

# RESPONSE OF COTTON LEAF PHOTOSYNTHESIS TO ITS LIGHT ENVIRONMENT

P. Kasemsap

Agronomy Department

Y. Crozat

CIRAD-CA

DORAS Project

Kasetsart University, Thailand

## Abstract

Light is one of the most important resources for plant. Light level in canopy varies greatly. Previous research using individual leaf shading showed no photosynthetic response to reduce light environment to main stem leaves. Our objective was to determine photosynthetic response of main stem, sympodial, and monopodial leaves to differential growth light environment. We monitored light environment on leaf surface and measured photosynthesis rates at different leaf ages. As leaf aged, light environment of main stem leaves slightly decreased while for sympodial and monopodial leaves it rapidly decreased.  $P_{max}$  for main stem and sympodial leaves rapidly decreased with increasing leaf age. That significant decline in  $P_{max}$  (70%) of main stem leaves was associated with non-significant reduction in leaf light environment indicated physiological response caused by leaf aging. Finally, the positive correlation between  $P_{max}$  and differential light environment suggest photosynthetic adaptation of cotton leaves to growth light environment, in addition to physiological changes with leaf aging.

## Introduction

Photosynthesis produces carbohydrates for cotton fruit production. Manipulating photosynthetic factory by crop management can substantially alter the cotton plant's ability to produce and retain fruiting forms during the reproductive cycle (Wells, 1997). Peng and Krieg (1991) showed that both leaf and canopy photosynthesis declined significantly as the cotton plant age increased from 70 to 115 DAP, the period with maximum boll dry matter accumulation rate. This decline in canopy photosynthesis was largely due to the decline in leaf photosynthesis of young leaves as plant aged and of older leaves as leaves aged rather than due to the reduction in leaf area.

The contribution of leaf senescence to declining canopy photosynthesis and to carbon availability for yield has been identified as a potential limitation in crop production (Wullschleger and Oosterhuis, 1992). Modification of leaf longevity and photosynthesis rates had potential to increase net carbon production by individual leaf and thus increase the potential for cotton yield (Landivar et al, 1983;

Wullschleger and Oosterhuis, 1990a). A key to improving leaf longevity and increasing leaf photosynthesis during leaf aging period is to understand how leaf adapts to light environment and to find a possibility of restructuring the canopy to alter light environment in order to reduce the physiological deterioration of photosynthetic activity during leaf senescence. Nevertheless, varying light environment of main stem leaf from 15% to 100% of full sun levels using artificial individual leaf shading did not obtain photosynthetic responses other than physiological changes within the aging leaf (Sassenrath-Cole, 1997).

In this study, single leaf photosynthesis rates at saturating light were measured at several leaf ages under field conditions. Differential light environment on leaf surfaces caused by natural mutual leaf shading was continuously monitored. Different leaf types, including monopodial, sympodial, and main stem leaves, unfolded on the same day were utilized to widen the range of variability of light environment. The objective was to evaluate the response of leaf photosynthesis to its natural light environment.

## Material and Method

### Crop Culture

Cotton plants (*Gossypium hirsutum* L., cv Srisumrong60) were grown during rainy growing season from seed planted on July 15, 1997 at research field in Suwan Station, Kasetsart University (latitude 14.7°N, longitude 101.2°E). Row spacing was 1.25 m with density of 5 plant m<sup>-2</sup>. The experiment was conducted under well-watered conditions to eliminate the influence of water stress on photosynthesis. Irrigation was applied using a sprinkler system. Pre-plant fertilizer and herbicide were applied 2 weeks before planting.

### Light Environment

Sixteen just unfolded leaves on main stem node 14-15, sympodial position 1 on node 11-12, and monopodial position were tagged on Sept 1, 1997. Light sensors were attached to leaf surfaces to continuously monitor light environment. The procedure presented by Thanisawanyangkura (1995) was selected and small modification was completed by using white paper as a photon flux reducer and diffuser (Adam and Sinoquet (1997). Photoelectric light sensor made of amorphous silicon (Solems, ZI Les Glaises, Palaiseau, France) was chosen because of its light weight (0.4 g) and small size (1.2x1.2x0.12 cm<sup>3</sup>) with relatively large sensitive surface area of 0.4x1.2 cm<sup>2</sup>. The sensors were calibrated with SKP 215 Quantum Sensor (Skye Instruments Ltd., U.K.). The analog signals were recorded by data logger model CR10 with multiplexer AM416 (Campbell Scientific Ltd., Logan, UT). Light sensors were attached to the center of upper leaf surfaces using double-sided tape when leaves were 10 DAU. Diurnal photosynthetically active photon flux (PPF) was measured as 20-minute average of 10-second readings.

