Interactive Effects of Nitrogen and Phosphorus Deficiency on Photosynthesis and Leaf Growth in Maize.

Dennis Timlin1, TCM Naidu2, David Fleisher1, and V.R. Reddy1
1USDA-ARS Crop Systems and Global Change Laboratory, Henry Wallace Beltsville Agricultural Research Center, Beltsville, MD, USA, 2 Regional Agricultural Plant Station (ANGRAU), India

Problem / Question

Nitrogen (N) and phosphorus (P) are often limiting in agricultural systems and must be augmented through fertilization. Simulation models that can account for N and P limitations are important tools for assessing the impact of nutrient limitations on crop yield. Both P and N affect photosynthesis and carbon assimilation but differ in their mechanism. A study was conducted to using outdoor sunlit growth chambers to evaluate the interactive effects of Nitrogen (N) and Phosphorus (P) on corn growth, development, chlorophyll content, and canopy photosynthesis. We evaluated quantitative effects on P and N on leaf addition rate, canopy and leaf photosynthesis, carbon assimilation and biomass partitioning to stem and leaf. The goal is to modify or develop new algorithms for the maize model MAIZSIM (Kim et al., 2012) to simulate the effects of P deficiency. Based on the study results, P and N appear to affect growth mainly through its effect on photosynthesis and carbon assimilation.

Objectives

- The objectives of this study are to
  - Quantify the interactive effects of N and P on maize leaf growth and photosynthesis
  - Develop approaches to model N and P effects

Growth (SPAR) Chamber Experiments

- Corn plants were grown in 12 outdoor, sunlit Soil Plant Atmosphere Research (SPAR) chambers with soilbins.
- 45 plants were germinated June 6, 2010 to allow for 4 destructive harvests.
- Nutrient treatments were applied as a factorial (12 treatments):
  - four levels of phosphorus i.e., 0, 0.01, 0.05 and 0.2 umol l⁻¹
  - three levels of nitrogen 2.0, 5.0 and 12.0 mmol l⁻¹
- Plants were fertigated three times a day for three minutes each @ 4 l per minute through an automated fertigation system.
- The maize plants were grown at constant 440 mmol CO₂ mole⁻¹ and 28/18°C day/night temperatures.
- Canopy photosynthesis, dark respiration, and transpiration were measured at every 5 minutes throughout crop growth period automatically using computerized instrumentation.
- Leaf level response and A/ci curves were measured with Li-Cor 6400 photosynthesis system. Additional plants were grown outdoors in pots to allow for destructive leaf measurements.
- Chlorophyll content was measured on leaf samples in the lab
- Destructive measurements were taken four times by harvesting the six to nine plants while maintaining the uniform space at the end of each harvest.
- Leaf area was measured on destructively sampled leaves.
- Non-destructive measurements of leaf number and length were taken on tagged plants 3 times a week.

Results

- Leaf appearance was calculated using a modified Beta function with parameters derived from previous SPAR research and the literature (figure lower right). The effect of N limitation was not as strong as the effect of P. Increasing P deficit resulted in fewer overall leaves and a slower appearance rate. The lowest N rate may have been too high.

Conclusion

- Phosphorus effects on growth and photosynthesis were larger than those for nitrogen in this study. Nitrogen deficiency effects were strongest in the high P treatment. The relative nitrogen content increased as P application decreased. This could possibly offset some of the effects of low N application at lower P applications.
- It appears that the primary impact of P deficit on growth and development was through its effects on carbon assimilation. Thus, for modeling purposes, the equations for photosynthesis will be modified. We have found that P deficit reduces the calculated values of V_{max} (maximum rate of Rubisco carboxylation) and J_{max} (maximum electron transport rate) in the Farquhar photosynthetic equations for potato (S. tuberosum) and the maize model (S. zea).
- The effects on leaf appearance rate also need to be accounted for, possibly based on carbon assimilation rate and potential demand of carbon for leaf expansion.
- P and N stress effects on partitioning of carbon among different organs may be related to the need for the plant to increase leaf expansion over stem growth to maximize light interception.