Seedling Responses to Fertilization Shortly After Germination

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Additions of commercial nutrient solutions shortly after germination of black locust, green ash, and red pine did not stimulate elongation or biomass accumulation of roots or shoots and did not enhance water stress avoidance of 3-week-old seedlings grown in pots filled with a peat-vermiculite mixture.

Survival of recently germinated tree seedlings is inhibited by a variety of environmental stresses (*6*); but as production of bare-root and containerized seedlings becomes more intensive, many environmental factors can be controlled and stresses can be reduced. Mineral nutrient deficiency is one stress that can be minized through fertilization. Elimination of nutrient deficiencies may be quite important because adequate mineral nutrition can increase small seedlings' resistance to other stresses (*7*). For example, improved nutrient availability can result in increased root growth and water uptake, which can increase water stress avoidance (*5*). However, such stimulated root growth has not generally been observed in seedlings less than 1 year old (*7*).

The proper timing of fertilizer application to small seedlings conserves fertilizers and, more importantly, minimizes the imposition of other environmental stresses such as high solute concentrations in soil, which could inhibit seedling growth and increase mortality. Generally, mineral nutrients stored in endosperm or cotyledons are available to support early growth of germinating embryos until root uptake is established (*8*); however, the size of this stored nutrient pool is variable and is linked to mineral supplies of parent plants (*2*).

The above factors complicate the formulation of recommendations for fertilizing nurserybeds and container seedlings. Brix and van den Driessche (*3*) reported that the growth of container seedlings could be helped by incorporating lime and slow-release nutrients into potting media during the first few weeks after germination. On the other hand, Tinus and McDonald (*12*) state that during the germination of container seedlings, mineral nutrients need not be added because they are supplied by the seed. They suggested that maintenance of a nutrient-poor medium could help control damping-off fungi, and they recommended that nutrient solutions be added to conifers after seed coats have been shed from cotyledons.

Fertilization of very young field-grown seedlings has also yielded mixed results. Rocky Mountain junipers (*Juniperus scopulorum* Sarg.) grown for 2 years in nurserybeds that were fertilized before seeding had much larger fresh weights than seedlings grown in unfertilized beds (*11*). On the other hand, fertilization of field plots of direct-seeded red pine (*Pinus resinosa* Ait.) resulted in increased seedling mortality during the first growing season (*1*). Alban (*1*) suggested that fertilizers prevented germination or killed seedlings before emergence.

With these considerations in mind, three studies were designed to investigate effects of various concentrations of nutrient solutions on growth, survival, and drought resistance of very small hardwood and conifer seedlings.

Materials and Methods

Study 1—seedling growth. Seeds of black locust (*Robinia pseudoacacia* L.), green ash (*Fraxinus pennsylvanica* Marsh.), and red pine were collected in southeastern Michigan in 1978, air-dried, and stored in plastic bags at 4° C. In February 1979, green ash seeds were surface-sterilized in 1% sodium hypochlorite and then stratified in plastic bags at 4 to 6° C for 120 days. In June, locust seeds were soaked in concentrated sulfuric acid for 10 minutes, rinsed, and germinated in aerated tap water. At the same time, red pine and stratified green ash seeds were germinated on wet paper toweling. When radicles protruded from germinated seeds, those seeds were planted in rectangular plastic pots (9 by 9 by 8 cm) filled with a 1 to 1 mix of sphagnum peat and vermiculite. Two seedlings were planted in each pot. After planting, pots were divided into four groups with 30 pots of each species per group. Grouped pots were watered with solutions containing various concentrations of nutrients as described in table 1.

All pots were placed on a greenhouse bench in mid-June and maintained under natural lighting and ambient temperatures (19 to 29° C). Seedlings were lightly watered daily and care was taken to prevent nutrient loss via leaching. Seedling heights and cotyledon lengths were measured at 3-day intervals for 21 days, then roots were collected and washed. Plants were separated at the root collar, and lengths and dry weights of roots and shoots were measured. This study was designed as a randomized complete block and data were subjected to a two-way analysis of variance.