Daily integration of PPF was used to quantitatively express light environment of the leaves being studied.

### **Photosynthesis Measurement**

Single leaf net photosynthesis rates at saturating light ( $P_{\max}$ ) were collected using portable photosynthesis system model LI-6200 (Li-Cor, Lincoln, NE) with one L chamber, under field condition between 10:00 to 14:00 at PPF greater than  $1800 \mu\text{mol m}^{-2}\text{s}^{-1}$ .  $P_{\max}$  was measured regularly until leaf was shed.

## **Results and Discussion**

### **Light Environment and Leaf Age**

Main stem leaves and sympodial leaves usually initiated under high light conditions at the top of the canopy. At 12-15 DAU, they received large daily PPF at  $28\text{-}32 \text{ mol d}^{-1}$  and  $20\text{-}30 \text{ mol d}^{-1}$ , respectively (Fig. 1). On the contrary, monopodial leaves initiated and developed in the shade of the canopy and thus received much less available light, being only  $14\text{-}17 \text{ mol d}^{-1}$  at 12-15 DAU. Light environment of main stem leaves slightly decreased with leaf age but large day-to-day variability. Statistical analysis showed non-significant change with DAU. Light environment of sympodial and monopodial leaves rapidly decreased with leaf age, showing more than 60% reduction from 12 DAU to 46 DAU. Although day-to-day variability in light environment of monopodial leaves was low, between-leaf variability was very large, being as much as 7 times difference.

### **$P_{\max}$ and Leaf Age**

After 25 DAU,  $P_{\max}$  for main stem and sympodial leaves rapidly decreased with increasing leaf age (Fig. 2) as previously reported by other scientists (Constable and Rawson, 1980; Wullschlegler and Oosterhuis, 1990; Jiang et al., 1993; Kasemsap et al., 1997; Sassenrath-cole et al., 1997), losing approximately 70% of the peak capacity at 46 DAU.  $P_{\max}$  of monopodial leaves also decreased substantially with leaf age and showed much more variability than for main stem or sympodial leaves. It ranged from as low as 25% to approximately equal to those for main stem leaves at the same leaf age as previously reported by Kasemsap (1997).

As leaf age increased, significant decline in  $P_{\max}$  (70%) of main stem leaves coincided with non-significant reduction in light environment of leaf. This supported Sassenrath-Cole's (1997) conclusion that decline in main stem photosynthetic activity with leaf aging would rather result from an alteration in physiological function than light. However, significant decline of  $P_{\max}$  (70%) of sympodial and monopodial leaves with leaf aging corresponded with large reduction in light environment (70%). This suggested the possibility of a photosynthetic response to reduction in light environment.

### **$P_{\max}$ and Light Environment**

$P_{\max}$  response to differential light environment at several leaf ages is shown in Fig. 3. Since light environment was disturbed during photosynthesis measurement, daily PPF on the day before measurement was selected for data analysis shown. Using daily PPF data on the day of photosynthesis measurement as representative of light environment showed very similar result (data not shown). At 25 days after unfolding,  $P_{\max}$  was proportional to light availability up to approximately  $20 \text{ mol m}^{-2}\text{s}^{-1}$  and  $P_{\max}$  was saturating at  $20\text{-}35 \text{ mol m}^{-2}\text{s}^{-1}$ . At 32 and 39 days,  $P_{\max}$  was linearly related to light availability that attained the greatest value at approximately  $25 \text{ mol m}^{-2}\text{s}^{-1}$ . At 39 days, 5 leaves turned yellowish and at 44 days those leaves were already shed and 2 more leaves turned yellowish. At 44 days, relationship between  $P_{\max}$  and light availability was not statistically significant. Regression equations for the relationship between  $P_{\max}$  and light availability (PPF) for different leaf ages of this study are: 25 days  $P_{\max} = 13.75 + 0.59(\text{PPF})$ ,  $R^2 = 0.64$ ; 32 days  $P_{\max} = 9.70 + 0.89(\text{PPF})$ ,  $R^2 = 0.54$ ; 39 days  $P_{\max} = 0.91(\text{PPF}) - 0.05$ ,  $R^2 = 0.63$ .

