EFFECT OF MOISTURE AND FERTILIZERS ON SUGAR MAPLE SEEDLING GROWTH

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Two ways to help satisfy the need for more high-quality sugar maple trees (Acer saccharum Marsh.) are by establishing plantations and by supplementing natural regeneration. To gain basic knowledge of seedling requirements for this species we studied the effects of soil moisture and nutrient levels on the growth of sugar maple seedlings in their first 3 years.

METHODS

To reduce some of the inherent genetic variability, we grew seedlings from seeds of a single tree. We germinated the seeds in sand. When their radicles were about 1 inch long, but before the cotyledons had unfolded, we transplanted 81 of them into 8-inch plastic pots filled with old-field soil.

The old-field soil was from the B horizon of a Paxton loam. In a partial chemical analysis, the soil's nutrient content seemed to be some-what lower than that of most glacial tills in Vermont. Robert O. Curtis and Boyd W. Post (unpublished data) found the concentrations of calcium, potassium, and magnesium in the B horizon in Vermont glacial tills to be 527 ppm, 611 ppm, and 3,792 ppm, respectively. Comparable values for the Paxton loam were 376 ppm, 211 ppm, and 2,400 ppm.

We screened the soil to remove the coarser particles. Then.we filled pots with the soil and determined the dry weight of the soil in each container. In early spring after the danger of frost had passed, we planted the germinated seeds in the containers.

We grew the seedlings in a plastic-covered structure to keep out rain and to protect them from wind damage. No artificial light or shading was provided. To help maintain uniform soil temperatures and to keep the pots clean so as to increase accuracy of weighing, we placed them in similar plastic pots sunk in the ground. In late fall we mulched the seedlings with hardwood leaves.

Three nutrient levels and three soil moisture levels were imposed in all combinations, giving a total of nine treatments, with nine seedlings in each treatment.

The three nutrient levels were: (1) low-level, old-field soil with-out supplemental fertilizer; (2) medium-level, equivalent of 1 liter of a complete Hoagland solution added to each pot (Table 1); and (3) high-level, equivalent of 2 liters of a complete Hoagland solution added to each pot. This was done at the beginning of the first growing season and was not repeated.

Table 1. Approximate Amount of Mineral Elements in Kilograms per Hectare Equivalent to One Liter of Hoagland Solution per Pot

Elementa	Kilograms per hectare
N	69.1
P	10.2
K	77.3
Ca	52.7
Mg	16.1
S	21.1
Fe	1.7

All other mineral elements less than 0.25 kilogram per hectare for each.

Three soil moisture levels were maintained to simulate different soil moisture stress conditions. Moisture retention values for the different treatments, as determined by laboratory analysis, were: (1) low moisture, 8 to 18 percent by weight, which approximated the range of soil moisture content between the permanent wilting point (15 atmospheres tension) and 1 atmosphere tension; (2) medium moisture, 18 to 28 percent by weight, the approximate range in soil moisture content between 1 and 1/3 atmosphere tension; and (3) high moisture, 28 to 38 percent by weight, the approximate range in soil moisture content between 1/3 and 1/10 atmosphere tension. The highest value (38 percent) is the average B-horizon moisture content found by Curtis and Post (unpublished data) in their soil-site study of northern hardwoods.

The three ranges of soil moisture content were maintained by first determining the amount of water necessary to bring each pot to its maximum assigned moisture percentage. This weight of water was then added to the containers of soil. Pots were rewatered when the soil moisture content approached the lower moisture limit.

We know that by watering in this manner we did not get uniform moisture distribution throughout the pot. For the low and medium moisture levels, particularly, the upper portions of the soil in the pots probably approached field capacity, while the lower portions were relatively dry. Kramer discussed this problem (4). But our figures refer to the average moisture content in the pots. Water for this study was obtained untreated from a deep well.

To compensate for increases in system weight due to seedling growth, we computed regression on green weight as a function of seedling height and diameter. These data were obtained from other 2-year-old seedlings that had received the same water and nutrient treatments. The regression was then used to estimate the green weights of seedlings in the study pots, which allowed us to maintain soil moisture content at the designated level.

At the end of the third growing season, the following measurements were recorded: (1) shoot height, (2) shoot diameter, measured 1 inch above the root collar, (3) shoot dry weight, and (4) root dry weight. Shoot height was also recorded at the ends of the first and second growing seasons.

RESULTS

Effect of watering treatment--Watering significantly increased all recorded aspects of growth (root dry weight, shoot dry weight, shoot height, and shoot diameter) (Table 2). Relative differences were greatest for shoot weight (minimum value less than one-third the maximum value) and smallest for shoot diameter (minimum value almost two-thirds the maximum value). Because shoot weight is proportional to shoot volume, and shoot volume tends to be proportional to the square of shoot diameter, it is not surprising that shoot weight increased more than shoot diameter.

