USE OF FLY ASH AS AN ALTERNATIVE LIMING SOURCE FOR IRRIGATED CORN PRODUCTION

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Abstract

Fly ash from the Gerald Gentleman Power Station in west central Nebraska can potentially serve as an alternative liming source without reducing corn grain yields. A study was conducted to assess the use of fly ash as an alternative liming source on three acid sandy soils of west central Nebraska where conventional liming sources can be uneconomical due to transportation costs. Corn grain yield, and soil pH change over time were assessed. Lime sources failed to raise the soil pH in the upper 8 inches or even the upper 2 inches of the soil to the target pH of 6.5 for all soils studied. Fly ash and agriculture lime treatments did not significantly increase corn grain yields compared to the control. This was potentially a result of a lack of sufficient fly ash or agricultural lime additions, or the soluble Al was not high enough to reduce grain yields in these soils. The fly ash utilized in this study increased soil pH just as well as agricultural lime and is an appropriate alternative for agricultural lime.

Introduction

Decreased crop yields and potential profitability from acidic soils is a concern that has generated considerable attention as seen by the vast research related to the subject in the past. The negative effects of soil acidity on plant productivity include, Al and/or Mn toxicity, H ion toxicity, decreases in essential nutrient (Mg, Ca, K, P, and Mo) concentrations, and conditions related to inhibition of root growth (Marschner, 1995). Approximately 25-30% of worlds' soils are acidic (Havlin et al., 1999).

In agroecosystems, soil acidity is mainly attributed to the nitrification processes (Heylar, 1976) and is enhanced by leaching of basic ions and conjugate bases such as nitrate ions (Patriquin et al., 1993). The incomplete return of neutralizing anions when nitrate is taken up by plants contributes to soil acidification (Barak et al., 1997). To ameliorate the negative effects of acidification, materials such as calcium oxide, calcium hydroxide, calcium and magnesium carbonates, marl, blast-furnace slag (by-product from steel production), fly ash (by-product from coal combustion), wastewater treatment sludge, and sugar lime are periodically applied to acid soils to increase soil pH (Havlin et al., 1999). In areas were conventional agricultural liming materials are unavailable or costs are increased due to transportation costs, local alternative liming sources may serve as a valuable asset for producers with acidic soils.

In west-central Nebraska, many acres of sandy soils have become acidic over time due to a low pH buffering capacity and yearly application of anhydrous ammonia applications on irrigated corn. Sources of conventional agricultural lime are located in eastern Nebraska. Transportation of these materials increases the costs of application. Because of this logistical problem, fly ash produced as a by-product of coal combustion from the Nebraska Public Power District's Gerald

Gentleman Power Station located in Sutherland, Nebraska can be more cost effective for farmers. However, there are concerns expressed by potential agricultural users due primarily to additions of B and Al to soils. These concerns are derived from past research, which have shown that elements such as B in fly ash can negatively affect plant growth (Adriano et al., 1980). However, it is important to point out that the positive and negative fly ash characteristics that affect crop growth are influenced by a variety of factors. These including the composition of the parent coal, coal combustion conditions, efficiency of collection and/or filtration devices, storage and handling procedures, and climate. This variability requires site-specific evaluation of fly ash sources as agricultural amendments.

The objective of this study was to assess the agronomic usability of fly ash obtained from the Gentlemen Station as an alternative liming source for corn production in west central Nebraska.

