OUTPLANTING SUCCESS OF NORWAY SPRUCE INFLUENCED BY NURSERY TREATMENT

Donald Bickelhaupt
SUNY College of Environmental Science and Forestry
Syracuse, NY

The purpose of raising seedlings in forest nurseries is to establish plantations of rapidly growing trees. Good quality seedlings are those which survive and do not experience reduced growth for a prolonged period of time following planting, often referred to as planting check.

It is generally assumed that judicious fertilization of conifer nursery stock improves seedling quality and increases the number of plantable seedlings. Numerous studies have reported that nursery cultural practices influence early plantation establishment and growth of several species (Anderson and Gessel 1966, Mullin and Bowdery 1978, van den Driessche 1984; Wilde et al. 1940). A study was undertaken at the Saratoga Tree Nursery to determine if nitrogen fertilizer application rates and amending the soil to specified levels of phosphorus and potassium influences the survival and growth of Norway spruce (Picea abies (L.) Karst.) seedlings after outplanting.

METHODS

Soil samples collected in the fall of 1981 in one section of the nursery were analyzed for pH, available phosphorus and

potassium (Bickelhaupt et al. 1983). The soil pH was 5.5, phosphorus was 78 ppm by the Troug method and exchangeable potassium was 24 ppm. A factorial experiment, with three replications, was established with three levels of nitrogen, phosphorus and potassium resulting in 27 treatment plots. Nitrogen (ammonium nitrate) Was applied at 0, 90 and 180 pounds per acre per year in five topdressings per year. Phosphorus (superphosphate) and potassium (muriate of potash) fertilizers were applied in May of 1982 to increase the concentration of each nutrient in the soil to 100 and 200 ppm. The concentration of available phosphorus recommended by The Forest Soil Fertility Laboratory is 100 ppm by the Troug method and exchangeable potassium should be maintained at 100 ppm. All fertilizers were broadcast by hand in plots 21 feet long and the width of the seedbed.

One week after fertilizer application in May of 1982 Norway spruce seeds were sown. The seedlings were lifted as 2-0 seedlings in April of 1984. Seedlings were graded and then thirty of the better seedlings were randomly selected from each treatment plot and planted at 3 x 3 foot spacing on a plowed and disked site near Tully, NY. The site had been used for hay production until the fall before planting. Weeds within 12 inches of each seedling were killed by the application of Roundup once during the 1984 and once during the 1985 growing seasons.

Seedling height at time of planting ranged from 0.4 inches to 14.5 inches. Seedlings were measured after planting and grouped into four size classes. Large seedlings were greater than 7.5 inches tall, medium size seedling were between 6.3 and

7.4 inches tall, small seedlings were between 3.1 and 6.2 inches tall while culls were less than 3.1 inches (Reese and Sadreika 1979).

RESULTS

The application of nitrogen increased the percentage of large seedlings while decreasing the percentage of cull seedlings (Table 1). Amending nursery soil phosphorus levels to 200 ppm, resulted in a greater percentage of large and medium size seedlings compared to the other two phosphorus treatments (Table 2). The addition of potassium had no significant effect on the percentage of seedlings in the various size classes (Table 3).

Survival at the end of three growing seasons after outplanting was 98% for all nursery fertilizer treatments and seedling height ranged from 4.7 to 50.3 inches. The application of 90 pounds per acre per year of nitrogen in the nursery resulted in significantly taller seedlings at the end of each growing season after outplanting (Table 4). Seedlings from nursery plots where phosphorus levels were amended to 200 ppm were taller compared to seedlings from plots amended to 100 ppm phosphorus or the untreated control at the end of each year in the field (Table 5). Seedlings from plots where potassium levels were amended to 200 ppm were significantly taller then seedlings from the other nursery potassium treatment plots at the end of each growing season in the field (Table 6).

Differences in seedling height growth were not evident between nitrogen treatments for any year except 1986 when seedlings from plots which had 90 pounds per acre per year of

Table 1. Percentage of seedlings by size class at time of planting as influenced by nitrogen treatment.

