the Minnesota Nurserymen's Research Corporation royalty program.

Lonicera tatarica 'Arnold's Red' and the selection described above have produced a number of resistant offspring when crossed with each other and with *Lonicera korolkowii* 'Zabelii.' Many of these resistant offspring should flower in spring of 1985. Selection for flower color can occur and they can also be used as parents to produce subsequent generations.

Significance to the Nursery Industry

Lonicera is a particularly important plant to the nursery industry in the midwest where honeysuckle is commonly used for informal hedge, screen and windbreak plantings. Zabel and Tatarian honeysuckle are the most widely used honeysuckles and both are very susceptible to the honeysuckle aphid. A resistant cultivar with suitable plant form and aesthetic qualities is needed to replace susceptible clones in nursery inventories. Observations indicate that resistant germplasm is available. Results of early crossing efforts indicate that resistance is readily transmitted to a large number of offspring. Insufficient data is available to determine mode of inheritance.

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Effect of Seedling Size and Transplant Bed Density on Performance of Eastern Hemlock Planting Stock[1]

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Abstract

After grading two-year-old Eastern hemlock (*Tsuga canadensis* (L.) Carr.) seedlings by height, performance was examined for one year under various transplant bed densities, and for 2 years in the field. In the nursery, average diameter growth and dry matter production were influenced by bed density; height growth was not. A transplant bed density of 65 plants/m^2 (6/ft^2) resulted in the greatest average diameter and dry weight, but densities up to 151 plants/m^2 (14/ft^2) yielded more usable transplants per unit of nursery bed. Although there were residual effects of transplant bed density, the major differences in growth after 2 growing seasons in the field were due to initial seedling size. Transplants originating from large seedlings outperformed those from small seedlings. Compared to small seedlings, larger plants require less time in transplant beds, are less troublesome to maintain in the field, and reach marketable size in fewer years, all of which increase their value relative to small seedlings.

Index words: *Tsuga canadensis,* Canadian Hemlock, transplanting

Introduction

Many factors affect the performance of plants in seedbeds, transplant beds and the field. Nursery bed density and seedling grade are two of the most important. In general, average plant size increases as bed density decreases (14), and the percent yield of usable seedlings is frequently higher at lower bed densities (9). Average size may occasionally decrease at extremely wide spacings if other factor(s) become limiting (13). Extremely low densities are not economical owing to the excessive nursery area required to produce a large crop. Thus, selection of optimum bed density (density which produces the maximum number of usable seedlings per unit area) often represents a compromise between the logistical problems of managing a nursery and the biological capabilities of the crop plant (9).

Seedling grade or quality is important, but there is no single parameter which adequately assesses quality (2). The easiest to measure are height and stem diameter, which are often well-correlated with later growth in the field (5, 14). Physiological indices of quality include root regeneration potential (11), nutrient status (14)

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drought tolerance (12), cold hardiness (6), and mycorrhizae (4). Attempts to correlate growth potential to carbohydrate reserves have generally been unsuccessful (7).

Eastern hemlock (*Tsuga canadensis* (L.) Carr.) (locally known as Canadian hemlock is indigenous to the eastern United States and Canada between latitude 34° and 48°N. It is extensively cultivated as a landscape plant throughout its range. In North Carolina, the customary procedure is to place two-year-old seedlings in transplant beds where they remain for at least one year before going to the field. Little information is available concerning the cultural requirements of Eastern hemlock. Therefore, the following study was undertaken to examine the influence of seedling size and transplant bed density on the performance of this species.

Materials and Methods

Nursery Experiment. Two-year-old Eastern hemlock seedlings were lifted and graded on April 8, 1981. Seedlings originated in western North Carolina, but the exact provenance was unknown. Seedlings were growing in a commercial nursery in Jackson County, North Carolina (35° 17' N. latitude, 83° 06' W. longitude, elevation = 670 m) (2200 ft) on a Congaree fine sandy loam. Bed density was approximately 1100 plants/m^2 (100/ft^2), and plants were undercut prior to lifting. Seedlings were lifted by hand and 3 height categories selected: 5 to 10, 13 t 18, and 20 to 25 cm (2 to 4, 5 to 7, and 8 to 10 in, respectively) (Table 1). Seedlings were sealed in polyethylene bags and stored in the dark at 3°C (38°F).

