Effect of Sugar Beet By-Products on the Solubility and Availability of Ferrous Sulfate in Soil

R. Jay Goos, Brian E. Johnson, Ryan A. Peterson, and Nathalie Kobes

Department of Soil Science, North Dakota State University, Fargo, ND 58105
rj_goos@ndsu.nodak.edu

Previous Research and Objective

Iron (Fe) deficiency chlorosis is common when soybeans are grown on alkaline soil. Fertilization options are limited, due to the high expense of chelates, low residual solubility of inorganic sources, and inconsistent or short-lived effects of foliar sprays. Currently, variety selection is the most practical control measure (Goos and Johnson, 2000). An inexpensive and effective fertilization option would be welcomed.

Previous research in Texas (Mostaghimi and Matocha, 1988; Matocha, 1984; Matocha and Pendelton, 1982) investigated a unique concept termed "plant complexed Fe." They showed that ferrous sulfate, when sprayed on crop or weed residues, and tilled into the soil, partially alleviated iron deficiency chlorosis of sorghum. Sugar beet by-products may have potential for such a use. Previous research in Germany (Bipp et al., 1998; Fischer et al., 1998; Leidmann et al., 1995) utilized chemically-altered sugar beet by-products to remove heavy metals from contaminated soils or fly ash. Carbohydrate-rich agricultural by-products, such as sugar beet molasses or waste sweet potatoes, have been used to manufacture glucoheptonate-based micronutrient fertilizers, including Fe-glucoheptonate (Clemens, 1990; Whitehurst and Clemens, 1984; Whitehurst et al., 1989). Four laboratory experiments and a field study were conducted, with the objective of determining if application of ferrous sulfate with sugar beet by-products would improve iron (Fe) solubility and availability in alkaline soils.

Experiment 1

All experimental methods are described in detail in a companion journal article (Goos, et al., 200x). In short, the laboratory experiments were incubations with 40 g of an alkaline Ulen soil from near Leonard, ND. Iron solubility was determined by the DTPA method of Lindsay and Norvell (1978), which is the standard Fe soil test in this region. Experiment 1 was a preliminary trial, performed to confirm the findings of Matocha and co-workers. The Ulen soil was treated with three different plant materials (alfalfa, pigweed, soybean meal), both with and without ferrous sulfate. Pigweed was included because this material was effective at increasing Fe availability in Matocha's studies.

The results of Experiment 1 are shown in Table 1. When applied without ferrous sulfate, none of the plant materials increased Fe solubility above the control. However, when applied with ferrous sulfate, the plant materials increased Fe solubility substantially over ferrous sulfate alone. The effect of plant material on Fe solubility appeared to be fairly long-lived, persisting to four weeks of incubation. All plant materials also increased DTPA-extractable manganese (Mn) in soil (data not shown, see Goos et al., 200x). Experiment 1 confirmed the studies of Matocha and associates in Texas. Subsequent experiments were designed to evaluate sugar beet by-products for this effect.

Experiment 2

This experiment was conducted in the same way as Experiment 1, except that a lower Fe rate and different plant materials were evaluated. The results are shown in Table 2. In general, all plant materials increased the solubility of Fe from ferrous sulfate, compared to ferrous sulfate applied alone. Application of ferrous sulfate plus sugar beet molasses gave the highest overall Fe levels. For example, after two weeks of incubation, there were 4.2 mg Fe/kg extracted from the control, 8.7 mg/kg extracted where ferrous sulfate alone was applied, but 20.8-27.4 mg Fe/kg where ferrous sulfate was applied with beet molasses.

Experiment 3

This experiment was performed to determine if the effect of plant material on Fe solubility was increased or decreased by inclusion of ammonium sulfate. Ammonium sulfate addition with wheat straw or beet molasses should stimulate microbial growth, by providing a nitrogen source to assist in decomposition. The results are shown in Table 3. In the absence of ferrous sulfate, straw tended to decrease Fe solubility compared to the control. Molasses had no effect on Fe solubility in the absence of ferrous sulfate. With ferrous sulfate, however, both straw and molasses increased Fe solubility. Molasses was superior to straw, even though it was applied at half the rate of the straw. Ammonium sulfate had no effect on Fe solubility, with or without ferrous sulfate or plant material.

Experiment 4

This experiment was performed to compare two different types of molasses, and method of application. Regular molasses was compared to spent molasses (also called desugarized molasses or raffinate). Spent molasses has little commercial value. The materials were applied as a spot application and also mixed with the soil. The results are shown in Table 4. In the absence of molasses or spent molasses, Fe solubility from ferrous sulfate was better with mixed application than spot application. This is possibly because the Fe had more opportunity to react with soil humus with a mixed application. Both molasses and spent molasses increased Fe solubility in the DTPA extracts, compared to ferrous sulfate alone. Even though it has a lower sugar content, the spent molasses was at least equal to regular molasses in increasing Fe solubility. This suggests a possible new use for spent molasses, to make fertilizer solutions with ferrous sulfate. Further studies are needed.

