used for growth-room benches. Double thickness Troy Flo Thru mats were used to ensure adequate water supplies for the high density plantings. Mats were 91 cm wide and 455 cm long. The maximum length of wet mat that could be used was not determined.

Batches containing 7 l of peat (loose Wisconsin), 7 l of vermiculite, 2 l of tap water, and 100 g of Osmocote (14-14-14) were made homogeneous in a small, electrically driven cement mixer. Styroblocks with 80 cavities per block were filled with the mixture after wicks were inserted (Fig. 12). Cavities were sown with seeds of paper birch, black locust, and European black alder, covered lightly with Oil Sorb, and germinated under clear polyethylene to keep the surface moisture high. Seedlings were thinned to the most vigorous seedling per cavity 2 weeks after germination. Growth in the greenhouse was continued for an additional 8 weeks. Natural day length was extended by using cool-white fluorescent tubes to give a 16-hour photoperiod. Universal (23-19-17) was applied by hand sprayer at a rate of 5 g/10 l of water midway through the growth period to ensure against deficiencies.

After 10 weeks in the greenhouse, Styroblocks were set outside, and the seedlings were watered with a garden sprinkler (time clock operated) for 2 weeks to permit hardening-off.

Seedlings of all three species showed good height growth and excellent foliar development (Fig. 13). Branches were absent in all species due to crowding in the Styroblocks (Fig. 13 and 14). Root development was prolific and essentially vertical (Fig. 14). Seedlings were easily extracted from the Styroblocks.

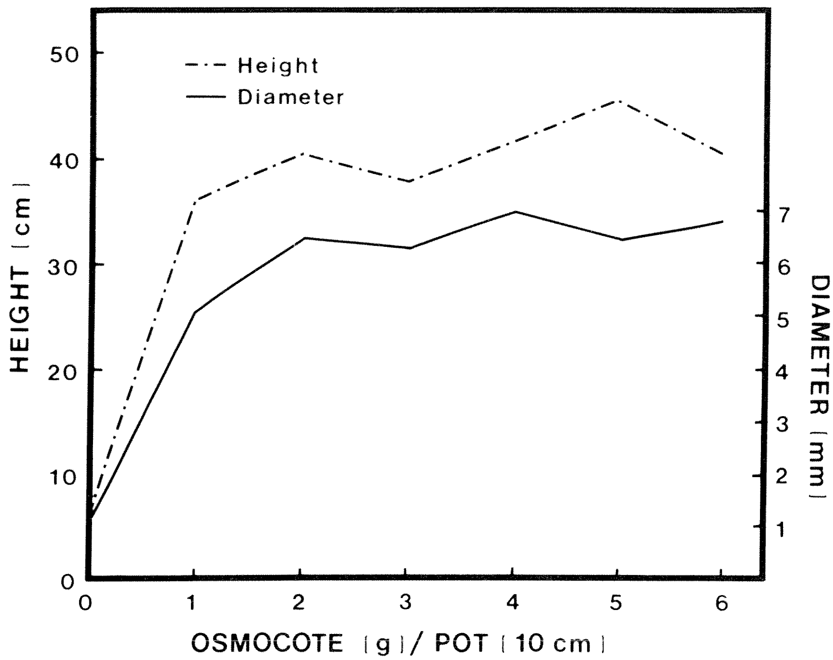


Figure 7.—Effect of Osmocote level on height and diameter growth of paper birch using Wisconsin peat moss and automatic mat watering (growth room).

