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Response of Different Crops to Various Rates of Furnace Ash Applied as a Soil Amendment

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Furnace ash from coal fired electrical generating steam plants has increased greatly in the last decade with the increased demand for electricity and increased restrictions on air pollution. The large volumes of ash are presenting disposal and containment problems for management of electrical generating plants. Property adjacent to the generating plants has been exposed to fly ash settling from the smoke stacks and ash over flowing from holding structures. The effects of the material on the land and its production are unknown and concern property owners.

Many of the chemical elements contained in the ash are needed for plant growth; therefore, the ash may be suitable as a soil amendment. But, the chemical characteristics of the soil and the ash must be compatible. Other studies show that adding ash to soils low in boron, phosphorus, potassium, molybdenum or pH increased crop yields when the ash used had a high content of the needed element and did not contain toxic levels of other elements. It is sometimes difficult to find soils that are compatible with the ash available locally.

In 1974 a greenhouse study showed that the ash used in the following experiments could raise the pH of soils. However, deleterious effects were noted as the rates increased. Grass plants (fescue, corn and wheat) had the greatest tolerance to higher rates of the ash, with fescue being the most tolerant. Soybeans were the most sensitive crop tested, and tobacco and clover were intermediate. We concluded that the negative effects from the high rates of ash were probably due to high salt and boron levels.

A field experiment was begun in 1975 to determine compatibility of local ash and soil characteristics and to determine its effect on crop yields.

CHARACTERISTICS OF FURNACE ASH

The chemical characteristics of ash vary greatly according to source of coal. It is not unusual for the amounts of the different elements in the ash to vary ten fold or more between sources of coal. Ash from each location is characteristic of the coal from which it is produced. Most coal used by the generating plants is from local sources so the chemical characteristics of the ash are fairly consistent.

The ash used in these experiments was from the Big Rivers RECC generating plant at Sebree, Kentucky. The analysis of the ash used in these trials was as follows:

Neutralization titration	0.0054 meq of HCl/gram to reach pH 6.5
Soluble salts	950 EC X 10^5 (1:2 dilution)
Magnesium	2.50%
Calcium	1.40%
Potassium	1.35%
Phosphorus	0.44%
Zinc	380 ppm
Boron	84.5 ppm
Copper	370 ppm
Molybdenum	10.2 ppm
Manganese	810 ppm
Sodium	537 ppm
pH	12.5

The material had a high pH and contained a number of plant nutrients. Physically it was a very fine powder and difficult to spread on the field by conventional lime and fertilizer equipment methods. The salinity was high, however, the sodium content was not high enough to cause problems.

EFFECT ON CROP YIELDS

In the field experiments, the furnace ash was weighed and applied in 60 feet wide strips. The specie treatments were planted perpendicular to the ash treatments. The ash was applied with trucks used to spread limestone on the first experiment in 1975 and by E-Z-Flo spreader in 1976 on the second experiment. Replicated plots were established at random in each of the treated and untreated areas.

In 1975 a field experiment was begun to study the effects of furnace ash on the yield of corn and on certain chemical properties of the soil. Furnace ash was applied in April 1975 to a Falaya silt loam soil in Henderson County. Ash was not applied in subsequent years. Yields of corn for 1975 through 1977 are shown in Table 1.

Table 1. Effect of Different Fly Ash Rates on the Yield and Population of Corn on a Falaya Silt Loam.

Treatment Tons/A	Yield Bu/Ac 1975	1976	1977	Plant Population Stalk/Ac 1975	1976	1977
0	113	148	101	15,160	17,871	17.811
25	104	162	94	13,243	18,429	19,533
50	107	178	90	14,637	18,429	19,166
65	69	119	*	13,591	17,871	*

*Not measured due to severe water damage to plot area

Yield data, visual observations, and plant population suggested that detrimental effects of the ash observed in the first year of the test (1975) diminished somewhat after one year of weathering. However, the yield trends were reversed in 1977. In 1976, the yields from the 25 tons/ac and from the 50 tons/ac rates were higher than the 65 tons/ac plot were the lowest for both years; however, the percent of decreased yield was less in 1976 when compared to the untreated check plots. In 1977 the yield trends were reversed, however, vegetative grwoth showed no detrimental effects and plant populations were higher on treated areas. The decreased yields could be the result of unfavorable weather.

An area was planted in soybeans for observation in 1975. At the 65 tons/ac rate all soybeans and weeds died, leaving the soil completely bare. By 1976, conditions in this area had improved enough to allow moderate growth of weeds, red clover and fescue.

A second experiment was begun in 1976 on a Grenada silt loam soil with a low pH. This location was also in Henderson County. The furnace ash was applied with an E-Z-Flo Spreader. Yields of corn, forage, and soybeans are shown in Table 2. Soybeans were planted to the area in 1976 where forage was harvested, but, due to inadequate weed control, soybean grain yields could not be determined. Consequently, the total vegetation was harvested and termed forage yields. Subsequent tests established in 1977 indicated the failure of the herbicide was not related to application of ash to the soil.

