INSECT CONTROL TERMINATION DECISIONS ACROSS IRRIGATED AND RAINFED MANAGEMENT ZONES IN CENTER PIVOT IRRIGATED COTTON

Tina Gray Teague
Erin J. Kelly
Arkansas State University – University of Arkansas Division of Agriculture
Jonesboro, AR
Diana M. Danforth
Department of Agricultural Economics and Agribusiness, University of Arkansas
Fayetteville, AR
David Wildy
Wildy Family Farms
Manila, AR

Abstract

Zone management for insecticide termination was evaluated in irrigated and rainfed management zones in a center pivot irrigated field during 2012 and 2013 growing seasons in Northeast Arkansas. A replicated strip trial across center pivot irrigated “circles” and rainfed “corners” was used to validate the use of NAWF-based measures of crop maturity to time the final late-season insecticide applications to control tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). There were three treatments: 1) a conventional blanket insecticide spray timed to protect susceptible irrigated cotton from plant bugs at infestation levels that exceeded recommended action thresholds, 2) management zone specific insecticide applied exclusively in the irrigated zone where plants had accumulated > 250 DD60s from physiological cutout but not in rainfed zones, or 3) untreated check. Spray patterns in the zone management strips were changed simply by the equipment operator manually turning the applicator on and off as he drove the 28-row high clearance sprayer through irrigated and rainfed cotton. The COTMAN crop monitoring system was used to gauge maturity among zones and allow identification of cutout, which was considered flowering date of the last effective boll population. Insect counts, plant monitoring and yield assessments were used to evaluate treatment effects. In both years, late season infestations of plant bugs increased to levels exceeding state recommended action thresholds, and following insecticide application, numbers were reduced to sub-threshold levels. In the unsprayed check, plant bug numbers increased to greater than six fold the action threshold in irrigated cotton. Plant bug numbers were significantly lower in the rainfed cotton in both 2012 and 2013. Plant monitoring results showed significant spatial and temporal differences in crop maturity among zones. Mean no. days from planting to physiological cutout (NAWF=5) differed between zones by 24 days in 2012, a drought year, and by 11 days in 2013, a cloudy and wet year. In both years, at the time of the final insecticide application, plants in the rainfed zones were well past the final stage of crop susceptibility (accumulated heat units from flowering date of last effective boll population was > 250 DD60s) while those in the irrigated zone were still susceptible stage to economic damage by tarnished plant bug. Rainfed cotton produced lower lint yields than irrigated cotton in 2012; there was no difference among irrigation zones in the rainy 2013 season. There were no differences in lint yield among insect control treatments. There was no yield penalty in following the COTMAN termination guide in management zones, which is an advantageous finding. Insecticide costs were reduced 14% with zone management compared to a broadcast application. The Fieldprint Calculator was used to evaluate sustainability, and Fieldprint output indicated that the zone approach was more efficient regarding resource management. Results from this insect control termination field study support the use of zone management in timing insecticide termination with both economic and environmental benefits.

Introduction

The question arises at the close of every cotton season …. *When* is the crop safe from insect pests? Requirements for late season crop protection from a particular pest are dependent upon crop maturity. Earlier maturity means that plants more quickly reach the final stage of crop susceptibility – that late season end-point when a pest species is no longer economically significant. To identify that endpoint is complicated because of the perennial nature of the cotton plant. Crop managers first must identify the last group of bolls that will make an economically significant contribution to yield. When those bolls are sufficiently mature, then it is safe to terminate control of new pest infestations.

Practical, when-to-quit guides have been developed in the COTMAN™ monitoring system (Danforth and O'Leary 1998; Oosterhuis and Bourland 2008) to allow managers to identify the last effective bolls and then determine when those bolls have reached the maturity end-point. Field scouts make weekly counts of nodes above white flower (NAWF) to determine the date of physiological cutout, the flowering date of the last effective boll population. Research has shown that Midsouth cotton has reached physiological cutout when plants average NAWF = 5 (Bourland et al 1992). As the last effective bolls mature, they become less susceptible to particular pests. Heat unit thresholds for the most important Midsouth cotton insect pests have been developed and validated (Bernhardt et al 1986, Bagwell and Tugwell 1992; Harris et al 1997, Cochran et al 1999, Fife et al 2000; Danforth et al 2004, Teague et al. 2006; Teague et al. 2008; Teague et al. 2010), and these are now routinely included in Extension recommendations for end-of-season management. In Arkansas, the recommended protection endpoint for tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) is cutout+250 DD60s (Studebaker et al 2013).

Crop earliness and end-of-season management is affected by an array of weather and production practices. Irrigation can have a considerable impact on both earliness and yield potential. Typically, non-irrigated, rainfed plants are lower yielding, and they reach cutout earlier than irrigated plants. Maturity and yield differences can be very apparent in Midsouth fields with center pivot sprinkler irrigation. The entire field is usually planted, including the rainfed corners. These corners represent large crop areas -- as much as 10 to18% of a production field. The maturity and yield differences over large predictable patterns make center pivot fields ideal candidates for zone management.

For this study, we examined the feasibility of implementing zone management for insecticide termination using irrigated and rainfed management zones. Because rainfed plants with early cutout reach the final stage of crop susceptibility sooner than irrigated plants, we hypothesized that they would not require prolonged applications of costly insecticides for protection from late season pest infestations of tarnished plant bug. A replicated strip trial across center pivot irrigated "circles" and rainfed "corners" was used to validate the use of NAWF-based measures to time the final late season insecticide. In addition to plant, pest and economic assessments, we used the Fieldprint Calculator (http://keystoneftm.zedxinc.com/fieldprint-calculator/) to provide an additional evaluation of how the zone management practice relates to resource management and sustainability.