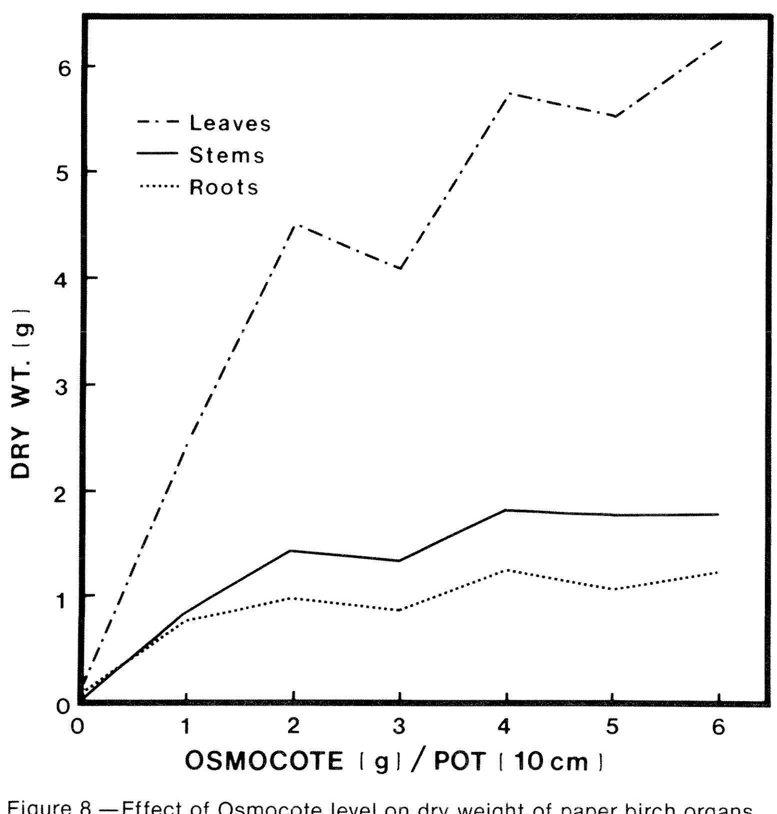


Figure 8.—Effect of Osmocote level on dry weight of paper birch organs using Wisconsin peat and automatic mat watering (growth room).

On the day of outplanting, seedlings were refertilized by immersing the styroblocks in a solution of Universal (Fig. 15). Seedlings were planted in dibble holes with Osmocote.

First-year survival on the prepared planting site in Maine with chemical brush control was 95% or better for all species. Paper birch made the greatest increase in height growth followed by black locust and black alder (Table 5).

Several other deciduous broadleaved species were grown under the same conditions described above with excellent results. Among those tested were yellow birch, red maple, silver maple, sweetgum, black cherry, pin cherry, and northern red oak. This last species required occasional treatments with Universal to keep the seedlings flushing.

Discussion

In the work described here, automatic mat watering produced hardwood tree seedlings of comparable or better development than hand watering. The three main advantages of mat watering were: simplicity, low cost, and being physiologically ideal.

The simplicity of automatic mat watering is evidenced by the absence of elaborate plumbing, electrical timers, weighing devices, solenoid valves, electric motors, and special nozzles. Instead, all of these are replaced by a wet mat, a piece of garden hose, and a simple float valve—the only moving part in the whole system.

Low cost is a result of the elimination of expensive apparatus and reduced wages for installation and maintenance. I have not made any comparisons of water use between mat watering and other systems, but suspect the former is less. Of course, the best strategy to reduce water consumption is to avoid growing seedlings during the hot days of summer when evapotranspiration is high.

Table 5.—First-year-height growth (cm) of alder, locust, and birch seedlings grown in Styroblocks in the greenhouse with PV, Osmocote, and automatic mat watering.

Species	Height		Percentage of increase
	Before planting	End of growing season	
European black alder	36	40	11
Black locust	50	82	64
Paper birch	27	54	100

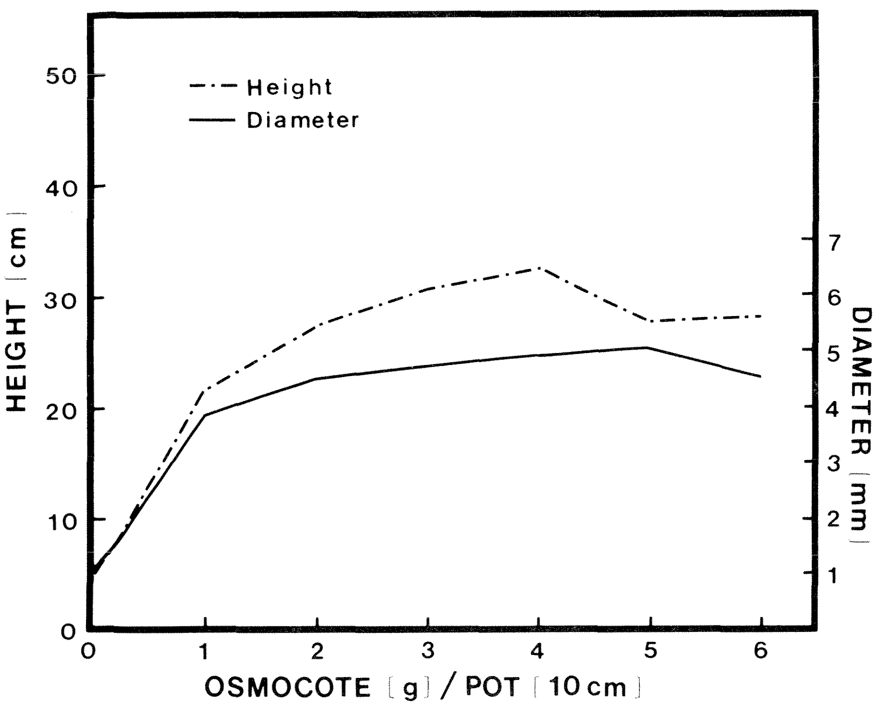


Figure 9.—Effect of Osmocote level on height and diameter growth of paper birch using Wisconsin peat moss and automatic mat watering (greenhouse).

