SEWAGE SLUDGE AFFECTS SOIL PROPERTIES AND GROWTH OF SLASH PINE SEEDLINGS IN A FLORIDA NURSERY

Charles R. Berry[1]

Abstract.--The effects of dried sewage sludge in quantities of 68 and 136 mt/ha were compared to normal fertilizer applications on growth of slash pine seedlings in experimental nursery plots at the M. D. Andrews Memorial Nursery in Chiefland, Florida. The fertility treatments were combined factorially with two mycorrhizal treatments, natural inoculation or inoculation with vegetative inoculum of *Pisolithus tinctorius*. Sewage sludge increased initial soil concentrations of total N, available P, and exchangeable K, Ca, Mg, Mn, Cu, and Zn. Cation exchange capacity and pH were also increased, but organic matter was not significantly altered. Seedling diameters and fresh weights were larger in plots amended with 136 mt/ha of sewage sludge than when amended with fertilizer. Inoculation of seedlings with *P. tinctorius* increased top fresh weight in the fetilizer and 68 mt/ha sludge treatments. Concentrations of extractable elements in the Newberry, Florida, sewage sludge used in the experiment were compared to those of sludge from Athens, Georgia, and Norman, Oklahoma, to illustrate some of the differences in mineral composition that may be expected from sewage sludge produced in different areas.

Additional keywords: Ectomycorrhizae, cation exchange capacity, organic matter, *Pinus elliottii* var. *elliottii*, *Pisolithus tinctorius*.

Sewage sludge is derived from organic and inorganic matter removed from wastewater at sewage treatment plants. The nature of the sludge depends on the wastewater source and the method of wastewater treatment. Nurserymen considering the use of sewage sludge as an organic amendment are particularly interested in the concentrations of plant nutrients, concentrations of toxic microelements, pH, percent organic matter, salt content, odors, and animal pathogens. Reasonable precautionary measures should be taken to guard against exposure to pathogens, although well stabilized sludges are relatively free of pathogens and odors.

Very little literature is available to furnish guidelines for the use of sewage sludge as a soil amendment in forest nurseries. In a loamy sand nursery soil applications of 224 and 448 mt/ha of screened compost (sewage sludge composted with wood chips) produced taller seedlings of yellow poplar (*Liriodendron tulipifera* L.) and flowering dogwood (*Cornus florida* L.) than 0 or 112 mt/ha of compost (Gouin and Walker 1977). Greater height of red maple (*Acer rubrum* L.) was obtained the following year using the same compost in the same unaltered nursery beds and at the same rate (224 and 448 mt/ha) than was obtained with 0 or 112 mt/ha (Gouin and others 1978). Total fresh weights of loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pine seedlings grown from seed were increased 4- to 6-fold by amending a clay soil with 138 mt/ha of sewage sludge in experimental nursery microplots (Berry and Marx 1976). In the same study, fresh weights of seedlings grown in plots amended with 69 or 275 mt/ha were significantly less than in plots amended with 138 mt/ha.

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[1] Plant Pathologist, Institute for Mycorrhizal Research and Development, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, Ga.

Sewage sludge from different localities varies considerably in nutrient concentrations. Total N varies from 1.5 to over 6.0 percent, total P from 0.7 to 4.0 percent, total K from 0.2 to 0.7 percent, and organic matter from 20 to 70 percent. The concentrations of readily available elements (as determined by Plasma Emission Spectograph after double acid extraction) also vary as shown by analyses of sludge from Newberry, Florida; Athens, Georgia; and Norman, Oklahoma (table 1). Of particular interest are the high concentrations of P in the Florida sludge and the high levels of Ca, Mg, and Na in the Oklahoma sludge. The effects of these sludges on growth of loblolly pine are currently under study in Athens, Georgia.

Table 1.--Available elements in sewage sludge from three locations

Element	Athens, Georgia	Norman, Oklahoma	Newberry, Florida
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P	549	790	1,464
K	218	201	199
Ca	1,740	6,072	3,900
Mg	56	561	373
Mn	20	32	14
Zn	251	100	351
Cd	2	1	3
Al	327	7	328
Na	21	320	50
Cu	24	3	20

Inoculation of nursery beds with *P. tinctorius*, already shown to be of value in standard nursery operation (Marx *et al.* 1976) was carried out to determine whether beneficial interactions with sewage sludge would occur. This paper, therefore, reports an experiment testing the value of Newberry, Florida dried sewage sludge as a soil amendment interacting with inoculation with *P. tinctorius* for production of slash pine (*P. elliottii* Englem. var. *elliottii*) seedlings at the M. D. Andrews Memorial Nursery in Chiefland, Florida during the summer of 1979.