Nitrogen lbs/ac/yr	Large	Medium	Small	Cull
90	18 a[1]	12 a	56 a	14 b
180	17 a	13 a	52 a	18 ab
0	9 b	10 a	55 a	26 a

[1] Values followed by the same letter within a column are not significantly different.

Table 2. Percentage of seedlings by size class at time of planting as influenced by phosphorus treatment.

Phosphorus	Large	Medium	Small	Cull
200	27 a[1]	18 a	48 a	7 a
100	11 b	11 b	56 ab	22 b
0	5 b	6 c	60 b	29 b

[1] Values followed by the same letter within a column are not significantly different.

Table 3. Percentage of seedlings by size class at time of planting as influenced by potassium treatment.

Potassium	Large	Medium	Small	Cull
100	17 a[1]	12 a	53 a	18 ab
200	14 a	12 a	60 a	14 b
0	13 a	12 a	50 a	25 b

[1] Values followed by the same letter within a column are not significantly different.

Table 4. Height of outplanted seedlings as influenced by nitrogen treatment in the nursery.

Nitrogen (lb/ac/yr)	1984 Spring	1984 Fall	1985	1986
	inches			
90	5.7 a[1]	8.7 a	15.9 a	22.4 a
180	5.6 a	8.3 b	15.0 b	20.8 b
0	4.9 b	7.9 c	14.6 b	20.3 b

[1] Values followed by the same letter within a column are not significantly different.

Table 5. Height of outplanted seedlings as influenced by phosphorus treatment in the nursery.

Phosphorus	1984 Spring	1984 Fall	1985	1986
	inches			
200 ppm [2]	6.2 a[1]	9.1 a	16.0 a	22.5 a
100 ppm [3]	5.2 b	8.2 b	15.3 b	21.5 b
0[4]	4.6 c	7.4 c	14.1 c	19.7 c

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm phosphorus by the Troug method.
[3] Soil amended to 100 ppm phosphorus by the Troug method.
[4] No additional phosphorus applied.

Table 6. Height of outplanted seedlings as influenced by potassium treatment in the nursery.

Potassium	1984 Spring	1984 Fall	1985	1986
	inches			
200 ppm [2]	5.5 a[1]	8.5 a	15.8 a	22.2 a
100 ppm [3]	5.5 a	8.3 b	15.0 b	20.7 b
0[4]	5.1 a	8.0 c	14.8 b	20.6 b

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm soil exchangeable potassium.
[3] Soil amended to 100 ppm soil exchangeable potassium.
[4] No additional potassium applied.

nitrogen applied grew best (Table 7). The best growth occured in 1985, when weed competition was controlled, while the poorest growth occurred in 1984, the year of planting.

There were no differences in height growth after outplanting between nursery phosphorus treatments except 1986 when seedlings from plots that were amended to 200 ppm phosphorus in the nursery grew significantly more than seedlings from the other two phosphorus treatment plots (Table 8). Seedlings that received the highest phosphorus application rate in the nursery grew the same in 1986 as in 1985. Height growth of the seedlings produced in nursery plots amended to 100 ppm phosphorus or those that received no additional phosphorus decreased in 1986 compared to 1985.

Differences in height growth were not detected between potassium treatment levels until 1986 when seedlings from plots that were amended to 200 ppm of potassium in the nursery grew best (Table 9). Again, 1985 had the best height growth while 1984 had the poorest.

When height growth is compared between size classes within each year, it is seen that in the year that the seedlings were outplanted the large size class seedlings grew less than the other size classes (Table 10). In 1985, the large seedlings did not grow any better than the culls and not as well the medium size class seedlings. In 1986, the third year after outplanting, when weed competition was not controlled, the large and medium size seedlings grew better then the small and cull size seedlings.

Table 7. Height growth of outplanted seedlings as influenced by nitrogen treatment

Nitrogen (lb/ac/yr)	1984	1985	1986	Total
	inches			
90	3.0 a[1]	7.2 a	6.5 a	16.7 a
0	3.0 a	7.2 a	5.7 b	15.9 a
180	2.7 b	6.3 a	5.7 b	14.7 b

[1] Values followed by the same letter within a column are not significantly different.