Materials and Methods

We conducted the experiment in 2012 and 2013 in a 150 acre commercial field irrigated using a 1/4 mile center pivot sprinkler. The study field, on Wildy Family Farms, located near Manila in northeast Arkansas, had soils classed as a Routon Dundee – Crevasse Complex, ranging from coarse sand to fine sandy loam. Production details for the two seasons are summarized in Table 1.

Table 1. Cultivars, dates of planting, defoliation and harvest are listed for 2012 and 2013 insecticide termination by management zone trial in a commercial field[1] on Wildy Family Farms, Manila, AR.

Year	Cultivar	Date of Planting	Dates of Irrigation	Date of Insecticide Termination	Date of Defoliation	Date of Harvest
2012	AM NG 1511 B2RF	1 May	12, 20, 25 June; 2, 17, 24, 30 July; 7, 14 August	1 August	10 September	2 October
2013	Fibermax 1944 GLB2	9 May	26 June, 3 , 10 , 17 July, 21 August	15 August	22 September	11 October

[1]Field trial was located in a center pivot irrigated field with 150.8 planted acres; 130.4 acres were irrigated and 20.4 acres were rainfed pivot corners (13.5% of field).

Sample sites were selected and georeferenced after crop emergence by scouts who had previous crop experience with monitoring and insect sampling for the private crop advisors responsible for pest management for the farm. Plants in each sample location were considered *high vigor* and appropriate for field level decision-making. There were 3 sites in irrigated and 3 sites in rainfed cotton. We placed tall (6ft) bicycle flags at each designated sample site, and plant and insect monitoring activities through the season occurred within a 12 row (38 ft.) radius of the flag. Scouts inspected two sets of five consecutive plants located on adjacent rows using standard COTMAN Squaremap sampling protocol (Danforth and O'Leary 2004). By the second week of flowering, scouts suspended Squaremap sampling and began taking NAWF counts. Ten plants with first position white flowers were selected in each sample quadrant weekly and number of main stem squaring nodes determined. Days to cutout (NAWF = 5) calculations were derived from the standard output from the COTMAN software (www.cotman.org). For insect monitoring, scouts used a drop cloth to take two samples in a transect across 4 adjacent rows per site. One scout was responsible for both insect and plant monitoring at each sample site.

The insecticide termination trials were initiated on 2 August 2102 and 15 August 2013 when late season infestation levels sampled by commercial scouts reached action thresholds. Insect control up until that point in the season had been maintained with broadcast applications of insecticide based on sampling and recommendations by the private crop advisor.

For the termination trial, insecticide was either 1) broadcast applied (Broad), 2) applied only to plants in the irrigated zone (Zone), or 3) untreated (Check). Strip size was one sprayer swath (28 rows) wide extending the 1/2 mile length of the field (Figure 1). There were three replications. Treatment strips were re-randomized in 2013. A John Deere 4730 self-propelled sprayer with 90ft boom applied dicrotophos + bifenthrin (Bidrin 8EC, 6.4 oz + Brigade 2EC, 6.4oz) in 10 gal/ac spray volume in both years. Spray patterns in the zone treatment were changed simply by the equipment operator manually turning the sprayer on and off as he drove through the tall irrigated plants and short rainfed plants in 2012. In 2013, the operator was assisted by use of an on-board, georeferenced field map on a tablet computer with GPS coordinates to cue the operator, if needed, when the sprayer was positioned over irrigated or rainfed cotton.

Scouts made pre and post-application insect and plant evaluations to assess insecticide efficacy. Counts of plant bug nymphs and adults were made using drop cloths as described above. Two georeferenced sample sites were designated in each irrigated or rainfed zone per strip (Figure 1). In 2012, assessments were made one day prior to application and 4, 9 and 16 days after the insecticide application. In 2013, strips were sampled one day prior to application and 4, 8, 12 and 20 days after the application. Variation in average number of collected nymphs and adults per drop was analyzed using ANOVA separately for each date.

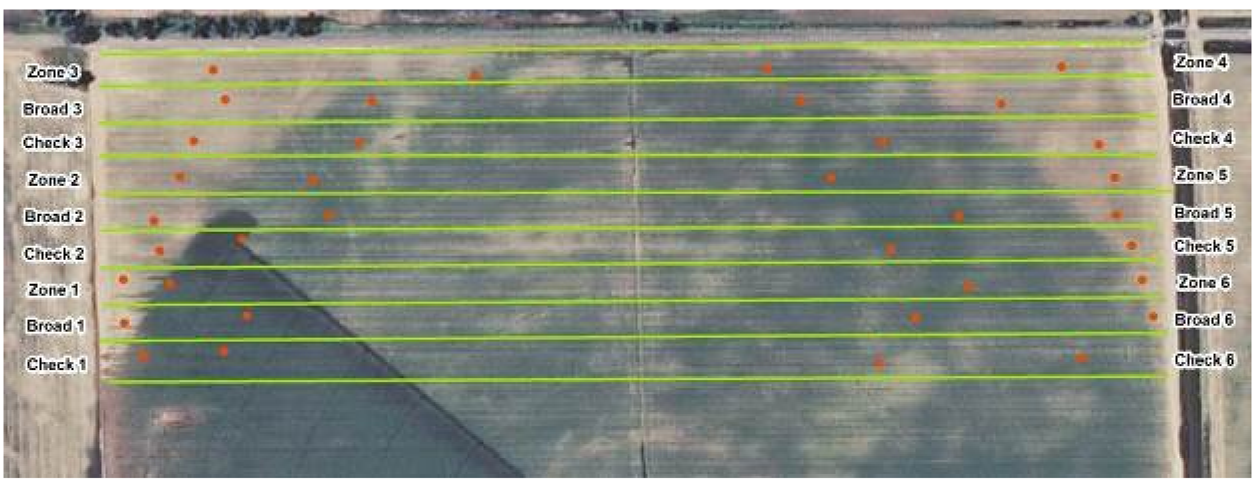


Figure 1. Irrigated circle and rainfed corners are apparent in this Google Map Image of the field test location. The center pivot irrigated commercial field in NE Arkansas is shown overlaid with treatment strips, labels and fixed sample sites -- Wildy Family Farms, Manila, AR.