MATERIALS AND METHODS

Treatment plots 1.2 m x 1.2 m (4 ft x 4 ft) were arranged in a randomized block design in the second nursery bed in from an irrigation riser line. Three fertility treatments, (1) normal fertilizer application, (2) 2.5 cm (68 mt/ha) of dried sewage sludge, and (3) 5.0 cm (136 mt/ha) of dried sewage sludge, were combined factorily with two mycorrhizal treatments--natural inoculation and inoculation with vegetative mycelium of *Pisolithus tinctorius* (Pers.) Coker and Couch (Pt), isolate 246. Sewage sludge obtained from Newberry, Florida and stockpiled at the nursery in March 1979, contained 1.15 percent total N, 20.0 percent organic matter, and concentrations of other elements as noted in table 1.

Sewage sludge was placed on oversize plots (1.5 m x 1.5 m) and thoroughly disked into the soil. The plots were fumigated on April 4, 1979 with methyl bromide (Dowfume MC-2, Dow Chemical Co., Midland, Mich.) under clear plastic at the rate of 504 kg/ha.

Pisolithus tinctorius inoculum was produced by methods described by Marx and Bryan (1975). After the beds had been shaped on April 17, mycorrhizal inoculum was broadcast onto the soil and incorporated by hand tools into the upper 10 cm of soil at a rate of 1.08 ℓ/m^2 (100 ml/ft^2).

Sulfur was applied to the soil 3 weeks prior to bed preparation at a rate of 336 kg/ha to adjust pH. Fertilizer was applied to the fertilizer plots according to the current prescription for this nursery--168 kg/ha of 10-10-10, 112 kg/ha of superphosphate, and 336 kg/ha of Sul-Po-Mag[1/] prior to sowing; 168 kg/ha of NH_4NO_3 applied once in June and again in July; and 140 kg/ha Sul-Po-Mag applied once in July, again in August, and a third time in October.

Soil samples for chemical analyses were taken in all plots from the upper 15 cm of nursery soil after application of sludge but prior to application of pre-season fertilizer.[2/] Seedlings were undercut, hand lifted, graded, and data recorded in January 1980. Data were analyzed by analysis of variance with means separation by Duncan's New Multiple Range Test. Ectomycorrhizae were visually estimated according to the procedure described by Marx and Bryan (1975).

Chemical analyses of seedling foliage and plot soil are being made from samples collected when the experiment was terminated, but are not available at this time. The results of these analyses will be published at a later date.

RESULTS

Five cm of sewage sludge applied to nursery plots increased soil nitrogen 3- to 4-fold, soil phosphorus 2½- to 3-fold, magnesium 3-fold, copper 20-fold, and zinc 20- to 30-fold (table 2). Organic matter was increased slightly, though not significantly, cation exchange capacity was doubled, and pH was increased in plots with 5 cm of sludge compared to nonamended plots, which later received fertilizer.

Slash pine seedlings grew better in plots amended with 5 cm of sewage sludge than in plots amended with fertilizer. Seedling density averaged 227 seedlings/m^2 (21/ft^2) and all plots had about 11 percent cull seedlings; treatment did not affect these parameters. Since seedlings were top pruned during the growing season, seedling height at lifting time did not differ between treatments. Seedling diameters and fresh weights, however, were significantly larger on plots that had received 5 cm of sewage sludge than on fertilizer plots.

Evaluation of seedling roots at lifting revealed that the percentages of short roots mycorrhizal with all fungi, with Pt and with indigenous species were relatively low. Although the degree of Pt infection was low in all treatments receiving Pt inoculum, it was lowest on seedlings from sludge treatment plots. Sporophores of Pt were found regularly late in the season in fertilizer plots, but were not detected in sludge-amended plots. In spite of the low level of Pt

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1/ Sul-Po-Mag is 18 percent magnesium sulphate as MgO with 21 percent water soluble potash.

2/ Soil samples analyzed by Dr. C. G. Wells, Forestry Sciences Laboratory, USDA Forest Service, Research Triangle Park, N. Car.

infection, however, seedlings from Pt infested plots had significantly greater top fresh weights than noninoculated seedlings in both the fertilizer-amended plots and plots amended with 2.5 cm of sewage sludge (table 3).