Table 8. Height growth of outplanted seedlings as influenced by phosphorus treatment

Phosphorus	1984	1985	1986	Total
	inches			
200 [2]	2.9 a[1]	6.8 a	6.5 a	16.2 a
100 [3]	3.0 a	7.1 a	5.9 b	16.0 ab
0 [4]	2.8 a	6.8 a	5.5 b	15.1 b

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm phosphorus by the Troug method.
[3] Soil amended to 100 ppm phosphorus by the Troug method.
[4] No additional phosphorus applied.

Table 9. Height growth of outplanted seedlings as influenced by potassium treatment

Potassium	1984	1985	1986	Total
	inches			
200 [2]	3.0 a[1]	7.3 a	6.4 a	16.7 a
0 [3]	2.9 a	6.9 a	5.8 b	15.6 b
100 [4]	2.8 a	6.5 b	5.7 b	15.2 b

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm soil exchangeable potassium.
[3] No additional potassium applied.
[4] Soil amended to 100 ppm soil exchangeable potassium.

Table 10. Height growth of outplanted seedlings as influenced by size of seedling at planting.

Size	1984	1985	1986	Total
	inches			
Large[1]	2.5 b[2]	6.7 bc	7.9 a	17.1 a
Medium	2.8 a	7.5 a	7.4 a	17.7 a
Small	3.0 a	7.0 ab	5.5 b	15.5 b
Cull	3.1 a	6.2 c	4.0 c	13.3 c

[1] Size classes as defined in the text.
[2] Values followed by the same letter within a column are not significantly different.

The medium and large size seedlings had more total height growth during the three years after outplanting than the small and cull size seedlings.

Height growth of the large size seedlings was greatest in 1986, the year that weed competition was not controlled. The small and cull size seedlings declined in height growth during the third year.

Seedlings that were 24 inches or taller three years after outplanting were assumed to be successfully established. The addition of nitrogen or potassium in the nursery had no effect on the percentage of seedlings 24 inches or taller (Tables 11 and 12). The addition of phosphorus in the nursery resulted in a greater percentage of seedlings being 24 inches or taller at the end of three growing seasons after outplanting (Table 13).

Over half of the seedlings classified as large when planted were 24 inches or taller at the end of three growing seasons after outplanting (Table 14). Approximately a quarter of the

Table 11. Percentage of seedlings 24 inches or taller three years after outplanting as influenced by nitrogen treatment in the nursery.

Nitrogen (lbs/ac/yr)	Percent
90	39 a[1]
0	34 a
180	34 a

[1] Values followed by the same letter within a column are not significantly different.

Table 12. Percentage of seedlings 24 inches or taller three years after outplanting as influenced by potassium treatment in the nursery.

Potassium	Percent
200 [2]	39 a[1]
0 [3]	36 a
100 [4]	33 a

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm soil exchangeable potassium.
[3] No additional potassium applied.
[4] Soil amended to 100 ppm soil exchangeable potassium.

Table 13. Percentage of seedlings 24 inches or taller three years after outplanting as influenced by phosphorus treatment in the nursery.

Phosphorus	Percent
200 [2]	40 a[1]
100 [3]	37 a
0 [4]	30 b

[1] Values followed by the same letter within a column are not significantly different.
[2] Soil amended to 200 ppm phosphorus by the Troug method.
[3] Soil amended to 100 ppm phosphorus by the Troug method.
[4] No additional phosphorus applied.

Table 14. Percentage of seedlings 24 inches or taller three years after outplanting as influenced by size of seedling at time of outplanting.

Size	Percent
Large [1]	58 a2
Medium	46 b
Small	27 c
Cull	8 d

[1] Size classes as defined in the text.
[2] Values followed by the same letter within a column are not significantly different.

small and less than 10% of the cull size seedlings were successfully established using this criteria.

