Estimating Canopy Dark Respiration for Crop Models

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Crop Models

• Crop production is obtained from accurate estimates of daily carbon gain.

• Canopy gross photosynthesis (Pgross) can be estimated from biochemical models of photosynthesis using sun and shaded leaf portions and the amount of intercepted photosynthetically active radiation (PAR).

• In turn, canopy daily net carbon gain can be estimated from canopy daily gross photosynthesis when canopy dark respiration (Rd) is known.
Crop Respiration

- Respiration in living cells allows for the controlled oxidation of carbohydrates and other substances, so that much of the energy can be retained in a useable form, such as ATP.

- aerobic respiration – (glycolysis, the Krebs cycle, and the ETR).
  - \[ 6 \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 -> 6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{energy} \]
Crop Respiration

• Respiration is difficult to estimate and several methods have been developed:
  • growth and maintenance
  • nitrogen content

• Measurements of respiration using $^{13}\text{CO}_2$ indicate that dark respiration is proportional to gross photosynthesis.
Empirical Approach: $R_d/P_{gross}$ ratio

• Using a constant $R_d/P_{gross}$ ratio can simplify crop models estimating canopy-scale daily carbon gain.

• Dark respiration has been assumed to be a constant fraction of $P_{gross}$ (Monteith 1977):
  • $R_d / P_{gross} = 0.4$

• $P_{net} = 0.6 * P_{gross} = 0.6 * \text{RUE} * \text{APAR}$
  • $\text{RUE} = \text{Radiation Use Efficiency}$
  • $\text{APAR} = \text{Absorbed PAR}$
Does $R_d/P_{\text{gross}}$ Vary with Light Intensity?

- The effect of light intensity (450, 630, 880, and 1010 \(\mu\text{mol m}^{-2} \text{s}^{-1}\)) on $R_d/P_{\text{gross}}$ of pepper plants was measured at a constant CO$_2$ concentration.
Does $[\text{CO}_2]$ affect $\text{Rd/Pgross}$?

- Several datasets including high CO2 concentrations (330 to 1300 ppm) were analyzed: pepper (this study), wheat (Monje et al. 1998), tomato and lettuce (Frantz et al. 2005). A mean canopy level $\text{Rd/Pgross}$ is 0.242 for C3 plants and the ratio is independent of light intensity and CO2 concentration.
Conclusion

• A gas exchange system was used to measure the effect of increasing light levels on the canopy level ratio of respiration to gross photosynthesis.

• A mean canopy level Rdark/Pgross is 0.242 for C3 plants, which is roughly half of that observed for the leaf level.

• The Rdark/Pgross ratio was found to be independent of light intensity and CO2 concentration.

• These properties make the Rdark/Pgross a suitable approach for simplifying crop models for estimating daily carbon gain.