CHANGE IN THE LIGHT EXTINCTION COEFFICIENT WITH ROW SPACING IN UPLAND COTTON

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Abstract

The light extinction coefficient, k, for cotton is important due to the increased interest in ultra-narrow cropping systems. The relationship between k, row spacing, and plant density will, in the future, be used in crop simulation models such as EPIC to more accurately predict crop response to various growing conditions. A two-year study was conducted in 1998 and 1999. The objective of this study was to characterize the effect of row spacing and plant density on the extinction coefficient of cotton. A split-plot, randomized complete block design with four replications was used with sixteen treatments consisting of row spacings of 0.15, 0.38, 0.76, and 1.00-m and plant densities of 150, 220, 300, and 450-thousand plants hectare^{-1}. In 1999 as row spacing increased, k decreased. This was attributed to an increase in LAI with row spacing. Plant density did not influence k, but yield increased as row spacing decreased.

Introduction

Many crop models use radiation use efficiency (RUE) as the theoretical basis for predicting the potential dry matter accumulation. RUE is the dry matter accumulation per unit of intercepted photosynthetically active radiation (IPAR) per day.

$$\text{RUE} = \text{Crop Dry Weight/IPAR}$$
(Rosenthal and Gerik, 1991)

Beer's law is used to estimate IPAR by a canopy as:

$$\text{IPAR} = \text{PAR} \times (1 - \exp(-k \times \text{LAI})$$
(Thornley, 1976)

where PAR is the total available photosynthetically active radiation, k is the light extinction coefficient, and LAI is leaf area index. k is calculated as:

$$k = -\ln(\text{TPAR/PAR})/\text{LAI}$$
(Flenet, et al., 1996)

where TPAR is transmitted PAR.

The light extinction coefficient has been determined for several crops, including soybean, sunflower, corn and sorghum. Each of the crops follows the same trend in response to row spacing. As row spacing increases, k decreases. The k-values for soybean and corn are very similar, while sunflower and sorghum differ somewhat from the other k-values (Figures 1a through 1d).

Materials and Methods

A two-year dryland study was conducted in Central Texas at the Stiles Farm Foundation in Thrall, Texas (1998) and the Blackland Research Center in Temple, Texas (1999). The experiment was designed as a split-plot, randomized complete block with four replications. The study consisted of sixteen treatments with row spacings of 0.15, 0.38, 0.76, and 1.00-m and plant densities of 150, 220, 300, and 450-thousand plants ha^{-1}. Tamcot Sphinx and Deltapine 451 were the cultivars used in 1998 and 1999, respectively. 168 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} was applied preplant. Plots were rainfed throughout the duration of the experiment. Insecticides and herbicides were applied consistent with local agronomic practices.

Data collected included canopy light interception, average plant height (cm) at time of light interception readings, plant number per area measured, LAI, leaf dry weight (g), stem dry weight (g), and yield. Canopy light interception (CLI) was characterized by measuring the above-canopy-incoming, above-canopy-reflected, and below-canopy-intercepted radiation. Two 0.8-m Decagon Sunfleck Ceptometers (Decagon Devices, Pullman, WA) were used to make the light interception measurements. The above-canopy-reflected PAR was measured by inverting the ceptometer above the canopy. Readings were taken on five 0.15-m rows, two 0.38-m rows, one 0.76-m row, and one 1.00-m row. CLI measurements were taken on four dates being at pinhead square at 900h, 1030h, and solar noon, where the 900h was assumed to be equal to the canopy light interception at 1600h and the 1030h to be equal to 230h. Two randomly chosen replications were measured on each date. The average of ten light measurements was recorded for each of the three positions in the canopy. On each date, after the solar noon reading, the aboveground plant material was harvested from the measured areas described above. The plants were separated into leaves and stems, and the number of plants and the average plant height were recorded for each area. Leaf area was measured on three representative plants per plot using a LI-COR area meter (LI-COR, Inc., Model LI3100, Lincoln, NE). These leaves were dried separately to determine the LAI of the entire plot. Leaves and stems were

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dried at 65°C for approximately four days. At this time the dry weights of the leaves (bulk), stems, and leaves (LAI sample) were recorded.

Data was analyzed using ANOVA, Fisher's LSD, and regression in PC-SAS (SAS Institute, Inc., 1990). A regression equation was developed for upland cotton relating the extinction coefficient to row spacing. The extinction coefficient was calculated according to the equation used by Flenet, et al. (1996). Yield and yield component comparisons between the four row spacings were carried out using Fisher's LSD.

Results

In 1998 LAIs did not differ greatly between row spacings nor did they increase significantly during the growing season due to severe drought. In 1998 a maximum LAI of only 1.5 was obtained. In 1999, however, the minimum LAI obtained early in the season was approximately 1.5 and the maximum obtained toward the end of the season was approximately 6.0. Figures 2a and 2b illustrate these differences. The large difference between years was attributed to the drought in 1998. Plant density did not influence the light extinction coefficient in either year.

Row spacing did not influence the light extinction coefficient in 1998 (Figure 3a). In 1998 LAIs were very low because the plants were abnormally small and therefore did not reach complete canopy for any row spacing. In 1999, however, row spacing had a significant influence on k. As row spacing increased k decreased (Figure 3b). Ultra-narrow row spacings were better able to intercept light due to their ability to reach canopy closure earlier. They accumulated LAI faster and earlier in the season. As the season progressed the wider row spacings overtook the narrow spacings due to crowding in the narrow spacings. Under normal growing conditions (1999) k was similar to that of Jackson and Hearn's (1990) (Figure 4). The slopes were basically identical. The intercepts differed somewhat, but this may have been due to different ranges in LAI. A higher intercept indicated higher LAIs throughout the season. LAIs may differ according to weather, varieties, and soil.