Harvest was completed with a John Deere 7760 cotton picker. Yield data were acquired with a yield monitor and were summarized using ArcGIS 10.2 to create yield maps. Yield from plants in the irrigated circle was calculated separately from yield of plants in rainfed corners in each strip. In addition yields of plants from plant/insect monitoring sample sites were calculated for small sub-samples representing 2 harvest swaths, 50 ft long.

Field Print Calculator

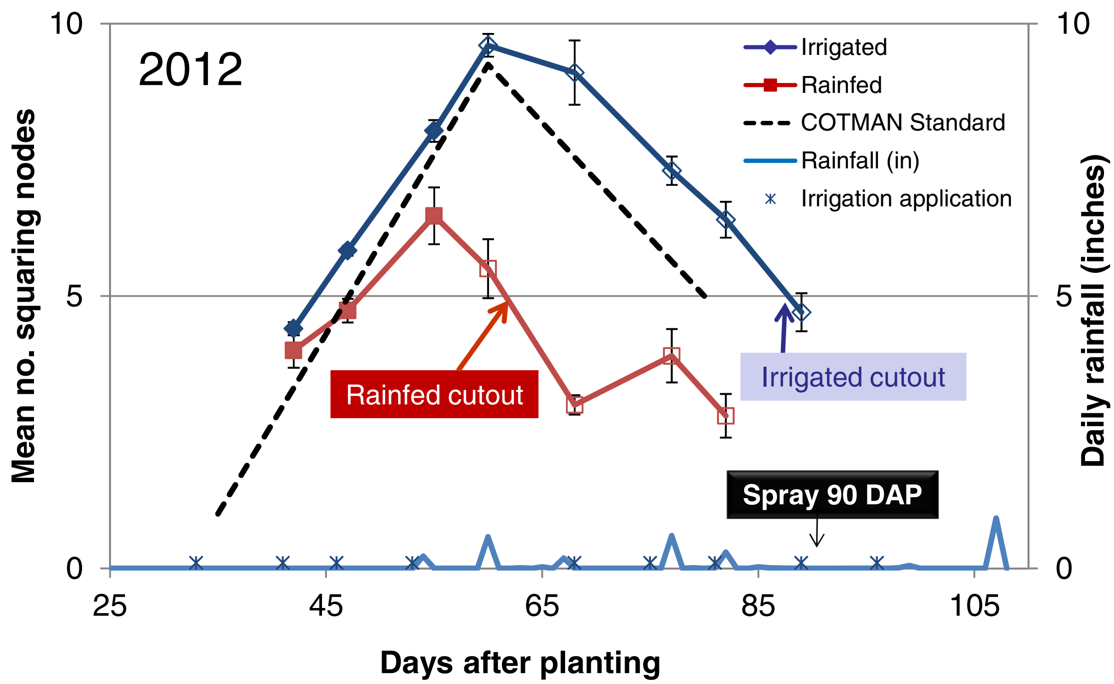
We used the Fieldprint Calculator (http://keystoneftm.zedxinc.com/fieldprint-calculator/) to provide an additional evaluation of how the zone management approach related to overall resource management and sustainability. Input and crop management information were analyzed and transformed into a "Fieldprint", which graphically represented the cooperating cotton producer's operation. Practices employed on Wildy Family Farms in 2012-2013 were used. In addition to irrigation and insecticide inputs, zone management included reductions in N fertilizer in rainfed corners (80 compared 120 lb N/ac).

Results

The hot and dry 2012 and wet and cloudy 2013 summer weather conditions resulted in very different plant growth patterns in irrigated and rainfed management zones over the two production years. In 2012, the producer applied four irrigation applications from first squares to first flowers (Table 1). First flowers were noted in COTMAN Squaremap sampling at 55 days after planting (DAP). By this date, water deficit stressed plants in the rainfed zones had produced fewer mean no. squaring nodes (6.5) compared to irrigated plants (8.0) as shown in COTMAN growth curves (Figure 2). By 60 DAP, mean NAWF for irrigated plants was 9.6 compared to 5.5 nodes for rainfed plants. The non-irrigated plants reached physiological cutout (NAWF=5) on 5 July. This was 23 days earlier than irrigated plants which reached NAWF-5 on 28 July (Table 2). Very low level infestations of tarnished plant bugs were observed through much of 2012, but numbers increased in late season exceeding Extension recommended action threshold (3 plant bugs per drop cloth sample) by 1 August. When insecticide was applied in the termination spray, the last effective boll population for plants in the rainfed zone had accumulated 653 DD60s from physiological cutout compared to 113 DD60s for plants in the irrigated zone.

Table 2. Crop maturity measurements, and the heat unit accumulations at the time of final insecticide application in the 2012 and 2013 insect control termination trial; Wildy Family Farms, Manila, AR.

