AMELIORATION OF ACID SOILS WITH FLY ASH

R. F. Keefer
R. N. Singh
H. E. Ghazi
D. K. Bhumbla

WEST VIRGINIA UNIVERSITY
Div. Plant & Soil Sciences
Morgantown, WV

ABSTRACT

Three extremely acid strip mine soils were amended with 0%. 33%. and 67% acidic fly ash as a technique for reclamation. In a greenhouse experiment. five crops were grown successively-two corn crops and three alfalfa crops. A field experiment using an alkaline fly ash at 0. 400. and 800 metric tons per hectare was also conducted on one of these same mine soil using alfalfa as the test crop. Results show that yield of corn and alfalfa crops were improved with heavy applications of fly ash. This was explained by improvement of phosphorus availability and decrease in exchangeable aluminum and extractable manganese which appears to be present in toxic levels on these mine soils. Use of these heavy rates of fly ash, however, must be used with caution as both test crops showed unusually high levels of boron and there could be other elements which have not yet been tested.

INTRODUCTION

Poor plant growth on very acid soils has often been attributed to low pH with concomitant toxic levels of Al and/or Mn (Adams and Pearson. 1967). By inference, extremely acid strip mine soils would contain toxic levels of Al and/or Mn. One possible way to reduce these toxicities on acid mine soils could e by amended them with fly ash since fly ash has been implicated in reducing Al and/or Mn toxicity (Elseewi et al. 1980). Research on use of fly ash for reclamation purposes in the eastern U.S. has been reported by Martens et al (1970). Adams et al (1972). Capp (1978), and Keefer et al. (1979) and fly ash has been reported to produce a positive response in plant growth (Engle and Capp. 1967; Martens et al.. 1970; Martens. 1971; Plank and Martens. 1973). However. fly ash often has relatively high concentrations of boron present (Capp, 1978) which needs to be considered prior to application of this soil amendment.

OBJECTIVES

1. to examine the effect of fly ash application on acid soils.
2. to evaluate growth and chemical composition of corn and alfalfa grown on acid soils amended with fly ash.

EXPERIMENTAL METHODS

Acid mine soils from three locations were used in this study: a) Valley Point (VP) - a loam, extremely acid mine soil classified as a Typic Udorthent; loamy-skeletal. mixed. acid. mesic. b) Lenox (LX) - a clay loam. extremely acid mine soil classified as a Typic Udorthent; loamy-skeletal. mixed. extremely acid. mesic. and c) Westover (WO) - a loam. extremely acid mine soil. classified as a Typic Udorthent; loamy-skeletal. mixed. extremely acid. mesic. Soil from the all three locations was originally mined in the early 1970's and abandoned. Fly ash was obtained from the electrical power generating station of American Electric Power near St. Albans. WV.

Greenhouse Experiment

After drying the soil and fly ash. an experiment was set up in a greenhouse using fly ash added at 0%. 33% and 67% of the mixture with the remainder being the mine soil from each of the three sites. Thus the pots containing 0% fly ash contained 100% of the mine soil. Corn seeds (Zea mays L. var. Dekalb XL72B) were planted and thinned to four plants after germination. Triplicate Pots for each treatment were randomly placed in the green-house. watered twice a day with deionized water. received supplemental fluorescent lighting for a 14 hour light period. and corn was harvested after 8 weeks of growth. Five successive crops, i.e.. two corn crops and three alfalfa (Medicago sativa L.), were grown. Alfalfa plants were thinned to 15 plants per pot. Alfalfa was harvested at 1/10 bloom (6 weeks after germination).

Soil samples were taken from each pot after harvesting. air dried, pulverized, and chemically analyzed. Plant samples were also chemically analyzed.

Field Experiment

A field experiment w as established near Lenox. WV on an area which had been stripped for coal about in 1970. Fly ash was applied in the fall of 1982 at three rates: 0. 400, and 800 metric tonnes per hectare and disced into the spoil. Half of each rate was seeded to lespedeza and half to alfalfa. Only the alfalfa yield and elemental concentrations for the second year will be considered here. The spoil/fly ash mix was also sampled for chemical analyses.

Plant subsamples from greenhouse and field were digested with nitric:perchloric acid mixture and the residue dissolved in HCl for chemical analysis by atomic absorption spectroscopy using a Perkin Elmer 5000. Boron was determined colorimetrically using a modified curcumin method. Only analyses for Al. Mn. and B are reported here.

Soil subsamples were analyzed for pH with a Beckman Expandomatic IV pH meter with a 1:1 soil/water ratio. Available soil P was determined by standard double acid (0.05 N HC1 + 0.025 N H_2SO_4) and by Bray P-1 method (0.03 N NH_4F in 0.025 N HCl). Exchangeable aluminum was extracted with 1 N KC1. manganese was extracted with dilute 0.1 N HC1, and both were determined using atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Two of the soils. Valley Point and Westover. had the same textural class -- loam, and the third -- Lenox -- was a clay loam (Table 1). The fly ash used was classified as a silt.