For water to be continuously available to the growing seedlings, the potting mix needs to be held at its maximum capillary capacity (MCC). MCC is the amount of water a mix can hold against the pull of gravity when adequate drainage is afforded. Put another way, MCC is the water retained in the micropores and small capillaries after water has drained out of the macropores under the pull of gravity. At this point, the mix is fully charged with plant-available water and the macropores contain the necessary air for aerobic respiration. This condition of the potting mix is considered to be physiologically ideal. Automatic mat watering continuously maintains this physiological ideal status in the potting mix. As a result, seedling growth is never retarded by too much or too little water, which frequently happens in the wet-up and dry-down cycle that occurs with all other systems of watering.

The composition of a potting mix is especially critical for automatic mat watering. The mixture must provide the necessary range of pores for adequate water and aeration. Also, the mix should have some capacity to ionically bind the basic plant nutrients Ca, Mg, and K, and it should be free of disease organisms and weed seeds. As reported here, a 1:1 mixture of peat moss and coarse-grade vermiculite is fully compatible with automatic mat watering. A commercially available peatlite, such as Jiffy-Mix, also gave excellent results with mat watering and pelleted fertilizer.

In my experience, the use of pelleted, slow-release fertilizer was the simplest, most economical answer to plant nutrition with mat watering. Materials such as Osmocote are not toxic, are easy to

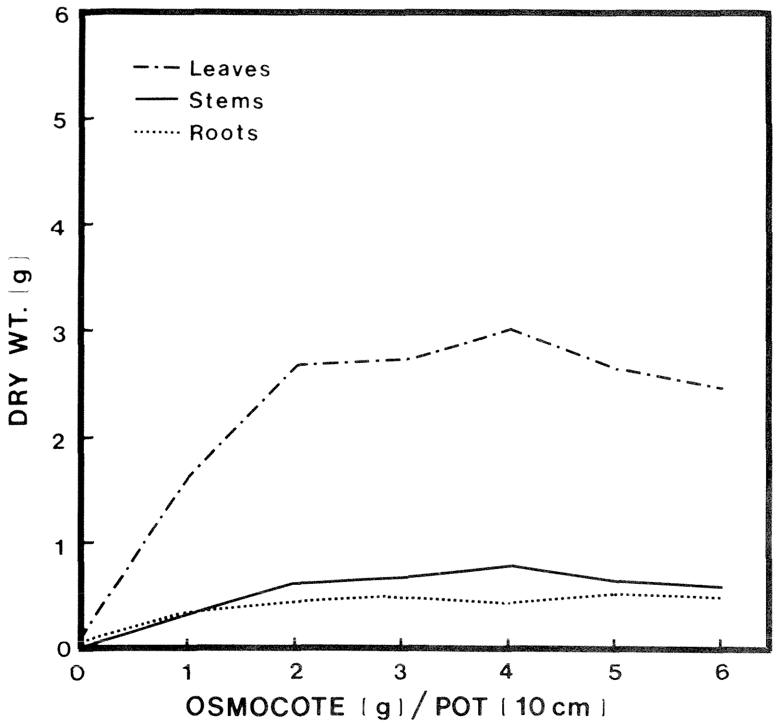


Figure 10.—Effect of Osmocote level on dry weight of paper birch seedlings using Wisconsin peat and automatic mat watering (greenhouse).