The planting site was located at the Mountain Research Station in Waynesville, North Carolina (35° 30' N. latitude, 83° 59' W. longitude, elevation = 670 m (2200 ft) on a Codorus loam. A raised nursery bed 1.3 m (4 ft) in width was prepared. It was fumigated with methyl bromide, limed with dolomite to attain a pH of 5.5, and amended with 110 kg/ha (100 lbs/acre) of N as diammonium phosphate (18-46-0) according to soil tests and standard recommendations (1).

Seedlings were hand planted at three bed densities (65, 108, and 151/m^2) (6, 10 and 14/ft^2) in a randomized complete block design with four replications on April 22, 1981. Row spacing was 15 cm (6 in), and density was controlled by changing the number of plants within rows. Plants were watered following planting, and mulched with a 0.5 cm (0.25 in) layer of sawdust. Each plot was approximately 1.3 x 1.3 m (4 x 4 ft) and roots were confined by black polyethylene dividers sunk to a depth of 20 cm (8 in) on each side. Open buffer strips 0.3 m in width separated plots in order to minimize shading effects. Plots were shaded with 50% black saran during the growing season, and watered as needed.

Table 1. Initial dimensions of 2-year-old Eastern hemlock seedlings of different morphological grades (Spring 1981).

Seedling grade[z]	Total height (cm)	Groundline diameter (mm)	Total dry weight (g)	Shoot:root ratio[y]
SMALL	8.3[x]	1.25	0.29	2.2
	(0.4)	(0.04)	(0.03)	(0.14)
MEDIUM	16.4	1.72	0.67	3.8
	(0.04)	(0.06)	(0.05)	(0.30)
LARGE	24.1	2.37	1.52	4.2
	(0.5)	0.06)	(0.09)	(0.38)

[z]based on height.

[y]dry weight basis.

[x]mean; value underneath in parentheses is standard error (S.E.); n = 30.

Transplants were lifted on April 10, 1982. Root growth had commenced, but shoots were still dormant. Approximately 20 plants from each plot, excluding border plants, were immediately measured for total height and groundline diameter. Five of the 20 measurement plants from each plot were selected for laboratory analysis, including the largest, smallest and three intermediates (based on groundline diameter). Remaining plants were heeled into nursery soil for use in the subsequent field experiment. Sample plants were dried to constant weight at 60°C (140°F) and weighed. For each treatment, dry weight data were composited for the 20 plants (4 replications x 5 plants), and an allometric equation developed to predict $\log_{10}$ DW using $\log_{10}$ D or $\log_{10}$ D^2H as independent variables, where DW = total dry weight, D = groundline diameter in millimeters, and H = total height in cm. These equations accounted for 95 to 97% of the variability in dry weight, and were used to determine the plant of average weight in each plot. This regression procedure was utilized in lieu of destructive sampling due to the limited size of plots in the nursery experiment. Data were subjected to standard analysis of variance procedures.

Field Experiment. The field planting was located in Cashiers, North Carolina (35° 06' N. latitude, 83° 06' W. longitude, elevation = 1060 m (3480 ft) on an Ashe sandy loam, rolling phase. The field was strip tilled (row spacing = 1.5 x 1.5 m (4 x 4 ft), strip width = 0.6 m (2 ft), strip depth = 15 cm (0.5 ft)), and dolomite, gypsum, and ammonium polyphosphate (11-55-0) were incorporated into strips at rates of 2300, 1100, and 660 kg/ha (2000, 1000, and 550 lbs/acre), respectively. These fertilizer amendments were based on soil testing recommendations (8) as well as experience of the grower on whose land the experiment was located. Transplants were hand planted on April 11, 1982 in a split plot design with four replications. Seedling grades were main plots; transplant bed densities subplots. Each subplot contained 16 plants on a 1.5 x 1.5 m (5 x 5 ft) spacing. A preemergence herbicide, oxyfluorfen, (1.1 kg/ha a.i., 1 lb/acre) was applied after the first rain, and weeds were controlled during late summer by mowing. During spring of the second season in the field, each plant received 14 g (0.5 oz) of N as urea-ammonium polyphosphate (28-28-0) and 14 g (0.5 oz) of potassium chloride (0-0-60). A preemergence herbicide, pronamide, (2.2 kg/ha a.i., 2 lbs/acre) was applied in March, 1982, and weeds were mown during late summer.

