Cotton Growth and Photosynthetic Acclimation to Phosphorus Nutrition and CO_2 Enrichment

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Introduction

1. Phosphorous is a major limiting factor for cotton growth and development particularly in acidic soils.
2. The availability of soil nutrients such as phosphate (Pi) exerts a major control over plant response to rising atmospheric CO_2 concentration.
3. Most of the previous studies in cotton have considered nutrients other than Pi, and its interaction with elevated CO_2 (eCO_2) has received little attention.
4. In general eCO_2 stimulates plant growth and photosynthetic processes, whereas Pi stress has an opposite effect.
5. Moreover, previous studies using long term elevated CO_2 indicated varying degree of photosynthetic acclimation/down regulation in cotton.
6. Regardless of the acclimation response, increased growth and biomass production were also evident in the same studies at elevated CO_2.
7. Studies on effect of the long term eCO_2 on sensitivity of the cotton growth and photosynthesis are limited.

Objective

❖ To determine the interactive effect of Pi supply and atmospheric CO_2 concentrations on cotton growth, development and photosynthetic processes.

Materials and Methods

1. Twenty cotton (cv. DP 555) plants were grown in each of six controlled environment chambers in 2011.
2. The chambers were maintained at a day/night temperature of 30/22 °C and 800 µmol m^{-2} s^{-1} photosynthetic photon flux density (PPFD, 15 h d^{-1}).
3. Plants were irrigated with full strength Hoagland's nutrient solution, except Pi concentration which, varied as 0.20 (optimum), 0.05 and 0.01 milimole (mM) at two levels of CO_2 [400, ambient (aCO_2); and 800, elevated (eCO_2) µmol mol^{-1}].
4. The P_{net} was measured and light (LRC) and CO_2 (CRC) response curves were developed using a Li-Cor 6400 (Li-Cor Inc., Lincoln, Nebraska, USA). Same leaves were used for tissue phosphorous (P) analysis.
5. The light saturated maximum Pnet ($Pnet_{max}$) and quantum yield (Φ) from LRC, and carboxylation efficiency (V_{Cmax}) from CRC were computed.
6. Plants were harvested three times (6 plants twice and 8 plants at the end) during the experiment and separated into leaves, stem, fruits and roots.

Measurements

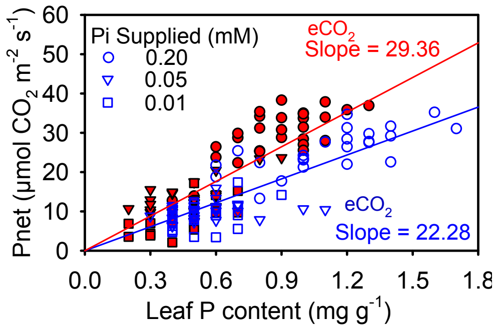

Fig. 1 . Leaf Pi content versus photosynthesis at ambient (aCO_2) and elevated (eCO_2) concentration.

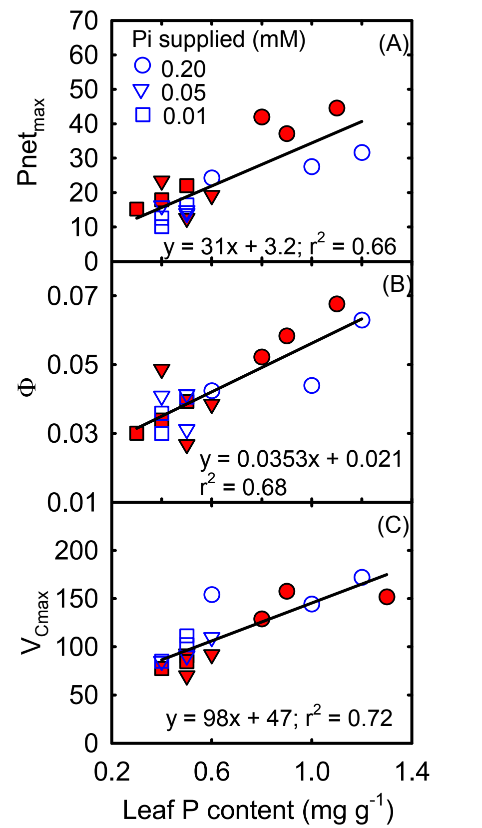

Fig. 2. Leaf P content versus parameters of photosynthetic capacity. Unfilled and filled symbols are aCO_2 and eCO_2, respectively.