DISCUSSION

Increasing the concentration of available soil phosphorus to 200 ppm, by the Troug extraction method, in the nursery improved the percentage of large and medium size seedlings and increased seedling height growth after outplanting. Phosphorus is essential for production of fibrous root systems (Wilde et al. 1979) and more fibrous root system, developed in the nursery, with greater surface area for absorption of water and nutrients, leads to improved seedling establishment and early growth. The best height growth after outplanting was achieved by seedlings from plots where the concentration of available phosphorus was increased to twice the recommended level. It is important to realize that different laboratory methods for extracting soil phosphorus provides different numerical results (Lathwell and Peach 1973). The 200 ppm of available soil phosphorus used in

this study is not directly comparable to 200 ppm of available phosphorus determined by other laboratory methods.

Differences in height growth between nursery fertilizer treatments did not become evident until the third year after outplanting. This is in agreement with studies of other species in the literature (Mullin and Christl 1981). Height growth was least the year of planting and greatest the second year. During the third year height growth generally decreased because of the influence of weed competition. The variation in height growth between years is expected. During the first growing season seedlings are becoming established and putting more energy into root production than top production. During the first two years after ouplanting, weeds, which competed with the seedlings for light, moisture and nutrients, were controlled. During the third year competing vegetation probably caused the reduction in height growth. Controlling competing vegetation during the first two years provided uniform conditions for seedling establishment and an opportunity to determine if nursery fertilizer treatment or seedling size was the major factor influencing growth.

Height growth of the large size seedlings was significantly less than seedlings in the other size classes the year of outplanting. These large seedlings were out of balance with large tops and average size root systems. Controlling the weed competition during the first two years after planting allowed the small and cull size seedlings to grow at the same rate as the medium size seedlings during the first year and the large seedlings the second year. When weed competition was not

controlled the small and cull size seedlings grew significantly less than the large and medium size seedlings. Total height growth of the smaller seedlings was significantly less than the large and medium size seedlings. Controlling weed competition probably improved survival but the percentage of smaller size seedlings that were successfully established and tall enough to compete with the weeds at the end of three years was low. Controlling vegetation at time of planting is important but it can not be substituted for high quality seedlings.

CONCLUSIONS

Nitrogen and phosphorus fertilizers applied in the nursery increased seedling size. Total height growth at the end of three years after outplanting was greater for large and medium size seedlings compared to the small and cull size seedlings. Seedling size at time of outplanting appears to be an important factor in determining the percentage of successfully established seedlings at the end of three growing seasons. The best fertilizer rate in the nursery for growing high quality Norway spruce seedlings appears to **be** 100 pounds'per acre of nitrogen per year in combination with increasing available soil phosphorus to 200 ppm, by the Troug method, and amending exchangeable potassium to 100 ppm.

LITERATURE CITED

Anderson, H.W. and Gessel, S.P. 1966. Effects of nursery fertilization on outplanted Douglas-fir. J. For. 64:109-112.

Bickelahupt, D.H., Davey, C.B. and White, F.H. 1983. Laboratory methods for forest tree nursery soil analysis. School of Forestry Misc. Pub. No.2 (ESF 83-004). SUNY Coll. Environ. Sci. and For. Syracuse, NY

Lathwell, D.J. and Peach, M. 1973. Interpretation of chemical soil test. Cornell Univ. Agric. Exper. Stat. Bull. 995. New York State Coll. of Agric. and Life Sci. Ithaca, NY.

Mullin, R.E. and Christl, C. 1981. Morphological grading of white spruce nursery stock. For. Chron. 57:126- 130.

Mullin, R.E. and Bowdery, L. 1978. Effects of nursery seedbed density and top dressing fertilization on survival and growth of 3+0 red pine. Can. J. For. Res. 8:30-35.

Reese, K.H. and Sadreika, V. 1979. Description of bare root shipping stock and cull stock. Ontario Min. of Nat. Res. Toronto, Ont.

van den Driessche, R. 1984. Effects of nitrogen and phosphorus fertilization on Douglas-fir nursery growth and survival after outplanting. Can. j. For. Res. 10:65-70.

Wilde, S.A., Corey, R.B., Iyer, J.G. and Voigt, G.K. 1979. Soil and plant analysis for tree culture. Oxford & IBH Publishing Co. New Delhi.

Wilde, S.A., Wittenkamp, R., Stone, E.L. and Galloway, H.M. 1940. Effect of high rate fertilizer treatments of nursery stock upon its survival and growth in the field. J. For. 38:806-809.