Year	Zone	Days from planting to cutout (NAWF = 5)	Date of NAWF = 5	Insecticide Application Date	Accumulated Heat Units from Cutout (DD60s)
2012	Rainfed	62	5-Jul	1-Aug	650
	Irrigated	85	28-Jul		113
2013	Rainfed	73	21-Jul	15-Aug	439
	Irrigated	84	1-Aug		258



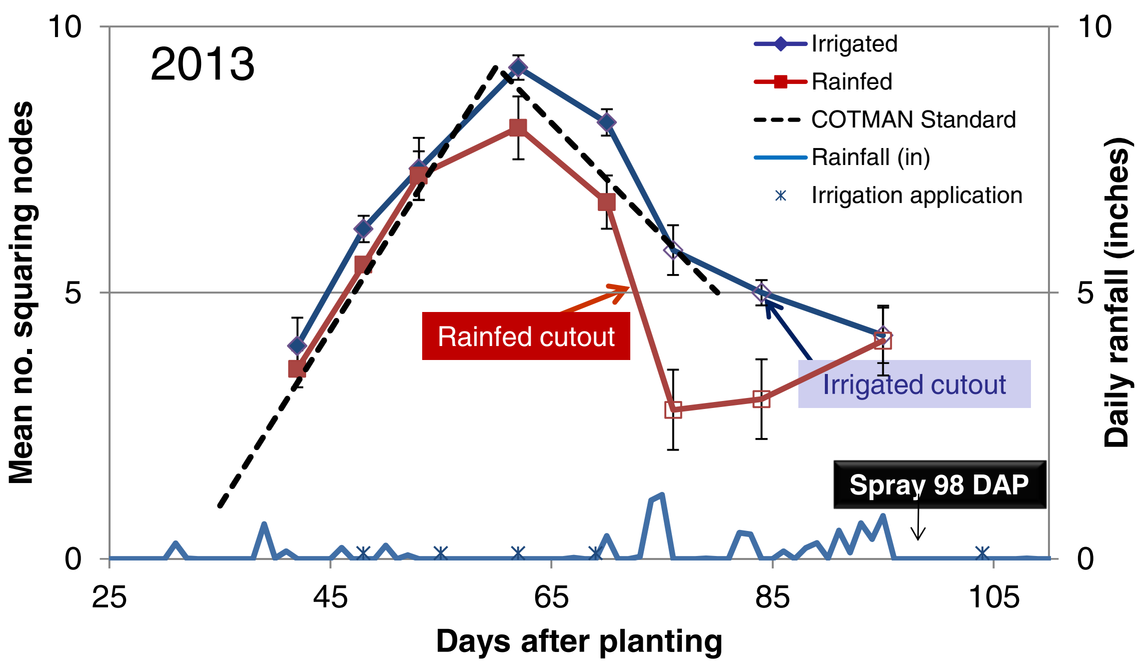


Figure 2. COTMAN growth curves for irrigated and rainfed plants in 2012 and 2013 with rainfall and irrigation dates.

Persistent rainfall in spring 2013 delayed planting one week in our test field compared to 2012. There was a rain-free period prior to first flowers, and irrigation applications were made on 48 and 55 DAP (Table 1). By first flowers, noted at 62 DAP, there were slightly more main stem sympodial nodes in irrigated (9.2) compared to rainfed plants (8.1 (Figure 2). Additional irrigation applications were made at 62 and 69 DAP; however, rains and cloudy weather followed in the next 2.5 weeks of flowering. No further irrigations were made until 104 DAP. The non-irrigated plants reached physiological cutout on 21 July, 11 days earlier than irrigated plants on 1 August (Table 2). For the 2013 termination trial, late season infestations of tarnished plant bug exceeded Extension thresholds on

15 August after plants in the rainfed zone had accumulated 433 DD60s from cutout and plants in the irrigated zone had accumulated 252 DD60s from date of cutout. COTMAN guides for insecticide termination recommend that the field be "clean" before insect control is terminated, so protection from late season plant bugs in irrigated cotton at this crop stage (cutout + 252 DD60s) was consistent the COTMAN recommendations.

Plant bug numbers were below the Extension recommended action threshold season long in 2012 until after cutout (Figure 3). Population densities were higher in 2013, but pests were maintained below economic injury levels using broadcast insecticides up until cutout. Mean no. of bugs typically was lower in rainfed compared to irrigated cotton.

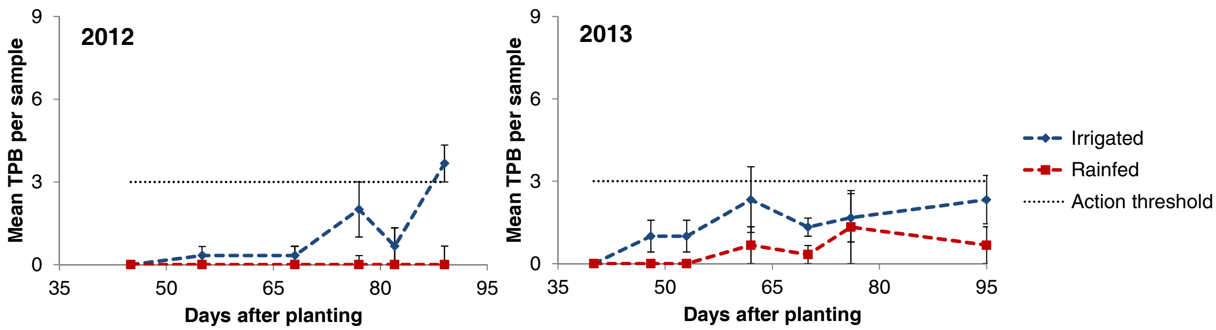


Figure 3. Seasonal abundance of tarnished plant bugs (mean no. ± SEM) in irrigated and rainfed sample sites for 2012 and 2013 seasons determined using drop cloth sampling; Wildy Family Farms, Manila, AR.

