THE EFFECT OF LOW RATES OF COMMERCIAL HUMIC ACID ON P AVAILABILITY AND SPRING WHEAT YIELD

C.A. Jones, J.S. Jacobsen, and A. Mugaas
Department of Land Resources and Environmental Sciences
Montana State University, Bozeman, Montana
clainj@montana.edu, (406) 994-6076

ABSTRACT

Humic acid (HA), a soluble fraction of humus, has been found to increase crop yields under certain conditions, possibly due to increased nutrient availability. A study was conducted to determine the effects of low rates of commercial HA on P availability and spring wheat yields in both a calcareous soil and non-calcareous soil. In Phase I, soluble P concentrations were monitored at 0.75, 1.5, and 2.25 in. from a MAP band that had either been coated with 1.5 lb HA/ac or left uncoated. In Phase II, P uptake and grain yield of spring wheat were measured in soils that had been fertilized with 15 or 50 lb P_2O_5/ac, again either coated with HA or left uncoated. Only one significant difference (P=0.05) was found in soluble P concentrations between HA and control treatments at time points ranging from 4 to 48 d after fertilization. In addition, no significant differences were found in grain yield or P uptake between HA and control treatments for either soil. The findings suggest that HA applied at 1.5 lb/ac had no substantial effect on P availability or spring wheat yield in either soil.

INTRODUCTION

Humic substances in organic matter are known to improve crop health when present in high enough quantities. Therefore, some researchers have studied the effect of adding these substances, such as fulvic and humic acids (HA), to soil to improve crop yield. For example, HA applied at rates of 100-600 lb/ac was found to significantly increase root and shoot biomass in corn, with rates of 100-200 lb/ac resulting in the highest growth responses (Sharif et al., 2002). Significant yield increases from high rates of HA have also been observed in sweet potato (Crawford et al., 1968). Causes of these types of growth responses include increases in water holding capacity, nutrient availability, or microbial growth and, hence, increased rates of organic matter mineralization (Sharif et al., 2002). However, the cost of commercially available HA ($1-$10/lb) makes high rates of application uneconomical for production of many crops in the Northern Great Plains. Therefore, more recent research has focused on the efficacy of applying low rates of HA (0.75–3 lb/ac) with fertilizer. Specifically, a 3 year study in Idaho found 5% higher potato yields and 20% more tubers greater than 10 oz. when HA was applied at 0.8 – 1.6 lb/ac (as a liquid) with 10-34-0 than when only the fertilizer was applied, although the differences were not consistently significant (Hopkins and Stark, 2003). Petiole P concentrations were 6-20% higher in the HA treatments compared to the controls, suggesting the growth increase was due to increased P availability. This result is consistent with the finding that HA decreases rates of calcium phosphate precipitation (Grossl and Inskeep, 1992). However, it is unknown if HA increases yields of small grains that require substantially less P than potatoes. Therefore, a study was undertaken to assess the effects of HA on P fertilizer solubility, P

availability, and spring wheat yield in both calcareous and non-calcareous soils. It was hypothesized that because HA decreases calcium phosphate precipitation rates, that HA should have a larger effect on P solubility and plant growth in calcareous than in non-calcareous soils.

MATERIALS AND METHODS

A calcareous silty clay loam (fine-silty, mixed, superactive, frigid Typic Haplustoll) was collected from the Montana State University Arthur Post Farm and a non-calcareous sandy loam (fine-loamy, mixed, superactive, frigid Calcidic Argiustoll) collected from Red Bluff Experiment Station. Roots and large stones were excluded from both prior to homogenizing and analyzing. Soil water content at field capacity was estimated by measuring water retention with a pressure plate at -1/3 bar. Olsen P concentrations were below the critical level of 16 ppm in both soils and soil test Zn concentrations were below the critical level of 0.5 ppm in the calcareous soil (Table 1). Soluble HA was obtained from both Luscar Ltd. Specialty Products Division (Dry Soluble 80) and Horizon Ag-Products (Quantum Spray Dry). The use of these products does not indicate support by MSU; the products were only selected as examples of commercially available humic materials. Each HA was coated onto an aliquot of granular MAP (< 2 mm in diameter) at a concentration needed to supply an equivalent rate of 1.5 lb HA/ac by adding each to a plastic bag and shaking until the coating was visually complete.

