EFFECT OF UREA AND UREA-FORMALDEHYDE ON THE GROWTH OF LODGEPOLE PINE SEEDLINGS IN A NURSERY

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It is usually difficult to maintain high organic matter and total nitrogen levels in forest nursery soils. Although large amounts of organic matter are often placed in the soil, nitrogen losses resulting from seedling removal and leaching often cause nitrogen deficiencies. Soluble nitrogen fertilizers are usually applied as a preseeding treatment, as topdressings at least once during the growing season, or as both. Wilde (L3) indicated that soluble fertilizers applied to the surface of the soil may result in inferior planting stock which has an unsatisfactory top-root ratio, excessive succulence, and physiological unbalance.

Urea-formaldehyde, a slowly available nitrogen fertilizer, has shown promise for crops that require uniform vegetative growth and where flush growth is undesirable (3,_I). May and Posey (6) used a single preseeding application of 248 pounds of 38-percent ureaform nitrogen per acre; loblolly pine seedlings 1 year after planting were as tall as seedlings receiving eight applications of ammonium nitrate totaling 376 pounds of nitrogen per acre. Franzmeier and Arneman (4) compared ammonium nitrate, ammonified peat, and ureaform as sources of nitrogen for red pine seedlings in the nursery. The choice of source had little effect on the concentration of nitrogen in the seedlings. However, urea-form initially released less available nitrogen than ammonium nitrate or ammonified peat. Since urea-form mineralization requires microbial decomposition, the effectiveness of surface applications would probably be small (5).

The Bessey Nursery, operated in central Nebraska since 1903, now produces about 5 million conifers annually. Use of liquid nitrogen fertilizer has improved seedling color and height growth. But the nursery does not have specific information on the best kinds, amounts, or methods of fertilizer application for the different conifer species being grown.

This experiment at the Bessey Nursery was initiated to acquire needed information on use of fertilizers. The objective was to determine the effect of urea-form and urea nitrogen on growth of lodgepole pine seedlings when the fertilizers are rototilled into the soil prior to seeding.

Experimental Procedure

The experiment was started in June 1961. The nursery soil is a well-drained loamy sand along a river bottom. The soil is low in total nitrogen (0.040 percent) and high in phosphorus and potassium (60-70 p.p.m. and 200-300 p.p.m., respectively). The pH varies from 5.8 to 6.5.

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The experimental design was a randomized complete block with three replications, all in one nursery bed. Plots were 4 by 5 feet, with a 1-foot isolation border between plots. Treatments were as follows:

Nitrogen source	Symbol	Nitrogen per acre (pounds)
Urea formaldehyde (granules).	UF	80, 160, 240, 320, 400, 480, 560, 640
Urea (granules).....	U	80, 160, 240
Urea drench (liquid urea topdressing).	UD	100
Check plot.....	C	0

All of the nitrogen sources but the urea drench were rototilled into the seedbed before seeding; the drench was applied twice at 50 pounds of nitrogen per acre during the second growing season. All plots received one-half ounce of concentrated sulfuric acid per square foot after seeding to control damping-off fungi. Lodgepole pine (Pinus c o n t o r t a latifolia Engelm.) seeds were drilled according to standard nursery procedure on June 20, 1961, to provide an expected density of 40 seedlings per square foot. The seedbed had been fumigated with methyl bromide 1 year prior to the experiment.

The urea-formaldehyde used in this study was a commercially available product (Nitroform) containing 38 percent nitrogen. The material had a urea-formaldehyde mole ratio of 1.39 and an activity indexof 50, the approximate figures found by several investigators to have the most desirable mineralization characteristics (8, 14). Approximately 25 percent of the total nitrogen is cold-water soluble and mineralizes in about 4 weeks. The remaining 75 percent mineralizes more slowly, 6 to 7 percent per month under greenhouse conditions (~).

Samples were taken in April 1963 after two growing seasons. Seedlings were removed from four 6-inch segments drawn at random from the middle four tree rows of the seedbed. Fresh seedlings from each segment were counted and weighed. Individual seedlings were measured for caliper (thickness) at the root collar, needle length, and height above the root collar. Roots, stems, and needles were ovendried and weighed, and analyzed for total nitrogen by the Kjeldahl method.

