Barley Response to Phosphorus Fertilization under Dry Conditions

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Introduction

Drought conditions are common in Montana, affecting crop yield and quality in much of the state. Phosphorus (P) has been found to increase drought tolerance (Rodriquez et al., 1996), although there are no known published studies that have assessed the effect of P fertilization on drought tolerance in Montana. The present study was undertaken to determine the effects of P fertilization on malt barley yield, kernel weight, biomass, and water use efficiency under water-stressed conditions in low and medium P testing soils.

Methods

The upper 6 inches of an Amsterdam silt loam was collected from the Montana State University Post Farm Research Station and mixed for 15 min. in a cement mixer. A portion of this medium STP soil (Olsen P = 7.6 ppm) was mixed 1:1 (v/v) with a coarse sand to create a low STP soil (Olsen P = 2.5 ppm). PVC columns (24 in. tall, 8 in. diameter) with 20 equally spaced watering ports (5 rows; 4 ports per row) were filled to 7 inches from the top with either the medium STP or low STP soil. Monoammonium phosphate (MAP) was mixed with an additional 6 in. of soil to obtain equivalent field application rates of 0, 15, and 50 lb P_2O_5/a. Each fertilizer rate and soil water treatment (dry or wet) was prepared in triplicate. Ammonium nitrate (34-0-0) was incorporated to bring the total N fertilization rate to 70 lb N/a, and potassium sulfate was added to provide 29 lb K_2O/a and 20 lb S/a. The fertilized soils were added to the top of each column. Seven malt barley seeds (Harrington) were planted 1 in. deep in each column, watered until emergence, and thinned to the five healthiest plants. The study was conducted in a greenhouse at MSU.

Pots were weighed approximately three times per week, and watering amounts calculated for each pot to bring individual pots to the target water status (dry or wet). Water was injected through the watering ports with plastic syringes fitted with 6 in. stainless steel pipetting needles. Watering was discontinued in all pots when it was determined that heading was largely complete. Measured water contents (lb-water/lb-soil) ranged from 4.9–6.6% and 6.1–9.4% for the dry and wet low STP soils, respectively, and from 11.9–16.6% and 20.1–25.4% for the dry and wet medium STP soils, respectively. The minimum water contents were only rarely attained; the water contents were kept near the maxima when possible. The substantially lower water contents in the low STP soil compared to the medium STP soil were due to large soil textural differences because of the added sand, but resulted in equivalent treatments in terms of plant water status.

Results

Fertilizing the medium STP dry soil with 50 lb P_2O_5/a increased total plant biomass by 110% (Figure 1). Conversely, P fertilization did not significantly (P=0.05) increase biomass in the low STP soil under dry conditions, likely because plant growth was limited by lack of water or subsurface P. Due to the added sand, the low STP soil had a lower amount of plant available water. The majority of the roots in the low STP soil pots were found below the 6 in. fertilization depth; therefore, these roots were not positioned to absorb the added P. In the wet treatments, P fertilization with 50 lb P_2O_5/a increased total biomass by approximately 120% and 40% for the low and medium STP soils, respectively. The similarity in biomass between the 50 lb P_2O_5/a treatment in the medium STP dry soil and the 0 lb P_2O_5/a treatment in the medium STP wet soil, suggests that P can somewhat compensate for a lack of water.

Grain yield was increased dramatically (4- to 50-fold) by P fertilization, although none of the increases were significant due to high variability among replicates (Figure 2). Only one head grew in any of the 9 low STP dry soils, demonstrating that P fertilization could not overcome the poor fertility in a dry, coarse, low STP soil. Grain yield was not increased in the medium STP wet soil when P fertilization was increased from 15 to 50 lb P_2O_5/a, whereas grain yield more than doubled in the paired dry soil. This finding suggests that decreased P and water uptake in the dry soils were limiting grain yield, and indicates that higher application rates of P may be necessary in dry years compared to wet years to maximize yield.

Fertilizer

Facts

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Average kernel weight in the medium STP dry soil was 2.5 fold higher in the 50 lb P_2O_5/a treatment compared to the check treatment, although the difference was not significant (data not shown). None of the grain met typical plump requirements (data not shown) for malt barley (e.g. 75-80%), possibly due to the greenhouse environment, insufficient initial soil P levels, or insufficient moisture in the pots during grain fill. However, the large increase in kernel weights with P fertilization of the medium STP dry soil suggests that higher P availability increases the likelihood that grain would meet plump requirements under dry conditions in the field.

