PHOSPHORUS - MANGANESE INTERACTIONS IN HYDROPONICALLY GROWN POTATO

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ABSTRACT

Potato production requires high soil phosphorus (P) application with potential negative environmental and nutrient uptake effects. Impacts of high available P on various species in potato cropping rotations are not adequately understood, nor have the causes of reduced yield and quality from excess P been fully explored. Antagonistic interactions with cationic micronutrients such as zinc (Zn) and manganese (Mn) are plausible explanations. Three hydroponic experiments were conducted with Russet Burbank potato (*Solanum tuberosum* L.) to elucidate P, Zn and Mn relationships. From the first two experiments, deficient, optimal and toxic concentration levels for a third experiment were established (see methods). The impacts of increasing solution Zn and P concentration on Mn uptake and distribution in potato is addressed in this part of the study (See companion poster # 1510 "Phosphorus and Zinc Interactions in Hydroponically Grown Russet Burbank Potato"). In addition to direct impacts of varied P and Zn on each other in potato nutrition, Mn is also affected by the P and Zn solutions varying from deficient to toxic. At low Zn concentrations and increasing P levels, a steep increase in root Mn is seen with little change of Mn in top leaves or middle plant parts. Although there is a gradual increase in root Mn as P increases regardless of solution Zn level, Zn seems to moderate Mn distribution among plant parts. As Zn level increases from deficient to optimal, a reduction in root Mn follows, but a further increase in Zn level from optimal to toxic produces an increase in root Mn. Yield reduction has often been attributed only to direct P-Zn interactions. This study suggests that Mn activity under P-Zn imbalances is a potential factor contributing to reductions in potato yields.

INTRODUCTION

High phosphorus (P) requirement in potato and low plant availability of P under high pH and calcium carbonate concentrations of arid-zone soils have led to elevated P fertilization in potato cropping systems (Marschner, 1986; Moraghan and Mascagni, 1991; Stark and Westerman, 2002). Consequently, many fields in the northwestern United States have received so much fertilizer P that soil tests are extremely high (Potash and Phosphate Institute, 2001). Continuing P fertilizer application may lead to deterioration of water quality from surface runoff and erosion, to micronutrient deficiencies, and to reductions in revenue in all species in potato cropping systems. Excessive P fertilizer application to potatoes is known to reduce Zn uptake (Christensen, 1972; Christensen and Jackson, 1981; Soltanpour, 1969) as well as yield and tuber size (Idaho Potato Commission, 1997). Additionally, excessive soil and/or fertilizer P may negatively affect crops grown in rotation with potatoes (Moraghan and Mascagni, 1991). The effects of excess available P on potato nutrition and on nutrition of crops grown following potato have not been adequately studied.

The causes of the reduction in crop yield and quality due to excess P have not been fully elucidated. One likely reason is an antagonistic interaction with other nutrients (James et. al., 1995; Brown and Tiffin, 1962). Although P interacts with many nutrients, the most commonly observed and studied antagonistic interaction is with Zn, which can bind with P, resulting in a P-induced Zn deficiency. Hopkins and coworkers (2003) reported Mn was the only other micronutrient consistently impacted in high P soils of southern Idaho, but no additional field study followed their observation.

Ultimately, greenhouse and field experiments will be required to understand P-micronutrient relationships in potato cropping systems and to recommend management guidelines. However, to accurately determine P impact upon Zn and Mn in potato without interference from conflicting variables present in soil environments, controlled nutrient hydroponic experiments were conducted to identify P-Zn relationships in potato tissue associated with sufficient, deficient and toxic levels of P and Zn. Potato Mn was strongly impacted by these variable levels of P and Zn. Further hydroponic studies with potato at variable solution P and Mn as well as deficient, optimum and toxic levels of solution Mn and Zn have just been completed and will be reported later.

METHODS

Three hydroponic experiments were conducted with Russet Burbank potato to elucidate P and Zn relationships and associated interactions with other nutrients. In the first two experiments treatment solutions were made with optimum levels of all essential plant nutrients except either variable Zn or P. Hydroponic solution pH was buffered between 5.9 and 6.1 with MES and KOH. Each experiment consisted of seven treatments of four plants each with four replications of each treatment. The third experiment was designed as a two variable (P and Zn) experiment using each possible combination of deficient, optimal and toxic P and Zn levels as determined in the first two experiments. The latter consisted of nine treatments of four plants each with three replications of each treatment. All treatments were conducted under a complete randomized block design. Potato plantlets grown on agar provided by University of Idaho, Moscow, Idaho, were transferred into pretreatment solution and grown for 17 days prior to placement into treatment solution for a period of 14 (first two experiments) or 17 days (third experiment). Plants were observed in their respective treatments for relative health and appearance, harvested at the end of each treatment period, oven dried (65°C), ground (20 mesh), digested in nitric-perchloric acid and analyzed by inductively coupled plasma (ICP) spectroscopy for P, Zn and other nutrients. Top leaves, middle leaves and stems, and roots were analyzed separately for dry weight and nutrient content. Analysis of variance with Duncan mean separation was used for statistical analysis.