Results and Discussion

Seedling Characteristics

Lodgepole pine responded little to additions of nitrogen during the first growing season. Nitrogen apparently was not a limiting factor during the first year when seedlings were small (2.3 cm. average height). There were no differences in height or color among treatments at the end of the first year, but differences were apparent at the end of the second growing season.

The effect of fertilizer applications on some characteristics of 2-year-old seedlings is shown in figures 1 and 2. Dry seedling weight increased with increasing amounts of ureaform, but the effect was significant over the check plot only when more than 320 pounds of nitrogen per acre of this fertilizer was applied. Needle length and stem caliper were more affected by urea-form than the other factors; height was not appreciably influenced. Needles were significantly longer when only 160 pounds of nitrogen per acre was applied; stem caliper increased a uniform 0.2 mm. for each 80pound increment of urea-form nitrogen.

The effect of soluble 45-percent urea nitrogen on the growth of lodgepole pine depended on the time and method of application. Urea rototilled into the seedbed had no measurable effect on seedling characteristics, but the seedlings that received two applications of a liquid topdressing of 50 pounds urea nitrogen per acre during the second growing season had a greater total weight, stem caliper, height, and needle length than seedlings that did not receive nitrogen.

To produce seedlings comparable to those obtained with the liquid urea treatment, 400 pounds of urea-form nitrogen per acre is generally required. Seedlings receiving the urea-topdressing were significantly taller than those in any other treatment. They were 28 percent taller than the mean of all treatments, and 16 percent taller than the tallest seedlings obtained with the other treatments.

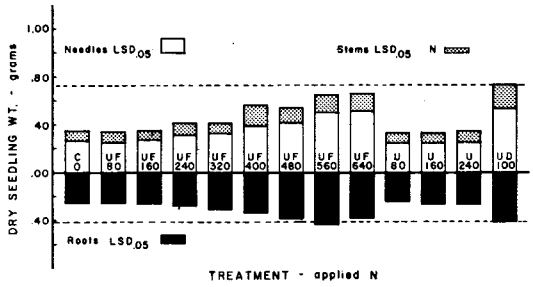

Figure 1.--Effect of fertilizer nitrogen on seedling dry weight of 2-year-old lodgepole pine: C = control, UF = urea-formaldehyde granules, U = urea granules, and UD = liquid urea drench.

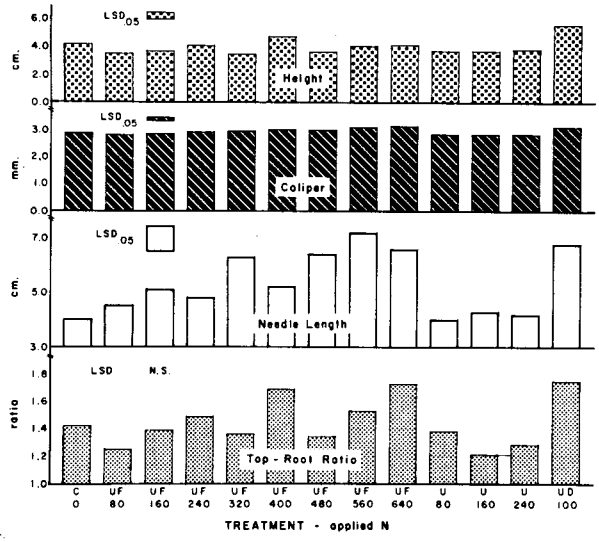

Figure 2.--Effect of fertilizer nitrogen on 2-year-old lodgepole pine seedling characteristics.

Seedlings responded well the second growing season if (1) a residue of nitrogen was present from the treatment the previous year or (2) the nitrogen was applied during the second year. The very low recovery of nitrogen from the rototilled urea treatments and the lower rates of urea-form probably resulted from low residual nitrogen carryover caused by a large leaching loss the first year. More than 320 pounds of urea-form nitrogen per acre had to be applied before enough residual nitrogen to cause a significant response was present during the second year. Although the response to urea-form was not significantly greater than the response to urea when applied at the same rate, there are indications that the insoluble nature of urea-form resulted in slightly more residual nitrogen the second year.