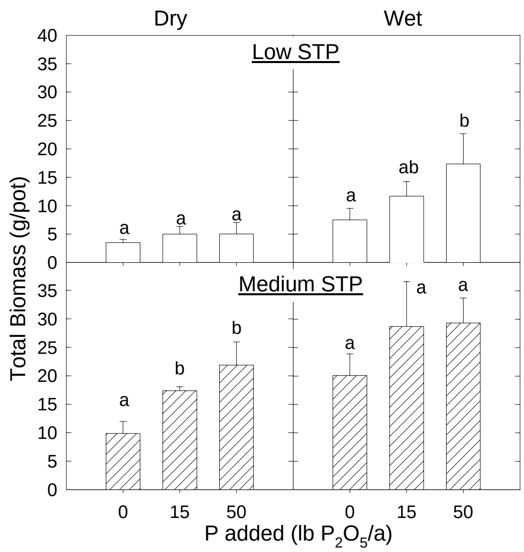

Figure 1. Effect of P fertilization on total malt barley biomass. Within each graph, bars with the same letter are not significantly different (P=0.05).

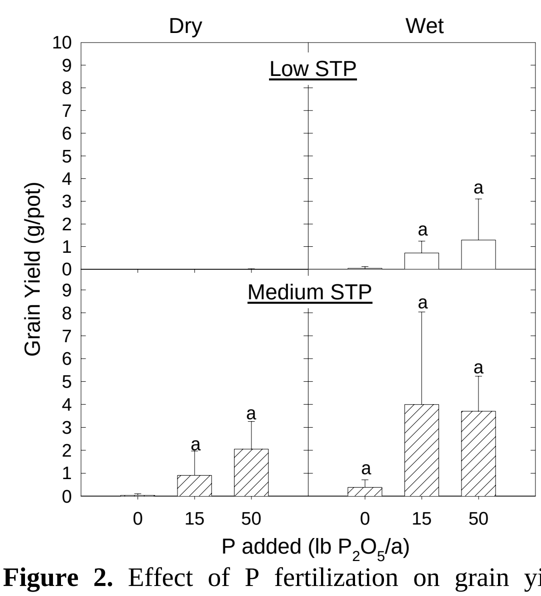

Figure 2. Effect of P fertilization on grain yield. Within each graph, bars with the same letter are not significantly different (P=0.05). The lack of a letter indicates that statistical significance was not determined because at least one pot for that treatment yielded no grain.

Increases in grain yield and plant biomass from P fertilization would be expected to be smaller in the field than in this greenhouse study because the plants that grew more received more water to keep the soil water content at the same level, whereas in the field, healthier plants would use more water yet not necessarily receive more water. Therefore, water use efficiency (plant dry weight/water used) may be a more useful measure of drought tolerance than yield or biomass in this type of greenhouse study. Water use efficiency (WUE) increased significantly with increased P fertilization in all but the low STP dry soil (Figure 3). The 50% increase in WUE in the medium STP dry soil suggests that a barley crop fertilized with 50 lb P_2O_5/a could produce approximately 50% more biomass than a crop that was not fertilized with P, while using the same amount of water. While the research was conducted specifically on malt barley, the findings are likely applicable to wheat and other small grains based on previous studies (Rodriquez et al., 1996).

Fertilizer Facts:

- P fertilization of medium STP soils can substantially increase malt barley yield, kernel weight, and water use efficiency under drought conditions.
- Increasing available soil P levels in medium STP soils is expected to reduce yield and quality losses of small grains during drought.

Acknowledgments

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References

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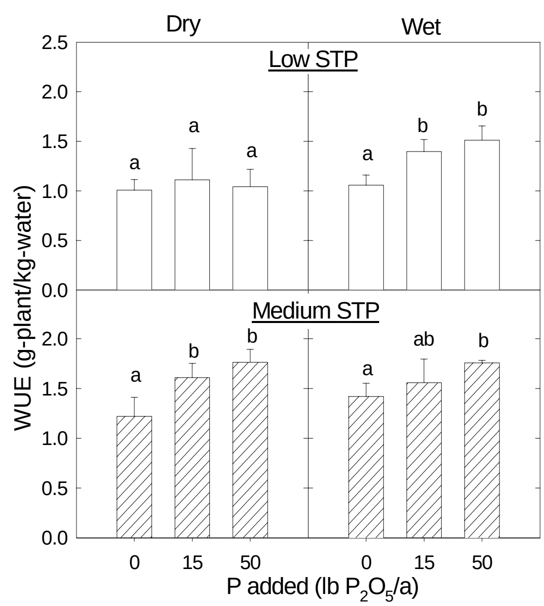

Figure 3. Effect of P fertilization on water use efficiency (WUE). Within each graph, bars with the same letter are not significantly different (P=0.05).