The two loam soils had similar pH levels, about 3.3. and the clay loam had a pH of 3.8 (Table 2). The fly ash was acidic with a pH of 4.9. Total and exchangeable aluminum were lowest in the VP soil . intermediate in the WO mine soil . and highest in the LX mine soil. Fly ash had 11.8% total Al . but only 0.2 meq/100g of exchangeable Al. Total Mn followed the same order for these soils with VP being the lowest at 119 mg/kg and LX being the highest at 428 mg/kg. Total Mn in the fly ash at 139 mg/kg was similar to that in the VP mine soil. Extractable Mn. however was highest in the Westover soil at 60 mg/kg. Low extractable Mn was present in the fly ash at 2 mg/kg and in the VP soil at 6 mg/kg. Total boron was high in all three mine soils from 319 mg/kg in the VP mine soil to 579 mg/kg in the LX mine soil. The flyash likewise was high in boron at 419 mg/kg.

Crop yields of corn in the greenhouse (Fig. 1) and alfalfa (Fig. 2) generally were increased by fly ash application to all three mine soils with the greatest yield increase on the LX mine soil. These yields may have been related to the increase in available phosphorus (P) in the mine soils as a result of fly ash application. This was evident in both the double acid extractable P (Fig. 3) and the Bray P-1 phosphorus (Fig. 4). Alfalfa yield in the field at Lenox benefited from fly ash application and the 400 tonnes per hectare rate. but no further yield increased resulted from the 800 rate (Fig. 5). These results likewise were inversely related to the concentrations of Al and Mn in both the crop and the soil.

The yields could also be related to changes in exchangeable Al and extractable Mn in the soil s. Aluminum is not required by plants and when present in high concentrations becomes toxic. Manganese is required by plants. but it too becomes toxic to plants at high concentrations.

Exchangeable Al was quite high in the LX and WO soil s receiving no fly ash (Fig. 6). As fly ash application increased from none to 33% to 67% the exchangeable Al decreased considerably in all three soils so that at the highest fly ash rate exchangeable Al was < 0.5 meq/100g. This is reflected in the aluminum concentrations in the corn plants (Fig. 7) and al so in the alfalfa plants (Fig. 8). No alfalfa grew on the mine soils without fly ash application.

Extractable Mn was also at very high levels in the VP and WO soil s (Fig. 9). but these levels decreased when fly ash was applied at 33% and 67% of the mix. This too is reflected by the Mn chemical analyses of the corn pl ants (Fig. 10) and of the alfalfa plants (Fig. 11). Manganese in the plant tissue likewise decreased as fly ash application increased from 0 to 67% level in the growth medium.

Thus, it superficially appears that fly ash at very high rates was beneficial to corn and alfalfa crops when grown on strip mine soils. However. when one looks more closely at the chemical analyses of the plant tissue, one observes a very high level of boron in plants grown on fly ash amended disturbed mine soils. For instance. the boron concentrations in corn plants averaged about 150 mg/kg when grown on mine soils amended with 33% fly ash and up to 250 mg/kg for the 67% fly ash rate (Fig. 12). The plants grown on the mine soils with no fly ash added contained boron at about 10 mg/kg which is the normal amount expected. The alfalfa plants grown on mine soils amended with fly ash likewise had high levels of boron. i.e. > 150 mg/kg.

(Fig. 13). however. alfalfa plants can often tolerate levels of boron up to 500 mg/kg before showing toxicity from this element. Consequently one must be aware that boron levels in plants which are grown on fly ash-amended mine soils may be quite high. There may be other elements in fly ash which could accumulate in plants or be toxic to plant growth. but this will require further testing.

CONCLUSIONS

Fly ash added in very large amounts to disturbed mine land appears to be beneficial to growth of plants as shown in the greenhouse in corn and alfalfa plants. This was also confirmed in the field for alfalfa plants. The improved yields from fly ash application could be explained on the basis of improved availability of phosphorus along with decrease in exchangeable Al and extractable Mn which could be toxic at very high levels. One must also be cautious in using fly ash at these high rates as the data reveal very high levels of boron in plants grown on the acid mine soils heavily amended with fly ash. There also may be other elements which could be toxic and must be examined further.

ACKNOWLEDGEMENTS

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Table 1. Some physical properties of the three mine soils and fly ash used.

	Soil			Fly
	Valley Point	Lenox	Westover	Ash
Particle Size Distribution:				
Sand (%)	50	27	40	15
Silt (%)	40	42	42	82
Clay (%)	10	32	18	3
Texture	loam	clay loam	loam	silt

Table 2. Some Chemical Properties of the Three Soils and Fly Ash

		Soil		Fly
	Valley Point	Lenox	Westover	Ash
pH	3.3	3.8	3.4	4.9
Total Aluminum (%)	6.4	9.8	7.7	11.8
Exchangeable Al (meq/100g)	2.6	5.4	3.4	0.2
Total Manganese (ppm)	119	428	235	139
Extractable Mn (ppm)	6	32	60	2
Total Boron (ppm)	319	579	519	419

