PHOSPHORUS AND ZINC INTERACTIONS IN HYDROPONICALLY GROWN RUSSET BURBANK POTATO

S.A. Barben, B.G. Hopkins, B.A. Nichols, V.D. Jolley, and B.L. Webb
Brigham Young University, Provo, UT

ABSTRACT

Potato production requires high soil phosphorus (P) application with potential negative environmental and nutrient uptake effects. Impacts of high available P on 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) are plausible explanations. Three hydroponic experiments were conducted with Russet Burbank (*Solanum tuberosum* L.) potato to elucidate P and Zn relationships and associated interactions with other nutrients. From the first two experiments, deficient, optimal and toxic concentration levels used in the third experiment were established (see methods). A direct impact of increasing solution Zn concentration on P uptake in potato was clearly observed. While Zn content increased in all plant parts as solution Zn increased, P concentration declined in both top leaves and middle leaves and stems with a concomitant increase of P in roots. At low level solution Zn, P also accumulated to very high concentrations in plant tops. Combined, these observations suggest a P-Zn complex formation in roots. An interaction occurs with solution P concentration and plant Zn uptake. Increasing solution P appears to balance or control Zn distribution in all plant parts regardless of solution Zn content--at low level solution Zn, uptake increases with increasing P; at mid level solution Zn, no change in Zn uptake is seen with increasing P; and at high level solution Zn, a decrease in Zn is seen with increasing P. From these hydroponic studies, a strong P-Zn interaction was observed, but variable Zn had more impact on P concentration and distribution than did P on Zn.

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 excess P that soil test levels are extremely high (Potash and Phosphate Institute, 2001). Continuing P fertilizer application could 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 can reduce Zn uptake (Christensen, 1972; Christensen and Jackson, 1981; Soltanpour, 1969) and 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 and on crops grown after 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.

Ultimately, greenhouse and field experiments will be required to fully understand P-Zn relationships in potato cropping systems and to recommend management guidelines. However, to accurately determine P impact upon Zn and other micronutrients 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.

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.

Low Level Zn 0.1 µM | Mid Level Zn 54 µM | High Level Zn 456 µM

Low Level P 32 µM / Mid Level P 128 µM / High Level P 1024 µM

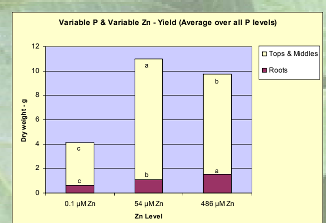

Figure 1

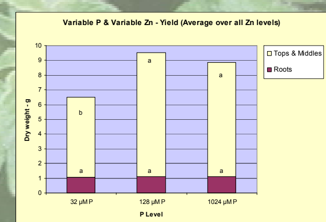

Figure 2

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 do variable P and Zn concentrations compare in their effect on plant dry weight in potato?

Deficiency of either P or Zn shows a much stronger reduction in yield compared with toxicity of either P or Zn (Figs. 1-2). Variable Zn promoted a much stronger influence on yield of all plant parts compared with P. Total dry weights from variable solution Zn range from about 4 to 11 g pot^{-1}; total dry weights from variable solution P range from about 6.5 to 9.5 g pot^{-1}. Root dry weights increase steadily with increased Zn, but no change in root mass is seen with increased P (Figs. 1-2).

Q. How does zinc concentration affect phosphorus distribution in potato?

As solution concentration Zn increases, top and middle plant part P declines with a concomitant increase of P in roots (Fig. 3). Under low level solution Zn, P accumulates at very high levels in top leaves (Fig. 4), indicating that without sufficient Zn, little control for P uptake exists resulting in excessive P in plant tops. These results suggest and support a P-Zn complex formation in roots that causes an imbalance of P--accumulating in tops at deficient Zn levels and in roots at toxic Zn levels.

Q. How does phosphorus concentration affect zinc distribution in potato?

An interaction is seen with P and Zn. Increasing solution P has a balancing effect on plant Zn in all plant parts. At low level solution Zn, increasing P improves Zn uptake; at high level solution Zn, increasing P reduces Zn uptake; and at mid level Zn, increasing P has no affect on Zn uptake (Fig. 5).

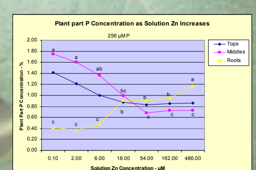

Figure 3

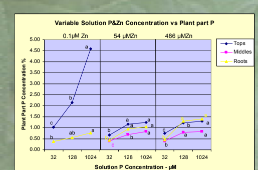

Figure 4

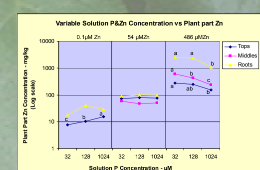

Figure 5

See Companion Poster # 1417 "Phosphorus - Manganese Interactions in Hydroponically Grown Potato" for Mn relationships.

CONCLUSIONS

A direct impact of increasing solution Zn concentration on P uptake in potato was clearly observed in these studies. As solution Zn increased, P concentration in both top leaves and middle leaves and stems declined with a concomitant increase of P in roots. An accumulation of P in top leaves at low Zn concentration was also observed. This suggests a P-Zn complex formation in roots preventing movement of P to the tops of plants under high Zn. An interaction was observed with increasing P on plant part Zn as a balancing effect, increasing Zn uptake at low solution Zn, reducing Zn uptake at high solution Zn and maintaining constant Zn uptake at mid level (optimal) solution Zn.

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