Field Studies

Three treatments were applied at five sites in October 1999. The treatments were a control, 40 lb/A of ferrous sulfate monohydrate (12 lb Fe/A), and 40 lb/A of ferrous sulfate plus 250 lb/A of beet molasses. The treatments were dissolved in water, and sprayed on untilled crop residues, allowed to dry for 1-2 days, and tilled in. At the Galesburg site, the crop residues were corn stalks, which were incorporated by moldboard plowing. Crop residues were wheat straw at all other sites, and the treatments were rototilled in. Soil samples were taken in November, 1999, and May 2000, and analyzed for DTPA-extractable Fe. The spring soil samples were also used to grow 'Glacier' soybeans in the greenhouse. The sites were planted to 'Glacier' soybean in late

May. Two chlorosis ratings (2-3 trifoliolate and 5-6 trifoliolate) and seed yields were determined.

The effect of ferrous sulfate and beet molasses on DTPA-extractable Fe at four field sites is shown in Table 5. The Galesburg site was not sampled, because the treatments were plowed, not mixed with the topsoil. With fall sampling, Fe solubility at all sites was increased with ferrous sulfate treatment, and the highest Fe levels found when ferrous sulfate was applied with molasses. Averaged across site, there were 7.6 mg/kg of extractable Fe in the control, 8.5 mg/kg with ferrous sulfate alone, and 9.5 mg/kg with ferrous sulfate plus molasses. The same trends were observed with the spring samplings. The data were erratic at the Argusville site, but at the other three sites the data were very similar to the fall samplings. Ignoring the Argusville site, the extractable Fe was 4.3 mg/kg with the control, 5.2 mg/kg with ferrous sulfate, and 6.2 mg/kg with ferrous sulfate plus molasses.

The spring soil samples were taken to the greenhouse, mixed in equal parts with sand, and grown at 15 and 20% water content, to induce differing amounts of chlorosis. The chlorophyll contents of the first and second trifoliolate leaves are shown in Table 6. There was no effect on treatment on leaf chlorophyll with soil from the Argusville and Casselton sites. With soil from the Arthur site, the chlorophyll tended to be increased by ferrous sulfate treatment with the higher water level. With soil from the Ayr site, application of ferrous sulfate, with or without molasses, increased the greenness of the leaves (reduced chlorosis).

Field estimates of chlorosis are shown in Table 7. The Arthur site was lost due to standing water after heavy June rains. There was no significant effect of treatment at any site. At the Ayr site, the control plots were more yellow in two of the three replicates, but the difference didn't reach statistical significance. This trend was evident both at the 2-3 and 5-6 trifoliolate stages. The effect of the field treatments on seed yield is shown in Table 8. No significant effects on yield were observed, although yields tended to be higher with fall ferrous sulfate treatment at three of four sites.

Conclusions

Application of ferrous sulfate with molasses and spent molasses increased Fe solubility in a calcareous Ulen soil. Spraying wheat stubble in the fall with ferrous sulfate, or ferrous sulfate with molasses, increased Fe solubility at four field sites. Chlorosis in soybean was somewhat reduced at one site of four, but the effect was not strong, possibly due to the long interval between application (October) and appearance of chlorosis (June). Perhaps a better crop response to ferrous sulfate plus molasses or spent molasses would be obtained with applications made at planting time. Given the widespread nature of Fe chlorosis of soybeans, and the large quantities of spent molasses available with little commercial value, this idea deserves another try, particularly with applications made at seeding time, perhaps as a band with or near the seed.

Literature Cited

Bipp, H.P., P. Wunsch, K. Fischer, D. Bieniek, and A. Kettrup. 1998. Heavy metal leaching of fly ash from waste incineration with gluconic acid and a molasses hydrolysate. Chemosphere 36:2523-2533.

Clemens, D.F., B.M. Whitehurst, and G.B. Whitehurst. 1990. Chelates in agriculture. Fertil. Res. 25:127-131.

Fischer, K., H.P. Bipp, P. Riemschneider, P. Leidmann, D. Bieniek, and A. Kettrup. 1998. Utilization of biomass residues for the remediation of metal-polluted soils. Environ. Sci. Technol. 32:2154-2161.

Goos, R.J. and B.E. Johnson. 2000. A comparison of three methods of reducing the severity of iron deficiency chlorosis in soybean. Agron. J. 92:1135-1139.

Goos, R.J., B.E. Johnson, R.A. Peterson, and N. Kobes. 200x. Effect of sugar beet by-products on the solubliltiy and availability of ferrous sulfate in soil. J. Sugar Beet Res. (in review).

Liedmann, P., K. Fischer, D. Bieniek, and A. Kettrup. 1995. Chemical characterization of silage effluents and their influence on soil bound heavy metals. Intern. J. Environ. Anal. Chem. 59:303-316.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Matocha, J.E. 1984. Grain sorghum response to plant residue-recycled iron and other iron sources. J. Plant Nutr. 7:259-270.

Matocha, J.E. and D. Pennington. 1982. Effects of plant iron recycling on iron chlorosis of grain sorghum grown on calcareous soils. J. Plant Nutr. 5:869-882.

Mostaghimi, S. and J.E. Matocha. 1988. Effects of normal and Fe-treated organic matter on Fe chlorosis and yields of grain sorghum. Comm. Soil Sci. Plant Anal. 19:1415-1428.

Whitehurst, B.M. and D.F. Clemens. 1984. Production of alkali metal glucoheptonate from sweet potatoes. U.S. patent 4,444,794.

Whitehurst, B.M., G.B. Whitehurst, and D.F. Clemens. 1989. Process for making compounds containing chelated metal ions and resultant products which are useful for agricultural, industrial, environmental and construction purposes. U.S. patent 4,888,421.