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

Thomas R. Butts, Jason K. Norsworthy, Greg R. Kruger, Lowell Sandell, Bryan Young, Lawrence E. Steckel, Mark M. Loux, Kevin W. Bradley, William G. Johnson, Vince M. Davis

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.

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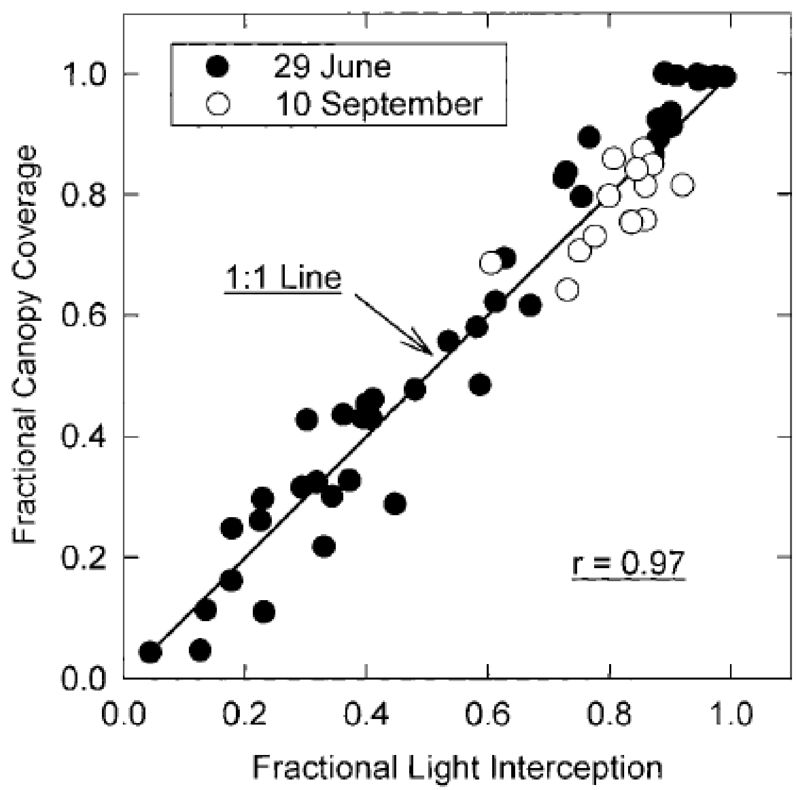
Introduction

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



Purcell, 2000. Crop Sci. 40:834-837; De Bruin et al., 2009. Crop Sci. 49:2225-2232

