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SEEDLING GROWTH RESPONSE IN A GREENHOUSE TO FOUR RATES OF OLD AND NEW PAPER MILL SLUDGE

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ABSTRACT

Four rates (0, 36, 75, and 112 DT/A) of both old and new pulp-mill sludges were tested in a greenhouse for impact on survival and growth of seedlings of loblolly pine (*Pinus taeda* L.). After one growing season no meaningful differences were detected for seedling survival and growth, number of flushes, and decomposition rate for old and new sludges regardless of rate. Seedling foliage showed increases in Mg and Ca and sludges exhibited high pH and increased salinity.

INTRODUCTION

Dewatered sludge from pulp and paper mills is known to stimulate agronomic crop production and could potentially stimulate pine seedling growth. Concerns associated with sludge application to selected pine sites include (1) a high sludge pH and calcium carbonate equivalency, which could rate soil pH above a desirable level for loblolly pine and alter the species composition of the herbaceous community on the site, (2) the presence of salts that could kill pine seedlings, (3) the duration during which salts persist in the soil, (4) a high carbon to nitrogen ratio known to immobilize nitrogen and thereby detrimentally influence pine growth, (5) increased levels of nutrient availability, which in the absence of weed control could enhance the growth of herbs to the detriment of pine seedling survival and growth, (6) numerous water soluble nutrients that may enter the ground water, (7) low levels of heavy metals in the sludge that accumulate in the soil and could limit reapplication of sludge, and (8) the intricate relationships between seasonal patterns of rainfall and temperature, availability of nitrogen, quantity and quality of sludge and soil texture as they relate to sludge decomposition rate, nutrient release, soil penetration, ground water percolation and tree uptake.

Deposition of mill sludge is generally achieved through a chain of sediment ponds or placement in a pit. One pulp and paper company spends over $125,000 annually on sludge deposition and pit maintenance. With seven pulp and paper mills in Arkansas, the annual cost to Arkansas' pulp and paper industry probably exceeds one million dollars annually. This large number is disturbing considering sludge deposition is totally a liability on the industry. A use for the mill sludge is needed.

The objectives of this study are: (1) to compare growth in height and groundline diameter, number of flushes, and nutrient constituents of needles from greenhouse-grown seedlings receiving postplant applications of 0, 36, 75 and 112 dry tons per acre (DT/A) of old or new sludge, (2) to contrast the nutrient constituents and electrical conductivity of sludge at the beginning and the end of the study, and (3) to examine rates of decomposition for sludge treatments.

Table 1. Fertilization regime for the first three weeks of the greenhouse study.

Element[1]	Concentration (ppm)
N	150.0
P	150.0
K	150.0
Ca	50.0
Mg	20.0
Cu	0.010
B	0.100
Mn	0.250
Zn	0.100
Mo	0.010
Fe	10.9
S	84.0
Cl	133.9
Na	111.1

[1] A 6-month, timed-release source of nitrogen, phosphorus, and potassium was used. All other elements were in three, weekly applications.

MATERIALS AND METHODS

Seedling Care

One hundred and seventy bare-root seedlings were planted during the third week of February in 7-gallon pots and placed in a greenhouse. Pots contained five gallons of a 1:1 mixture of peat moss and vermiculite plus a 6-month, timed-release fertilizer containing nitrogen, phosphorus and potassium. Media were watered to saturation twice weekly, Care was taken to avoid flushing pots with excessive water.

Seedlings began breaking bud in mid-March, at which time they received the first of three weekly applications of selected nutrients (Table 1). Potting media were glazed with fertilizer and followed with sufficient water to move the nutrients throughout the root zone. It should be noted that only nitrogen, phosphorus, and potassium continued to be provided by the timed-release fertilizer. Some additional nutrients were released by the decomposing sludge.

Sludge Treatments

Seedlings were grown for approximately one month and then screened prior to the application of sludges. Those seedlings with an injury, brown needle-tips, or other signs of stress or abnormality were discarded. All seedlings were retained in the study once sludges were applied.

Both sludges used in this study originated from a Kraft pulp and paper mill near Ashdown, AR. The old sludge had been in a disposal pit for approximately one year. The new sludge was fresh from the mill. Samples of sludges were weighed, oven-dried, and reweighed to determine the percent content. Sufficient timed-release fertilizer was mixed with the sludges to bring the C:N to 20:1. During the second week in April, old and new sludges were applied to 84 seedlings at wet rates equivalent to 0, 36, 75, and 112 DT/A.

Morphological Analysis

Seedlings were measured at the time of planting for height (HT) and groundline diameter (GLD). Incremental height and groundline diameter were determined as follows:

Total HT − Initial HT = Incremental HT

Total GLD − Initial GLD = Incremental GLD

Nutrient Analysis

Initial nutrient levels were computed by averaging data from 12 sacrificed seedlings. In July four to six grams (green weight) of needles were collected from each seedling. Samples were collected from the south side of the upper one third of the crown according to the methods of White (1954) and Wells and Metz (1963).