The termination insecticide application reduced plant bug numbers to below threshold in both 2012 and 2013. Numbers remained low in sprayed strips relative to the untreated check for two weeks (Table 3); however within that time, numbers of plant bug nymphs increased to over six fold the action threshold in the irrigated, unprotected check plants (Figure 4). In both years, significantly fewer tarnished plant bugs were observed in rainfed compared to irrigated cotton ($P<0.01$) (Table 3).

Table 3. Mean no. plant bugs per drop cloth sample date in the broadcast, zone application or untreated check. Wildy Family Farms, Manila, AR.

Date	Days after planting	Days after spray	Accumulated Heat Units (DD60s) from Cutout		Mean no. plant bugs per drop cloth sample (3 ft of row)					
					Broadcast Application		Zone Application[1]		Untreated Check	
			Rainfed	Irrig.	Rainfed	Irrig.	Rainfed	Irrig.	Rainfed	Irrig.
2012										
1 Aug	89	-1	653	110	0	3.0	0.1	3.0	0.1	2.8
6 Aug	94	4	750	232	0	1.2	0.3	1.4	1.3	3.3
13 Aug	101	11	905	360	0	3.2	1.0	4.8	0.3	30.5
18 Aug	106	16	985	442	0	4.7	1.3	6.7	1.0	25.5
22 Aug	110	20	1046	503	0	10.3	0.5	10.5	1.5	25.0
2013										
14-Aug	97	-1	433	252	0.7	2.7	0.0	0.7	3.0	2.5
19-Aug	102	4	488	307	0.2	0.2	0.3	0.2	0.0	9.3
23-Aug	106	8	568	388	1.2	1.7	2.7	4.5	0.0	20.5
27-Aug	110	12	650	470	0.5	1.3	7.2	1.7	3.0	11.0
4-Sept	118	20	813	632	1.7	1.8	6.5	1.7	1.5	4.5

[1]The rainfed area in the zone treatment strips received no insecticide, but insecticide was applied in the irrigated portion of those treatment strips; broadcast treatment received insecticide across the field and no insecticide was applied in the untreated check. Significant differences in plant bug abundance was measured among irrigated and rainfed zones in 2012 and sprayed and unsprayed treatments were noted in 2012 and 2013 ($P<0.05$).

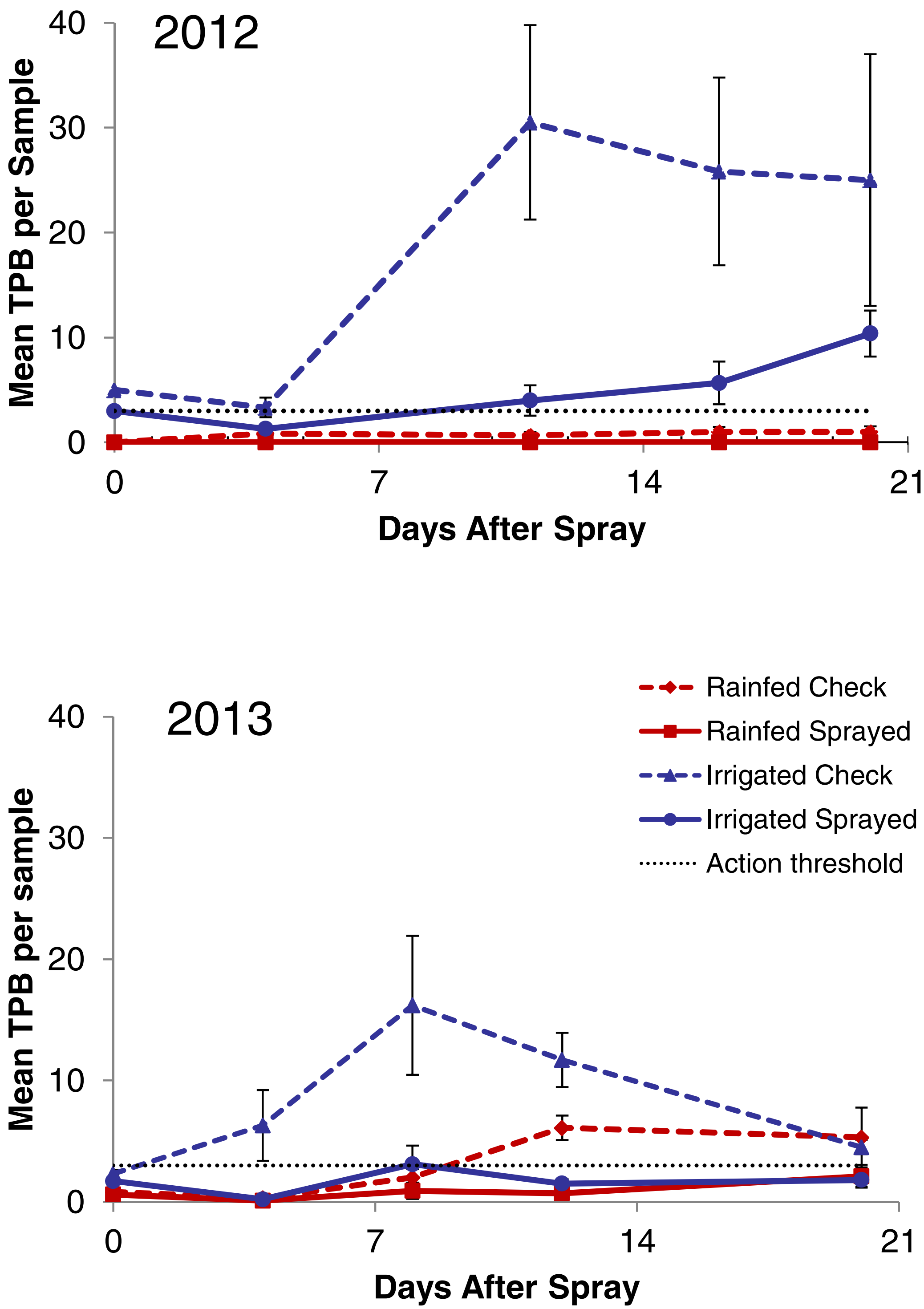


Figure 4. Mean number of plant bugs observed per 3 ft of row in irrigated compared to rainfed cotton measured using drop cloth sampling across 4 adjacent rows per sample site; samples were taken 1-day pre-application on 89 and 97 DAP in 2012 and 2013, respectively, and continuing for 3 weeks following the final insecticide application in either sprayed or unsprayed cotton. Insect counts for zone treatments are combined with appropriate irrigation and/or spray treatment effects.