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

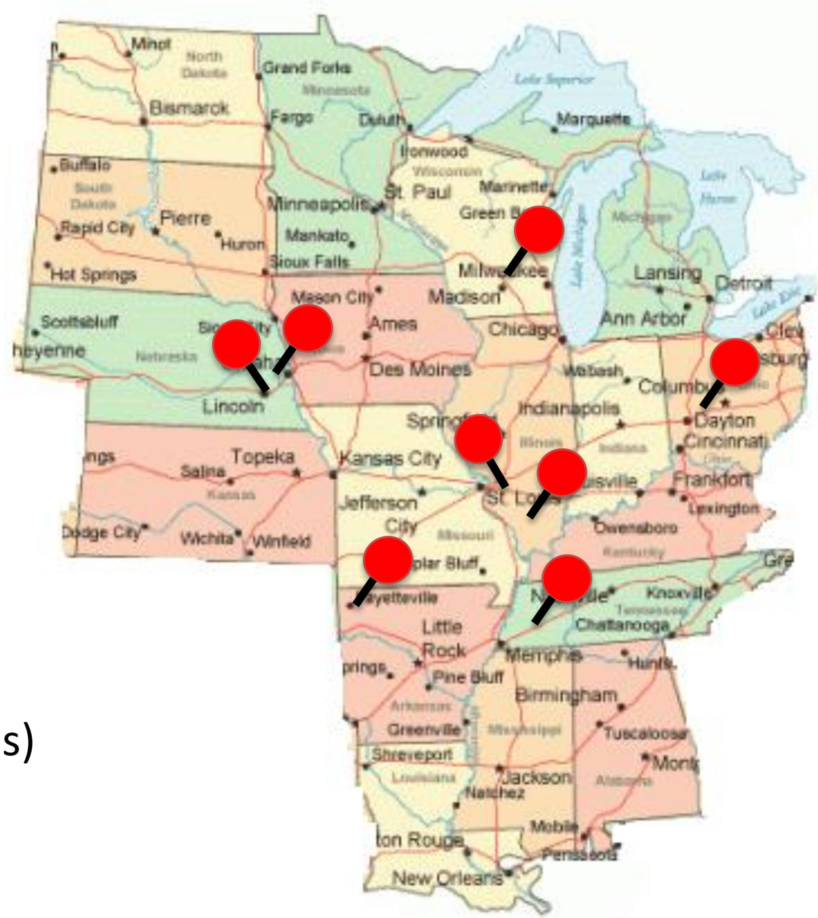
Experimental Design

- 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

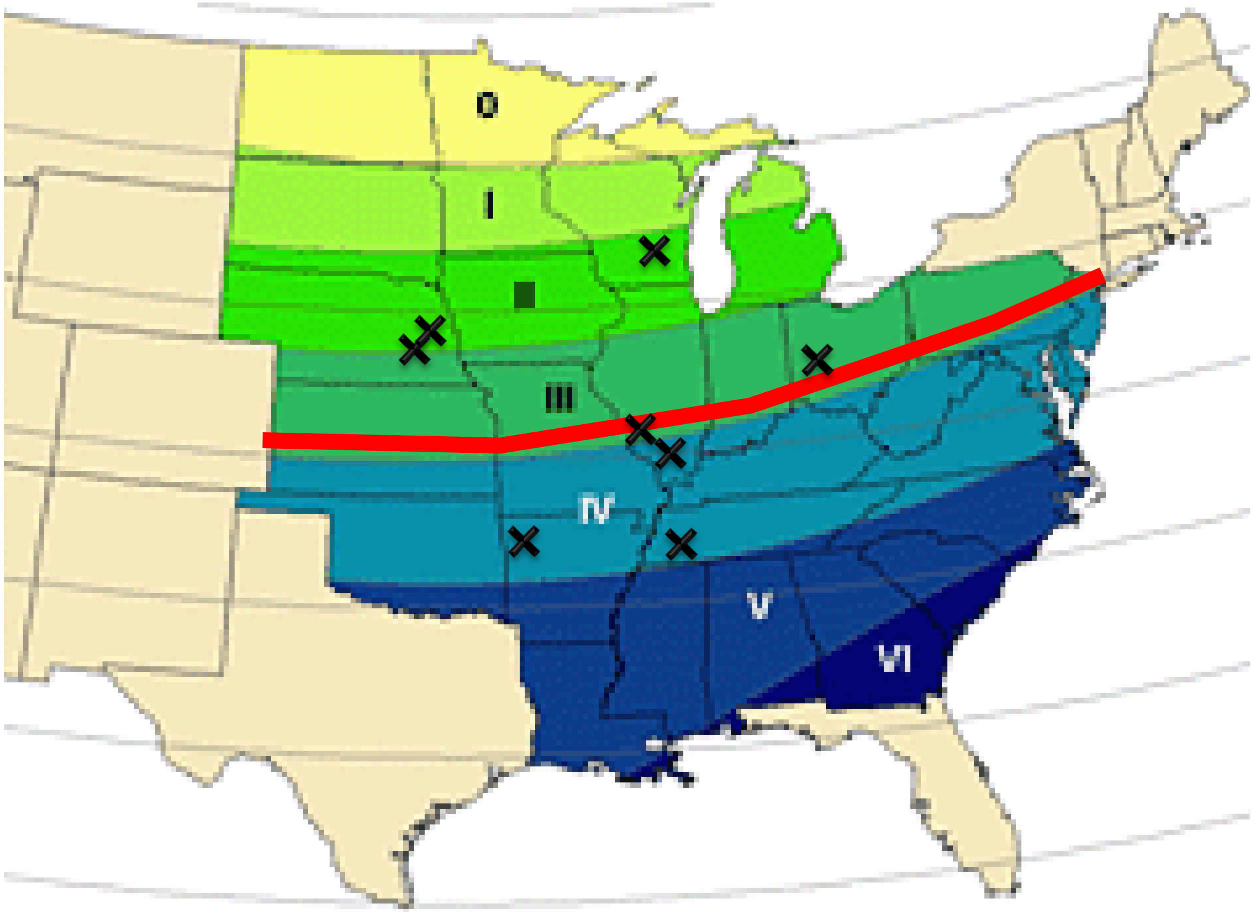
Locations

- **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.

