Light interception in soybean determined through digital imagery analysis affects soybean yield and weed suppression


Abstract

Digital imagery analysis provides a unique option to determine soybean light interception (LI) throughout the growing season. Subsequently, LI is used to calculate cumulative intercepted photosynthetically active radiation (CIPAR) which has been shown to affect soybean yield. This research evaluates whether early-season soybean CIPAR also has an effect on the amount of pigweeds (Amaranthus spp.) present at the postemergence (POST) herbicide application timing.

A field study was conducted in cooperative effort with seven universities across eight locations in 2013 representing eight site-years. Locations were combined relative to their optimum adaptation zone for soybean maturity groups. The North region was comprised of Nebraska, Ohio, and Wisconsin, and the South region was comprised of Arkansas, Southern Illinois, and Tennessee. Two row widths (≤38 and ≥76 cm), three seeding rates (173,000, 322,000, and 470,000 seeds ha⁻¹), and two herbicide strategies (preemergence plus postemergence (PRE + POST) vs. POST-only) were arranged in a randomized complete block split-plot design with row width as the main plot factor and a 3x2 factorial of seeding rate and herbicide strategies as the subplots. Across all locations, PRE applications were made within two days of planting, POST-only applications were made approximately 14 days after the V1 (DAV1) soybean growth stage, and POST following PRE applications were made 28 to 35 DAV1. Pigweed density was measured prior to the POST herbicide applications and soybean harvest. Digital images of each
plot were taken weekly from V1 to August 1 and analyzed using SigmaScan Pro 5® software to provide weekly LI percentages. Quadratic models were fit for each plot to estimate daily LI percentages from V1 to 50 DAV1 for each location, and subsequently used with daily average solar radiation estimates to calculate CIPAR. CIPAR was then summed for 29 DAV1 (early-season CIPAR) for analysis with pigweed densities at the POST herbicide application and summed for 50 DAV1 (total CIPAR) for analysis with soybean yield. Early-season CIPAR was inversely correlated with pigweed density at the POST herbicide application in the North ($R^2=0.3363$) and South ($R^2=0.1272$) regions. A one MJ m$^{-2}$ increase in early-season CIPAR led to a decrease of one pigweed m$^{-2}$ in both regions. A PRE + POST herbicide strategy increased early-season CIPAR in the North ($P=0.0300$) and South ($P=0.0236$) regions by 23.55 and 16.46 MJ m$^{-2}$, respectively. Similarly, this herbicide strategy significantly increased total CIPAR in the North ($P=0.0212$) and South ($P=0.0166$) regions by 29.79 and 18.35 MJ m$^{-2}$, respectively. An increase in seeding rate of 148,000 seeds ha$^{-1}$ was required to achieve an equivalent increase in CIPAR. Furthermore, a PRE + POST herbicide strategy increased yields in both the North ($P=0.0400$) and South ($P=0.0329$) regions by 458 and 377 kg ha$^{-1}$, respectively. Soybean yield was positively correlated with total CIPAR for both the North ($R^2=0.2010$) and South ($R^2=0.2200$) regions. In conclusion, through digital imagery analysis we determined a PRE + POST herbicide strategy increases early-season and total CIPAR in both North and South regions of the Midwest. The increase in CIPAR aids in both weed suppression and soybean yield. To support these conclusions, data from 2014 will be analyzed to provide 16 total site-years.
Light interception in soybean determined through digital imagery analysis affects soybean yield and weed suppression

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2014 NCWSS Annual Meeting
Introduction

- Standard method of light interception (LI) estimation:
  - Light quantum sensor
  - \[ LI = [1 - (\text{PAR beneath canopy}) \times (\text{PAR above canopy})^{-1}] \]
- Digital imagery analysis
  - Less labor intensive
  - 1:1 relationship

Objectives

• To calculate Cumulative Intercepted Photosynthetically Active Radiation (CIPAR) from LI identified through digital imagery analysis
• To evaluate factors that influence CIPAR in soybean systems
• To determine if increasing CIPAR will reduce pigweed (Amaranthus spp.) pressure
Materials & Methods

