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Project Summary

Soil Temperature and Sewage Sludge Effects on Plant and Soil Properties

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A field study was conducted at the University of Maryland Plant Research Farm to evaluate the effects of soil temperature on sewage sludge nutrient release for corn growth. Survival of bacterial indicator organisms as a function of soil temperature was also determined.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Experimental Design and Procedures

The experimental design was a split-plot with three replications. Target soil temperature regimes (whole plots) of ambient (mean value = 22 C), 16, 27, and 35 C were maintained in 4.5 x 1.8-m plots, of which 1 5 x 1.8-m sub-plots received sludge rates of 0, 56, and 112 metric ton/ha. On a dry matter basis, the sewage sludge contained 3.0% N, 2.0% P, 0.1% K, 0.8% Ca, and 1.1% Mg; and 4000 µg/g Zn, 2200 µg/g Cu, 140 µg/g Pb, 170 µg/g Ni, and 16 µg/g Cd.

Field corn (*Zea mays* L.) was planted in the spring of 1975 and 1976 in each plot, and radishes (*Raphanus sativus* L.) were planted between the corn rows. Corn was sampled at the following stages: seedling (8 to 9 leaf), ear leaf (anthesis), and stover and grain (hard dent). Stover and grain yields were measured. Ear leaf samples were analyzed for P, K, Ca, and Mg, and all samples were analyzed for Zn, Cu, Ni, Cd and Pb. Forage quality of corn stover was also determined. Radishes were harvested prior to bolting.

Following removal of corn in the fall of 1975, oats (*Avena sativa* L., var. Norline), wheat (*Triticum aestivum* L., var. Arthur), rye (*Secale cereale* L., var. Balboa), crimson clover (*Trifolium incarnatum* L., var. Auburn), and arrowleaf clover (*Trifolium vesiculosum* Savi, var. Yuchi) were planted. The temperature regulation equipment was inactivated for the tests with these crops. In the spring of 1976, forage of small grains was harvested in the boot stage and legumes at 1/10 bloom; plant yields were not taken. Sample preparation and assay for heavy metals was as for corn tissue. The corn and radish planting followed shortly after harvest of these crops. All conditions, including the sludge, were the same as for the 1975 planting.

Soil cores were taken from each plot at 0, 3, 7, 12, 20, 40, 56, and 68 weeks following initiation of the study, and available metals were determined by double acid and diethylene triamine pentaacetic acid (DTPA) extraction. Filtrate was analyzed for Zn, Cu, Cd, and Ni. Soil samples were also analyzed for organic matter content, pH, and cation exchange capacity At the conclusion of the experiment, soil samples were analyzed for water stable aggregation and bulk density. Soil samples were also collected at 0, 21, 49, 91, and 147 days after sludge addition and analyzed for fecal coliform.

Conclusions

Soil temperature had a pronounced effect on corn growth. Below-ambient soil temperature (16 C) significantly reduced yields of grain and stover. This was expected because corn is a warm season plant that makes optimum growth at temperatures of 24 to 30 C. The largest increases in yields occurred as soil temperature increased from 16 C to ambient (22 C). Above ambient soil temperatures produced no significant grain or stover yield changes in 1975, but in 1976, an increase in yields was noted. The 1976 response may be attributed to an increase in plant yield potential by soil heating during an abnormally cool spring. In both years, plants were taller, had more leaves, and matured earlier at 35 C than at 16 C. Highest quality stover was produced at 16 C, possibly because of reduced lignin biosynthesis and stem elongation.

Sewage sludge application had little effect on grain or stover yields at most soil temperatures in 1975, but grain yields were significantly increased on plots subjected to a 16 C soil temperature. In 1976, check plots had significantly lower grain yields at all soil temperatures than those to which sludge was applied. Stover yields were significantly lower for check plots than plots amended with 112 ton/ha sludge at all temperatures except 16 C where no significant effect was observed.

Sewage sludge application increased N, P, Mg, and Ca concentrations in corn ear leaves in both years of the experiment. Potassium levels were not increased. Nutrients added in the sludge increased concentrations in the ear leaves and may be responsible for higher yields from sludge amended plots in 1976. Higher concentrations of N, P, and K were found in corn ear leaves from 35 C plots than from 16 C plots in both years. Calcium concentrations were consistently higher in ear leaves from 16 C plots.

Sewage sludge application increased the Zn, Cu, Cd, and Ni levels in corn plants. Zn and Cu were present to the largest extent in aerial portions of the plant. Zn and Cd appeared to be translocated from soil to aerial tissues more readily than did the other heavy metals evaluated. Lead levels in plants were not increased due to sewage sludge application.

The effects of soil temperature on heavy metal concentrations in plants varied considerably according to year, metals, and plant materials. Soil temperature had no significant effect on Ni and Pb concentrations in stover, grain, ear leaves, or seedlings. Zinc levels in ear leaves and seedlings from plants grown on sludge amended plots were significantly higher for both years at a soil temperature of 35 C than at 16 C. Soil temperature effects on stover Zn concentrations were variable and possibly masked because of the effect of dry matter. Lower Cu concentrations were observed in ear leaves, stover, and seedlings at 16 C than at other soil temperatures. This was not significant all years and for all sludge rates. Seedling Cd concentrations were significantly higher each year at 35 than at 16 C. Cadmium levels in ear leaves and stover were not significantly affected by soil temperature.

Sewage sludge application resulted in significant increases in soil organic matter, pH, and DTPA and double acid extractable metals. Organic matter levels in sludge amended plots decreased significantly during the 68 weeks of the experiment. Available Zn and Cu concentrations as measured by DTPA extraction increased from the start to the end of the experiment. No consistent changes occurred in Ni and Cd concentrations. Soil bulk density decreased and soil aggregation increased as a result of sewage sludge application.

Effects of soil temperature on soil organic matter and DTPA extractable metal levels were small and nonsignificant within soil samplings taken during the experimental period. At all sludge rates, 35 C and 27 C soil temperatures resulted in a significant reduction in soil pH by the conclusion of the experiment. Ambient and 16 C soil pH values were not significantly different. Soil temperature had no effect on bulk density or aggregation.

Increases in sewage sludge application rates significantly increased the heavy metal concentrations in both radishes and forages. Radish tops had higher metal concentrations than roots. The effects of temperature and sludge treatment were more apparent on radishes than on corn. Legumes grown during winter months, when soil temperature was not regulated, had higher metal concentrations than did small grains, but the legume or small grain metal levels were not significantly affected by residual soil temperatures from the preceding series of tests.

Higher levels of heavy metals found in plants at 35 C versus 16 C soil temperatures appear to be a function of temperature stimulation of plant uptake and translocation processes, since heavy metal availability to plants as measured by DTPA extraction was only slightly affected by soil heating. No residual temperature effect on metal content of legumes or grasses was observed.

Both temperature level and application rate affected survival of indicator bacteria. Fecal coliform and fecal streptococcus survived longer at the lowest temperature (16 C), and the shortest survival was found at the highest temperature (35 C). At the highest soil temperature (35 C), the addition of sludge at the high rate (112 metric ton/ha) resulted in the longer survival time for both of the indicator bacteria.

These data indicate that sludge addition at high rates when soil temperatures are low would result in the greatest pathogen survival (about 2 logs reduction in 50 days); low sludge addition when soil temperatures are high would result in the lowest rate of pathogen survival (about 4 logs reduction in 50 days).

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***G. K. Dotson** is the EPA Project Officer (see below).*

The complete report, entitled "Soil Temperature and Sewage Sludge Effects on Plant and Soil Properties," (Order No. PB 81-191 199; Cost: $11.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

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