Table 1. Soil characteristics.

Soil test	Calcareous	Non-Calcareous
Olsen P (ppm)	9.1	10.8
Exch. K (ppm)	282	370
NO_3-N (ppm)	0.9	10.2
DTPA-TEA Zn (ppm)	0.26	0.96
pH	8.5	6.9
O.M. (%)	1.7	3.1
$CaCO_3$ (%)	12.0	<0.1
Water content at -1/3 bar (g H_2O/g soil)	0.256	0.165

Phase I

The goal of Phase I was to determine the effect of HA on soluble P concentrations in the vicinity of a MAP band. Polypropylene bins (15"x10"x5") were fitted with four ceramic high flow lysimeters (1 in. x ¼ in., Soil Moisture Corp.) that had been glued to stainless steel syringes. Three of the lysimeters were installed 1 in. deep and 0.75, 1.5, and 2.25 in. away from the center line, and one was installed so that it would lie 1.5 in. below a fertilizer band (Figure 1). Each soil was added to 12 containers until the soil surface was 1.5 in. from the top of the container. The soil was packed to attain a final bulk density of 81 lb/ft³ and watered to attain the water content for –1/3 bar (Table 1). Lysimeters were evacuated to -0.5 bars 24 hour prior to sampling, and 1 mL was

Figure 1. Container and lysimeter design for Phase I.

withdrawn through Tygon® tubing for P analysis via the molybdate blue method.

Monoammonium phosphate (MAP) was applied immediately after sample collection 1 in. below the soil surface in a narrow band at a rate equivalent to 50 lb P_2O_5/ac. Treatments consisted of an uncoated MAP control, and MAP that had been treated with one of the HA products (HA 1 or HA 2). Each treatment was replicated four times, although several lysimeters cracked in the non-calcareous soil, leaving some treatments with three replicates. Lysimeters were subsequently sampled at 4, 8, 16, and 32 days after fertilizer application in both soils and 48 days in the calcareous soil. After the experiment with the calcareous soil was terminated, both the upper 2 in. of soil and the 2–3 in. depth interval were collected from 1 in. either side of the fertilizer band for Olsen P analysis.

Phase II

The goal of Phase II was to determine if HA causes an increase in wheat shoot biomass, grain yield, or P uptake. Each column (pot) consisted of a 2 foot, 8 in. diameter PVC pipe fitted with a PVC base that was drilled with holes to allow drainage and subsoil aeration. Each column was packed with both soils as in Phase I. Seven 'McNeal' spring wheat seeds were planted 1 in. deep, offset from the column's centerline by 0.75 inches. MAP, either coated with 1.5 lb HA/ac (of HA 2) or left uncoated, was band-applied 1.5 in. to the side of the seed at rates equivalent to 15 or 50 lb P_2O_5/ac. HA 2 was selected because it produced slightly higher soluble P concentrations than HA 1 in Phase I, and a higher concentration of HA 2 could be coated on the MAP. Each treatment was replicated four times. Each column was fertilized with 34-0-0 to attain an available N concentration of 165 lb/ac (including soil NO_3-N, plus N in the MAP), based on a yield potential of 50 bu/ac (Jacobsen et al., 2003). Soil water contents were maintained near 90% of field capacity. After emergence, each pot was thinned to 5 plants. When the grain reached maturity, grain and shoot were harvested, dried, ground, and digested by dry ashing, treated with 2 M HCl, and filtered. The digest was analyzed for P with ICP-AES.