Material and Methods

This study was established over a two-year period on five different soil types. In 1997 three sites were established and in 1998 two more sites were established. Three of the sites will be presented in this paper. These sites include the Anselmo (coarse-loamy, mixed, superactive, mesic Typic Haplustoll), Hord (fine-silty, mixed, mesic Cumulic Haplustoll), and Valentine (mixed, mesic Typic Ustipsamment) series. Various liming treatments-agricultural lime, beet lime (by-product of sugar beet processing), dry fly ash and a screened sample of the "water-added" fly ash material were applied at rates between 0.5 and 1.5 times the recommended liming rate based on soil tests in plots on farmers fields representing three sandy soils in a complete randomized block design with five replications. General properties of the liming materials are given in Table 2. Lime rates were calculated based on a target pH of 6.5 as determined by Woodruff buffer (Woodruff, 1967). Agricultural lime and fly ash were applied in the spring 1997 on the Hord and Anselmo soil sites, and agricultural lime, fly ash, and beet lime were applied in spring of 1998 on the Valentine soil site (Table 1). Plots were sampled at 2-inch increments to a depth of 8 inches prior to lime applications and in the spring of 1999 and 2002. Soil samples were analyzed for pH using a 1:1 soil: water volume ratio. In the fall of each year corn grain yields were determined for each treatment.

ANOVA was utilized to test grain yield and average 0 to 8 inch soil pH differences for lime treatment, year, and lime treatment/year interaction main effects. Duncan's Multiple-Range Test was utilized for mean separation of significant main effects. Significance was assessed at the 0.05 level. Soil pH at depth interval data trends are also presented.

Results

Lime treatments had no significant effect on corn grain yields on both the Anselmo and Hord soils compared to the controls (Figure 1). The Valentine soil yields are not presented due to highly variable yields as a result of hail damage. Lime recommendations were based on a target pH of 6.5 determined by the Woodruff buffer. However, there was no treatment that increased soil pH to that level for the surface 8 inches (Figure 2) or at 2-inch increments to 8 inches (Figure 3). A lack of significant grain yield increases from lime applications may be attributed to a lack of pH increase after lime application and constant subsoil acidity (Figure 3). Lime recommendations potentially need to be examined for applicability in these soil types. Chemical analysis indicates that B and Al additions in fly ash are not significant enough to negatively affect crop growth and grain yield. An 8,000 lb/acre application of fly ash would apply only 3.2 lbs of B/acre. The analysis indicates that the fly ash used in this study is suitable as a soil amendment and will not negatively affect plant growth.

Effects of agricultural lime and dry fly ash down to a depth of at least 6 in are seen for all soils. All lime treatments showed trends of increasing soil pH from soil samples after lime application on all three soils with some being statistically significant (Figure 2). The 2002 soil sample pH showed differing trends for the three soils. The Hord soil pH stabilized to levels similar to the 1999 levels while the pH levels continued to increased for the Anselmo soil. The Valentine soil pH levels in 2002 showed trends of decrease toward pre-lime application levels. The higher fraction of sand and lower pH buffering capacity in the Valentine soil likely contributed to this decrease. Soil pH levels at depth intervals of 2 inches show stratification of pH to a depth of 8 inches (Figure 3). Stratification is most noticeable on the Hord and Valentine soils. Tillage and N fertilizer management of producers is most likely the cause.

Preliminary Conclusions

Results from this study show that fly ash from the Gerald Gentleman Power Station is an acceptable alternative liming source. The lack of corn grain yield response from added lime sources is potentially a result of one of two issues: 1) Lack of sufficient lime additions to raise the soil pH to a level in which a response would have been seen. 2) Soluble Al concentrations in these acid sandy soils were not sufficiently high to reduce yields. Further research is needed to assess if lime additions are needed on these types of soils.

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Table 1. Description of soil sites and lime treatments.

Site	Lime Treatment	Amount Added per Acre (lbs)	Fraction of Recommended Lime Requirement
Anselmo Fine Sandy Loam	Control	0	0
	Agricultural Lime	4,000	1.0
	Dry Fly Ash	8,000	1.4
	Wet Fly Ash	8,000	1.2
Hord Fine Sandy Loam	Control	0	0
	Agricultural Lime	4,000	1.0
	Dry Fly Ash	8,000	1.4
	Wet Fly Ash	8,000	1.2
Valentine Fine Sand	Control	0	0
	Agricultural Lime	5,000	1.0
	Beet Lime	5,500	1.0
	Dry Fly Ash	6,400	0.9
	Dry Fly Ash	9,600	1.3

Table 2. Selected constituent content in fly ash from the Gerald Gentleman Power Station.