The positive correlation between  $P_{\max}$  and differential light environment suggest photosynthetic adaptation of cotton leaves to growth light environment, in addition to physiological changes with leaf aging. Responding to low growth light environment, shade leaves developed small  $P_{\max}$  compared to sun leaves (Loomis and Connor, 1992). More study is needed to evaluate other physiological and morphological response of leaf to growth light environment. Those characteristics may include chlorophyll and carboxylase per unit area, capacity of electron transport, photosynthetic light response function, dark respiration, and specific leaf mass.

### **Acknowledgement**

The authors would like to thank H. Sinoquet and S. Thanisawanyangkura for providing the expertise in light measurement system. The assistance of DORAS project's researchers, especially Arm, Chaimongkol, and Duangrat, is gratefully acknowledged. This research was supported by European Commission STD3-DGXII n° TS3-CT 94-0288 and by DORAS project, Kasetsart University.

### **References**

- Adam, B. and H. Sinoquet. 1997. Micro-capteurs de rayonnement pour la mesure des éclaircissements foliaires. Cahier des techniques de l'INRA. In press.
- Constable, G. A., and H. M. Rawson. 1980. Effect of leaf position, expansion and age on photosynthesis, transpiration and water use efficiency. Aust. J. Plant Physiol. 7:89-100.
- Jiang, C. J., S. R. Rodermel, and R. M. Shibles. 1993. Photosynthesis, rubisco activity and amount, and their

regulation by transcription in senescing soybean leaves. *Plant Physiol.* 101:105-112.

Kasemsap P., Y. Crozat, and D. Satakhun. 1997. Influence of position on relationship between net photosynthesis rate and age of cotton leaf. In *Proc. Beltwide cotton conferences*. Vol. (2): 1427-1431.

Landivar, J. A., D. N. Baker, and J. N. Jenkins. 1983. Application of GOSSYM to genetic feasibility studies. II. Analyses of increasing photosynthesis, specific leaf weight and longevity of leaves in cotton. *Crop sci.* 23:504-510.

Loomis, R. S., and D. J. Connor. 1992. *Crop Ecology: productivity and management in agricultural systems*. Cambridge University Press. Australia. 538 p.

Peng, S., and D. R. Krieg. 1991. Single leaf and canopy photosynthesis response to plant age in cotton. *Agron. J.* 83:704-708.

Sassenrath-Cole G. F., G. Lu, H. F. Hodges, and J. M. McKinion. 1997. Photon flux density versus leaf senescence in determining photosynthetic efficiency and capacity of *Gossypium hirsutum* L. leaves. *Environ. Exp. Bot.* In press.

Thanisawanyangkura, S. 1995. Distribution spatio-temporelle du feuillage et des éclaircissements foliaires dans un couvert de cotonnier. *Memoire de DEA. INA-PG / universite Paris-Sud / CIRAD-CA / INRA.* 49 p.

Wells, R.. 1997. The birth, life, and death of the photosynthetic factory or the top ten reasons why cotton photosynthesizes like it does and why we love it so!. In *Proc. Beltwide cotton conferences*. Vol. (2): 1347-1349.

Wullschleger, S. D., and D. M. Oosterhuis. 1990a. Photosynthetic carbon production and use byu developing cotton leaves and bolls. *Crop Sci.* 30:1259-1264.

Wullschleger, S. D., and D. M. Oosterhuis. 1990b. Photosynthesis of individual field-grown cotton leaves during ontogeny. *Photosyn. Res.* 23:163-170.

Wullschleger, S. D., and D. M. Oosterhuis. 1992. Canopy leaf area development and age-class dynamics in cotton. *Crop Sci.* 32:451-456.

Figure 1. Light environment as a function of leaf age for main stem (MS), sympodial (FB), and monopodial (VB) leaves. Symbols are for daily averages. Heavy lines show trends. Light lines show minimum and maximum.

Figure 2.  $P_{max}$  as a function of leaf age for main stem (MS), sympodial (FB), and monopodial (VB) leaves.

Figure 3. Response of  $P_{max}$  to differential light environment of leaf recorded one day before photosynthesis measurement at different day after leaf unfolding. Open circles represent main stem leaves, squares represent sympodial leaves, and closed circles represent monopodial leaves.