Location	PRE	POST-only	POST fb PRE
	DAP[a]	———DAV1[b]———	
Fayetteville, AR	0	14	14
Collinsville, IL	0	1	19
De Soto, IL	0	5	21
Fremont, NE	0	7	29
Havelock, NE	0	1	28
South Charleston, OH	2	9	37
Jackson, TN	2[c]	1	1
Arlington, WI	1	4	23

[a]Abbreviation: DAP, Days after planting
[b]Abbreviation: DAV1, Days after V1 soybean growth stage
[c]Application made two days prior to planting

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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:**

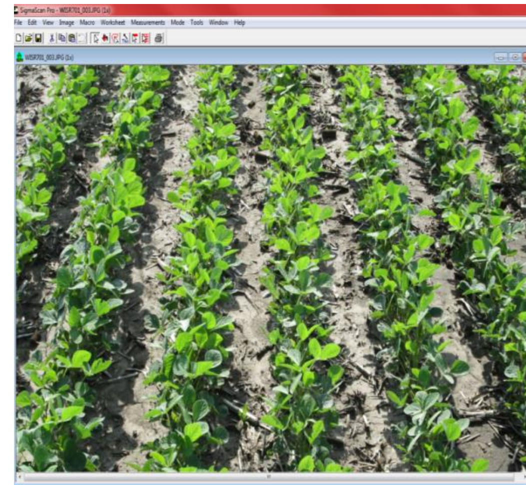
  0.59 kg a.i. ha^{-1} glufosinate plus 1.21 kg a.i. ha^{-1} s-metolachlor plus 0.27 kg a.i. ha^{-1} fomesafen