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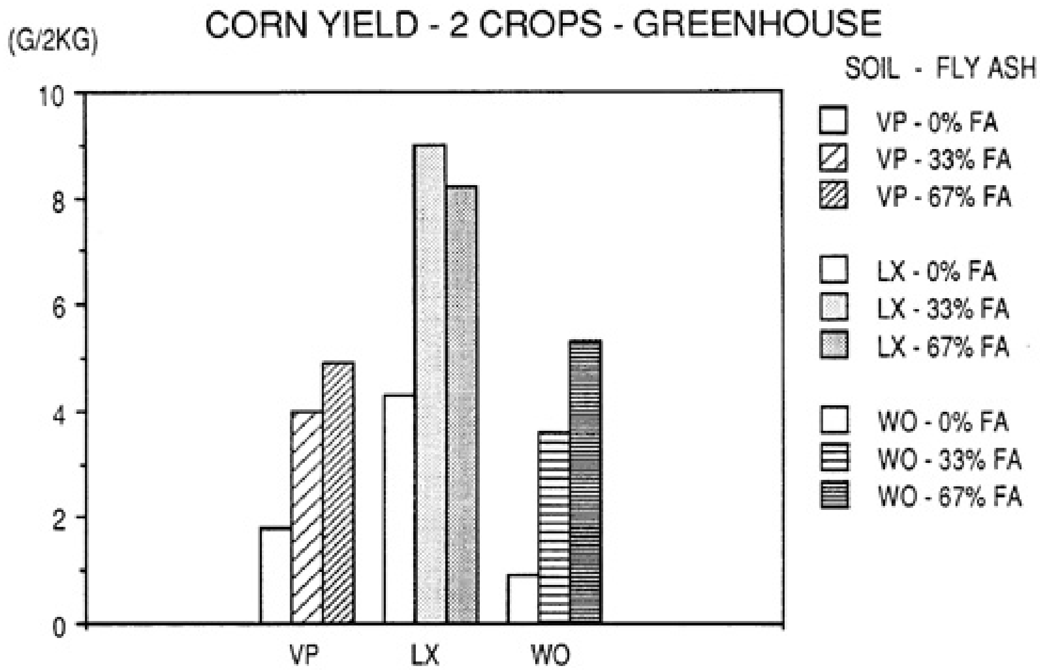


Figure 1. Yield of Two Corn Crops Grown on Lenox Soil in the Greenhouse with Varying Rates of Fly Ash.

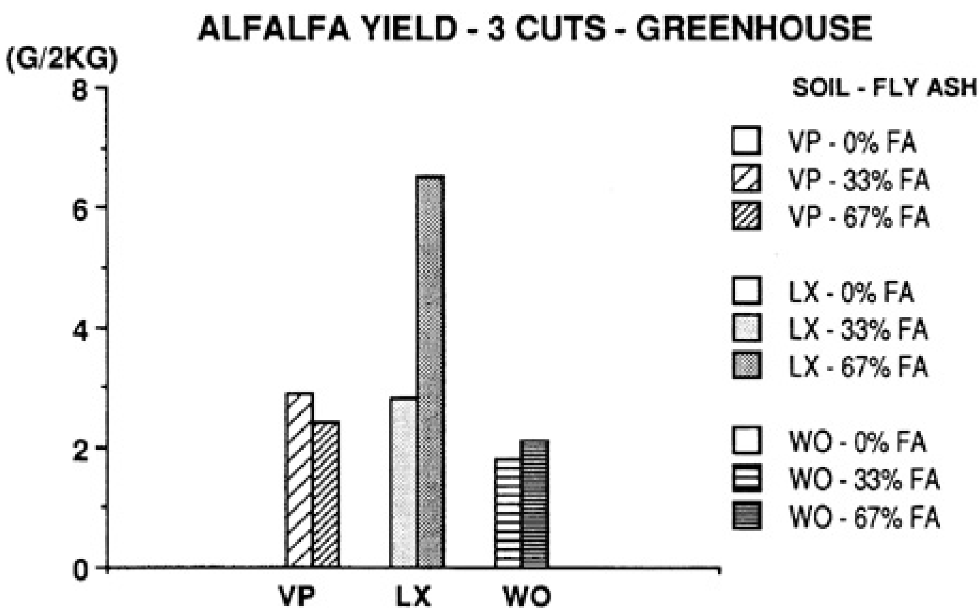


Figure 2. Yield of Three Cuttings of Alfalfa Grown on Lenox Soil in the Greenhouse with Varying Rates of Fly Ash.