Lint yields were significantly different across row spacings for both years (Figure 5). Ultra-narrow rows (0.19-m) were significantly higher than all other row spacings. As row spacing increased yield decreased. This indicated that greater light interception translated into higher lint yield. Primarily this is due to the fact that plants planted in narrow rows are typically shorter and produce a more evenly distributed canopy allowing a greater percentage of leaves to receive and photosynthesize incoming radiation. For a crop like cotton, this is particularly important because the earliest fruit is found on the lower part of the plant deep in the canopy, and these fruit contribute most to the final yield.

Conclusions

Results suggest that plant density did not influence the canopy extinction coefficient. However, as row spacing increased k decreased. This indicated ultra-narrow row systems more efficiently intercepted and converted incoming PAR to photosynthetic energy. This is, in part, attributed to the fact that UNR systems are typically shorter and produce a more evenly distributed canopy. Increased interception of PAR also translated into higher yields. In both 1998 and 1999 as row spacing decreased yields tended to significantly increase. This again is due to UNR systems possessing a more evenly distributed canopy. Brown (1968) and Constable and Rawson (1982) demonstrated that assimilates for a cotton boll are derived mainly from adjacent leaves. Therefore, crops with denser canopies may set fewer or smaller early fruit, and for a crop like cotton it is this early fruit which contributes most to the final yield.

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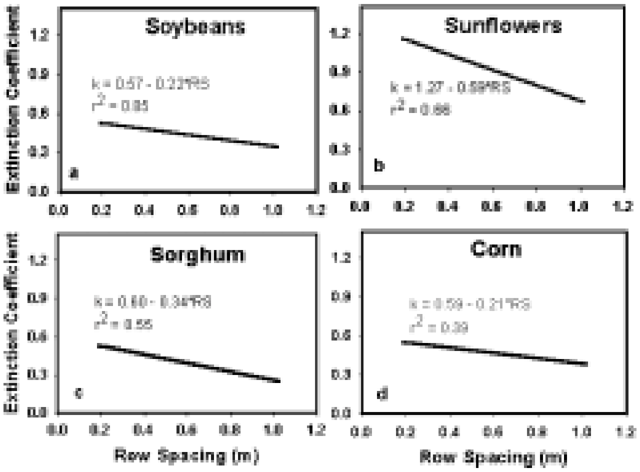

Figure 1. The light extinction coefficient estimate for (a) soybean, (b) sunflowers, (c) sorghum, and (d) corn (Flenet et al., 1996).

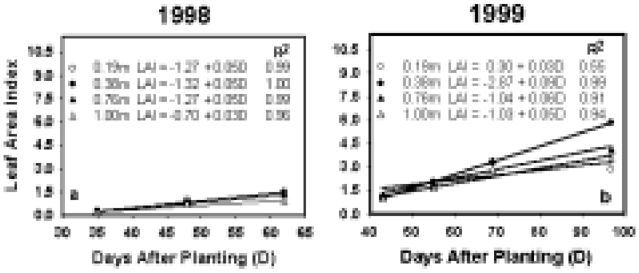

Figure 2. Leaf area indices across four row spacings in 1998 (a) and 1999 (b).

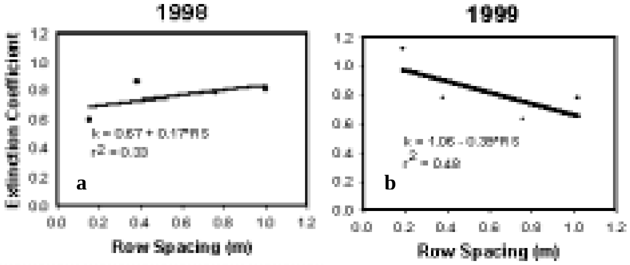

Figure 3. The light extinction coefficient as influenced by row spacing in 1998 (a) and 1999 (b).

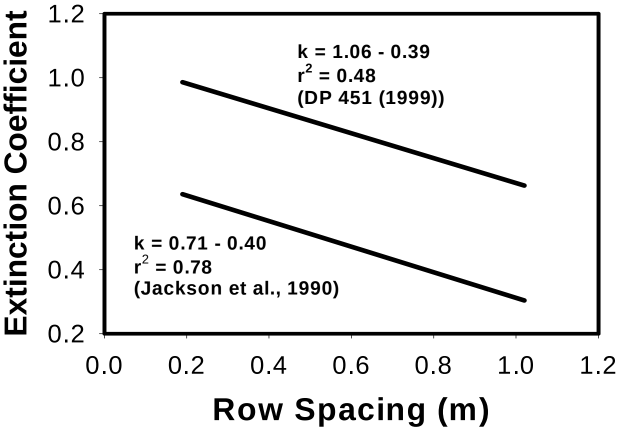

Figure 4. Comparison of k estimated by Jackson et al. (1990) and Steglich (1999).

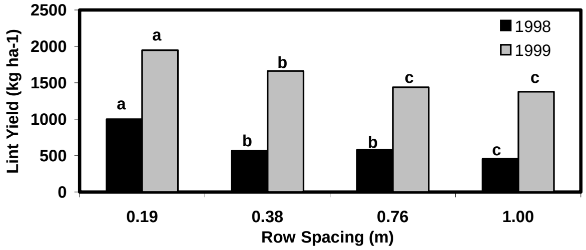

Figure 5. Lint yield over four row spacings in 1998 and 1999. Columns marked with same letter are not significantly different (P=0.20) based on LSD's means comparison test. Letters are independent for each year.