Following the first growing season in the field, plants were trained to a single leader, and lateral branches pruned off the leaves 5 cm (2 in) of the main stem. In October 1983, total height was measured as well as stem diameter 5 cm (2 in) above groundline. From each plot, the two plants nearest the mean stem diameter and height were selected for aboveground biomass measurements, giving a total of 8 per treatment. In instances where several plants were candidates for selection, precedence was given to the diameter measurement since diameter is more closely correlated with weight than height. Plants were dried to constant weight at 60 °C (140 °F), and weighed.

Results

Transplant bed. All seedling grades had satisfactory survival and grew rapidly in the transplant beds (Table 2). Large seedlings were almost twice as tall, one-third larger in diameter, and twice as heavy as small seedlings following one year in the transplant bed. Bed density significantly affected diameter and dry weight, but not survival and height. The effect of bed density increased with seedling size. Large seedlings grown at 65/m² (6/ft²) were almost 100% heavier than those grown at 151/m² (14/ft²), compared to a difference of 40% for small seedlings. Increasing bed density from 65 to 108/m² (6 to 10/ft²) decreased potential dry matter production more than an increase from 108 to 151/m² (10 to 14/ft²).

Field. After 2 growing seasons in the field, the superior performance of large transplants was still evident and, in some respects, even more pronounced than after a year in the transplant bed. Seedling grade at the 2-year-old stage had a marked effect on overall dimensions 3 growing seasons later in the field (Table 3). Large plants grown at 65/m² (6/ft²) in the transplant bed were 5 times heavier aboveground, twice as large in diameter, and about 50% taller than small plants grown at 151/m² (14/ft²).

Transplant bed density had a negligible effect on height growth in the field. The residual effect of transplant bed density was most apparent in large plants, where average dry matter production and diameter of those previously grown at 65/m² (6/ft²) was significantly greater (5% level) than in plants previously grown at 108 or 151/m² (10 or 14/ft²). In every case, mean diameter after 2 growing seasons in the field was significantly greater for plants previously grown at 65/m² (6/ft²), compared to those grown at 151/m² (14/ft²).

Table 2. Performance of Eastern hemlock seedlings during one year in transplant beds as affected by morphological grade and transplant bed density.

Transplant bed density (plants/m²)	Survival (%)	Total height (cm)	Groundline diameter (mm)	Total dry wt (g)
		——SMALL[z]——		
65	94 a[y]	24 a	4.2 a	6.9 a
108	94 a	23 a	3.8 b	5.3 ab
151	96 a	24 a	3.6 b	5.0 b
		——MEDIUM[z]——		
65	93 a	32 a	5.0 a	11.9 a
108	97 a	31 a	4.4 b	8.5 b
151	91 a	31 a	4.1 c	7.0 b
		——LARGE[z]——		
65	96 a	41 a	5.7 a	16.4 a
108	92 a	40 a	5.0 b	11.5 b
151	93 a	39 a	4.6 c	8.8 c

[z]Planted as 2-year-old seedling stock, and remained in transplanting bed for one year. Morphological grades were based on height as a 2-year-old seedling.

[y]Each value is based on 4 replications. For each seedling grade, means within columns followed by the same letter or letters are not significantly different at the 5% level using Duncan's Multiple Range Test, 5% level.

Discussion

Results in the nursery confirm the principle that height growth is relatively constant over a wide range of stand densities (10). During the first year in the transplant bed, height growth was virtually unaffected by bed densities ranging from 65 to 151/m² (6 to 14/ft²) (Table 2). As would be expected, however, mean diameter and dry matter production were more sensitive to density, particularly with larger seedlings. This is in keeping with the principle that dry matter production or volume growth in well stocked stands is relatively constant over a wide range of densities (10).