As collected, samples were sealed in plastic bags and immediately placed in a refrigerator. In the laboratory, the needles were rinsed in distilled water, 1% HCL, and three distilled demineralized water baths. Needle samples were then dried at 65 °C in a forced-air oven. After drying, the tissue was ground in a Wiley mill using a 20-mesh stainless steel sieve and stored in airtight bottles.

At the initiation of the project and again in July, a sample of old and new sludges were collected from each pot for analysis. Sludges were not washed prior to analysis.

The concentration of phosphorus was determined by the colorimetric method (Trough and Meyer, 1929). Standard atomic absorption techniques (Issac and Kerber, 1971) were used to determine concentrations of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). A conductivity meter was used to measure the electrical conductivity of aqueous sludge samples.

Statistical Analysis

The study was conducted as a randomized block design with three blocks. Analyses of variance and covariance were used to evaluate treatment differences. Duncan's Multiple Range test was used to contrast means. Dependent variables were growth in height (cm) and groundline diameter (mm), survival (%), number of flushes per tree, and DT/A of decomposed sludge. Initial height and initial groundline diameter were the covariates. All statistical tests were conducted at the 0.05 probability level.

Table 2. Seedling growth and decomposition of old and new sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Age	Survival	Initial HT	Initial GLD	Incremental HT	Incremental GLD	No of Flushes	Sludge Decomposition[2]
	%	cm	mm	cm	mm		DT/A
Check	92 B[1]	23	4	32 A	6 A	3 A	0 B
New	97 A	23	4	36 A	6 A	3 A	29 A
Old	89 B	24	5	39 A	6 A	3 A	32 A

[1] Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

[2] Based on mid-April and mid-August dry weights of sludge.

RESULTS AND DISCUSSION

Sludge Age

Seedlings growing in new sludge exhibited higher survival than seedlings growing in old or no sludge (Table 2). Only six seedlings died: one in no sludge, one in new sludge and 4 in old sludge. Survival percenttges are high enough that at normal planting rates mortality would not be of operational significance.

No significant differences were detected in height growth, groundline diameter growth or number of growth flushes per tree (Table 2). Seedlings receiving sludge treatments responded with at least similar growth in height or groundline diameter as untreated check seedlings regardless of the age of the sludge. No inhibition of growth was detected.

The proportion of applied sludge remaining in August was similar for old and new sludges. This suggests that allowing fresh sludge to age for a year in the sludge pit had no effect on the subsequent rate of decomposition after it was spread in the field. It appears then that greater or additional applications are no more possible for old than new sludges.

Table 3. Seedling responses to 0, 36, 75 and 112 dry tons per acre (DT/A) of sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Rate	Survival	Initial HT	Initial GLD	Incremental HT	Incremental GLD	No of Flushes	Sludge Decomposition[2]
DT/A	%	cm	mm	cm	mm		DT/A
0 (Check)	92 A[1]	23	4	32 A	6 A	3 A	0 B
36	96 A	23	5	43 A	7 A	3 A	31 A
75	92 A	24	5	33 A	5 A	3 A	29 A
112	92 A	24	5	38 A	5 A	3 A	32 A

[1] Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

[2] Based on mid-April and mid-August dry weights of sludge.

Table 4. Seedling responses to four rates of old and new sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Age and Rate	Survival	Initial HT	Initial GLD	Incremental HT	Incremental GLD	No of Flushes	Sludge Decomposition[2]
DT/A	%	cm	mm	cm	mm		DT/A
Check 0	92 B[1]	23	4	32 A	6 A	3 A	0 A
New 36	92 B	21	4	42 A	7 A	3 A	30 A
New 75	100 A	26	4	31 A	5 A	3 A	29 A
New 112	100 A	23	5	36 A	6 A	3 A	28 A
Old 36	100 A	24	5	43 A	7 A	3 A	34 A
Old 75	84 C	22	5	35 A	5 A	3 A	29 A
Old 112	84 C	25	5	40 A	5 A	3 A	35 A

[1] Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

[2] Based on mid-April and mid-August dry weights of sludge.

Rate of Application

Analyses showed no differences in seedling survival, growth, number of growth flushes or sludge decomposition rate occurred as a result of application rate (Table 3). It is important to realize that sludge treated seedlings did not grow significantly more or less than untreated check seedlings. Therefore, stimulation or inhibition of seedling growth was not detected.

Sludge Age By Rate of Application Interaction

A statistically significant interaction between age of sludge and rate of application was detected for seedling survival (Table 4). Results show that survival was best for seedlings growing in new sludge or 36 DT/A of old sludge. However, the sample size was such that each dead seedling represents an 8% decrease in survival. Therefore, the two high rates of old sludge each had two dead trees while the check and the low rate of new sludge each had one dead tree. These differences are probably not meaningful. A significant interaction was not detected for the growth parameters or number of flushes per tree.