Inspection of yield maps shows distinct patterns corresponding to the irrigated circle and rainfed corners for the 2012 termination trial (Figure 5). No circle patterns were discernable in the 2013 map following a production season with abundant rainfall. Lint yields were significantly higher for irrigated compared to rainfed cotton in 2012, but not 2013 (Figure 6). Plant bug infestations had no significant impact on yield in either year. For both the dry 2012 and wet 2013 production seasons, feeding injury from the late season plant bugs apparently came too late to damage harvestable bolls. The highest numbers of insects in the irrigated, unsprayed check appeared after the last effective boll population had surpassed the 250 DD60 heat unit threshold. In 2012 irrigated plants reached cutout +250 DD60s on 7 August, and the late season upsurge in plant bug numbers was observed at cutout + 330 DD60s. In 2013, plants reached the cutout+250 DD60s termination endpoint on 2 August, and the late season plant bug upsurge was not observed until cutout + 388 DD60s.

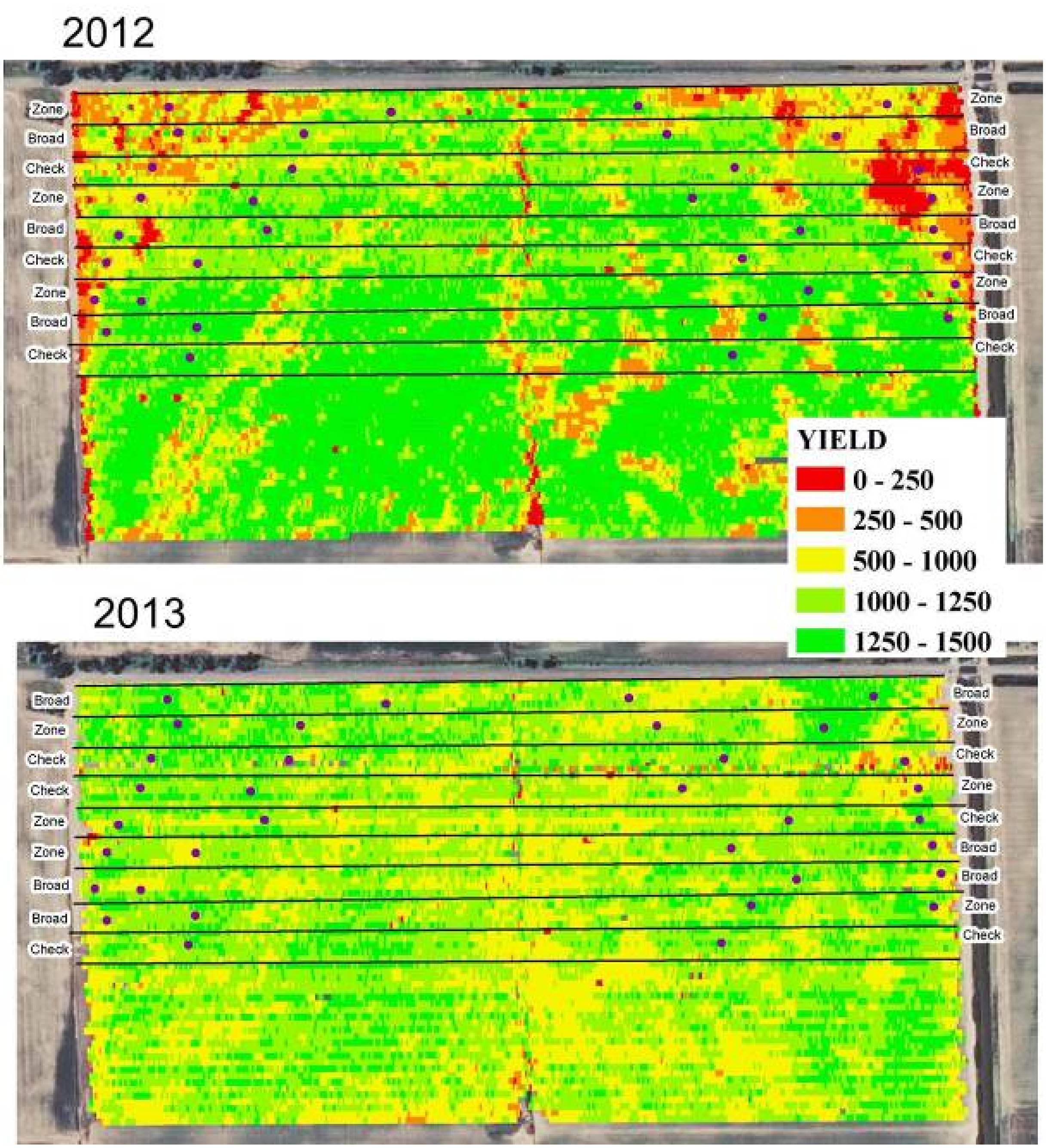


Figure 5. Yield maps shown with treatment strips, labels and fixed sample sites. Note Irrigated circle and rainfed corners are apparent for the 2012 drought year but not the 2013 season.