RESULTS AND DISCUSSION

Phase I

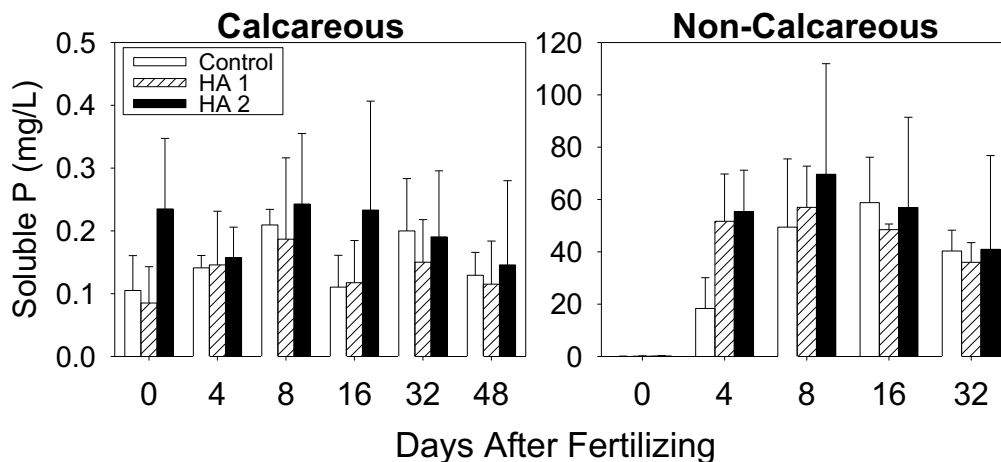There were no significant differences (P=0.05) in soluble P concentrations at 0.75 in.

Figure 2. Soluble P concentrations 0.75 in. to the side of a MAP band that had been coated with a humic acid product (HA 1 or HA 2) or left uncoated (Control). Day 0 samples were collected immediately prior to fertilizer application. None of the

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from the fertilizer band between treatments for any time point for either soil (Figure 2). The only substantial difference was at Day 4 in the non-calcareous soil, when soluble P concentrations in both HA treatments were approximately 2.5 fold higher than the control. High natural heterogeneity in soluble P concentrations prevented these differences from being statistically significant. Although the HA 2 treatment appeared to have higher P concentrations than either HA 1 or the control at most time points, HA 2 concentrations were also higher before fertilizer application. Concentrations of P were over 100 fold lower in the calcareous soil than in the non-calcareous soil likely due to Ca-P precipitation in the calcareous soil.

There were no significant differences at any time point for either soil between the control and the two HA treatments at 1.5 in. to the side of the band (Figure 3). Again, there was almost no change in P concentrations in the calcareous soil following fertilizer application, although P concentrations increased by about a factor of 8 in the non-calcareous soil by Day 16. Soluble P
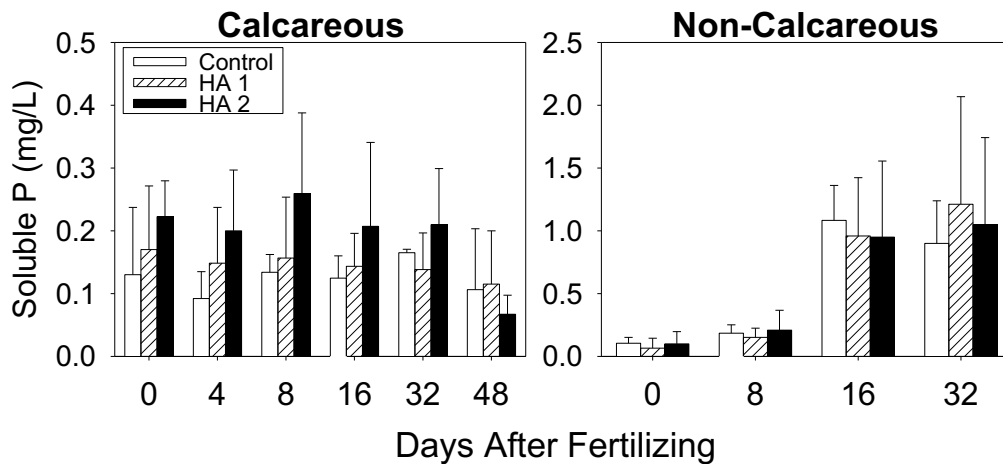

Figure 3. Soluble P concentrations 1.5 in. to the side of a MAP band.

concentrations at 2.25 in. from the band were not substantially different than at 1.5 in. from the band, although concentrations peaked near 0.15 mg/L in the calcareous soil and 0.5 mg/L in the non-calcareous soil (data not shown).