Constituent	**Content**
Boron	400 mg/kg
Calcium	18.8%
Copper	213 mg/kg
Iron	3.7%
Magnesium	3.0%
Manganese	252 mg/kg
Phosphorus	0.16%
Potassium	0.18%
Sulfur	1.14%
Zinc	100 mg/kg
Aluminum	7.95%
Arsenic	7.5 mg/kg
Cadmium	0
Cobalt	11.9 mg/kg
Chromium	12.1 mg/kg

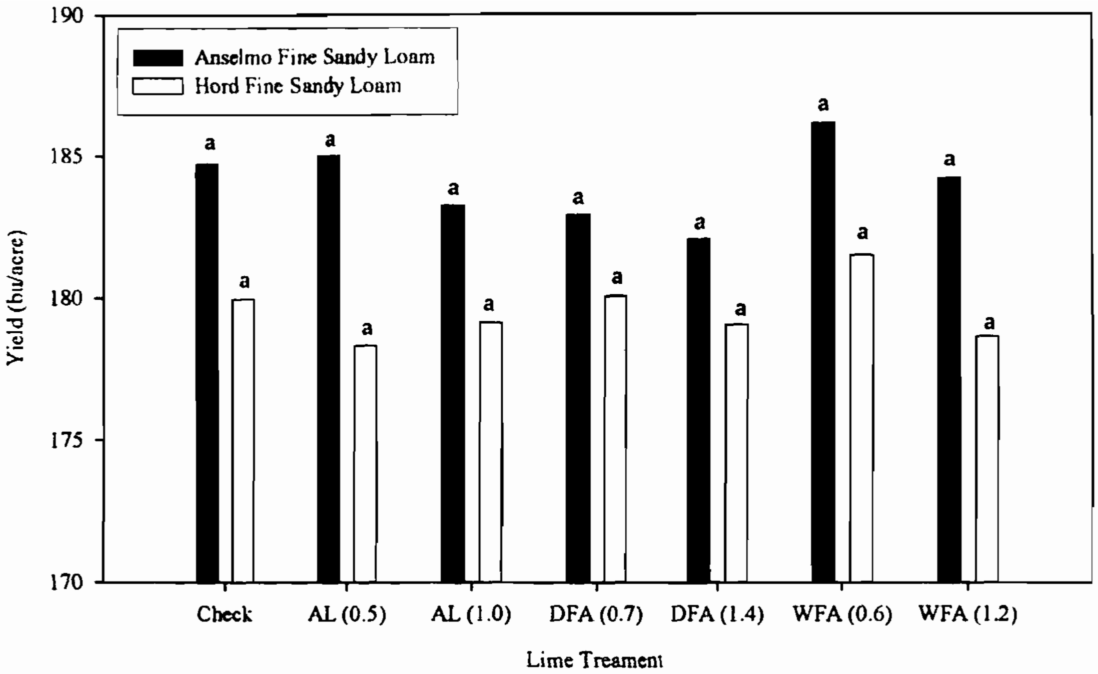

Figure 1. Five year average corn grain yield averages for all lime treatments (AL-agricultural lime; DFA-dry fly ash; WFA-wet fly ash) on an Anselmo soil and Hord soil (fine sandy loam). The number in parentheses corresponding to each lime treatment, is the fraction of the recommended lime requirement to reach a target pH of 6.5 based on the Woodruff buffer method. Columns with the same letter are not significantly different within each soil.