Even though some residual effects of transplant bed density were significant in the field, the major differences were due to initial seedling grade (Table 3). Most large and medium plants grew well in the field, indicating that bed density over the range tested was not of great importance to the practitioner. This suggests that 2 + 0 seedlings destined to spend one year in transplant beds can be grown successfully at densities well above the traditional 65 plants/m² (6/ft²), which would reduce land requirements and other nursery costs. On the other hand, if seedlings remain in transplant beds for 2 years, density should be reduced to approximately 65/m² (6/ft²). In this context, large and medium seedlings required only one year in transplant beds, whereas small seedlings could have easily been left for two years or culled.

In the simplest sense, a good quality plant is one which survives and grows well when outplanted in the field, assuming normal care during outplanting (3). Transplants from the medium and large seedling grades easily conformed to this definition. The advantages of these plants include (1) better expression of apical dominance and less likelihood of producing multiple shoots, (2) rapid height growth and quicker emergence above

Table 3. Growth of Eastern hemlock transplants during 2 years in the field, as affected by seedling morphological grade and transplant bed density.

Nursery		After 2 years in the field		
Seedling grade[z]	Transplant density (plants/m²	Total height (cm)	Stem diameter[y] (mm)	Aboveground dry weight (g)
SMALL	65	80 a	11.7 a[x]	58 a
	108	82 a	11.7 a	58 a
	151	76 a	10.3 b	43 a
MEDIUM	65	109 a	16.0 a	123 a
	108	104 a	15.0 ab	107 a
	151	100 a	14.6 b	110 a
LARGE	65	126 a	18.9 a	205 a
	108	122 a	16.4 b	136 b
	151	116 a	16.6 b	150 b

[z]Based on height as a 2-year-old seedling.

[y]Five cm above groundline.

[x]Each value is based on 4 replications. For each seedling grade, means within columns followed by the same letter or letters are not significantly different at the 5% level using Duncan's Multiple Range Test, 5% level.

competing weeds and grasses, (3) better visibility and less susceptibility to destruction or mechanical damage by mowers, and (4) less basal pruning is required.

Commercial nurserymen normally try to produce sheared hemlock trees 1.2 to 1.5 m (4 to 6 ft) in height which requires 5 to 6 years in the field in the mountains of North Carolina. Although it is risky to make long-term projections based on attributes of planting stock, seedling morphological parameters are useful in predicting vigor and growth over periods as long as 5 to 10 years (5). This was confirmed in this study. Plants which were largest as 2-year-old seedlings were still the largest and move vigorous after 1 year in transplant beds and 2 years in the field, particularly with respect to diameter and dry weight (Tables 1, 2, and 3). Because nurserymen begin shearing and shaping in the field before plants reach a height of 1 m (3 ft), much of the potential height growth is sacrificed to confine branch growth in a smaller crown volume, thus yielding denser plants. Even though shearing reduces diversity and increases uniformity, the initial 3 years of this study leave little doubt that selection of larger, more robust 2-year-old seedlings can result in at least a 2-year reduction in time to reach marketable size, which is significant in rotations less than 10 years.

Significance to the Nursery Industry

Size grading of eastern hemlock at the 2-year-old seedling stage is worthwhile because larger plants require less time in transplant beds, maintain their superiority in the field, have several indirect benefits which facilitate handling and reduce maintenance costs, and reach marketable size quicker. The net result is shorter rotations and more profit to growers. The traditional planting density for 2-year-old seedlings in transplant beds is 65 plants/m^2 (6/ft^2). Density can be increased to 108/m^2 (10/ft^2) without compromising plant quality, provided transplants remain in the bed only one year. This reduces costs and land requirements, and increases the number of usable transplants per unit of nursery area. Grading allows for more efficient handling of plants regardless of size, eliminates unacceptable plants at the outset, and greatly improves uniformity of the final crop (transplants or trees in the field).

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