In the first experiment, P solution concentration was constant at 256 µM while Zn concentration varied: 0.1, 2, 6, 18, 54, 162 and 456 µM Zn. In the second experiment, solution concentration Zn was constant at 6 µM while P concentration varied: 32, 64, 128, 264, 512, 1024 and 2048 µM P. Deficient, optimal and toxic solution concentrations for the third experiment were 0.1, 54 and 456 µM Zn and 32, 128 and 1024 µM P.

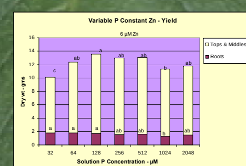


Figure 1

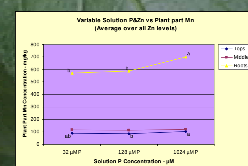
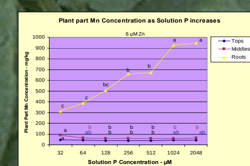


Figure 2



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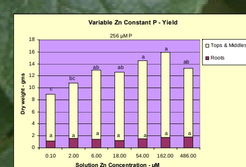

Figure 4

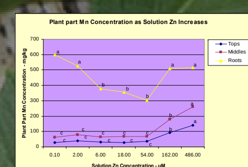

Figure 5

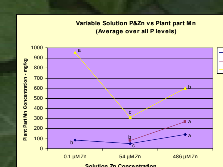

Figure 6

RESULTS AND DISCUSSION

Plants grown in mid level treatments (6, 18 and 54 µM Zn and 128 and 256 µM P) were most healthy based on visual observation. Plants grown in low level treatments of Zn appeared stunted with upturned leaves and general purpling and exhibited reduced growth in both tops and roots. Although plants grown in the upper level treatments of Zn generally exhibited rapid growth and often more plant mass than plants grown in mid level Zn treatments, unhealthy symptoms of yellowing, mottling, curling, burning at leaf edges and early leaf drop in older leaves were observed. The impact of variable P was not as clear based on visual observation.

Q. How does solution P concentration affect potato yield and related Mn content and distribution in potato?

Potato yield exhibited a bell curve with maximum yield between 128 and 256 µM P (Fig. 1). Even though dry matter yield rises and eventually drops with increasing P, a steep incremental increase in root Mn is observed with increasing P under this relatively low solution Zn level (6 µM). There is a concomitant gradual decrease and leveling off of top and middle plant part Mn with increasing solution P (Fig. 2). In the third experiment (every combination of three levels each of P and Zn), a gradual root Mn increase is also seen as P increases. The lower rate of Mn increase is likely moderated by higher solution Zn (Fig. 3).

Q. How does solution Zn concentration affect potato yield and Mn distribution in potato?

Yield incrementally increases from 0.01 to 162 µM Zn and declines at 456 µM (Fig. 4). Root Mn generally decreases incrementally as solution Zn increases while top and middle plant part Mn remains relatively flat as solution Zn increases from deficient to optimal levels (0.1 to 54 µM); and from optimal to toxic solution Zn levels (54 to 456 µM), Mn increases in all plant parts (Fig. 5). These results are confirmed in the third experiment (Fig. 6). Furthermore, because solution P level does not affect this trend, Zn solution concentration appears to have a stronger influence on moderating or controlling Mn uptake.

While direct interactions with P and Zn exist and clearly affect potato health and dry matter yields (see companion poster # 1510 "Phosphorus and Zinc Interactions in Hydroponically Grown Russet Burbank Potato"), the impact of P and Zn on Mn uptake and distribution in potato also appears to be an important factor to consider. Additional Mn, P and Zn experiments have just been completed*.

CONCLUSIONS

In addition to direct impacts of P and Zn on potato observed in this study, Mn uptake and distribution were also affected by both solution P and Zn. A steep increase of Mn in roots was observed with increasing solution P under low solution Zn. Mn in top leaves and stems and middle leaves decreased slightly with initial increment of P and flattened off thereafter. Regardless of solution P levels, increasing solution Zn resulted in lower root Mn up to the optimal level of solution Zn (54 µM), but between optimal and toxic solution Zn root Mn increased again. A slight decrease in Mn concentrations of top leaves and middle leaves and stems was seen from low to optimal solution Zn followed by a relatively strong increase in Mn at mid to high level solution Zn levels. This study suggests that Mn activity under P-Zn imbalances is a potential factor contributing to reductions in potato yields and that there is a need for further study of Mn-P-Zn interactions.

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