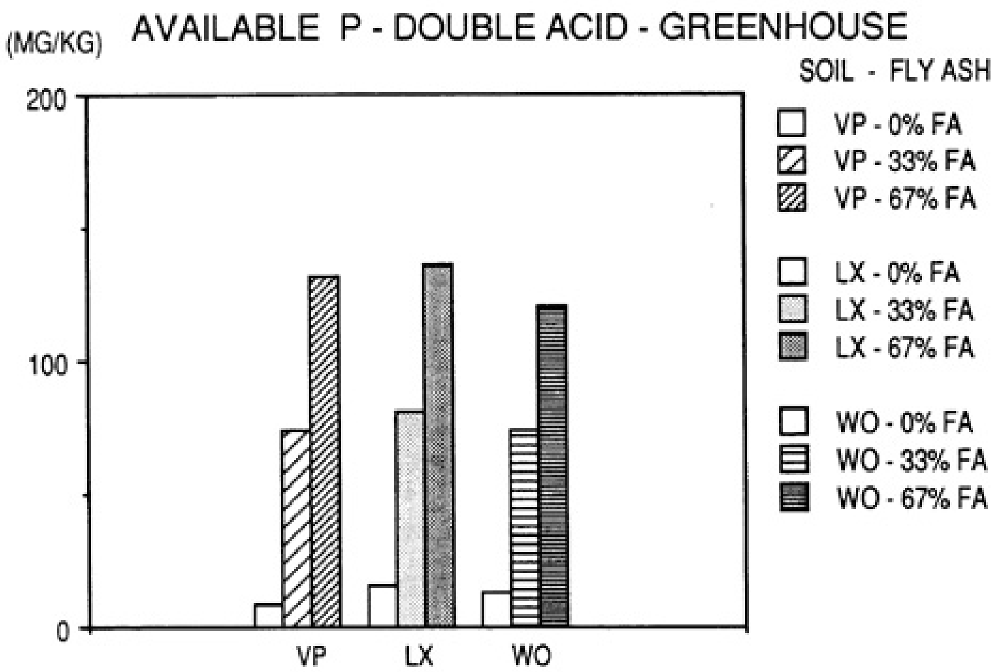


Figure 3. Available Soil Phosphorus by Double Acid Method in Lenox Soil Amended with Varying Rates of Fly Ash in the Greenhouse.

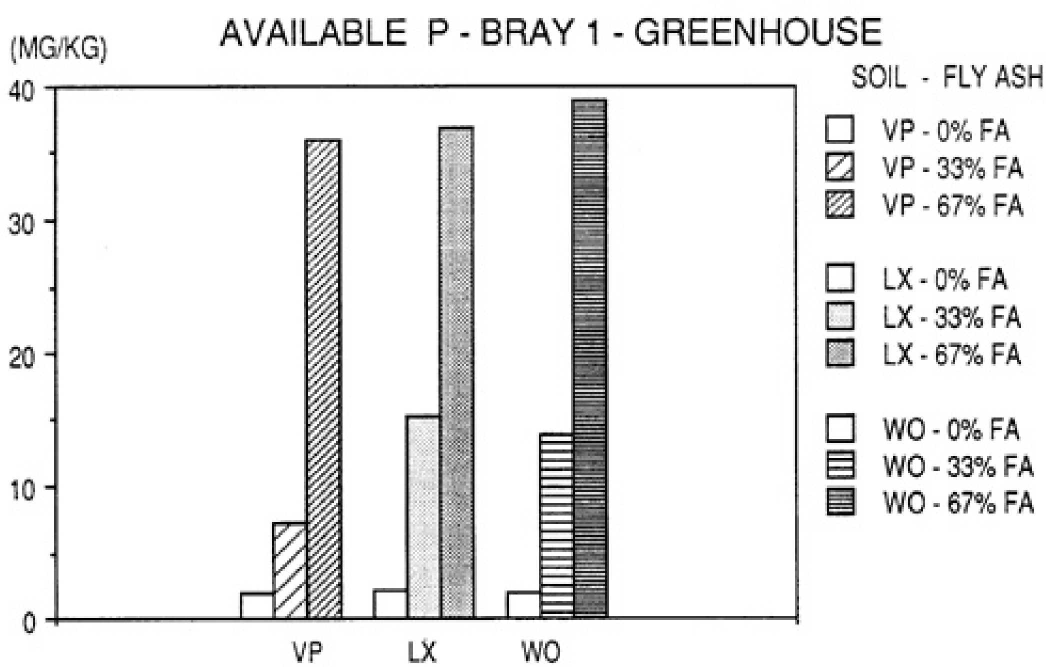


Figure 4. Available Soil Phosphorus by Bray P-1 Method in Lenox Soil Amended with Varying Rates of Fly Ash in the Greenhouse.