Experimental Design

• RCB Split-Plot Design
• Main Plot Factor:
  • (2) Row Width
    • ≤ 38 cm
    • ≥ 76 cm
• Sub Plot Factors:
  • (3) Seeding Rate (seeds ha⁻¹)
    • 173,000
    • 322,000
    • 470,000
  • (2) Herbicide Strategy
    • Preemergence + Postemergence (PRE + POST)
    • Postemergence only (POST-only)
• Liberty Link® soybean system
Materials & Methods

Locations

• **North Region:**
  • Nebraska (2 locations)
  • Ohio
  • Wisconsin

• **South Region:**
  • Arkansas
  • Southern Illinois (2 locations)
  • Tennessee
Region Grouping Justification

Zhang et al., 2007. Crop Management. 6:1
## Herbicide Applications

### Table 1. Herbicide application timings across locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>PRE</th>
<th>POST-only</th>
<th>POST fb</th>
<th>PRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fayetteville, AR</td>
<td>0</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Collinsville, IL</td>
<td>0</td>
<td>1</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>De Soto, IL</td>
<td>0</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Fremont, NE</td>
<td>0</td>
<td>7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Havelock, NE</td>
<td>0</td>
<td>1</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>South Charleston, OH</td>
<td>2</td>
<td>9</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Jackson, TN</td>
<td>2(^c)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Arlington, WI</td>
<td>1</td>
<td>4</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Abbreviation: DAP, Days after planting

\(^b\)Abbreviation: DAV1, Days after V1 soybean growth stage

\(^c\)Application made two days prior to planting
Herbicide Applications

• PRE:
  1.21 kg a.i. ha\(^{-1}\) s-metolachlor plus 0.27 kg a.i. ha\(^{-1}\) fomesafen plus 0.42 kg a.i. ha\(^{-1}\) metribuzin

• POST only:
  0.59 kg a.i. ha\(^{-1}\) glufosinate plus 1.21 kg a.i. ha\(^{-1}\) s-metolachlor plus 0.27 kg a.i. ha\(^{-1}\) fomesafen

• POST fb PRE:
  0.59 kg a.i. ha\(^{-1}\) glufosinate
Data Collection

- Pigweed density recorded at POST herbicide application and soybean harvest
- Weekly digital images from soybean V1 growth stage to August 1
- SigmaScan Pro 5® software
- Linear models established to estimate LI in POST-only treatments before POST
CIPAR Calculation

Quadratic models estimate Daily LI values from V1 to 50 DAV1

Hargreaves-Samani Model\(^{(1)}\) used to estimate average daily solar radiation

\[
\text{Average daily solar radiation} \times 0.5 = \text{Daily Incidence PAR}
\]

\[
\text{Daily LI} \times \text{Daily Incidence PAR} = \text{Daily Intercepted PAR}\(^{(2)}\)
\]

Sum Daily Intercepted PAR (29 DAV1) = early-season CIPAR

Sum Daily Intercepted PAR (50 DAV1) = total CIPAR

Materials & Methods

CIPAR

University of Illinois, 1999
Results

Pigweed Density at POST vs. Early-Season CIPAR in North Region

$R^2 = 0.3363$
Results

Pigweed Density at POST vs. Early-Season CIPAR in South Region

$R^2 = 0.1272$
Pigweed Density at POST vs. Early-Season CIPAR

Equates to a decrease of one pigweed m\(^{-2}\) for an increase of one MJ m\(^{-2}\) of early-season CIPAR.
## Herbicide Strategy Effects
### North Region

**Table 2.** Herbicide strategy effect on early-season CIPAR, total CIPAR, and soybean yield.

<table>
<thead>
<tr>
<th>Factor</th>
<th>North Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early-Season</td>
</tr>
<tr>
<td></td>
<td>CIPAR&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Herbicide Strategy</td>
<td></td>
</tr>
<tr>
<td>PRE + POST</td>
<td>130.6</td>
</tr>
<tr>
<td>POST-only</td>
<td>107.0</td>
</tr>
<tr>
<td>P-Values</td>
<td>0.0300</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means within the column followed by a different letter are significantly different according to Fisher’s Protected LSD at α=0.05.
# Row Width x Seeding Rate Interaction