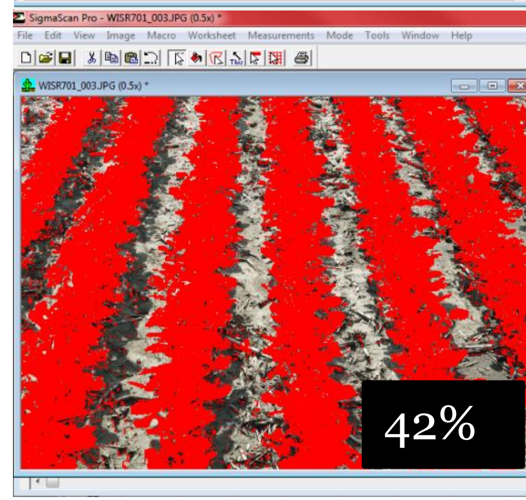
- **POST fb PRE:**

  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

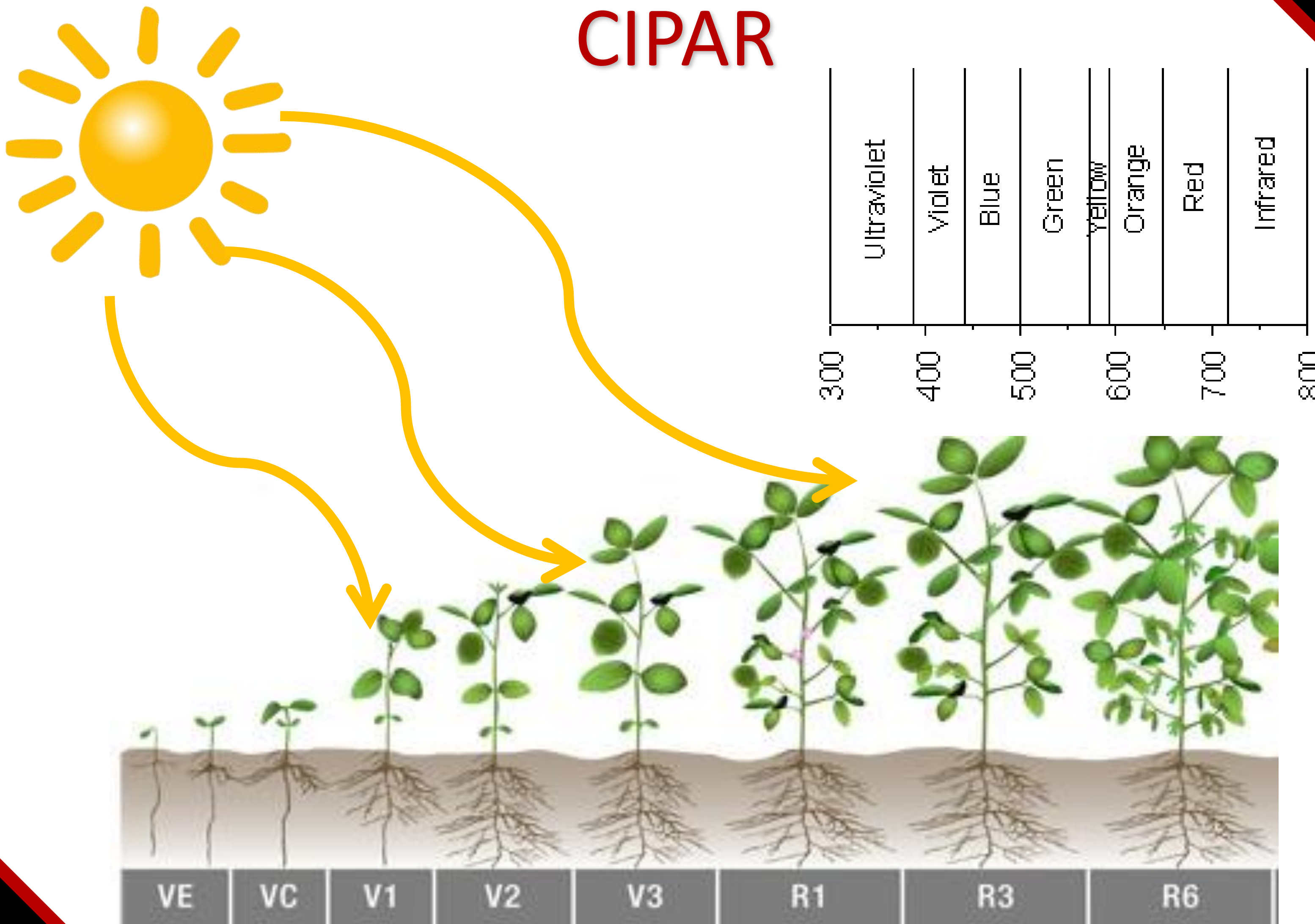
Average daily solar radiation * 0.5 = Daily Incidence PAR

Daily LI * Daily Incidence PAR = Daily Intercepted PAR[2]

Sum Daily Intercepted PAR (29 DAV1) = early-season CIPAR
Sum Daily Intercepted PAR (50 DAV1) = total CIPAR

