Radiation Use Efficiency of Cotton in Two Contrasting Environments

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RESEARCH PROBLEM

Yield variability in cotton (Gossypium hirsutum L.) from year to year in different environments (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 in cotton have not been described for contrasting environments.

BACKGROUND INFORMATION

Crop growth (accumulation of dry matter) depends mainly on 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. Reported values of RUE for different cotton cultivars range from 1.31 to 1.92 g MJ⁻¹ of intercepted photosynthetic active radiation (PAR) (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).

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

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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 for each location.

RUE 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 photosynthetic active radiation 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 1.771 g•MJ⁻¹ of intercepted PAR at Marianna and 1.353 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 1. 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.

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.

ACKNOWLEDGMENTS

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LITERATURE CITED


Table 1. Radiation use efficiency, productivity, heat units, and intercepted radiation at the two locations of the study recorded between PHS and FF+3.

<table>
<thead>
<tr>
<th>Location</th>
<th>RUE (g MJ⁻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>1.771</td>
<td>11.6</td>
<td>902</td>
<td>261.8</td>
</tr>
<tr>
<td>Fresno, Calif.</td>
<td>1.353</td>
<td>17.4</td>
<td>982</td>
<td>443.2</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>—</td>
<td>3.39</td>
<td>—</td>
<td>47.31</td>
</tr>
</tbody>
</table>

Table 2. Mean values of environmental factors at the two locations of the study recorded between PHS and FF+3.

<table>
<thead>
<tr>
<th>Location</th>
<th>VPD (kPa)</th>
<th>High temperature (°C)</th>
<th>Low temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>PAR (MJ m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marianna, Ark.</td>
<td>1.212</td>
<td>33.7</td>
<td>21.3</td>
<td>67.50</td>
<td>10.12</td>
</tr>
<tr>
<td>Fresno, Calif.</td>
<td>2.183</td>
<td>37.2</td>
<td>19.3</td>
<td>43.70</td>
<td>13.61</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>0.142</td>
<td>1.19</td>
<td>1.21</td>
<td>2.17</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Fig. 1. Daily values of vapor pressure deficit between PHS and FF+3 for Marianna, Ark., and Fresno, Calif.