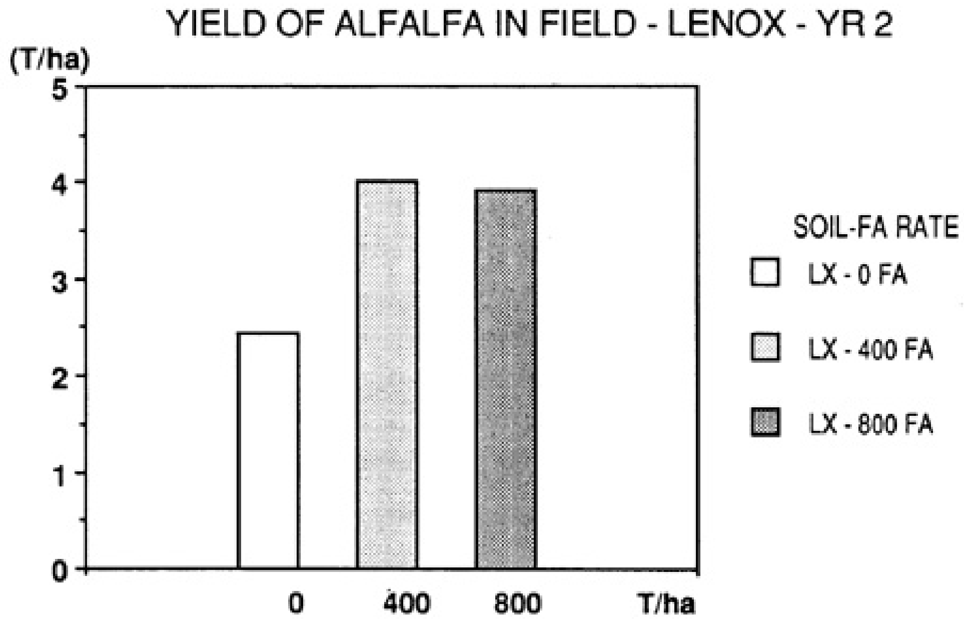
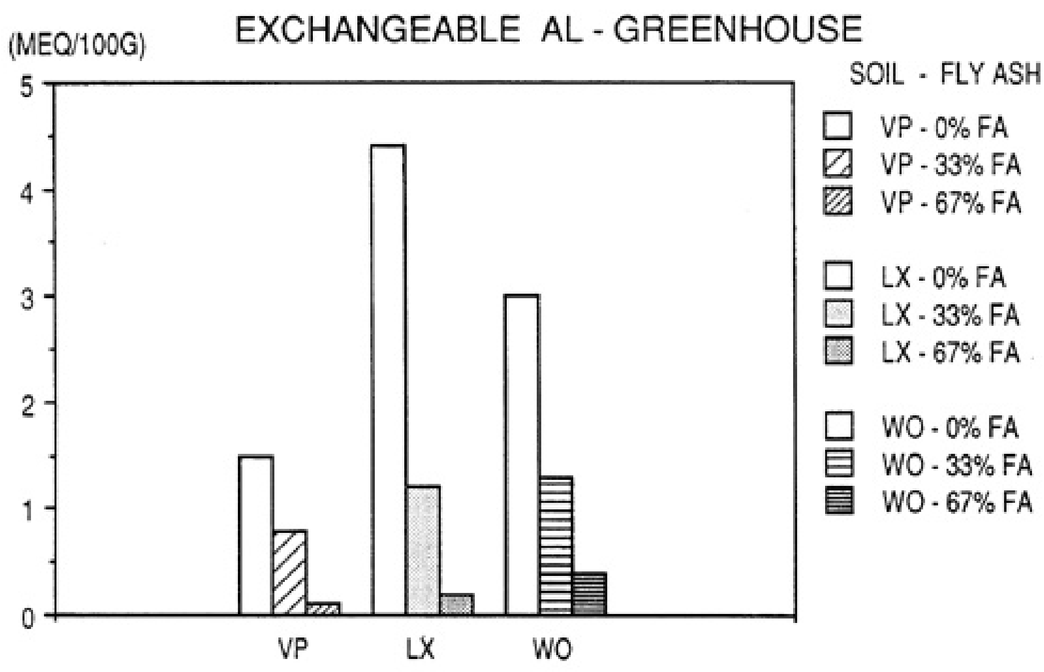


Figure 5. Yield of Alfalfa for Year 2 Grown on Lenox Soil in the Field with Varying Rates of Fly Ash.



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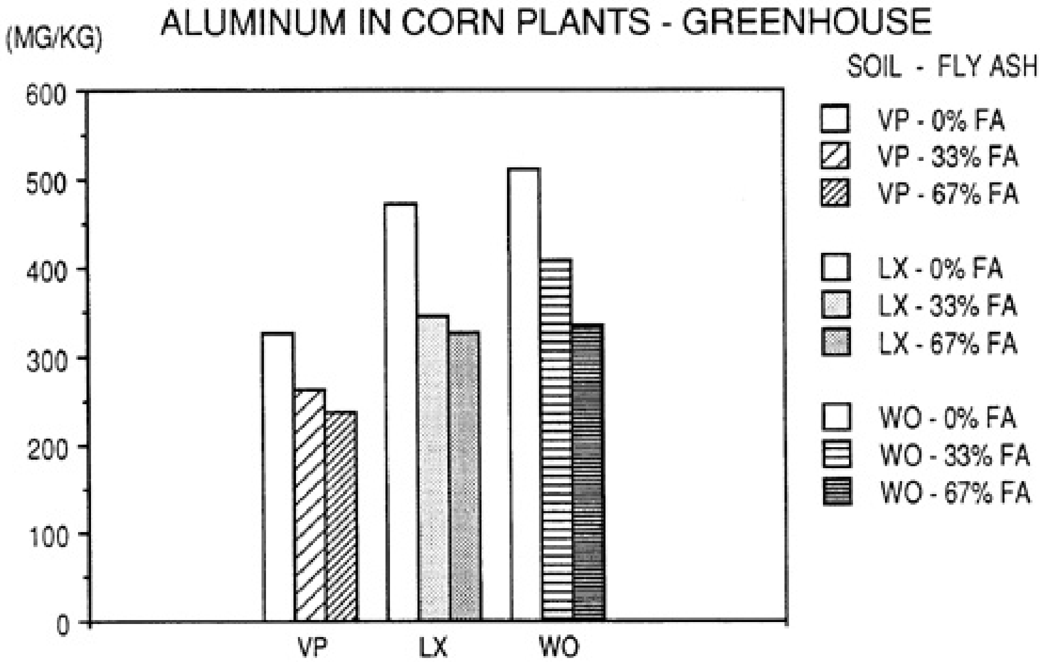


Figure 7. Aluminum Concentration in Corn Plants Grown on Lenox Soil in the Greenhouse Amended with Varying Rates of Fly Ash.