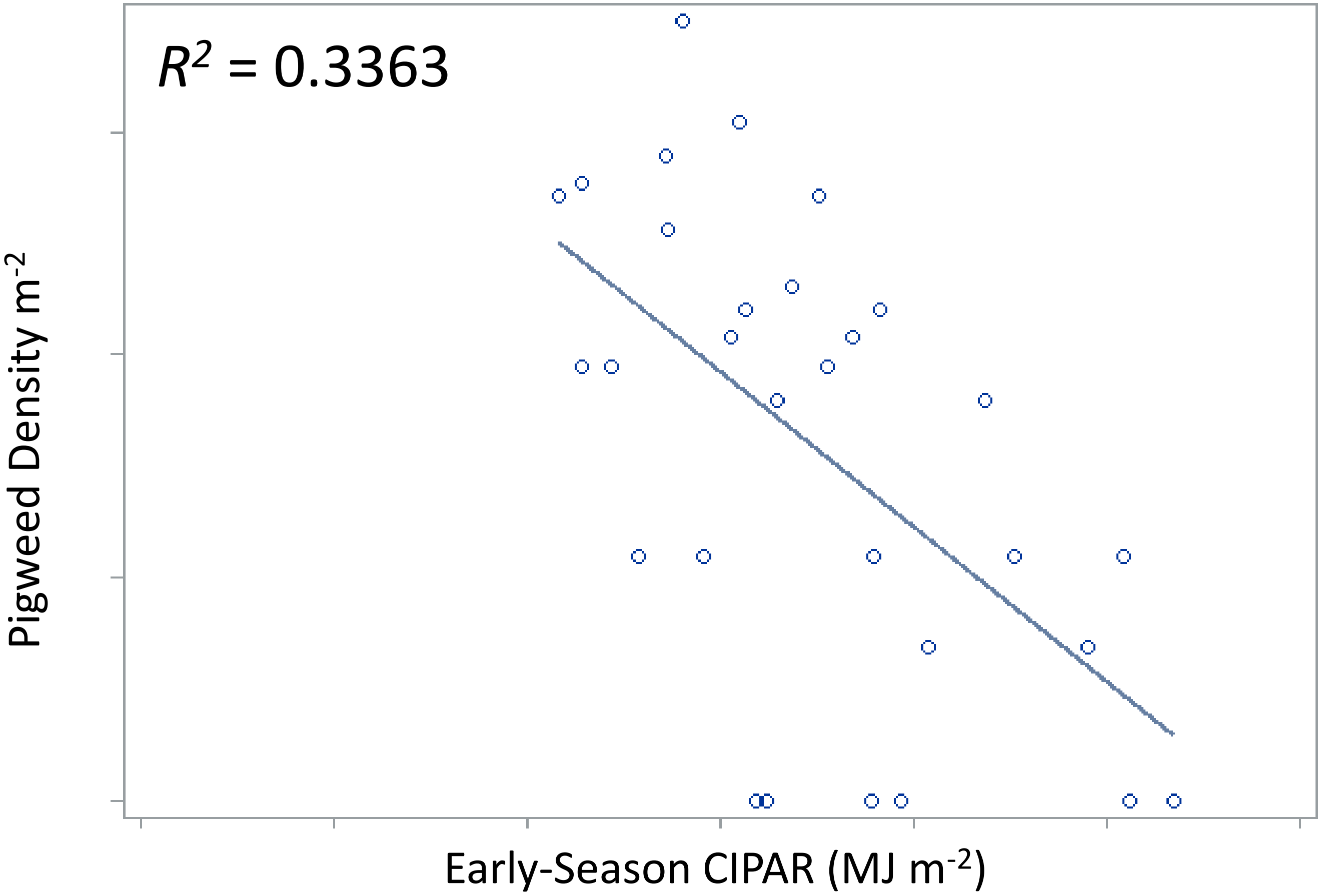
[1]Ball et al., 2004. Agron J:391-397; [2]Edwards et al., 2005. Crop Sci:1778-1785