Table 2. Sugar Maple Seedling Growth--Effects of Watering Levels After Third Growing Season

			Treatment		
Variable		Low water	Medium water	High water	Statistical significance
Shoot weight	(g.)	2.9	6.8	11.6	**
Root weight	(g.)	9.0	15.0	28.1	**
Shoot height	(cm.)	24.4	42.4	60.5	**
Shoot diameter (mm.)		5.1	6.9	8.4	**

**Significant at 0.01 probability level.

Treatment differences in seedling growth (total shoot height) were much more apparent after the third growing season than after the first growing season. After the first growing season, seedlings that had received the high watering treatment were only 1.1 cm. taller than those that had received the low watering treatment; but this average difference had increased to 36.1 cm. after three growing seasons (Figure 1).

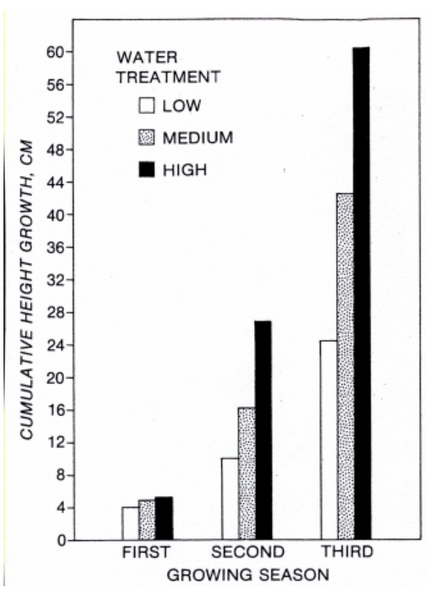

Figure 1. Total height of sugar maple seedlings after each of three growing seasons: effect of watering treatments.

Effect of nutrient treatments--None of the recorded aspects of seed-ling growth were significantly stimulated by fertilization (Table 3), nor were there any statistically significant interactions between watering levels and nutrient levels.

Table 3. Sugar Maple Seedling Growth--Effects of Nutrient Levels After Third Growing Season

			Treatment		
Variable		Low nutrients	Medium nutrients	High nutrients	Statistical significance
Shoot weight	(g.)	6.6	8.0	6.7	N.S.a
Root weight	(g.)	17.5	18.0	16.4	N.S.
Shoot height	(cm.)	43.4	46.4	37.9	N.S.
Shoot diameter (mm.)		6.7	7.1	6.6	N.S.

N.S. Statistical probability greater than 0.05.

DISCUSSION

As is evident from the results of this study and from data reported for many other species (4, 7), moisture stresses that develop within plants in response to low levels of soil moisture undoubtedly inhibit shoot growth. Maintenance in the nursery of soil moisture content at or near field capacity should, by reducing internal moisture stresses and stimulating shoot growth, provide larger seedlings for outplanting.

However, rapid seedling growth, due to optimum soil moisture conditions, may not be entirely beneficial because an abundance of water tends to produce a succulent seedling with a relatively low root:shoot ratio (1, 5, 7). This was apparent in the results of our study. Seedling root:shoot ratio (root dry weight divided by shoot dry weight) was 3.1 for the low watering treatment, but only 2.2 and 2.4 for seedlings receiving the medium and high watering treatments. In selecting high-quality outplanting stock, it is generally recommended that seedlings have a high root:shoot ratio (2, 3). Thus by producing tall succulent shoots with inadequate root systems, high levels of soil moisture in the nursery may result in reduced survival of outplantings. This should be tested with sugar maple seedlings.

The addition of Hoagland solution did not significantly stimulate sugar maple seedling growth. A sufficient amount of essential nutrients was available in this old-field soil to support rapid growth when moisture was not limiting.

As previously stated, seedlings were irrigated with water from a deep well rather than with distilled water. This procedure simulates actual methods of irrigating nursery stock. But the well water contained trace amounts of dissolved mineral elements. This external source may partially explain the lack of seedling response to applied nutrients.

There were no statistically significant differences in the 3-year results of the nutrient treatments. But in comparison with controls, 1 liter of Hoagland solution per pot (medium level) stimulated growth slightly, and 2 liters per pot (high level) tended to inhibit growth. For all parameters recorded, maximum growth was obtained with the medium level of nutrients (Table 3); and, except for stem weight, all minimum values were recorded for the high nutrient level.

Steinbeck (6), who fertilized sycamore seedlings weekly with 0.1-, 0.5-, 1-, and 3-normal Hoagland solution, found that growth increased with fertilizer concentration; but total dry weight was greater with the 1-normal than with the 3-normal solution. His results are not really comparable with those of our study because he had more soil (builder's sand) in his containers, and he flushed the soil weekly with distilled water to prevent buildup of salt. Our high dosage of nutrients may have been slightly toxic, possibly due to the manner in which nutrients were applied. In long fertilization studies it would probably be better to add the nutrients in several small doses than to add the entire amount at the start of the experiment.

SUMMARY

Growth of 3-year-old potted sugar maple seedlings was significantly affected by watering levels. Shoot growth responded more than root growth to additional water; thus high levels of soil moisture result in a relatively low seedling root:shoot ratio, and this may retard establishment of outplanted sugar maple seedlings. For the old-field soil used in this experiment, added nutrients did not significantly affect growth.

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