## North Region

Table 3. Row Width x Seeding Rate Interaction Effect on CIPAR in North Region.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Row Width</th>
<th>Seeding Rate</th>
<th>Early-Season CIPAR&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Total CIPAR&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>seeds ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>MJ m&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>MJ m&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>≤ 38</td>
<td>173,000</td>
<td>100.1</td>
<td>de</td>
<td>279.0</td>
</tr>
<tr>
<td>≤ 38</td>
<td>322,000</td>
<td>132.5</td>
<td>b</td>
<td>325.0</td>
</tr>
<tr>
<td>≤ 38</td>
<td>470,000</td>
<td>159.1</td>
<td>a</td>
<td>359.1</td>
</tr>
<tr>
<td>≥ 76</td>
<td>173,000</td>
<td>87.7</td>
<td>e</td>
<td>249.7</td>
</tr>
<tr>
<td>≥ 76</td>
<td>322,000</td>
<td>111.3</td>
<td>cd</td>
<td>288.2</td>
</tr>
<tr>
<td>≥ 76</td>
<td>470,000</td>
<td>121.9</td>
<td>bc</td>
<td>301.4</td>
</tr>
</tbody>
</table>

P-Values: 0.0132 0.0170

<sup>a</sup>Means within the column followed by a different letter are significantly different according to Fisher’s Protected LSD at α=0.05.
### Results

## Herbicide Strategy Effects

### South Region

**Table 4.** Herbicide strategy effect on early-season CIPAR, total CIPAR, and soybean yield.

<table>
<thead>
<tr>
<th>Factor</th>
<th>South Region</th>
<th>Early-Season CIPAR&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Total CIPAR&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Yield&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>---MJ m&lt;sup&gt;-2&lt;/sup&gt;---</td>
<td>---MJ m&lt;sup&gt;-2&lt;/sup&gt;---</td>
<td>---kg ha&lt;sup&gt;-1&lt;/sup&gt;---</td>
</tr>
<tr>
<td>Herbicide Strategy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE + POST</td>
<td></td>
<td>164.0 a</td>
<td>375.1 a</td>
<td>3994 a</td>
</tr>
<tr>
<td>POST-only</td>
<td></td>
<td>147.5 b</td>
<td>356.8 b</td>
<td>3617 b</td>
</tr>
<tr>
<td>P-Values</td>
<td></td>
<td>0.0236</td>
<td>0.0166</td>
<td>0.0329</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means within the column followed by a different letter are significantly different according to Fisher’s Protected LSD at α=0.05.
Results

Seeding Rate
South Region

Table 5. Seeding Rate Fixed Effect on CIPAR in South Region.

<table>
<thead>
<tr>
<th>Seeding Rate (seeds ha⁻¹)</th>
<th>Early-Season CIPAR (MJ m⁻²)</th>
<th>Total CIPAR (MJ m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>173,000</td>
<td>132.4 c</td>
<td>338.6 c</td>
</tr>
<tr>
<td>322,000</td>
<td>158.9 b</td>
<td>369.8 b</td>
</tr>
<tr>
<td>470,000</td>
<td>176.0 a</td>
<td>389.4 a</td>
</tr>
</tbody>
</table>

P-Values: 0.0003 0.0003

Means within the column followed by a different letter are significantly different according to Fisher’s Protected LSD at α=0.05.
Yield vs. Total CIPAR
North Region

$R^2 = 0.2010$

Results

Yield vs. Total CIPAR
South Region

\[ R^2 = 0.2200 \]

Soybean Yield (kg ha\(^{-1}\))

Total CIPAR (MJ m\(^{-2}\))

Conclusions

- PRE + POST herbicide strategy increased early-season and total CIPAR for both location regions
- Combination of PRE + POST herbicide strategy and increased CIPAR led to increased soybean yield and decreased pigweed densities
Conclusions

Table 6. CIPAR differences between the herbicide strategy and seeding rate factors.

<table>
<thead>
<tr>
<th></th>
<th>North Region</th>
<th>South Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early-Season CIPAR</td>
<td>Total CIPAR</td>
</tr>
<tr>
<td>Herbicide Strategy (PRE + POST vs. POST-only)</td>
<td>23.6</td>
<td>29.8</td>
</tr>
<tr>
<td>Seeding Rate (470,000 vs. 322,000 seeds ha⁻¹)</td>
<td>26.6</td>
<td>34.1</td>
</tr>
</tbody>
</table>

- To support these conclusions, data from 2014 will be analyzed to provide 16 total site-years
Thank-you

I would like to thank all of the undergraduate research assistants, graduate research assistants, and research support staff who assisted with this project.
Questions?