Effects of FGD-Gypsum, Used-Wallboard and Calcium Sulfate on Corn and Soybean Root Growth

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INTRODUCTION

Gypsum produced as a byproduct of flue gas desulfurization (FGD-gypsum) in electric power plants increased 44% from 2007 to 2008 [1]. In 2009, 18 million Mg of FGD were produced; however, only about 8 million Mg were beneficially used [1]. The major use of FGD-gypsum today is production of gypsum wallboard products. Reduction in building construction, however, has reduced the demand for gypsum wallboard.

In 2009, only 282 thousand Mg of FGD-gypsum was used in agriculture to improve soil physical and chemical properties [2]. There is a potential for agriculture to become the second largest user of FGD-gypsum, which will reduce the strain on landfill capacity. FGD-gypsum has been shown to be effective as calcium and sulfur fertilizer and as a neutralizing agent for sodic soils [3]. Gypsum can be recycled from used wallboard, which could be used for agriculture thereby reducing landfill volume. It has been reported that the addition gypsum and calcium sulfate affected soybean root growth[4]. Therefore, the objective of this study was to determine the effects of FGD-gypsum, used-wallboard and reagent-grade calcium sulfate on the root length of corn and soybean grown in sand media.

Materials and Methods

Used-wallboard gypsum and FGD gypsum for this study were provided by Dr. Ron Chamberlain from the company, earth ANEW (Indianapolis, IN). As a control, reagent-grade calcium sulfate was obtained from Fisher Scientific (Pittsburgh, PA). All materials were ground to pass through 200 mesh screen. The pH values of the byproducts were measured in a 1:2 (byproduct: water) slurry using a combined electrode; electrical conductivity was determined using an Orion conductivity meter; and organic carbon and sulfur were determined with an Elementar CS analyzer Mt. Laurel, NJ (Table 1). Chemical constituent of byproducts were determined using a hot nitric acid method[5]. Calcium, Mg, K, P, Mn, Cu, Pb and Zn concentrations in byproducts solution were determined using an Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES).
Six hundred grams of Ottawa sand were placed into 0.5-liter plastic cups without drainage holes. The FGD-gypsum, used-wallboard gypsum and calcium sulfate were each mixed with the sand at the rate of 0, 0.075, 0.15 and 0.30 g/600 g sand which represents field applications of 0, 280, 560 and 1120 kg ha^{-1}, respectively. There were 3 treatments x 4 rates x 2 crops x 3 replications.

Either four corn (*Zea mays*) seeds or 4 soybean (*Glycine max*) seeds were planted in each cup. Immediately after germination, plants were thinned to two per cup. After 14 days, plants were removed from the sand, placed in zip lock plastic bags, and refrigerated. Total root length was determined using a Win Rhizo instrument Ottawa Canada. Analysis of variance (ANOVA), included in SAS Windows Version[6] was used to determine significant differences among treatment results. Separation of means was with Duncan's Multiple Range Test[7].

RESULTS AND DISCUSSION

The chemical characteristics of the FGD-gypsum and recycled wallboard gypsum are presented in Table 1. The pH and electrical conductivity values were similar for the two gypsum byproducts. The pH of calcium sulfate was slightly lower than those the byproducts, and the electrical conductivity was higher. Aluminum, Mg, P, K and Zn concentrations were higher in used-wallboard, while iron and manganese concentrations were higher in the FGD-gypsum. Total calcium, copper and lead concentrations were similar for the two byproducts (Table 1). With the exception of calcium, sulfur and magnesium, macro and microelements concentrations in the calcium sulfate were lower than those of the byproducts. In all cases, elemental composition of the sand was lower than that of byproducts and calcium sulfate treatments.

Table 1: Hot nitric acid extractable nutrients and metals from gypsum byproducts and reagent-grade calcium sulfate

Byproduct Properties	Wallboard gypsum	FGD gypsum	Calcium sulfate	Sand control
pH	7.93	7.95	7.44	5.93
EC ms/cm	2.26	2.25	5.55	0.01
S (%)	14.6	14.5	19.7	<0.01
Ca (%)	17.8	17.2	19.6	6.74
Al ($mg\ kg^{-1}$)	505	332	142.7	5.29
Cu ($mg\ kg^{-1}$)	4.82	4.88	3.87	0.19
Fe ($mg\ kg^{-1}$)	841	1087	50.8	37.5
K ($mg\ kg^{-1}$)	190	80.2	36.6	1.08
Mg ($mg\ kg^{-1}$)	6975	1758	1634	4.31
Mn ($mg\ kg^{-1}$)	15.9	45.4	17.9	<0.01
P ($mg\ kg^{-1}$)	68.1	12.5	<0.01	<0.01
Pb ($mg\ kg^{-1}$)	1.76	1.57	11.00	<0.01
Zn ($mg\ kg^{-1}$)	5.65	2.63	0.02	0.04

Corn grown on the byproducts and calcium sulfate amended sand had a larger number of fine roots than the sand (Figure 1). The higher nutrients of the amended sand may have enhanced fine root growth.