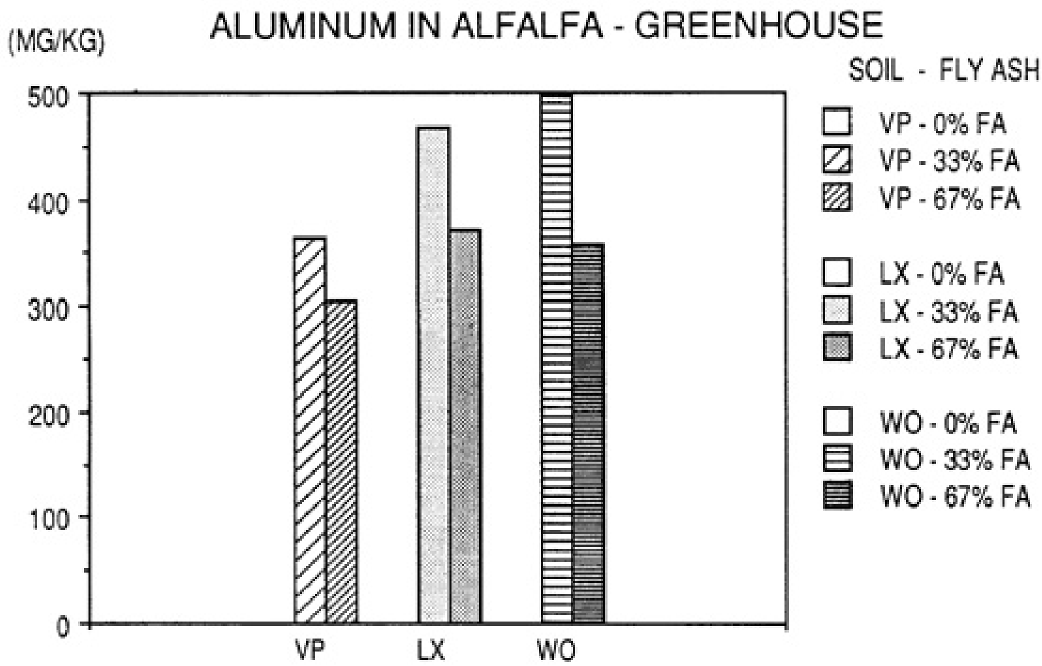


Figure 8. Aluminum Concentration in Alfalfa Plants Grown on Lenox Soil in the Greenhouse Amended with Varying Rates of Fly Ash.