Seedling dry weight, top-root ratios, caliper, and height are often used to express seedling quality. There were no significant differences in top-root ratios among the treatments; however, increased nitrogen tended to increase the ratio (fig. 2). None of the seedling characteristics measured indicated seedling quality decreased because of the nitrogen treatments.

Application of urea or urea-form at seeding time did not significantly effect seedling density; however, there was a trend toward fewer seedlings with increasing rates of ureaform (table 1). Auten (1) found that nitrogen applied at seeding time greatly reduced the density of shortleaf and pitch pine seedlings. Application of sulfuric acid in this experiment immediately after seeding apparently controlled damping-off fungi effectively, even with applied nitrogen.

Analysis of covariance of plot means (where X = caliper and Y = seedling density) failed to show a significant effect of density on caliper. However, a multiple regression analysis of caliper and density from individual subsamples indicated a highly significant relationship, R = 0.87 (fig. 3). Since caliper increased linearly with increasing rates of urea-form, a given caliper could be maintained at higher densities by applications of nitrogen. The equation relating caliper to density and rates of urea-form nitrogen was as follows:

$$\underline{Y} = 7.05 + 0.0067\underline{X}_1 - 2.74 \log \underline{X}_1 + 0.00097\underline{X}_2$$

where $\underline{X}_1$ = seedling density per sq. ft.
$\underline{X}_2$ = pounds of urea-form nitrogen applied
$\underline{Y}$ = caliper at root collar in mm.

Caliper has been used as a measure of seedling quality because it is closely correlated with seedling weight (12). In this experiment the correlation coefficient between caliper and seedling weight was 0.968. Density and fertility relationships with seedling caliper confirm the findings of other investigators (2, 9, 11).

TABLE 1.--Effect of different fertilizer nitrogen treatments[1] on seedling density, nitrogen removal, and the recovery of applied nitrogen, Bessey Nursery, Nebr., 1963

Treatment	Seedling density	Nitrogen removal	Nitrogen recovery[2]
	No./ft.^{2}	*Lb./acre*	*Percent*
Check.....	70	55.9	0.0
UF_{80}	67	54.2	.0
UF_{160}	62	55.2	.0
UF_{240}	65	60.7	2.0
UF_{320}	56	59.3	1.1
UF_{400}	59	65.5	2.4
UF_{480}	57	74.7	3.9
UF_{560}	57	88.1	5.7
UF_{640}	49	74.5	2.9
U_{80}	58	48.4	.0
U_{160}	67	50.6	.0
U_{240}	63	57.7	.7
UD_{100}	64	92.4	36.5

[1]All UF (Urea-form) and U (Urea) treatments were rototilled into the seedbed just before seeding. UD (liquid urea) treatment was applied at 50 lb./acre twice during the second growing season.

[2]Percent recovery = $\frac{\text{lbs. N from fertilized plot - lbs. N from check plot}}{\text{lbs. applied N}} \times 100$

Nitrogen Uptake

The liquid urea treatment used resulted in a nitrogen application that was six times more efficient than the best urea-form treatment (560 pounds nitrogen per acre, table 1). The seedlings treated with a liquid urea topdressing recovered 37 percent of the applied nitrogen, while the seedlings treated with the 560pound application of urea-form recovered only 6 percent. Recovery values for urea-form were very low (0-6 percent). There was almost no recovery from the rototilled urea treatments.

The coarse nursery soil and frequent irrigation provided ideal leaching conditions. Much mobile nitrate nitrogen apparently was lost during the first growing season, when the seedlings' nutrient demand was low. During the second growing season, essentially all of the soluble fertilizer nitrogen had been removed by leaching, and only high rates of urea-form provided any nitrogen for seedling uptake. The low recovery of nitrogen obtained with the liquid urea topdressing during the second growing season indicates that much of this nitrogen may also have been lost.