Table 2. Corn, Forage, and Soybean Yields from a Low pH Soil Treated with Furnace Ash - Spring 1976

Treatment Tons/Ac	Corn Plant Population Stalks/Ac 1976	Corn Yield Bu/Ac 1976	Forage Yield Tons/Ac 1976	Soybeans Bu/Ac 1977
0	13,068	105.0	5.20	42.5
10	11,906	117.1	3.76	44.5
20	13,358	82.5	3.54	48.1
30	12,478	81.4	4.04	44.1

Corn yields at the 20 tons/ac and the 30 tons/ac were significantly lower than the 10 tons/ac and the untreated check plot. Reduction of vegetative growth of corn was observed during the season on all treated plots compared to untreated check plots. In 1977 the soybean yields were high on all treatments, again indicating that the deleterious effects were alleviated after one year of weathering. In 1977, part of the check area was treated with five tons of furnace ash per acre. The soybeans from this area yielded 48 bu/ac and no unusual effects were observed. This again indicated that the material can be used at low rates without ill effects.

EFFECT ON SOIL PROPERTIES

The soils were analyzed by A & L Laboratories in Memphis, Tenn. The phosphorus is reported as weak Bray (P_1). Calcium, magnesium and potassium are reported as neutral normal ammonium acetate extractable. Zinc and manganese were extracted by 0.1 N HCl and boron is reported as hot water soluble extractable.

Soil test results from soil samples collected from the Falaya silt loam soil in the fall of 1975, 1976 and 1977 are shown in Table 3.

Table 3. Changes in Chemical Properties of Falaya silt loam treated with different rates of Furnace Ash following corn production.

Treatment Tons/Ac	Soil pH 1975	Soil pH 1976	Soil pH 1977	Boron (ppm) 1975	Boron (ppm) 1976	Boron (ppm) 1977
0	6.8	7.2	7.5	3.0	1.0	0.7
25	7.4	8.0	7.6	10.0+	3.3	0.9
50	7.6	7.7	8.0	10.0+	5.4	1.1
65	7.6	7.7	8.0	10.0+	9.8	0.8

Treatment Tons/Ac	Soluble Salts (mmhos/cm) 1975	Soluble Salts (mmhos/cm) 1976	Zinc (ppm) 1975	Zinc (ppm) 1976	Zinc (ppm) 1977	Manganese (ppm) 1975	Manganese (ppm) 1976	Manganese (ppm) 1977
0	0.8M	0.5L	3.2M	3.3M	4.2	60H	42H	98VH
25	1.8H	0.6L	3.4M	3.7M	4.5	72VH	60H	100VH
50	2.6H	0.8L	4.1M	4.0M	4.6	75VH	61VH	97VH
65	3.4H	1.3M	3.8M	3.4M	3.9	100VH	54H	112VH

These data show a substantial decrease in boron and soluble salts after 18 months of weathering. However, boron appears to have leached from the soil at a slower rate than the soluble salts. Boron reached a low level in all treatments after two years. The pH of treated soils increased and remained at a high level but it apparently had no adverse effect on the growth of corn. There was an increase in pH on the untreated soil which can not be explained. This ash contained a high amount of manganese and zinc. There may have been an increase in extractable soil manganese, but there is no evidence that extractable zinc level was affected.

The data also showed a slight increase in soil phosphorus from application of furnace ash. The other elements monitored -- potassium, calciu, and organic matter -- showed no definite trends.

The effect of furnace ash on the soil chemical properties from the experiment on the Grenada silt loam are shown in Table 4.

Table 4. Soil Chemical Properties of a Low pH soil Treated with Furnace Ash - Spring 1976.

Treatment Tons/Ac	pH Spring 1976	pH Fall 1976	pH 1977	Boron (ppm) Fall 1976	Boron (ppm) 1977	Manganese (ppm) Fall 1976	Manganese (ppm) 1977	Soluble Salts (mmhos/cm) Fall 1976
0	5.3	6.4	6.7	.9M	1.0M	25H	68VH	0.4L
10	5.3	5.5	6.2	1.4H	1.0M	34H	103VH	0.5L
20	5.3	5.5	6.2	2.3H	1.5H	34H	32VH	0.5L
30	5.3	7.3	7.4	4.6VH	0.8M	39H	69VH	0.6L

Boron was higher in the treated plots in the fall of 1976 as compared to the untreated check. Soluble salts apparently leached from the soil enough to pose no problems. However, since these soil samples were collected in December, salinity could have been a problem earlier but subsided with subsequent rains. Manganese may not be a factor since the 10 tons/ac plot gave an increased yield over the 20 tons/ac plot, yet these plots had identical values for soil pH and manganese (Table 2). The 1977 samples indicate that high amounts of boron had been leached from the soils after one year of weathering. The variability in soil pH is higher and more erratic than expected. The benchmark sample taken in the spring of 1976 was a composite of all plots. Samples taken later from individual plots indicate that variability within the plot area was very high. The neutralizing value of the ash, which was found to be low by laboratory analysis, shows the same effects in these experiments. Very large amounts were required to make noticeable changes in the soil pH.

SUMMARY

It appears that applications of furnace ash in excess of 10 tons per acre will result in reduced yields the first year after application. Major contributing factors to yield reduction may be high levels of boron and increased soluble salts. It also appears that one year of weathering will reduce this effect since normal yields were produced on these plots the second year following application rates of up to 50 tons per acre.

It seems unlikely that furnace ash would be economically feasible as a soil amendment and is not likely to become recommended as such. However, it is quite apparent that certain micronutrients can be supplied in this material and that rates up to 50 tons per acre are not detrimental to crop production after a period of one year from application.

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