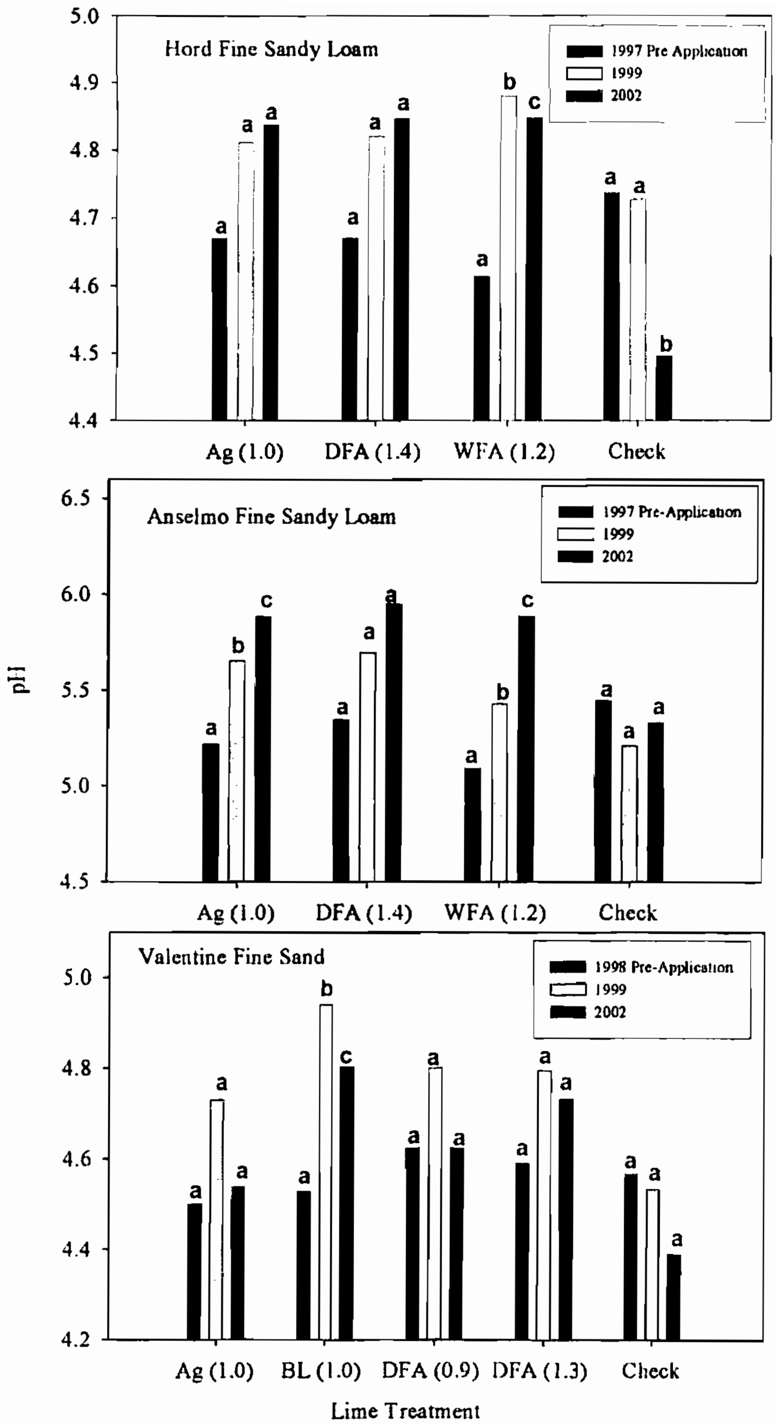

Figure 2. Average pH in upper 8 inches of soil profile for selected lime treatments (AL-agricultural lime; DFA-dry fly ash; WFA-wet fly ash; BL-Beet lime) and soils over time. The number in parentheses corresponding to each lime treatment, is the fraction of the recommended lime requirement to reach a target pH of 6.5 based on the Woodruff buffer method. Columns with the same letter are not significant within each treatment.