Table 1.—*Treatment descriptions for study 1*

Treatment no. and fertilizer concentration	Description
1 (0)	50 milliliters of deionized water per pot.
2 (Low)	50 milliliters of dilute nutrient solution per pot. This solution contained 1 gram per liter of a commercial fertilizer.'
3 (Medium)	Same as treatment 2, but the nutrient solution contained 3.5 grams of fertilizer' per liter.
4 (High)	Same as treatments 2 and 3, but the nutrient solution contained 10 grams of fertilizer' per liter.

[1]Analysis of Miracle-Gro fertilizer: 15 percent N, 30 percent P, 15 percent K, 0.05 percent Cu, 0.1 percent Fe, 0.05 percent Mn, and 0.05 percent Zn.

Study 2—root elongation rates. Seeds were collected, handled, and germinated as described in study 1. Germinated seedlings were planted in rectangular plexiglas tubes (50 by 10 by 10 cm) filled with a 1 to 1 mix of sphagnum peat and vermiculite. Ten tubes with one seedling per tube were used for each species for each treatment. Treatments were the same as in study 1 (table 1) except 100 milliliters of nutrient solutions were added to each tube when seedlings were planted. Tubes were placed in a greenhouse and exposed to ambient light and temperature. Tubes were angled 30° from vertical so that elongating root tips would be visible on the lower plexiglas surface. Locations of elongating root tips were marked at 2-day intervals during the 2d and 3d weeks of seedling growth. Root elongation rates were determined from subsequent measurements.

Study 3—seedling drought resistance. Seeds were collected, handled, and planted as described in study 1. Treatments were the same as shown in table 1, except 10 pots (one seedling per pot) of each species were used per treatment. Seedlings were grown for 2 weeks as described in study 1; then water was withheld for 1 week. After 21 days of growth, seedling heights were measured and stem water potentials of seedlings were determined with a PMS pressure chamber (9). Shoot dry weights were subsequently measured. Data were analyzed as described in study 1.

Results and Discussion

Study 1—seedling growth. Moderate and high concentrations of nutrients inhibited height growth of 3-week-old