CIPAR

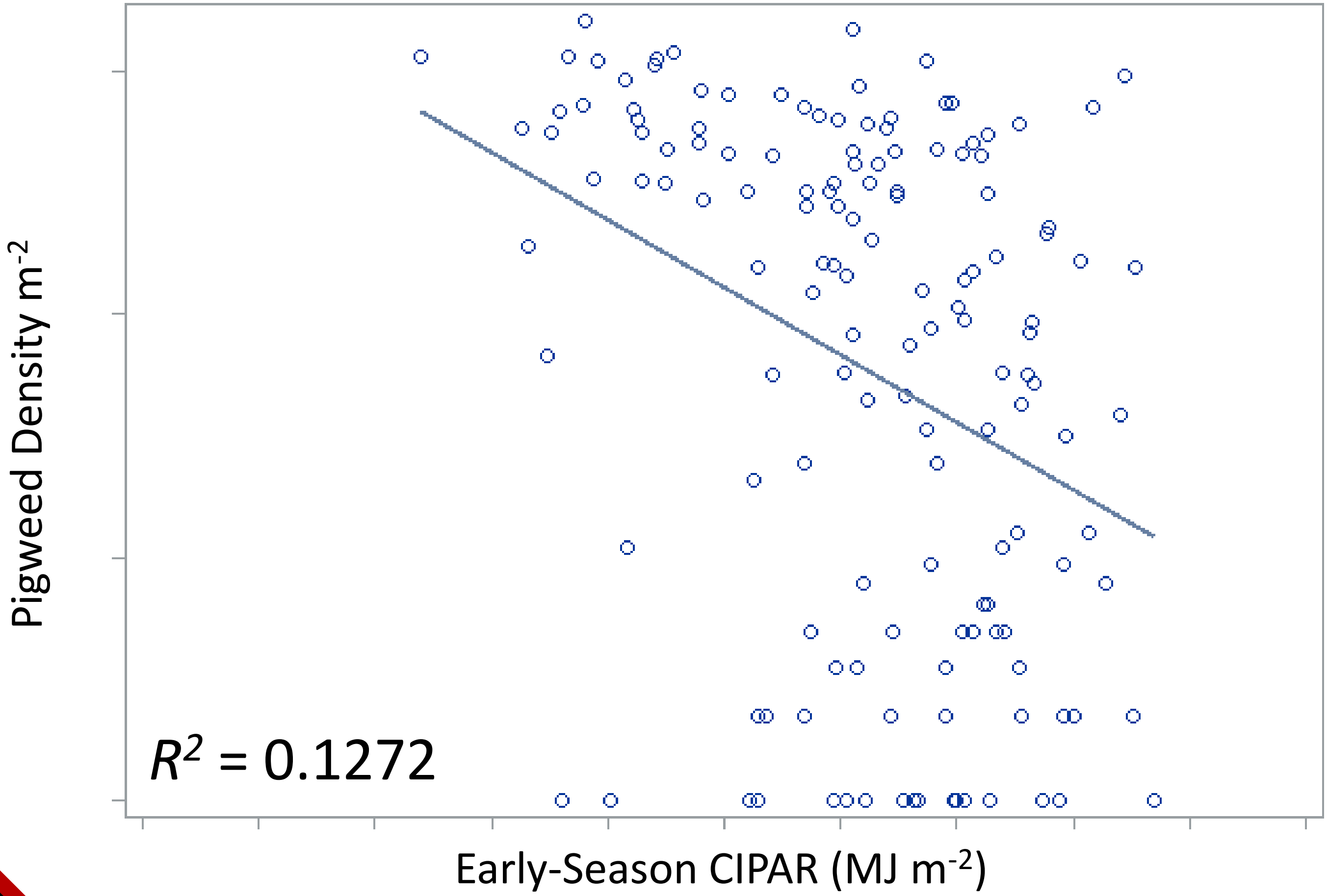


University of Illinois, 1999

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



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



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.

	North Region		
Factor	Early-Season CIPAR[a]	Total CIPAR[a]	Yield[a]
	—MJ m^{-2}—	—MJ m^{-2}—	—kg ha^{-1}—
Herbicide Strategy			
PRE + POST	130.6 a	315.3 a	3134 a
POST-only	107.0 b	285.5 b	2676 b
P-Values	0.0300	0.0212	0.0403

[a]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.

Factor			
Row Width	Seeding Rate	Early-Season CIPAR[a]	Total CIPAR[a]
———cm———	—seeds ha^{-1}—	——MJ m^{-2}——	—MJ m^{-2}—
≤ 38	173,000	100.1 de	279.0 d
≤ 38	322,000	132.5 b	325.0 b
≤ 38	470,000	159.1 a	359.1 a
≥ 76	173,000	87.7 e	249.7 e
≥ 76	322,000	111.3 cd	288.2 cd
≥ 76	470,000	121.9 bc	301.4 c
P-Values		0.0132	0.0170

[a]Means within the column followed by a different letter are significantly different according to Fisher's Protected LSD at α=0.05.

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Herbicide Strategy Effects
South Region

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

	South Region		
Factor	Early-Season CIPAR[a]	Total CIPAR[a]	Yield[a]
	—MJ m^{-2}—	—MJ m^{-2}—	–kg ha^{-1}–
Herbicide Strategy			
PRE + POST	164.0 a	375.1 a	3994 a
POST-only	147.5 b	356.8 b	3617 b
P-Values	0.0236	0.0166	0.0329

[a]Means within the column followed by a different letter are significantly different according to Fisher's Protected LSD at α=0.05.