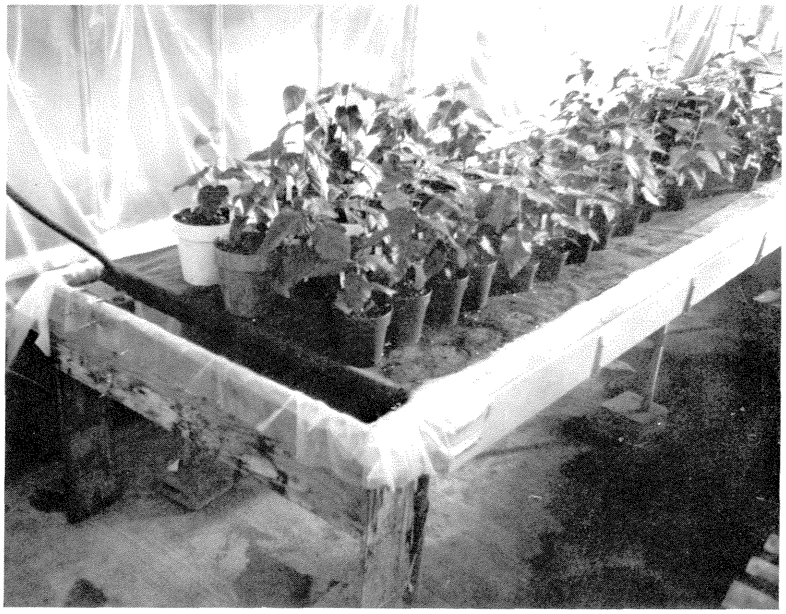


Figure 11.—Greenhouse bench with plastic cover, wet mat, and water trough with float valve setup for automatic mat watering.

handle, and require one application (at time of mix preparation). About 5 g of Osmocote/10-cm pot should suffice. Some species such as northern red oak may require additional fertilizer treatment. This can be accomplished with a complete nutrient solution such as Universal. Obviously, interested growers should make some tests of their own.

The local water supply worked well for us. The chemicals added by the municipal treatment plant were a nuisance rather than a problem. For example, in our growth room salt accumulated at the end of the mat and this could reduce seedling growth in containers in the immediate area. Salt accumulation was caused by a constant high temperature (27°C) and low humidity (<20% RH), which resulted in high rates of evaporation. Three recommendations if this problem occurs are: First, hang a triangular piece of wet mat over the end of the bench to elute the salts periodically; second, cut off the end portion (about 45 cm) and replace it with new mat; or third, do not place pots on the end portion. Remember, however, that salt accumulated only with pots in our growth room and not with pots or Styroblocks in our greenhouse or growth chamber, where evaporation from the mat was much lower.

All types of rigid containers tested worked well with automatic mat watering as long as wicks were placed in the drain holes. Plastic pots of all diameters and all sizes of Styroblocks were used successfully in our greenhouse, growth room, and controlled environment growth chambers.

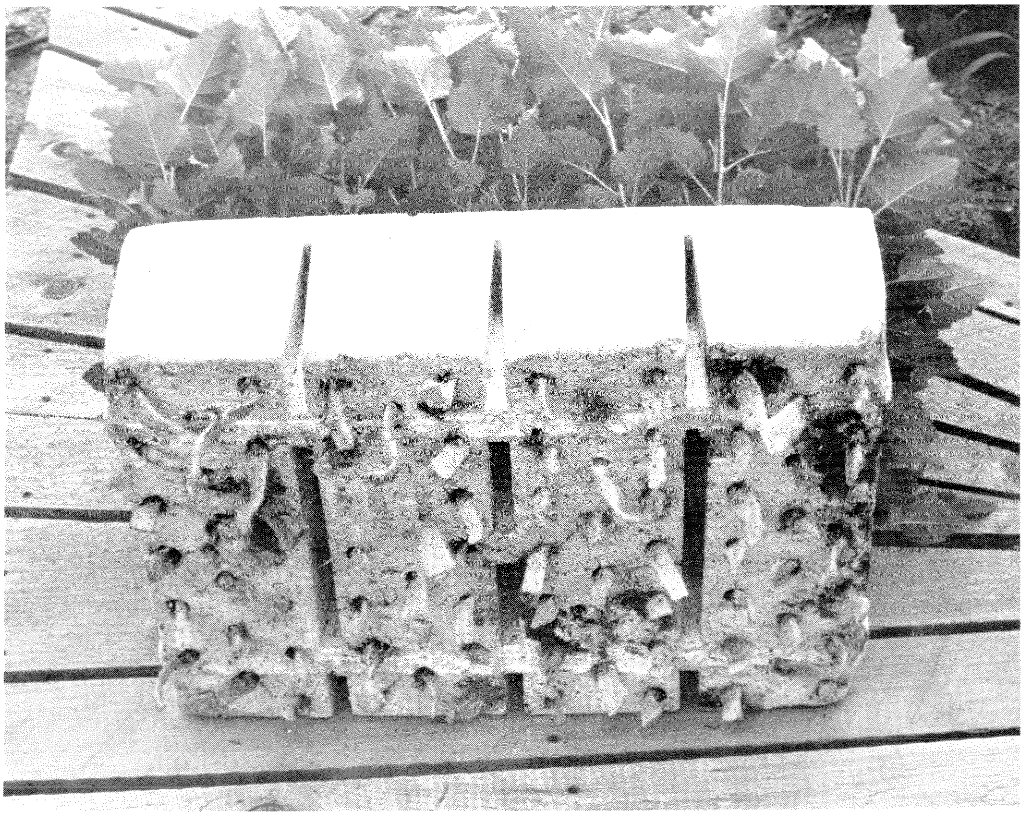


Figure 12.—Styroblock shows the wicks used with automatic mat watering.