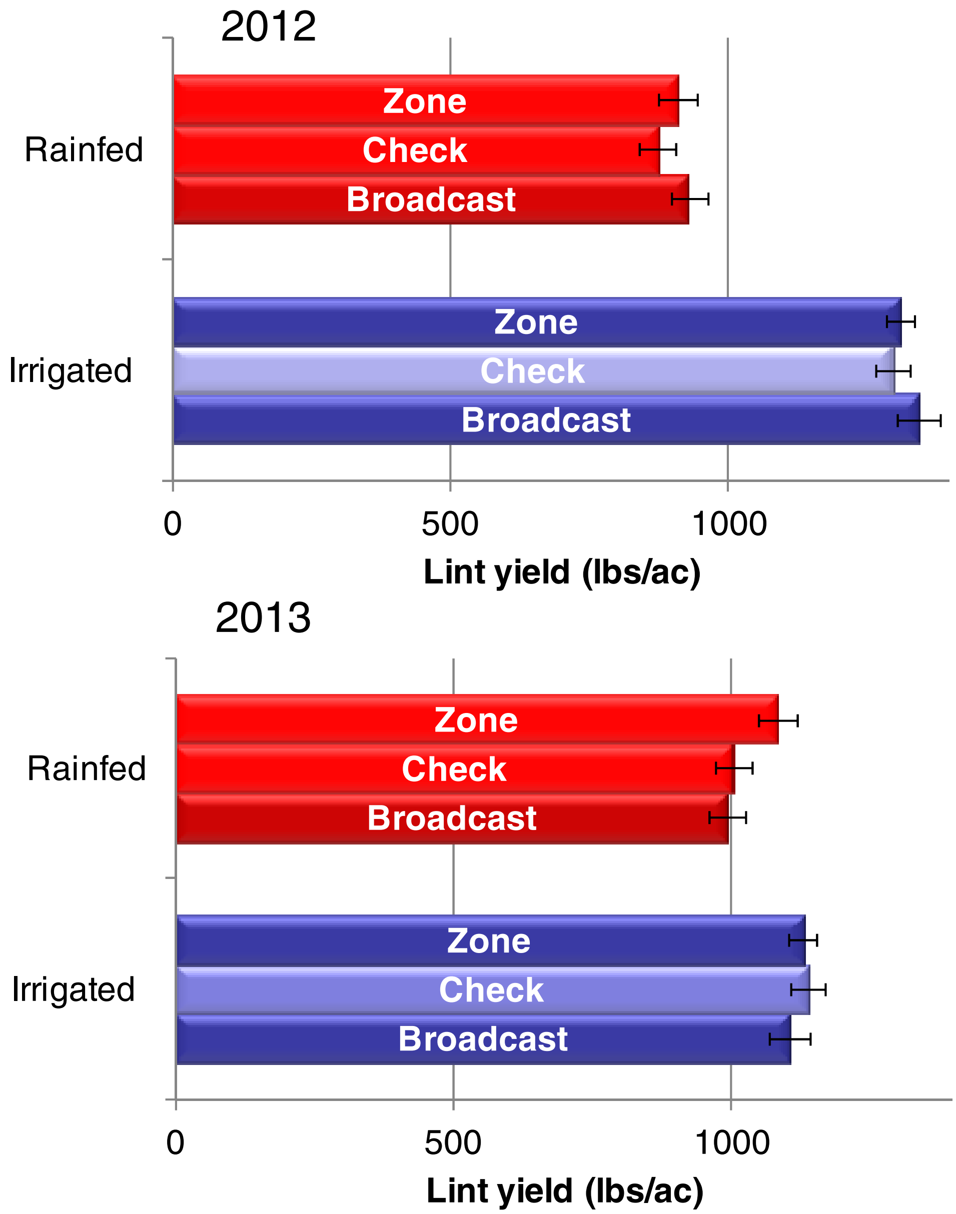


Figure 6. Mean lint yields (±SEM) in irrigated compared to rainfed areas of the study field for zone, broadcast or check spray strips in 2012 and 2013 in insect control termination trial, Wildy Family Farms, Manila, AR.

Field Print Calculator

Results from the Fieldprint Calculator reflected lower inputs in field corners and indicate that the zone practice was more efficient regarding resource management (Figure 7). The Fieldprint values plotted on the spidergram axes provided relative indices on a scale of 1 to 100 that represented the resource use or impact per unit of output in each of the five resource areas. Lower values closer to the center of the spidergram indicate a lower impact on each resource; the smaller the total area of the Fieldprint on the spidergram, the smaller the overall resource impact. Our results (blue) are compared to the state average (orange) and national (green) averages.