Seeding Rate

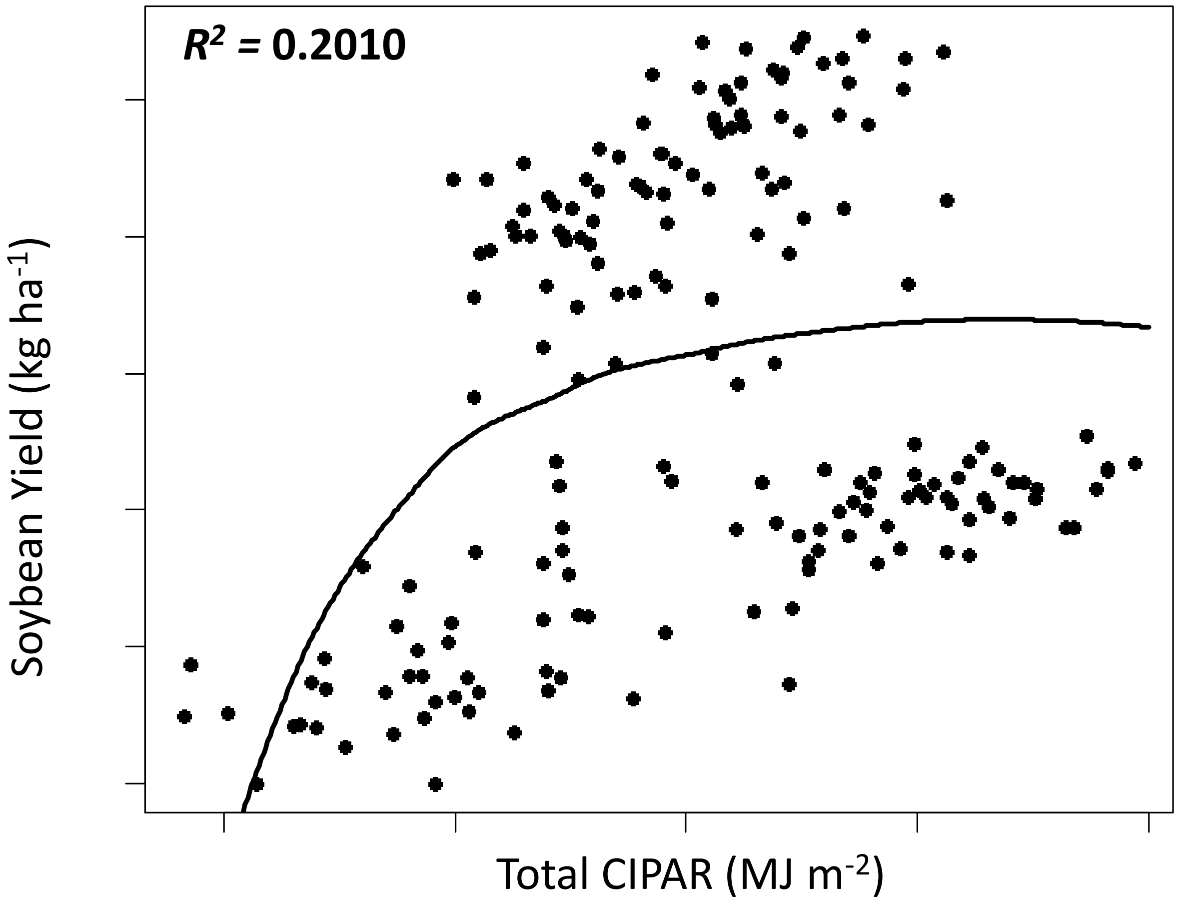
South Region

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

Factor		
Seeding Rate	Early-Season CIPAR[a]	Total CIPAR[a]
—seeds ha^{-1}—	—MJ m^{-2}—	—MJ m^{-2}—
173,000	132.4 c	338.6 c
322,000	158.9 b	369.8 b
470,000	176.0 a	389.4 a
P-Values	0.0003	0.0003

[a]Means within the column followed by a different letter are significantly different according to Fisher's Protected LSD at α=0.05.