Figure 13.—Styroblocks with 10-week-old seedlings, from left, black locust, European black alder, and paper birch, produced in the greenhouse with PV mix, Osmocote, and automatic mat watering.

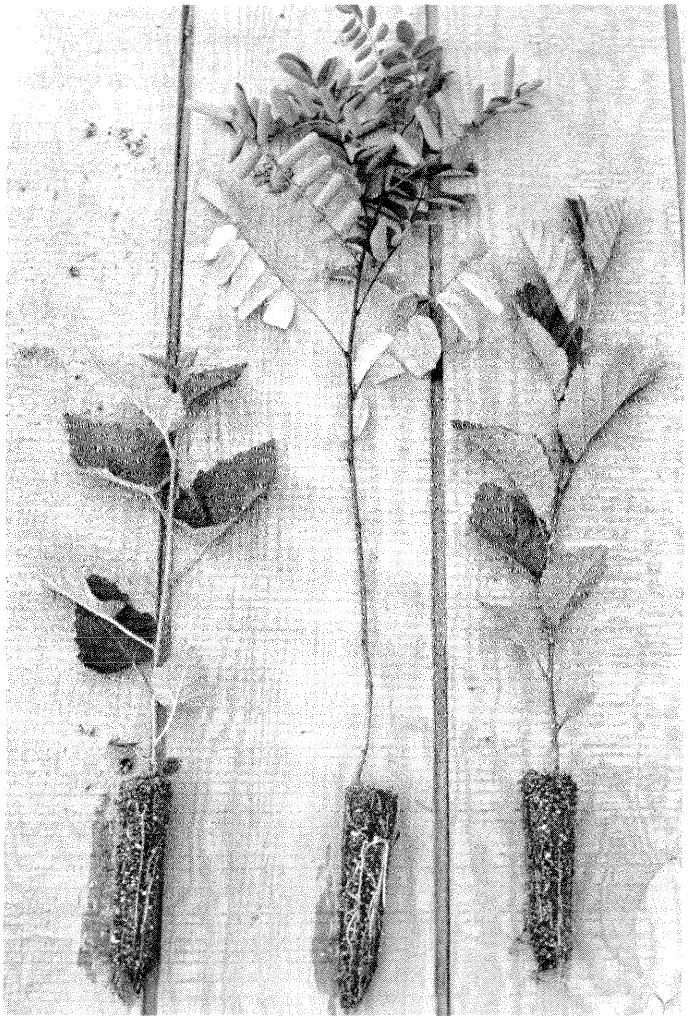


Figure 14.—Top and root development, from left, paper birch, black locust, and European black alder seedlings grown in a greenhouse. (Conditions as in Fig. 13)

Figure 15.—Plastic-lined soaking box contains a dilute solution of Universal for treating container-grown seedlings before outplanting.

Acknowledgments

I am indebted to Martha Ward and Patrice Rodgers for their able technical assistance and to Dr. Larry Safford for the growth data given in Table 5.

Literature Cited

Boodley, J. W.; Sheldrake, R. **Cornell peatlite mixes for commercial plant growing.** 1967; Cornell Ext. Bull.1104; 11 p.

Tinus, R. W.; McDonald, S. E. **How to grow tree seedlings in containers in greenhouses.** 1979; USDA For. Serv. Gen. Tech. Rep. RM-60.

Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. **Proceedings of the North American containerized forest tree seedling symposium.** 1974; Great Plains Agric. Counc. Pub. No. 68. 458 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-505-012:7

Hoyle, Merrill C. **Economical and simple production of containerized hardwood seedlings.** Broomall, PA.: Northeast. For. Exp. Stn.; 1982; USDA For. Serv. Res. Pap. NE-500. 12 p.

An automatic mat-watering system for growing hardwood seedlings in containers was designed and tested. The system has only one moving part, and no electrical requirements. There is no need to calculate different watering schedules for different growth phases, different hardwood species, or different evapotranspiration conditions. Results were excellent with mat watering combined with simple, peat-vermiculite mixes, and pelleted, slow-release fertilizers. The system is economical, simple, and physiologically ideal. Mat watering was effective in growth rooms, controlled environment chambers, and greenhouses.

ODC: 232.329.6

Keywords: Automatic mat watering, pelleted fertilizers, containerized seedlings.

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.