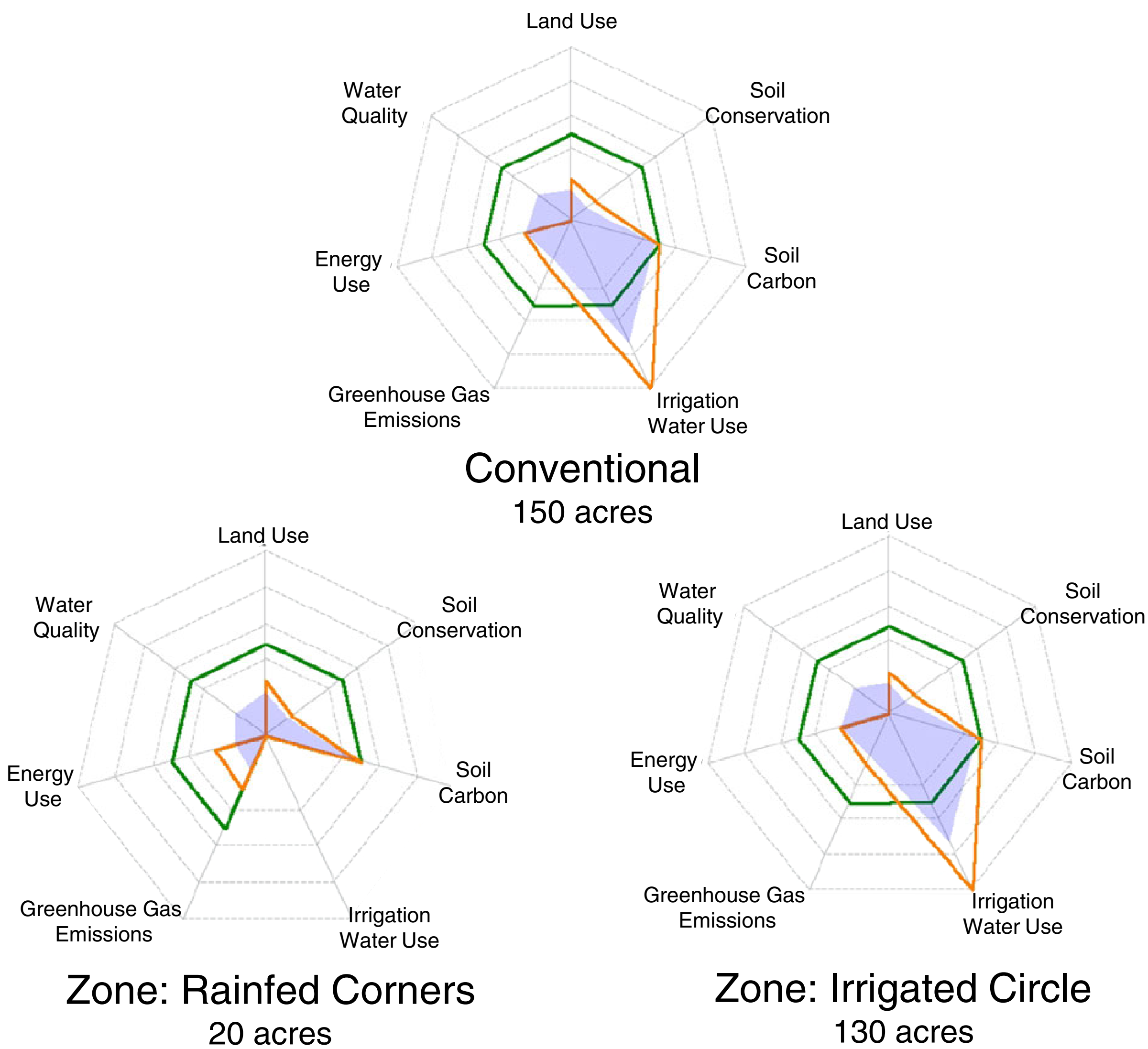


Figure 7. Fieldprint spidergrams representing output from the Fieldprint Calculator results from a conventional approach with broadcast management of the 150 acre pivot irrigated field compared to Zone Management with irrigated and rainfed portion of the field managed differently -- Wildy Family Farms, Manila, AR. Our results (blue) are compared to the state average (orange) and national (green) averages.

Producers can increase input use efficiency using zone management to terminate crop protection appropriately in irrigated compared to rainfed field areas. On Wildy Family Farms in 2012, our cooperators estimated they achieved an 18% savings in insecticide cost for late season applications in fields across their farm when they incorporated an irrigation zone management approach compared to broadcast applications in late season crop protection. In the replicated strip trial summarized in this paper, insecticide costs for the specific test field were reduced 14% with a zone approach. Insecticide product cost in 2012 for the producer was $16.92/acre. Broadcast cost for the 75.4 acre field was $1276. If only the irrigated zone (65.2 acres) was sprayed, insecticide cost was $1103.

Conclusions

In most years, late season applications of costly crop protectants are unneeded in the early-maturing rainfed corners of center pivot fields where pests are irrelevant because of low numbers and/or reduced plant susceptibility. At the time of the 2012 and 2013 termination trials, irrigated plants typically still had upper canopy squares, and most rainfed plants had very few. It is not surprising that bugs would be more abundant where squares were most abundant. Adult plant bugs move within and among cotton fields to find more attractive and nutritious host plants, and their ovipositional preferences as well as the survival rates of the next generation of newly hatched nymphs will be affected by the quality of those host plants. Had growing conditions been such that terminal regrowth of rainfed plants generated late season squares, then greater numbers of plant bugs likely would have been observed in those plants. Regardless, a late season upsurge in plant bug numbers after cutout + 250 DD60s would have occurred well ***after*** the last effective boll population had reached the final stage of crop susceptibility for tarnished plant bug.

Results from this study indicate that there is no yield penalty to following the COTMAN termination rule in management zones in a pivot irrigated field, which is an advantageous finding. We observed reductions in total insecticide use which provided farm-level economic benefits. Also, evaluations with the Fieldprint Calculator indicate positive environmental benefits. Implementation of zone management based on spatial or temporal crop variability is an advancement in precision agriculture.

Historically, site specific management practices for insects have been associated with a landscape feature (e.g. use of border sprays to protect the crop from migrating pests moving from adjoining overwintering habitat or alternative host plants). Results from this on-farm study in Northeast Arkansas demonstrate that producers can expand their use of zone management to include late season crop protection. COTMAN NAWF-based termination rules fit well with management zones in center pivot fields. Insecticide termination in management zones is practical for the producer who already has sprayers with GPS guidance and controllers, and who is using NAWF-based endpoints for terminating insect control. Additional costs for scouting time required for zone management, if any, should be identified by the producer and crop advisor and compared to potential cost savings.

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