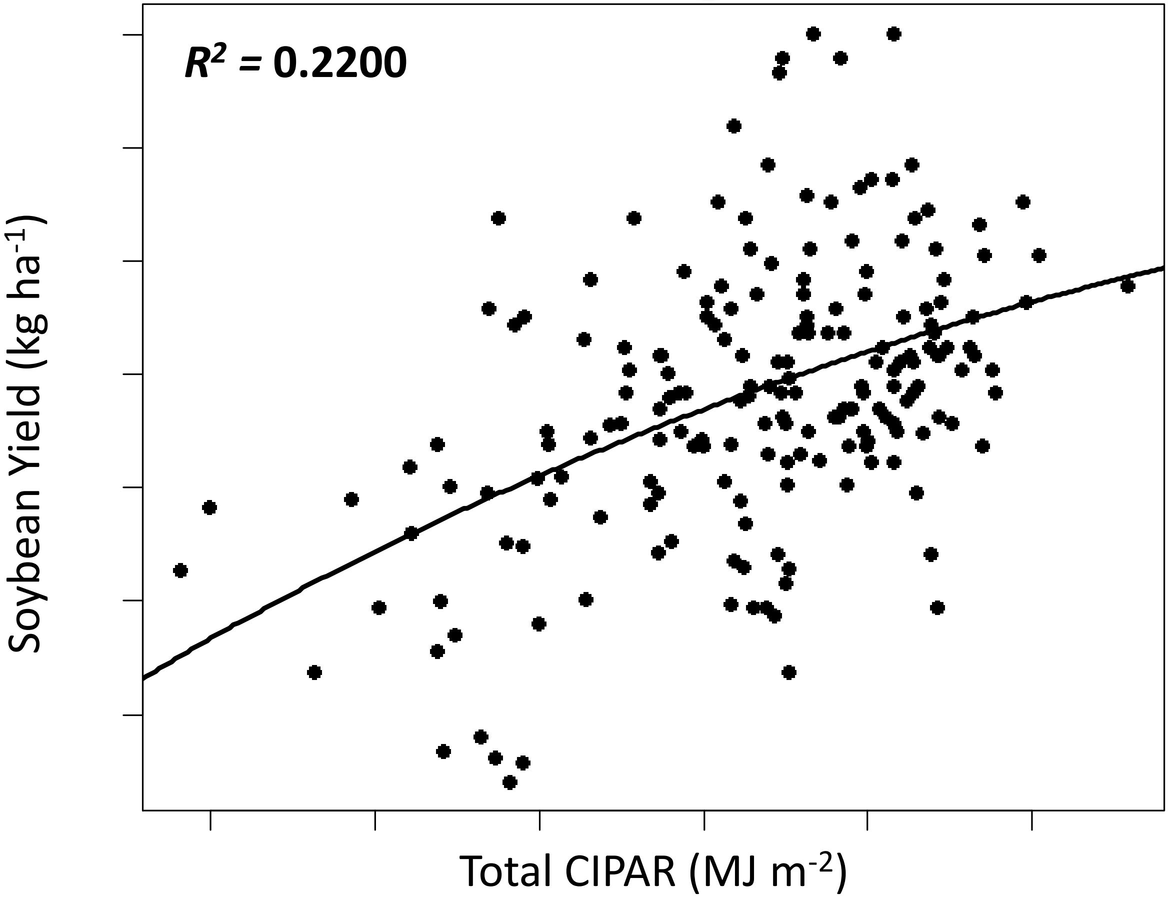
Yield vs. Total CIPAR
North Region



Edwards et al., 2005. Crop Sci:1778-1785

Yield vs. Total CIPAR

South Region



Edwards et al., 2005. Crop Sci:1778-1785

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

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Conclusions

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

	North Region		South Region	
	Early-Season CIPAR	Total CIPAR	Early-Season CIPAR	Total CIPAR
Herbicide Strategy (PRE + POST vs. POST-only)	23.6	29.8	16.5	18.3
Seeding Rate (470,000 vs. 322,000 seeds ha^{-1})	26.6	34.1	17.1	19.6

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

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Thank-you

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Questions?