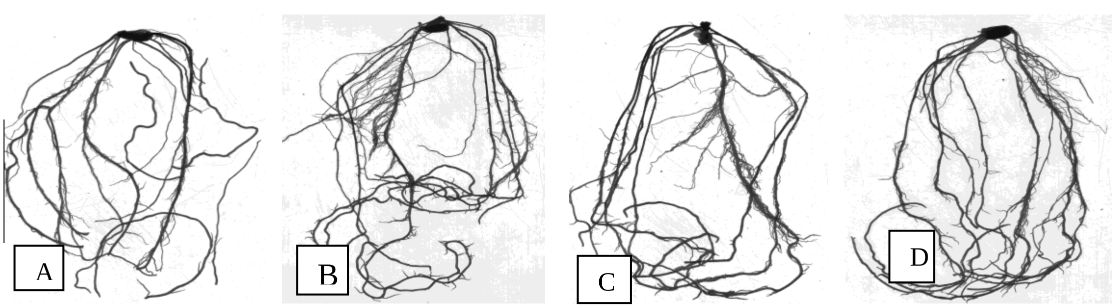

Figure 1: One corn root system grown in sand (A), low rates of FGD-gypsum (B), used-wallboard (C) and calcium sulfate (D)

Soybean grown on the calcium sulfate treatments had fewer fine roots than those grown in the control and byproduct amendments (Figure 2).

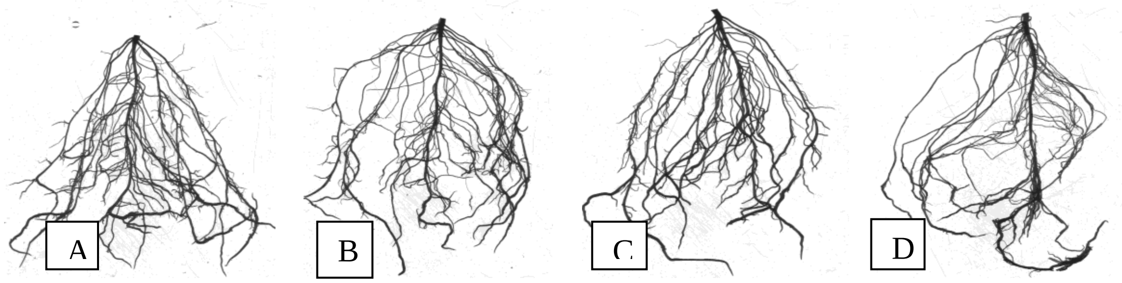

Figure 2: One soybean root system grown in sand (A) low rate of FGD-gypsum (B), used-wallboard (C) and calcium sulfate (D)

Averaged over treatments, total lengths of corn root were greater than those of the control grown in sand (Figure 3), which was the result of the added nutrients from the amendments (Table 1). Total root length of corn plants grown on the calcium sulfate treatments were greater than those grown on the FGD-gypsum and used-wallboard treatments. There was no significant difference in corn root length between the two byproduct treatments (Figure 3). This similarity in total root length was also reflected in the nutrient concentration of the two byproducts (Table 1).

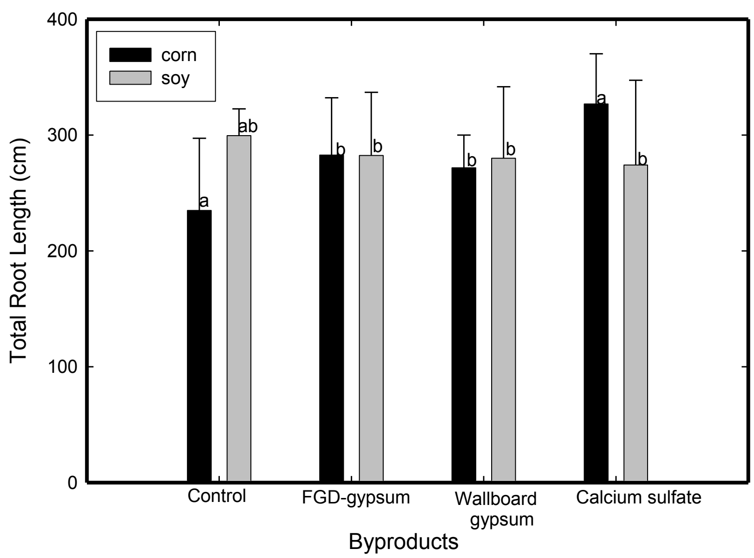

Figure 3: Effects of FGD-gypsum, used wallboard and calcium sulfate on corn and soybean root length averaged over application rates. Means plus standard deviation n=3. Values within crop column having letter in common are not different at p<0.05 level.

Soybean grown in sand had longer roots than those grown in the three treatments (Figure 3). The difference, however, was not significant.

At all rates of calcium sulfate, corn root lengths were higher than those of the byproducts treatments (Figure 4). This may due to the higher calcium and low aluminum in this compound compared to the byproducts (Table 1). Increasing byproduct application rate did not significantly change total corn root length (Figure 4). However, corn root length was slightly reduced when FGD and calcium sulfate treatments rates were doubled. The small difference in corn root length with increasing byproduct rates indicates that these materials had little toxic effects on these roots.