Soluble P concentrations in the calcareous soil increased until Day 32 in both HA treatments at 1.5 in. below the band, whereas concentrations decreased in the control (Figure 4).
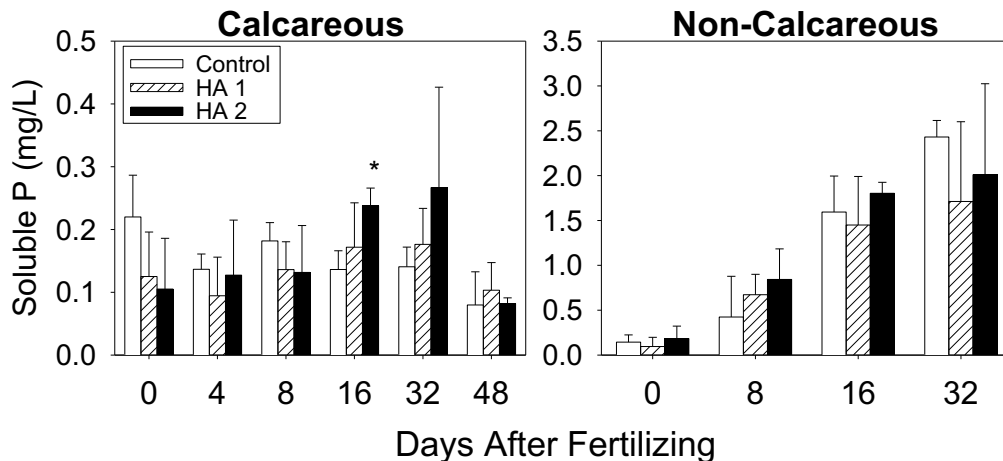

Figure 4. Soluble P concentrations 1.5 in. below MAP band. * - Significant at P = 0.05.

Although the only significant difference between HA treatments and the control was at Day 16 between the control and HA 2 treatment, the trends suggest that HA may have somewhat increased P solubility and mobility. It is not known why P concentrations dropped so substantially by Day 48, although microbial uptake, P sorption, or Ca-P precipitation likely accounted for the differences. Soluble P concentrations were higher 1.5 in. below the band than 1.5 in. to the side of the band in the non-calcareous soil, indicating that there was some downward advection of both water and P. Due to the trends observed in the calcareous soil at 1.5 in. below the MAP band, soil in the vicinity of the band (0-2 in.) and below the band (2-3 in.) was analyzed for Olsen P, yet no significant differences were observed (Figure 5).
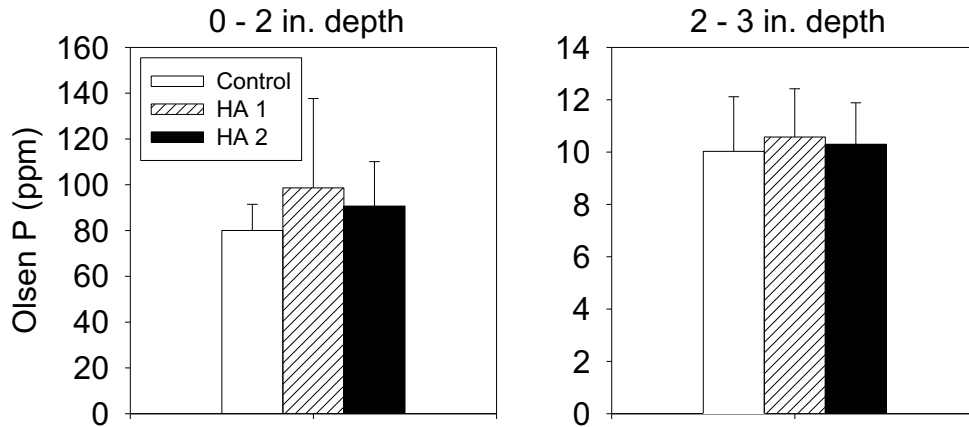

Figure 5. Olsen P concentrations in a band located 1 in. to each side of the fertilizer band at depths of 0-2 in. and 2-3 in. below the surface of the calcareous soil. Samples collected 48 d after fertilizer application.