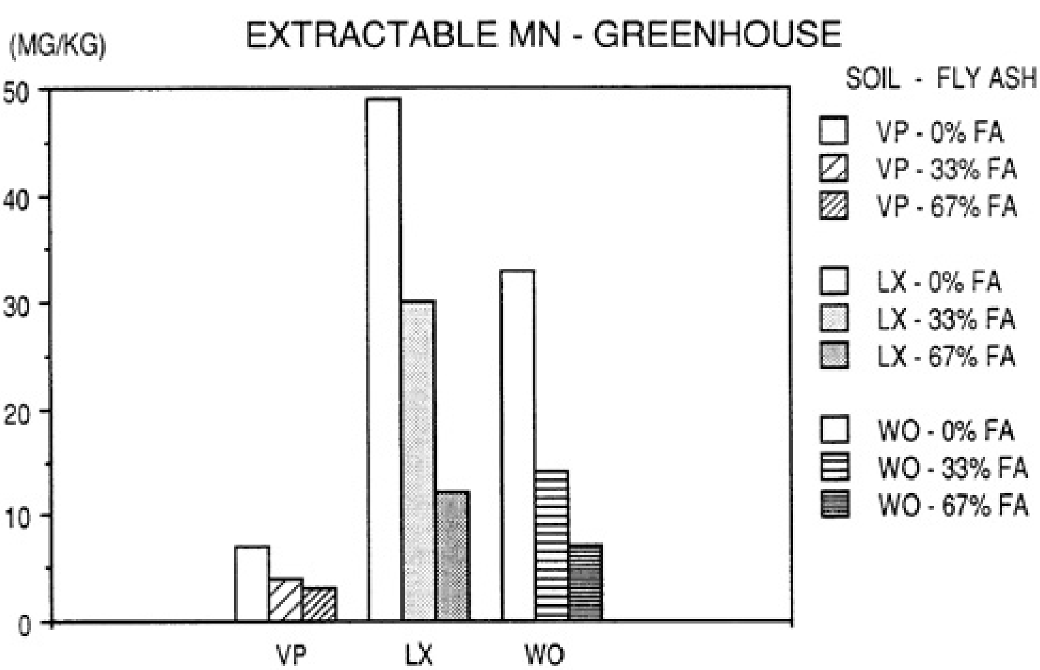
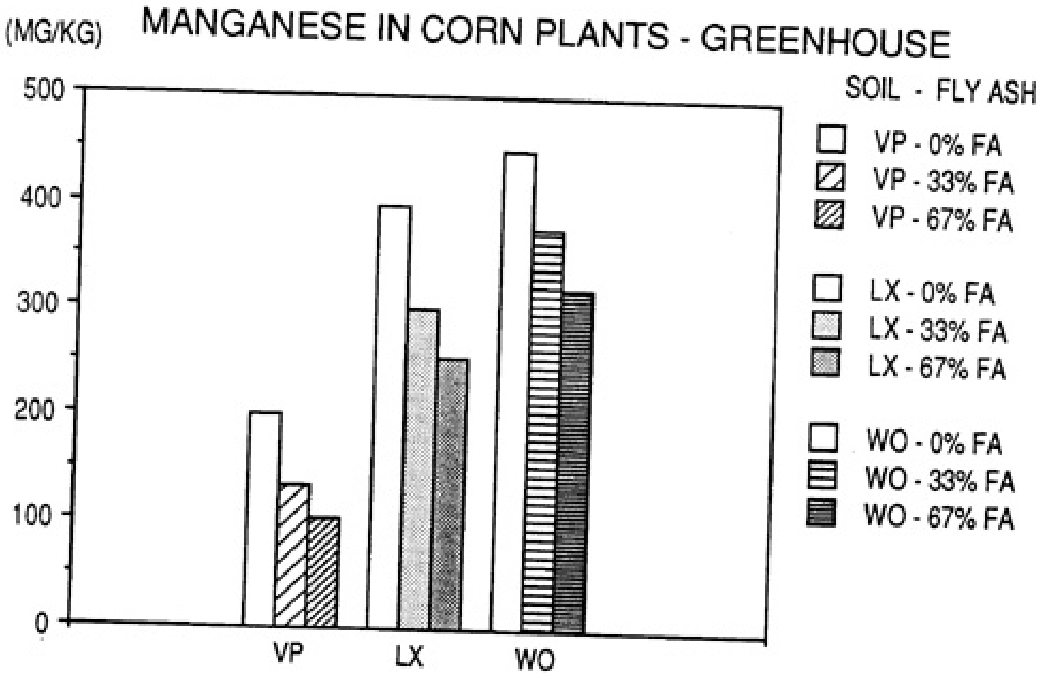


Figure 9. Extractable Manganese in Lenox Soil Amended with Varying Rates of Fly Ash in the Greenhouse.



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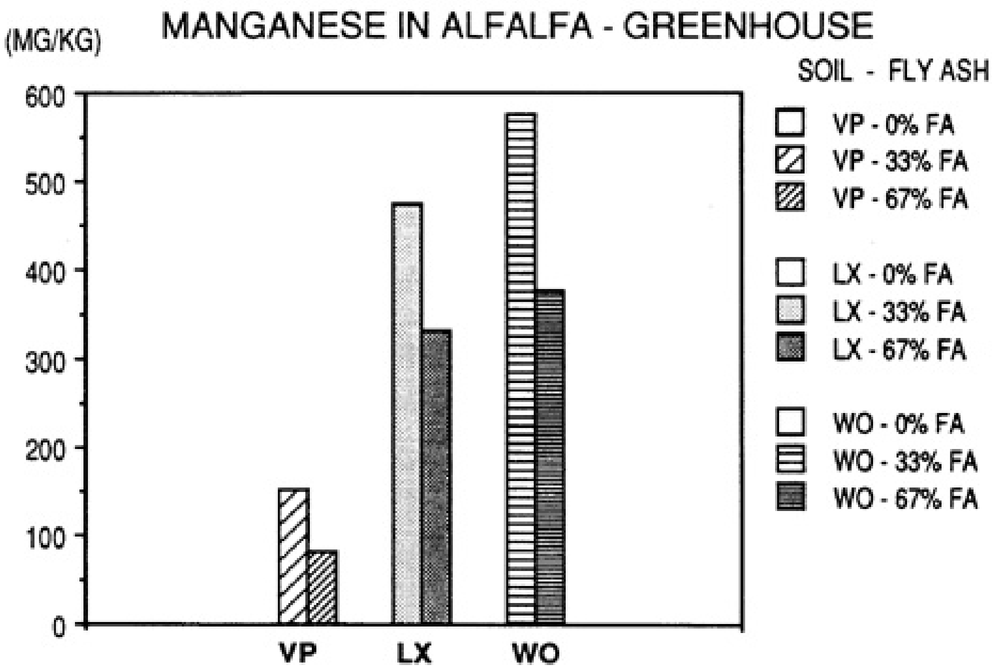

Figure 11. Manganese Concentration in Alfalfa Plants Grown on Lenox Soil in the Greenhouse Amended with Varying Rates of Fly Ash.

