Effect of Phosphorus Deficiency on Cotton Physiology

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RESEARCH PROBLEM

Phosphorus (P) is an essential element in plants that 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 grower profit margins and reduce the potential for offsite loss of P in drainage waters. Rapid introduction of modern cotton (Gossypium hirsutum L.) cultivars and changes in production practices in the past several decades have 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.

BACKGROUND INFORMATION

Phosphorus (P) is an essential macronutrient required for energy transfer (i.e., ATP and NADPH), genetic information (i.e., DNA and RNA), and formation of phospholipids, and it plays an important role in membrane integrity. Phosphorus is mobile in the plant such that young leaves or developing bolls can be nourished from the labile-P of older tissues, i.e. P is redistributed from older to younger parts. In cotton, 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 state’s petiole monitoring program. Prior to 2006, no P fertilizer

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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 thus P 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.

MATERIALS AND METHODS

The experiment was conducted in a growth chamber at the University of Arkansas Altheimer 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 DDL 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 four 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 P 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. Four plants in each treatment were harvested weekly for four 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 HNO₃ and 30% H₂O₂ 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 one week after P was omitted from the nutrient solution (Fig. 1A). Membrane leakage also increased significantly by one week for the P-deficient treatment compared to the P-sufficient plants (Fig. 1B). Withholding P caused photosynthesis to decline by three weeks below that of cotton plants in the P-sufficient treatment (Fig. 1C). Fluorescence, as a measure of plant stress, only reflected significant stress by four weeks in the P-deficient plants (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 APPLICATION

This growthroom 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 (ML), (C) leaf photosynthesis (PN), and (D) fluorescence (FL) measured weekly starting 28 days after planting when P was withheld from the P-deficient treatment. The asterisk (*) indicates significant differences at P≤0.05 between P treatments within a sample week.