BORON AVAILABILITY TO PLANTS FROM COAL COMBUSTION BY-PRODUCTS

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Abstract. Agronomic use of coal combustion by-products is often associated with boron (B) excess in amended soils and subsequently in plants. A greenhouse study with corn (Zea mays L.) as test plant was conducted to determine safe application rates of five fly ashes and one flue gas desulfurization gypsum (FDG). All by-products increased soil and corn tissue B concentration, in some cases above toxicity levels which are 5 mg hot water soluble B (hwsB) kg⁻¹ soil and 100 mg B kg⁻¹ in corn tissue. Acceptable application rates varied from 4 to 100 Mg ha⁻¹ for different by-products. Leaching and weathering of a high B fly ash under ponding conditions decreased its B content and that of corn grown in fly ash amended soil, while leaching of the same fly ash under laboratory conditions increased fly ash B availability to corn in comparison to the fresh fly ash. Hot water soluble B in fly ash or FDG amended soil correlated very well with corn tissue B. Hot water soluble B in fly ash amended soil could be predicted based on soil pH and B solubility in ash at different pH values but not so in the case of FDG. Another greenhouse study was conducted to compare the influence of FDG and Ca(OH)₂ on B concentration in spinach (Spinacia oleracea L.) leaves grown in soil amended with the high B fly ash. The Ca(OH)₂ significantly decreased tissue B content, while FDG did not affect B uptake from fly ash amended soil.

1. Introduction

In many countries, coal combustion is the main source of energy. In 1984, coal combustion in the US generated about 62.6 million Mg of ash. Only a small proportion of this material is used in industry, the remainder being stored in lagoons and landfills. Recently, increased requirements for atmospheric protection have lead to the production of flue gas desulfurization gypsum (FDG) in electric power plants where SO₂ is removed from flue gas usually by reaction with lime slurries in scrubbers. Although desulfurization technologies are relatively new, 14.5 million Mg of flue gas desulfurization waste was produced in the US in 1984 as a result of coal combustion and the quantity is projected to reach 45.4 million Mg per year by the end of this century (Carlson and Adriano, 1993).

Much research has been conducted to evaluate the potential benefits and negative impacts of fly ash application on agricultural land. Depending on its composition, fly ash may correct Mo, Se, B, and S deficiencies (Plank and Martens, 1974; Elseewi et al., 1978; Gutenmann et al., 1979). Alkaline fly ashes can increase soil pH when applied at high rates (5–10%). Furthermore the water holding capacity of coarse texture soils can be improved with high rates of fly ash (Campbell et al., 1983). Laboratory incubation and weathering studies (Warren and Dudas, 1985) suggest that fly ash over time, could increase soil sorptive capacity. On the
other hand, investigations of the agricultural usefulness of FDG are more limited because of the more recent appearance of this material. Use of mined gypsum as a nutrient source and soil amendment has been common for many years in the Southeast of the United States and elsewhere (Sumner, 1993). Investigations have demonstrated its effectiveness in reducing clay dispersion and consequently improving water infiltration and movement through the soil (Miller et al., 1991). Furthermore, FDG may prove to be a source of B and Se in addition to Ca and S. It has also proved effective in ameliorating the soil acidity syndrome (Sumner et al., 1986). Often mixtures of fly ash and FDG are produced when utilities decide not to separate them or when the electrostatic precipitators fail to efficiently remove the fly ash from the gas stream. There are several factors limiting fly ash and FDG application to agricultural land. Boron (B) toxicity to plants is one of the most often reported (Elseewi et al., 1980; Walker and Dowdy, 1980; Aitken and Bell, 1985). The objective of the present investigation was to examine five fly ashes from the Southeast of the United States and one FDG from Illinois to establish acceptable rates of application which would safely supply B for plant growth in a Cecil soil. In addition, the influence of Ca from two different sources, FDG and calcium hydroxide, on B accumulation in plant tissue was investigated.

2. Materials and Methods

2.1. CHARACTERIZATION OF COAL COMBUSTION BY-PRODUCTS

Freshly precipitated fly ashes from Georgia and Alabama electric power plants (ashes A, C, D, E and F) and FDG from Illinois power plant were used in this experiment as a source of B. The effectiveness of weathering and leaching processes as a factor in decreasing B toxicity in fly ash was examined by comparing a sample of fresh fly ash A (high B) with the same material which had been stored under ponding conditions at the power plant and then transferred to a landfill (A_Lag). In addition, fresh fly ash A was leached under laboratory conditions (A_Art) by storage for three weeks in distilled water (1 kg fly ash:3 L water) then rinsing three times with distilled water and drying at 65 °C. Electrical conductivity (EC) and pH of all materials were measured after 24 hours equilibration (solid:water v/v 1:2.5). Boron, Ca, Mg, K and Na in all coal combustion by-products were determined by ICP after digestion of 2g representative samples in 20 mL of concentrated HNO₃ on a hot plate for 4 hrs. This procedure is assumed to determine the pool of elements which could be released to the environment under the most extreme conditions.

Boron release from fly ash and gypsum was studied at different final pH values of the extracting solution (hot 0.01 M CaCl₂) adjusted by addition of HNO₃ or NaOH. Hot water soluble B (hwsB) was determined according to the standard procedure used for soils (Bingham, 1982) by boiling fly ash in 0.01 M CaCl₂ in a ratio of 1:2 for 5 min. After boiling, the suspension was filtered, pH measured and