LIMITATIONS TO OPTIMAL CARBON UPTAKE WITHIN A COTTON CANOPY

G.F. Sassenrath-Cole and J.J. Heitholt
USDA-ARS
Mississippi State and Stoneville, MS

Within any agronomic crop, multiple processes contribute to the loss of carbon uptake. Leaves within an indeterminate crop canopy experience lower insolation levels with increasing age due to development of leaves at higher canopy positions. This overshadowing occurs concurrently with declining photosynthetic activity due to physiological alterations with leaf aging. Research exploring the photosynthetic response to these changing light conditions and leaf senescence has failed to adequately separate environmental from physiological responses.

Photosynthetic capacity of cotton leaves on sympodial branches is maximal just prior to anthesis of the subtending flower and declines rapidly thereafter. Although new leaves with higher photosynthetic rates continue to develop, the canopy photosynthesis rate per unit leaf area declines significantly with increasing plant age. During the boll development period, the leaf subtending the boll has very low photosynthetic activity and receives low photon flux density. The loss of photosynthetic capacity limits photoassimilate supply to the developing boll, and under conditions of extreme shade, can result in ovule abortion and boll abscission. This loss of photosynthetic capacity may be due in part to increased shading from upper leaves. Due to the indeterminate growth habit of cotton, changes in leaf aging occur coincidental to adjustments to more shaded conditions. The photosynthetic machinery responds to these changes in ambient light intensity incident to the leaf surface in specific ways, ostensibly in an effort to optimize photosynthetic activity under the changing light environment within the crop canopy.

The photosynthetic capacity, the maximum photosynthetic activity under saturating light conditions, is the upper limit of leaf carbon uptake. Although this is a good measure of the health of the photosynthetic machinery within a leaf, a more realistic measure may be the photosynthetic efficiency, which is the photosynthetic rate at the limiting photon flux densities (PFD) commonly experienced by leaves in the natural environment. The efficiency of photosynthesis under non-saturating PFD's has been suggested to be a major limiting factor in crop performance and has been observed to decline with leaf age and after exposure to deleterious growth conditions. A change in photosynthetic efficiency could significantly limit carbon uptake in lower canopy leaves.

In this study, we examined the physiological versus environmental limitations that give rise to the reductions in carbon uptake within a cotton (*Gossypium hirsutum*, L.) canopy. We wanted to determine the relative contribution of the changing light environment within the canopy versus the physiological changes during leaf senescence to the potential carbon uptake within the canopy. Both photosynthetic efficiency and capacity decreased rapidly and substantially as the leaves aged; the decline in maximal photosynthetic capacity was more substantial than that of the photosynthetic efficiency. Even upper canopy leaves receive only short periods of saturating illumination over the course of the day; lower canopy leaves receive substantially lower PFD levels due to intermittent shading from upper canopy foliage. Therefore, although the decline in maximal photosynthetic activity was greater than the decline in quantum yield, the loss of photosynthetic efficiency during leaf aging presented a more substantial inhibition to carbon uptake, particularly for low-light leaves deeper in the canopy. Moreover, the environmental alterations that resulted in lowering incident photon flux during leaf senescence presented a much more substantial limitation to carbon uptake than the physiological loss of photosynthetic activity due to leaf aging. It may be possible to circumvent some of the loss of potential carbon uptake through the use of different leaf types, such as okra leaf, that allow a greater photon flux to lower regions of the canopy.

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