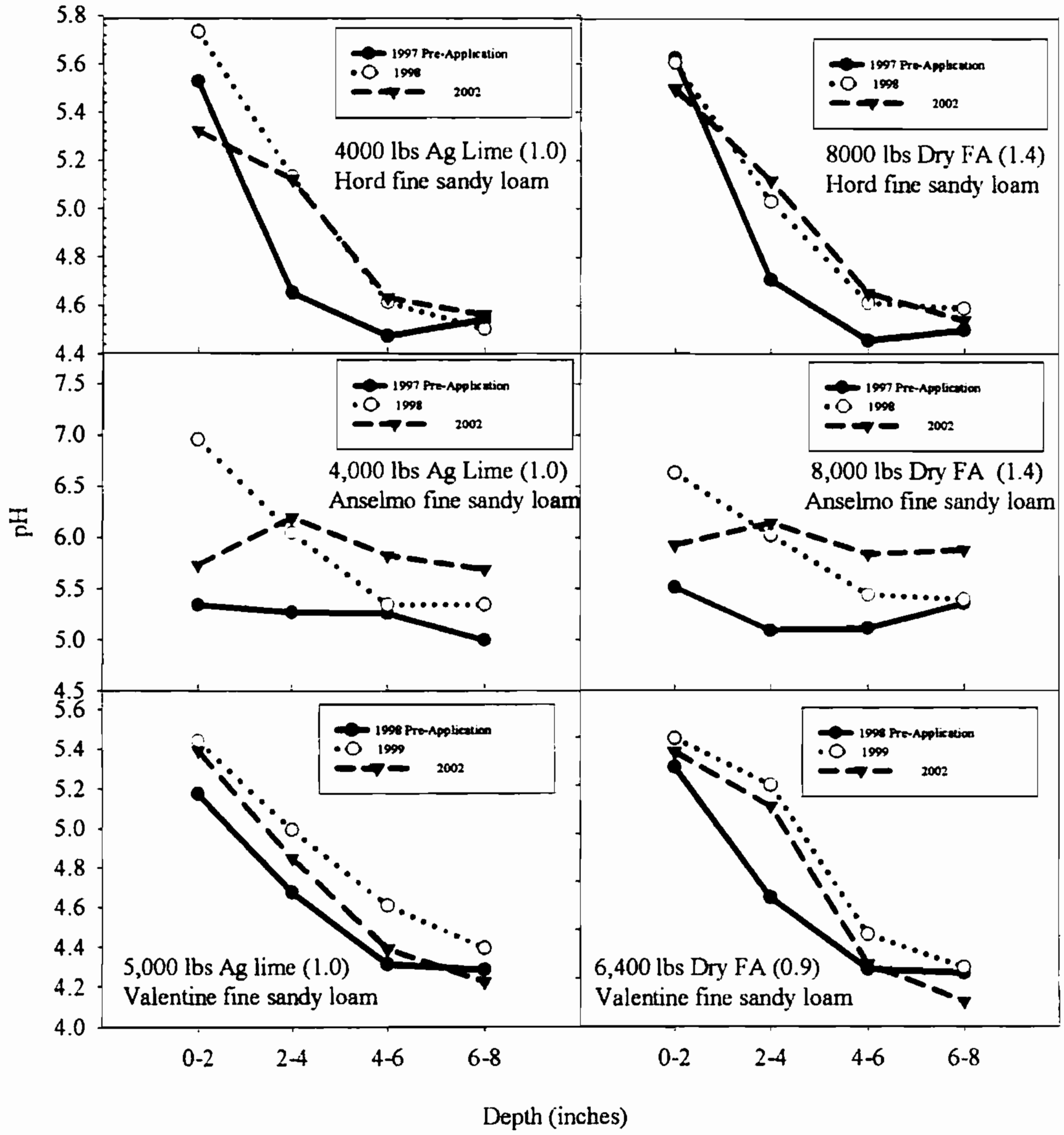

Figure 3. pH versus sample depth trends for selected lime treatments and soils over time. The number in parentheses corresponding to each lime treatment, is the fraction of the recommended lime requirement to reach a target pH of 6.5 based on the Woodruff buffer method.

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