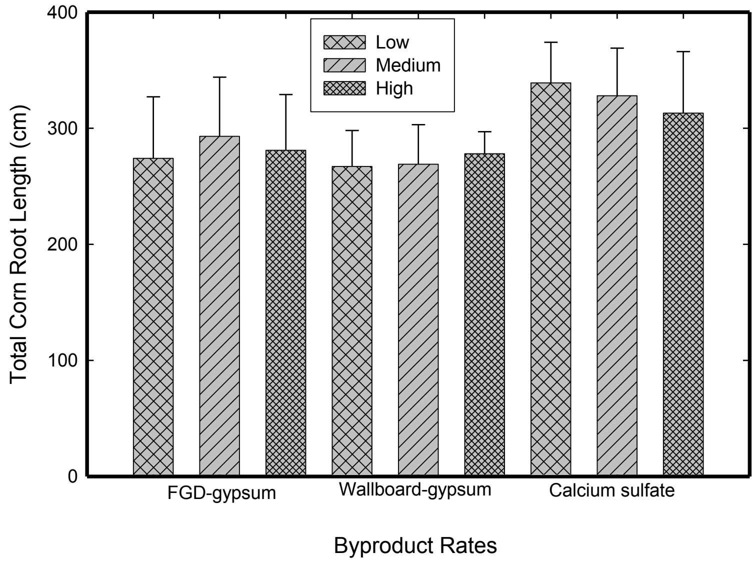

Figure 4: Effects of application rates of FGD-gypsum, used wallboard and calcium sulfate on corn root length. Means plus standard deviation n=3.

Soybean root length gradually reduced with increasing treatment application rates of the byproducts (Figure 5). Soybean root lengths were similar for the low and medium rates of calcium sulfate.

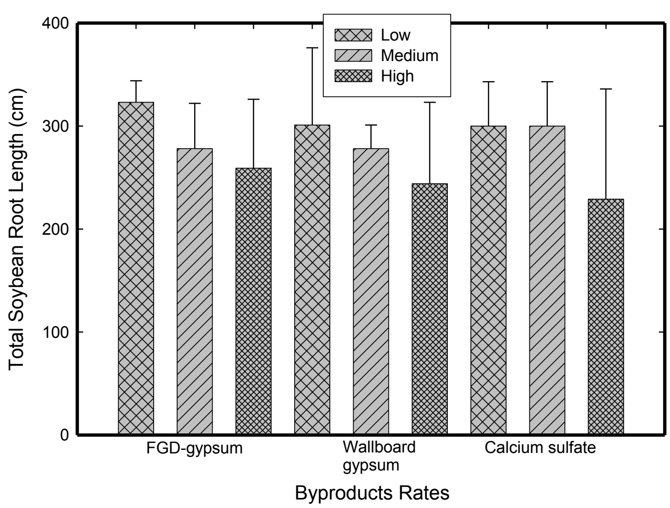

Figure 5: Effects application rates of FGD-gypsum, used wallboard and calcium sulfate on soybean root length. Means plus standard deviation n=3.

Only at the highest application rate of calcium sulfate treatment was there a reduction in root Soybean was more sensitive to these amendments than corn.

CONCLUSIONS

Corn root length for plants grown on FGD was not different from that of used-wallboard treatment. Byproducts enhanced corn root growth but not that of soybean. Soybean was more sensitive to the materials than corn; therefore one should take into account the crop to which these materials will be applied. The reduction observed in soybean root length with increasing byproduct application rate may not occur if these materials are applied to soil which has higher buffering capacity than sand. Also in this study cups were not allowed to drain compared to field condition where drainage will occur. Further studies are needed in soil media with longer growth period to determine the effects of these materials on root growth.

REFERENCES

[1] Goss, D. Coal Combustion Products beneficial use shows steady growth. *In* Ash at work Issue 1. American Coal Ash Association. 2010a, p. 14-17.

[2] Goss, D. Usage declines may signal beginning of troubling trend. *In* Ash at work Issue 2. American Coal Ash Association. 2010b, p. 14-17.

[3] Norton, D. Increased awareness of no-tillage farmers of the benefits of applying gypsum to their soils. Workshop on agricultural use of FGD gypsum. 2009.

[4] Shumway, R. H., Bigger, J. W., Morkos, F., Bazza, M., and Nielsen, D. R. Alleviation of aluminum toxicity to soybean by phosphogypsum or calcium sulfate in dilute nutrient solution. Soil Sci. 1998, 147, p. 286-298.

[5] US EPA. Hot nitric acid digestion Method 3052 for hot plate. www2.shimadzu.com/applications/icp/Shimadzu_ICPE_Soil.pdf: 1996. Verified February, 2011

[6] SAS Institute. The SAS system for windows. Release 9.1. Cary, NC, SAS Inst. 2003.

[7] Steel, R. G. D. and Torrie, J. H. Duncan's new multiple range test. *In Principle and Procedures of Statistics*. McGraw-Hill, New York, 1980, p. 187-188.