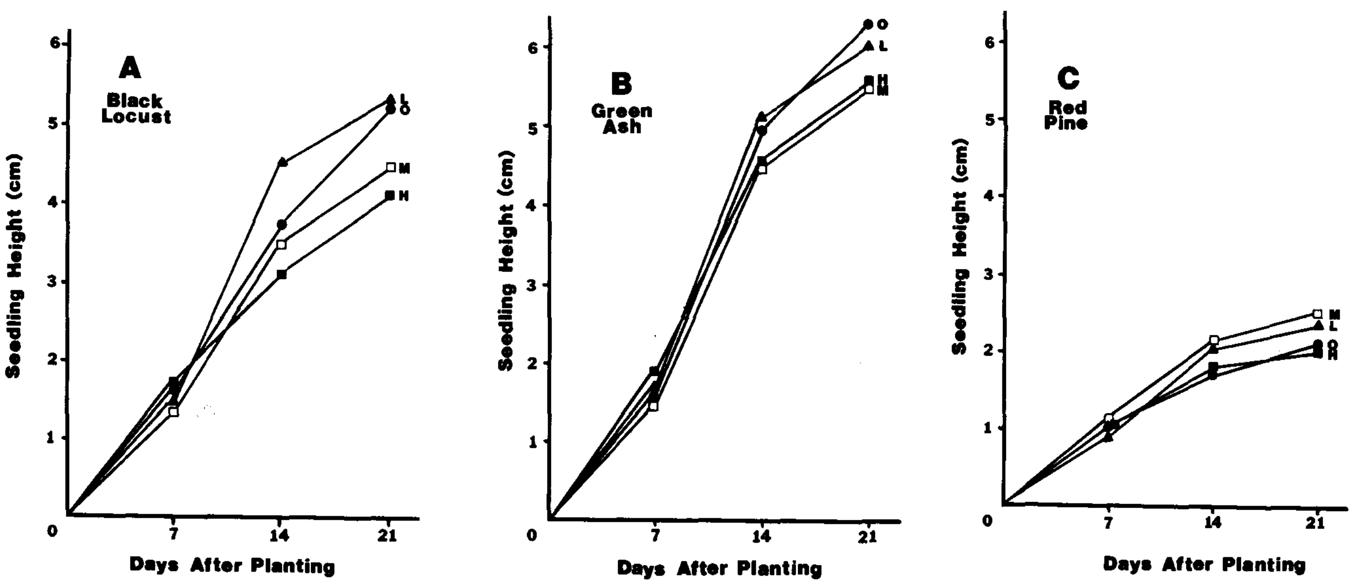

Figure 1.—*Changes in seedling heights during the first 3 weeks of growth for black locust (A), green ash (8), and red pine (C). 0 = no fertilizer added, L = low concentration, M = moderate concentration, H = high concentration. (See table 1 for treatment descriptions.)*

black locust and green ash seedlings (fig. 1A and B). Although differences were significant (p <0.05), they were not large. Fertilization did not affect height growth of red pine (fig. 1C).

Shoot dry weights of 3-week-old red pine and green ash seedlings were not significantly affected by fertilizer concentration (fig. 2A). Shoot biomass of black locust seedlings was enhanced more by low and moderate fertilizer concentrations than by other treatments. This suggested that no fertilizer applications may result in some nutrient deficiencies, but that high concentrations of nutrients may lead to direct toxicity or osmotic problems for black locust (fig. 2A). Moderate and high concentrations of nutrients significantly (p-- 0.05) inhibited root biomass accumulation of 3-week-old green ash seedlings, and high concentrations inhibited roots of black locust (fig. 2B). Red pine root biomass was unaffected by fertilizer concentration (fig. 2B).

Kramer and Kozlowski (*6*) stated that excessive fertilization in nurseries stimulated excessive top growth of seedlings and the resultant low root to shoot ratio led to poor survival after outplanting. Our results suggest that excessive fertilization alters root to shoot ratios of small seedlings, not because of top-growth stimulation, but because of root growth inhibition.

Study 2—root elongation. Roots of unfertilized black locust and green ash seedlings elongated faster than those of heavily fertilized seedlings (table 2). Root lengths of pine seedlings were unaffected by fertility level. These results correspond closely to root biomass results from study 1.

Large differences in primary root length were apparent among the three species. Three-week-old seedlings of black locust generally had longer roots

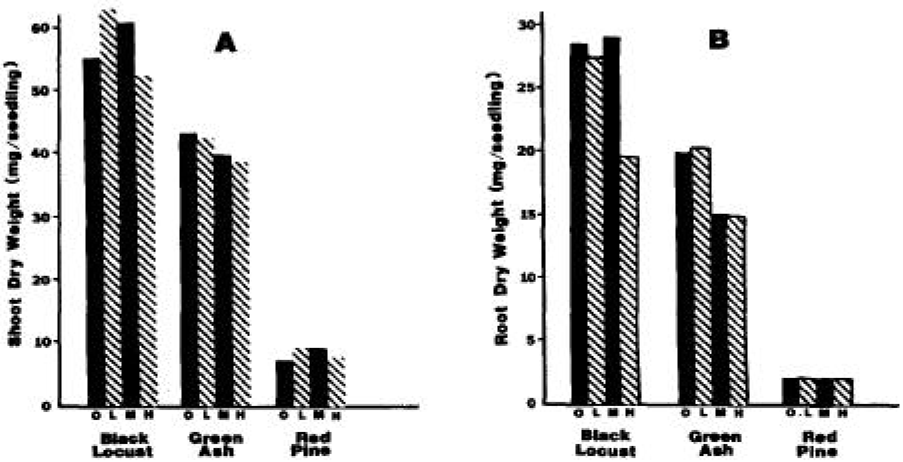

Figure 2.—*Shoot (A) and root (B) dry weights of 3-week-old seedlings grown under various fertilizer* concentrations. *0 = no fertilizer, t = low concentration, M = moderate concentration, H = high concentration (See table 1 for treatment descriptions.)*

Table 2.—*Root elongation rates and total root lengths of seedlings grown in various fertilizer concentrations*