Measurements cont.

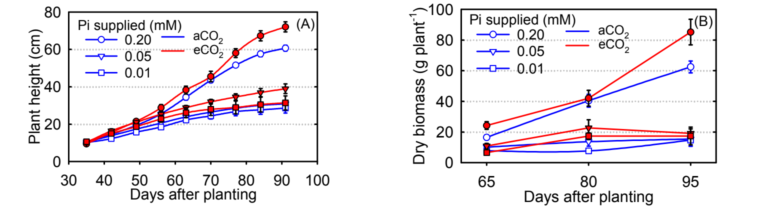

Fig. 3. Effect of CO_2 concentrations and Pi on plant height and total dry biomass

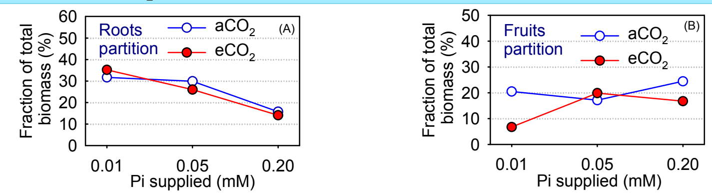

Fig. 4. Effect of CO_2 concentrations and Pi on biomass partitioning

Results

1. Growth and photosynthesis declined drastically with decreased Pi (Fig. 1 & 3).
2. When measured at growth CO_2 concentration, plants grown at eCO_2 had higher Pnet but lower leaf P content compared to plant grown at aCO_2 (Fig. 1).
3. The eCO_2 failed to alleviate the negative effect of severe Pi stress on Pnet.
4. The $Pnet_{max}$, Φ and V_{Cmax} increased linearly with leaf P content (Fig. 2).
5. A minor increase in $Pnet_{max}$ and quantum yield at eCO_2 occurred only at high leaf P content (Fig. 2A), however V_{Cmax} was lower or unaffected at eCO_2 (Fig .2C).
6. Irrespective of growth CO_2, Pi stress caused decrease in plant height (45-55%) (Fig. 3A) and biomass (75-80%) (Fig. 3B).
7. Pi stress caused more dry matter partitioning towards the roots (Fig. 4A) but lesser towards the leaves, stems and fruits (Fig. 4B for Fruits).
8. Regardless of Pi nutrition, the eCO_2 increased total dry biomass of cotton.

Conclusions

1. The reduced growth and biomass under Pi stress were mainly caused due to slower rate of stem elongation, leaf area expansion and photosynthesis.
2. The photosynthetic processes and reproductive structures were the most sensitive to Pi stress under both current and projected CO_2 environments.
3. When measured at growth CO_2, the relationship between Pnet and leaf P content was altered by eCO_2 indicating higher Pnet per unit increase in leaf P content.
4. Irrespective of the P supply, photosynthetic acclimation of cotton plants to eCO_2 were evident from the reduced carboxylation efficiency.
5. It is notable that eCO_2 did increase Pnet when measured at growth CO_2 and improved quantum yield specially at sufficient phosphorus supply.
6. Regardless of Pi nutrition, the observed increase in biomass at eCO_2 was attributed to rapid growth and associated increase in total canopy photosynthesis.

Reference: Barrett, D.J., Gifford, R.M., 1995. Acclimation of photosynthesis and growth by cotton to elevated CO_2: interactions with severe phosphate deficiency and restricted rooting volume. Aust. J. Plant Physiol. 22, 955-963.