Phase II

Grain yield differences were greater with increased P application rate, especially in the calcareous soil where 50 lb P_2O_5/ac produced approximately 30% more grain than 15 lb P_2O_5/ac for both the HA 2 treatment and control, although these differences were not significant (Figure 6). This finding suggests that if HA increased P availability in this soil, yield responses should be observed. Instead, grain yields were almost identical between treatments for both P application rates, indicating that HA did not substantially affect P availability. Higher grain yields in the non-calcareous soil were likely due to higher concentrations of available nutrients and O.M. (Table 1). P uptake was somewhat less in the HA 2 treatment than in the control in the calcareous
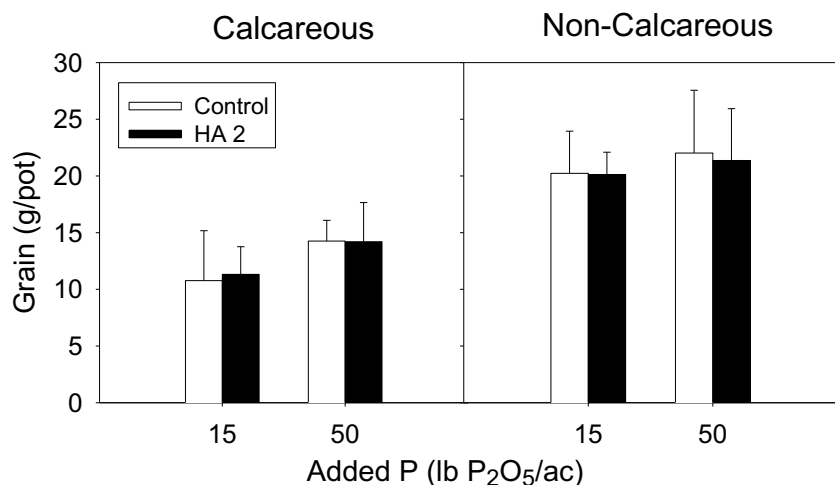

Figure 6. Grain yield response from two fertilizer rates in the presence and absence of HA 2.

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soil, and slightly higher in the HA 2 treatment in the non-calcareous soil, although again these changes were not significant (Figure 7). Although it has been shown that HA can substantially decrease precipitation rates of calcium phosphate minerals in solution (Grossl and Inskeep, 1992), this inhibitory effect may be less in soil or may not increase P availability for a sufficiently long period. In addition, P may sorb to insoluble HA, possibly counteracting the effect of decreased calcium-P precipitation.
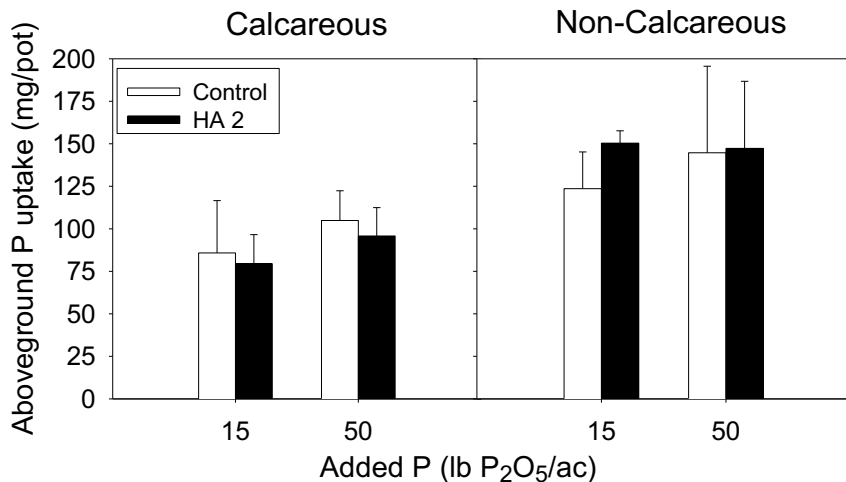

Figure 7. Aboveground P uptake in presence and absence of HA 2.

CONCLUSION

In conclusion, HA coated on MAP fertilizer at 1.5 lb HA/ac did not significantly affect P solubility, availability, P uptake, or spring wheat yield, although HA may have increased P solubility 1.5 in. below the MAP band in a calcareous soil. Due to low P availability in many soils of the Northern Great Plains, additional work to determine the potential effects of different HA rates and placement methods on P uptake and yield of a range of crops may prove useful.

ACKNOWLEDGMENTS

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