Radiation Use Efficiency of Cotton in Contrasting Environments

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RESEARCH PROBLEM

Yield variability in cotton (Gossypium hirsutum L.) from year to year (geographical locations) is a major production problem for farmers (Oosterhuis, 2002). Higher yields have been recorded in the drier environment of California, compared to the more humid environment of Arkansas. However, the effect of environmental factors, such as temperature, relative humidity, and vapour pressure deficit, on the radiation use efficiency of cotton has not been described for contrasting environments.

BACKGROUND INFORMATION

Crop growth (accumulation of dry matter) depends mainly in the amount of intercepted radiation and the time allowed for growth (Sinclair and Muchow, 1999). The effectiveness of a crop to convert intercepted radiation to dry matter is called radiation use efficiency (RUE), and is defined as the amount of dry matter produced (g) per unit of radiation intercepted (MJ) by the crop canopy. Monteith (1977) described this correlation as linear and the slope in the RUE. Reported values of RUE for different cotton cultivars range from 1.31 to 1.92 g•MJ\(^{-1}\) of intercepted photosynthetically active radiation (Pinter et al., 1994; Rosenthal and Gerik, 1991; Sadras and Wilson, 1997). Reduced values of RUE at higher vapour pressure deficits (VPD) have been documented for crops other than cotton. For sorghum and corn, RUE values based on PAR decreased with increasing VPD with a slope of 0.65 and 0.85 g•MJ\(^{-1}\)•kPa\(^{-1}\), respectively (Stöckle and Kiniry, 1990).

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RESEARCH DESCRIPTION

To determine the effect of environmental factors on RUE, field studies were established in Marianna, Ark. (Cotton Branch Station, University of Arkansas) and Fresno, Calif. (Campus Farm, California State University, Fresno). In both locations, the cotton cultivar ‘DP444’ was used. The studies included two plant populations (5 and 10 plants/m²) established two weeks after planting with five replications. Management practices were used as recommended in each location.

Radiation use efficiency was estimated by the slope of the increase in dry matter over the accumulated intercepted radiation. Dry matter was determined at the pinhead square growth stage (PHS), first flower (FF) and three weeks later (FF+3), by collecting plant samples from 1-m² ground area. Intercepted radiation was calculated by multiplying the incident radiation (measured by a weather station located at the edge of the field) with the fraction of intercepted radiation. The light interception by the crop canopy was measured weekly, starting at PHS, by measuring photosynthetically active radiation (PAR) above and below the canopy in unobstructed sunlight, close to solar noon, using a LI-191S line quantum-source quantum sensor (Li-Cor, Lincoln, Neb.).

RESULTS AND DISCUSSION

Although the study in Fresno, Calif., showed higher daily productivity of dry matter than in Marianna, Ark., the RUE in Fresno was lower (Table 1). The RUE was calculated as 2.2 g•MJ⁻¹ of intercepted PAR at Marianna and 1.80 g•MJ⁻¹ in Fresno. The higher values of productivity in Fresno can be attributed to higher amounts of incident and intercepted PAR between PHS and FF+3 compared to Marianna.

The environmental conditions between PHS and FF+3 for both locations are summarized in Table 2. It is apparent that Fresno had higher day temperatures and lower night temperatures, and lower relative humidity than Marianna. In addition, vapour pressure deficit values were lower for Marianna than for Fresno (Fig. 1). The lower values of RUE in Fresno can be explained by the higher values of VPD compared to Marianna. Data collected in 2006 and 2007 indicated that increasing vapour pressure deficit decreased radiation use efficiency by a slope of 0.47 g•M•kPa⁻¹.

PRACTICAL APPLICATION

Although higher yields have been reported in drier environments, such as California, than in the more humid environment of Arkansas, this study described higher RUE in Arkansas. However, dry matter production, as measured by daily crop productivity, was higher for California, possibly due to the larger amount of incident and intercepted radiation. As in the case of crops other than cotton, high values of vapour pressure deficit appear to decrease the efficiency of the crop to convert radiation energy to dry matter.

LITERATURE CITED


<table>
<thead>
<tr>
<th>Location</th>
<th>RUE (gMJ⁻¹)</th>
<th>Productivity (g•m⁻²•d⁻¹)</th>
<th>Heat units (MJ•m⁻²)</th>
<th>Intercepted radiation (MJ•m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marianna, Ark.</td>
<td>2.27</td>
<td>16.43</td>
<td>754</td>
<td>249.2</td>
</tr>
<tr>
<td>Fresno, Calif.</td>
<td>1.800</td>
<td>20.38</td>
<td>718</td>
<td>433.4</td>
</tr>
<tr>
<td>P-value</td>
<td>0.045</td>
<td>0.007</td>
<td>--</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Isolines</th>
<th>Lint yield (kg/ha)</th>
<th>Gin turnout (%)</th>
<th>Bolls (#/m²)</th>
<th>Boll weight (g/boll)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal-leaf</td>
<td>1738.6</td>
<td>39.17</td>
<td>85.9</td>
<td>5.385</td>
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<tr>
<td>Okra-leaf</td>
<td>1662.3</td>
<td>39.72</td>
<td>76.8</td>
<td>5.446</td>
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<tr>
<td>P value</td>
<td>0.520</td>
<td>0.399</td>
<td>0.084</td>
<td>0.572</td>
</tr>
</tbody>
</table>
Fig. 1. Daily values of vapor pressure deficit between PHS and FF+3 for Marianna, Ark., and Fresno, Calif.