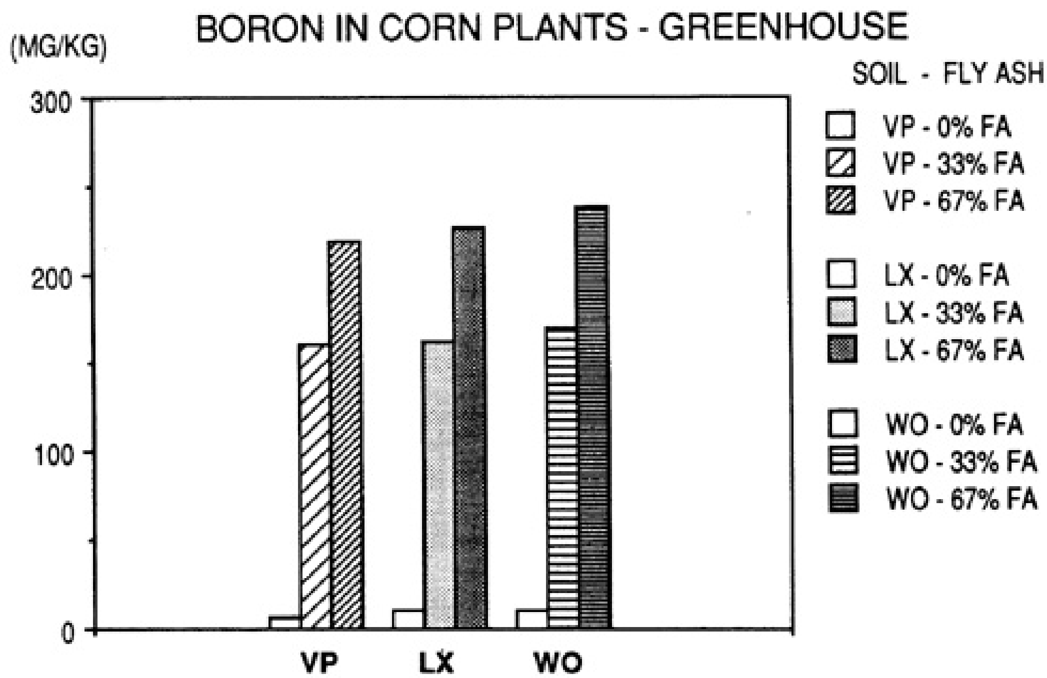

Figure 12. Boron Concentration in Corn Plants Grown on Lenox Soil in the Greenhouse Amended with Varying Rates of Fly Ash.

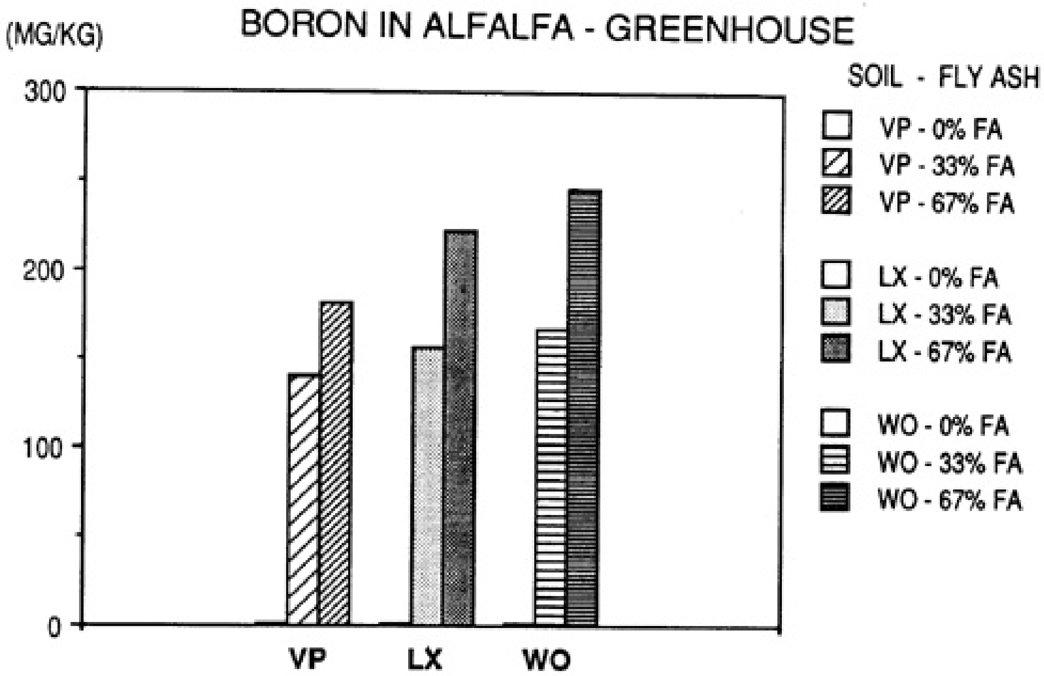

Figure 13. Boron Concentration in Alfalfa Plants Grown on Lenox Soil in the Greenhouse Amended with Varying Rates of Fly Ash.