Table 2.--Soil analyses of experimental plots following application of sewage sludge but prior to application of fertilizer

Element	Control[1/]	Sludge 68 mt/ha	Sludge 136 mt/ha
N	297c[2/]	552b	1,072a
P	86c	153b	258a
K	22c	23b	30a
Ca	279c	504b	790a
Mg	13c	27b	44a
Mn	13a	13a	13a
Cu	2c	12b	24a
Zn	2c	21b	47a
O.M. %	0.8a	0.8a	1.2a
CEC me/100gm	0.7c	1.0b	1.4a
pH	4.9c	5.9b	6.3a

1/ After soil analyses fertilizer was applied to control plots.

2/ Means within the same line followed by the same letter do not differ at P=0.05.

Table 3.--Growth and ectomycorrhizal development of slash pine seedlings after 8 months in soil infested with *Pisolithus tinctorius* (Pt) and amended with dried sewage sludge

Treatment	Height (cm)	Root collar dia (mm)	Fresh weight (gm)			Percent short roots ecto-mycorrhizal with	
			Top	Root	Total	Pt	All fungi
NI[1/] with fertilizer	26.8a[2/]	5.1c	14.4d	3.2c	17.6b	0	33.2b
Pt with fertilizer	27.0a	5.9bc	18.9bc	5.0bc	23.9ab	14.5a	34.0b
NI-sludge 68 mt/ha	28.8a	6.0bc	18.2c	5.6ab	23.8ab	0	39.4ab
Pt-sludge 68 mt/ha	27.5a	6.8ab	20.8ab	5.9ab	26.7a	8.0a	34.6b
NI-sludge 136 mt/ha	26.0a	6.9ab	22.3a	7.8a	30.1a	0	47.6a
Pt-sludge 136 mt/ha	27.2a	7.2a	22.8a	7.5a	30.3a	7.3a	42.0ab

1/ NI - plots not inoculated with *Pisolithus tinctorius* vegetative mycelial inoculum.

2/ Means within the same column followed by the same letter do not differ at P=0.05.

DISCUSSION

Five cm of dried sewage sludge applied to plots at the Andrews Memorial Nursery stimulated more growth of slash pine seedlings than the normal fertilizer applications. Even though seedlings in plots amended with 2.5 cm of sludge were of good size and quality, only among noninoculated plots were top and root fresh weights significantly better than on fertilizer plots.

Although the degree of Pt infection was not high in any treatment, it was slightly lower in all sludge plots. In addition, the lack of Pt sporophores on sludge plots indicates either a lower rate of Pt colonization of roots in these plots or the presence in sludge of a factor that inhibits sporophore production. In spite of lower Pt colonization and lack of sporophore production, Pt was still responsible for greater seedling top fresh weights in the 2.5 cm sludge plots.

Amendment with sewage sludge did not increase soil organic matter as much as calculations had indicated. For example, a 2.5 cm application of sewage sludge weighing approximately 68 metric tons per hectare and containing 20 percent organic matter should, theoretically, increase soil organic matter in the upper 15 cm by 1.4 percent. Additional organic matter in sludge plots was barely detectable, possibly due to inadequate sampling techniques or analyses methods, when soil samples were taken 2 weeks after application. The increase in organic matter, even in the 5.0 cm application, was less than the expected increase in the 2.5 cm application.

The role of phosphorus in the production of seedlings that will perform well after outplanting continues to be of intense interest. We know that development of endomycorrhizae on sweetgum is suppressed when soil phosphorus concentrations are higher than 75 to 125 ppm (Kormanik, unpublished data). On the other hand, Marx (unpublished data) has obtained good Pt ectomycorrhizal development on pine in soils with phosphorus concentrations up to 125 ppm. Phosphorus concentrations in the nonamended soil and the Newberry, Florida sewage sludge were fairly high. Adding sewage sludge or superphosphate fertilizer to this soil may have resulted in levels of P that were inhibitory to Pt synthesis. The effect of increasing soil pH to 6.3 on Pt ectomycorrhizal development has not been established, but it is known that the fungus grows better under more acid conditions.

The most important result of this work, however, is that sewage sludge proved to be an excellent soil amendment for a sandy soil in a Florida nursery. Since past experience indicates that it should be just as effective in nurseries with soil having more clay (Berry and Marx 1976), more consideration should be given to the use of this valuable waste product.

Field performance is, of course, the final criterion for measuring the value of a nursery treatment. By fall of 1981 we expect to have data to evaluate initial field performance of the trees produced in this experiment.

A large part of the 2.2 million metric tons of sewage sludge produced annually in the United States should be suitable for forest nursery use. In the future we will continue to evaluate sludge from different areas in different soils to acquire a better understanding of its use in nurseries and elsewhere. The relationship of soil phosphorus concentrations, organic matter, possible phytoxicity of heavy metals, and possible deleterious pH effects must be determined before this byproduct of society can be considered useful in forestry.

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