In contrast to the findings of other investigators (3, 10), the application of nitrogen did not affect the percentage of nitrogen concentration in the seedlings or seedling parts. Although differences were not significant, the seedlings receiving the liquid urea topdressing tended to be lower in percentage of nitrogen

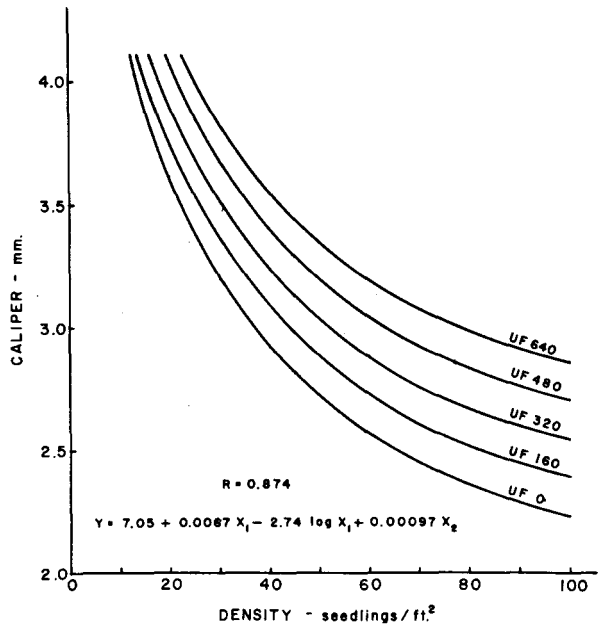

Figure 3.--Caliper of lodgepole pine seedlings as related to density (X_1 = seedlings per ft.^{2}) and rates of applied urea-form nitrogen (X_2 = pounds of urea-form nitrogen per acre).

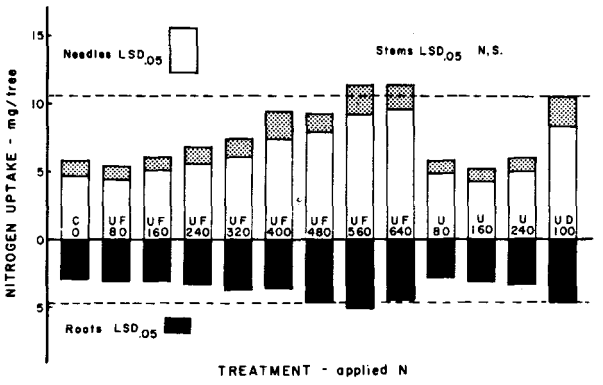

Figure 4.--Influence of fertilizer nitrogen on the uptake of nitrogen by 2-year-old lodgepole pine.

than seedlings receiving any other treatment. However, the nitrogen uptake per tree increased with increasing rates of nitrogen because seedling weights were increased by treatment (fig. 4). Average nitrogen percentages for the needles, stems, and roots were 1.83, 1.20, and 1.18, respectively.

Summary

The value of a 38 percent urea-form nitrogen fertilizer for production of 2-year-old lodgepole pine seedlings in the Bessey Nursery (in Nebraska) was evaluated in terms of seedling characteristics and uptake of nitrogen. The urea-form fertilizer and a 45 percent nitrogen urea fertilizer were rototilled into the seedbed prior to seeding and were compared with a liquid urea treatment applied twice during the second growing season.

The experiment indicated that leaching is significant in the nitrogen nutrition of lodgepole pine seedlings. The coarse soil and frequent irrigation promoted heavy leaching losses of nitrogen. Since lodgepole pine seedlings respond to applications of nitrogen only during the second growing season, application of nitrogen at seeding time proved very inefficient.

To obtain a residue of nitrogen for the second growing season, the urea-form had to be applied at a rate of more than 400 pounds of nitrogen per acre. Soluble urea nitrogen applied as a liquid topdressing of 50 pounds nitrogen per acre twice during the second growing season resulted in seedling characteristics equal to 400 to 560 pounds of ureaform nitrogen per acre. None of the nitrogen treatments, including the liquid urea topdressing, decreased seedling quality, as measured by morphological characteristics of the seedlings.

Rototilling urea-form or soluble urea into the seedbed prior to seeding did not significantly affect stand density when seeded beds were treated with one-half ounce of sulfuric acid per square foot.

A highly significant multiple correlation (R = 0.874), which related lodgepole pine seedling caliper with seedbed density and amounts of applied urea-form nitrogen, indicated the optimum seedling density in terms of caliper depends upon the fertility level.

None of the treatments significantly influenced nitrogen concentration in the seedlings or seedling parts. The lack of a relationship between applied nitrogen and its concentration in the seedlings suggests that foliar analysis is of limited utility as a tool

for determining nitrogen needs of lodgepole pine growing in the nursery.

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