Species	Fertilizer Concentration[1]	Root elongation 1st week	Root elongation 2nd week	Length of longest root after 3 weeks[2]
		cm/week—		cm
Black locust	0	7.0	8.7	20.2
	Low	6.4	6.4	19.9
	Medium	6.0	5.9	16.9
	High	5.1	4.8	11.7
Green ash	0	5.7	4.8	15.1
	Low	5.3	4.7	13.1
	Medium	4.3	3.7	9.0
	High	3.9	3.2	8.3
Red pine	0	1.8	1.6	4.3
	Low	1.6	1.7	4.4
	Medium	1.5	1.7	4.7
	High	1.7	1.5	4.8

[1]Fertilizer concentrations correspond to treatments described in table 1. Low = 1 gram fertilizer per liter, medium = 3.5 gams per liter, high = 10 grams per liter.

[2]Numbers connected by vertical bar are not significantly different at the 5-percent level.

and larger root biomass than those of green ash. Red pine roots were very small compared to the other two species. Such differences between roots of locust and pine persist at least through the end of the 1st year of seedling growth (*4*).

No inoculum of nitrogen-fixing bacteria was applied to black locust roots, nor was inoculation likely in the greenhouse. No nitrogen-fixing nodules were observed on roots of any black locust seedlings during this study. Previous attempts to induce nodule formation on roots of 2- to 4-week-old black locust seedlings have been unsuccessful. Therefore, it is unlikely that symbiotic nitrogen fixation was a factor in this study.

Study 3—seedling drought resistance. Although fertility levels did not significantly ($p \leq 0.05$) affect stem water potentials within each species, trends in the data suggest that stem water potentials of fertilized black locust and green ash seedlings were more negative (seedlings more stressed) than nonfertilized seedlings (table 3). This could account for part of the observed differences in shoot elongation and shoot and root biomass of seedlings grown at different fertilizer concentrations. Since differences in stem water potentials were small among all four treatments, fertilizer concentration did not appear to markedly affect drought avoidance by small seedlings.

Although treatment effects were not significant within individual species, differences among species were highly significant (table 3). After 1 week without water, green ash and black locust seedlings had stem water potentials that were much more negative than those of red pine. This indicated that small red pine seedlings were less stressed by drought than were seedlings of green ash or black locust.

Schulte (*10*) found similar results when black locust and jack pine *(Pinus banksiana* Lamb.) seedlings were grown for 5 weeks after germination in root media of varying osmotic potential. In that study, growth rates and survival of locust seedlings were much lower than those of jack pine when both species were grown under water-stressed conditions.

Results from the current study showed that 3-week-old ash and locust seedlings have much larger root and shoot biomasses, larger foliage surface areas, and longer primary roots than red pine seedlings. Although larger root systems may be able to absorb more water, transpirational water losses per seedling are undoubtedly much higher for young green ash and black locust seedlings than for red pine. Schulte (*10*) suggested that small jack pine seedlings had better stomatal control of transpiration and thus had better drought resistance than did small black locust seedlings.

Table 3.—*Stem water potentials of 3-week-old seedlings*

Species	Fertilizer concentration[1]	Stem water potential (bars)[2]
Black locust	0	-4.68
	Low	-5.70
	Medium	-5.50
	High	-5.60
Green ash	0	-5.15
	Low	-5.35
	Medium	-6.15
	High	-5.85
Red pine	0	-3.65
	Low	-2.50
	Medium	-3.80
	High	-2.65

[1]Fertilizer concentrations correspond to treatments described in table 1. Low = 1 gram fertilizer per liter, medium = 3.5 grams per liter, high = 10 grams per liter.

[2]Numbers connected by vertical bar are not significantly different at the 5-percent level.

Conclusions

Additions of various concentrations of fertilizers did not stimulate growth or biomass accumulation or enhance water stress avoidance of very young seedlings of black locust, green ash, or red pine. However, excessively high concentrations of fertilizer did inhibit root and shoot growth of locust and ash seedlings. Results were not conclusive, but indicate that reductions were due, at least partly, to increased water stress at high fertility levels. Fertilizers may be relatively ineffective if incorporated into growth media for container seedlings, if applied heavily to nurseybeds before seeding, or if applied to containers or nurserybeds just after germination. For the species used in this study, fertilizers may be more effective if applied several weeks after germination.

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