Nutrient Analysis

There were no major differences in sludge nutrient levels for P, Na, Mg, or Ca related to age or rate of application. Sludge salt levels, as measured by electrical conductivity, were observed to increase between March and July while sludge alkalinity and K decreased (Table 5). Changes in these values probably resulted from partial decomposition of sludges and/or the presence of fertilizer.

There were some differences in foliar nutrient levels. Needles of live seedlings treated with sludge contained higher levels of Mg and Ca but

Table 5. Analyses of needles from live seedlings and sludge from pots supporting live seedlings. Results are expressed in percent of dry weight. Control seedlings did not receive a treatment of sludge.

		P	K	Nutrient Na	Mg	Ca	pH	Conductivity[1]
				PREPLANT LEVELS[2]				
Needles		.11	.37	.07	.09	.31		
Old Sludge		.09	.20	.21	.11	.43	7.0	2.4
New Sludge		.09	.18	.22	.07	.57	7.4	2.7
Media		t	t	t	t	t	5.8	2.2
				JULY				
Control	needles	.12	.25	.09	.05	.29		
Old 36	needles	.15	.11	.11	.14	.57		
Old 36	sludge	.08	.09	.21	.17	.31	6.6	3.0
Old 75	needles	.16	.16	.06	.10	.52		
Old 75	sludge	.16	.11	.22	.18	.45	6.7	3.9
Old 112	needles	.15	.16	.06	.11	.53		
Old 112	sludge	.06	.06	.19	.12	.47	7.1	3.6
New 36	needles	.14	.19	.18	.15	.35		
New 36	sludge	.08	.10	.20	.16	.41	6.1	3.4
New 75	needles	.17	.17	.07	.08	.52		
New 75	sludge	.07	.06	.17	.11	.49	6.3	3.9
New 112	needles	.19	.11	.11	.14	.43		
New 112	sludge	.09	.10	.16	.12	.51	6.7	3.7

[1] Expressed in mmhos per cm.

[2] Initial levels are from 1 sample of sludge. July values are means from 1 sample taken from each of 12 pots.

lower levels of K than did the needles of untreated check seedlings (Table 5). Levels of P and Na varied little. Seedling growth was not highly correlated with nutrients levels (Ca: $r = .21$, Mg: $r = .29$, K: $r = .37$). This suggests that while the sludge treated seedlings metabolized more Mg and Ca and less K than control seedlings, the difference did not translate into enhanced or reduced seedling growth. The levels of Mg, Ca, and K observed in pine needles of both sludge-treated and control seedlings is within the range observed by other researchers (White, 1954, Wells and Metz, 1963, van Buijtenen *et al.*, 1977) and considered acceptable for reasonable growth. Similarly, these same researchers have shown that the tendency of foliar levels of Mg and Ca to increase, and K to decrease is inherent to the seasonal trends characteristic of loblolly pine.

In general, nutrient levels in dead seedlings were similar to those in live seedlings, although 3 dead seedlings had Mg levels which were double that of their living counterparts (Table 6). The pH of sludges around dead seedlings was generally similar to those for live seedlings and for both was higher than the optimum for loblolly pine. At the time of analysis (July), salinity levels were higher for dead seedlings than for live seedlings and also higher than at the initiation of the study. This suggests that a salt problem may develop during the decomposition of the sludge which could lead to increased mortality.

CONCLUSIONS

In conclusion, results showed both sludges have potential for field application and should be field tested. Neither sludge stimulated nor inhibited seedling survival or growth. Nutrients in seedling foliage were generally within accepted normal levels. Increases in Mg, Ca, pH and electrical conductivity suggest future studies should examine the potential impact of salts and lime on both seedling development and site quality. Mill sludge should be tested as a mulching agent to increase soil moisture by reducing competition from herbaceous plants. Incorporating sludge into the soil prior to planting should also be evaluated for its impact on seedlings and site quality.

Table 6. Analyses of needles from dead seedlings and sludge from pots supporting dead seedlings. Samples were collection when death appeared imminent. Results are expressed in percent of dry weight. Seedlings in the control did not receive a sludge treatment.

Treatment		P	K	Nutrient Na	Mg	Ca	pH	Conductivity[1]
Control	foliage	.10	.47	.11	.10	.33		
New 36	foliage	.22	.18	.16	.33*	.41		
	sludge	.09	.11	.23	.41**	.66	6.9	4.9
Old 75	foliage	.19	.15	.09	.11	.61		
	sludge	.10	.13	.21	.18	.41	6.7	4.8
Old 75	foliage	.20	.19	.07	.25*	.66		
	sludge	.07	.13	.20	.33**	.50	6.6	4.7
Old 112	foliage	.22	.20	.11	.18	.63		
	sludge	.11	.10	.21	.31**	.48	6.9	4.1
Old 112	foliage	.22	.23	.10	.21*	.57		
	sludge	.11	.13	.18	.18	.47	6.7	3.9

[1] Expressed in mmhos per cm.

* Dead seedlings whose Mg level is significantly greater than observed in live seedlings receiving the same sludge treatment.

** Significantly greater Mg levels in the sludge of dead seedlings than live seedlings reeeiving the same sludge treatment.

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