Effect of Phosphorus Deficiency on Cotton Physiology

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) is an essential macronutrient required for energy transfer (i.e., ATP and NADPH), genetic information (i.e., DNA and RNA), a formation of phospholipids, and plays an important role in membrane integrity. In cotton (*Gossypium hirsutum* L.), the critical-P concentrations range from 0.20 to 0.31% (Crozier et al., 2004; Cox and Barnes, 2002). For cotton grown in the southern regions of the USA, the critical P-concentration range in the upper mature leaf at first flower or first square is 0.30 to 0.50% (Plank, 1988). In Arkansas, a critical P-concentration range for petioles is not used because P is not recommended by the petiole monitoring program.

Prior to 2006, no P fertilizer was recommended for cotton when modified Mehlich-3 (1:7 extraction ratio)-extractable P was >100 lb P/acre. In 2002, approximately 95% of the soil samples submitted from cotton fields had soil-test P >100 lb/acre. This suggests that past P-fertilization practices have resulted in buildup of P in Arkansas soils and recommendations need to be updated. Information on the range of tissue-P concentrations that are sufficient for currently grown commercial cotton cultivars is an important component of developing improved P-management recommendations.

Phosphorus (P) is required for vital structural and metabolic functions. A shortage of P will lead to a breakdown of plant membranes and reduce energy transfer within the plant. Crop fertilization programs must insure adequate P to support the critical role of this element in plant metabolism. Improving P-fertilizer recommendations and increasing P-use efficiency will increase the growers profit margin and reduce the potential for offsite loss of P in drainage waters. Rapid introduction of modern cotton cultivars and changes in production practices in the past several decades has created a need to update the science base of cotton P-fertilization recommendations. The objectives of this study were to quantify the effects of P deficiency on the physiological growth of cotton.

PROCEDURES

The experiment was conducted in a growth chamber at the University of Arkansas Alzheimer Laboratory in Fayetteville, Ark. The growth chamber was programmed for a 12-hour photoperiod, with day/night temperatures of 30/20°C and relative humidity of 60 to 80%. The cotton cultivar DPL 444 was planted in 2-L pots filled with washed sand. Each pot had a 2-cm diameter hole in the base for drainage. After emergence, seedlings were thinned to one plant per pot. All pots were watered with one-half strength Hoagland’s nutrient solution during the first 4 weeks after planting to maintain a sufficient nutrient and water supply. Four weeks after planting all pots were flushed with deionized water and separated into two groups: P-sufficient and -deficient. The P-sufficient treatment continued to receive the half-strength Hoagland’s nutrient solution during the first 4 weeks after planting to maintain a sufficient nutrient and water supply. Four weeks after planting all pots where flushed with deionized water and separated into two groups: P-sufficient and -deficient. The P-sufficient treatment continued to receive the half-strength nutrient solution with P, while the P-deficient treatment received half-strength Hoagland’s nutrient solution without P. Five plants in each treatment were harvested weekly for 4 weeks after the initiation of the P treatments. The effects of P deficiency on plant growth, dry matter accumulation, and partitioning were determined as described by Zhao and Oosterhuis (2002). The plants were separated by plant part (leaves, main stem and branches, petioles, fruits, and roots) and the tissues were oven dried, weighed, and
digested with concentrated HNO$_3$ and 30% H$_2$O$_2$ for determination of tissue-P concentrations. The experiment was a randomized complete block design with five replications. A $t$-test was performed to determine whether significant (P ≤ 0.05) differences existed between treatment means.

RESULTS AND DISCUSSION

Leaf phosphorus concentration declined significantly for the P-deficient cotton treatment within 1 week after P was omitted from the nutrient solution (Fig. 1A). Membrane leakage also increased significantly by 1 week for the P-deficient treatment compared to the P-sufficient plants (Fig. 1B). Withholding P caused photosynthesis to decline below that of cotton plants in the P-sufficient treatment by 3 weeks (Fig. 1C). Fluorescence, as a measure of plant stress, only reflected significant stress in the P-deficient plants by 4 weeks (Fig. 1D). The rapid effect of P deficiency on membrane leakage was expected in view of the critical role of P in the formation of phospholipids in plant membranes. Membrane leakage is a measure of cell integrity and provides a sensitive indicator of the plant stress suffered due to P deficiency. The data suggest that leaf-P concentrations <2000 mg P/kg have an adverse effect on plant physiological parameters.

PRACTICAL APPLICATIONS

This growth room study quantified the effect of P deficiency on the physiological growth of cotton plants. Membrane leakage was a sensitive indicator of plant stress due to P deficiency. Leaf-P concentrations <2000 mg P/kg (0.20%) resulted in significant reductions in the plant physiological functions of membrane leakage and photosynthesis.

LITERATURE CITED


Fig. 1. The effect of P deficiency on (A) leaf-P concentration, (B) membrane leakage, (C) leaf photosynthesis, and (D) fluorescence measured weekly starting 28 days after planting. The asterisk (*) indicates significant differences at $P \leq 0.05$ between P treatments within a sample week.