ZONE MANAGMENT IN CENTER PIVOT IRRIGATED FIELDS – IMPROVING EFFICIENCY IN INSECT CONTROL TERMINATION USING COTMAN IN SPATIALLY VARIABLE COTTON FIELDS

Tina Gray Teague
Erin J. Kelly
D. Keith Morris
Arkansas State University
Jonesboro, Arkansas
Diana M. Danforth
University of Arkansas
Fayetteville, AR

Abstract

Progressive growers in Arkansas incorporate site-specific zone management practices in center pivot sprinkler irrigated fields, reducing both seeding and fertilizer rates in the lower yielding non-irrigated portions of the field relative to irrigated crop areas. We wanted to find out if this zone approach was practical for use in an insect pest management program. Are differences in plant growth and pest risk among irrigation zones sufficient to be worthy of extra time and effort required for increased sampling time by scouts? During the 2011-2012 growing seasons, we monitored large commercial fields to compare crop growth and tarnished plant bug infestations across irrigated and rain-fed management zones - irrigated "circles" and rainfed "corners". Crop monitoring using COTMAN and sampling for tarnished plant bug were made season long in three sites per field for each management zone. COTMAN crop growth curves showed significant spatial and temporal differences in crop maturity. Days to cutout differed from 1 to 3 weeks between zones. Such maturity differences are sufficiently large to warrant differential crop protection practices in late season if infestation levels exceed action thresholds. In 2012, tarnished plant bug numbers increased above recommended action levels in late season, and we installed an embedded, replicated strip trial in one field to evaluate insect control termination in a conventional blanket spray compared to management zone approach. Plants in the rainfed zone were well past the "safe" stage while those in the irrigated zone were still in the susceptible stage for tarnished plant bug. Spray patterns in the zone management strips were changed simply by the operator manually turning the sprayer on and off as he drove through irrigated and rainfed cotton. After harvest, yield monitor data were used to evaluate treatment effects. Results from the control termination trial support the use of zone management in timing insect control termination. Rainfed cotton produced lower lint yields than irrigated cotton. No differences in lint yield were observed if insect control was terminated according to COTMAN guidelines regardless of zone or broadcast approach. There was no yield penalty associated with eliminating the final insecticide application. Insecticide costs were reduced 14% with the zone approach compared to a broadcast application.

Introduction

Few US cotton producers have adopted site specific zone management practices for insect control. Producers must recognize an economic, social or environmental benefit associated with the time and expense required to identify and manage zones. Even if they are using precision methods for fertility and other production inputs, they or their crop advisors may consider a precision agriculture approach too complex, too risky, and too much trouble for insect pest management. Other producers may lack physical capital requirements such as appropriate communication networks, tools, and machinery. Often they simply do not have trained personnel capable of implementing site specific pest management. For all of these decision makers, a simple process is needed to establish management zones that will be worth the time and effort required to modify their existing crop management schemes.

From a practical standpoint, candidate fields for zone management should have predictable spatial patterns in sufficiently large "crop management worthy" areas. Typically these spatial patterns are related to soil and water factors or to landscape features that affect risks from pest arthropods, disease or weeds. Different zones generally have different yield potential. In zone management, production and protection inputs should be gauged to match yield potential.

Recently, some producers in northeast Arkansas have adopted a simple zone management approach in fields with center pivot sprinkler irrigation. They set two crop management zones – irrigated and rainfed. In the Midsouth the entire center pivot irrigated field is planted including the rainfed corners. Rainfall may be sufficient to produce high yields across the field in some years, but generally profitable production requires timely supplemental irrigation. In low rainfall years, zones based on irrigation appear to meet the “management worthy” criteria set forth above. The rainfed corners represent large crop areas -- as much as 18% of a production field – and the spatial patterns are predictable. The early maturing rainfed plants have lower yield potential than irrigated plants. A benefit to the irrigation zone approach is that it requires no expensive or complex sensors to set or maintain the zones.

Requirements for late season crop protection from insect pests vary with crop maturity. Earlier maturity means that plants more quickly reach the final stage of crop susceptibility – that late season end-point when pest insects are no longer economically significant. Using crop maturity measures to decide “when to quit” was the basis for development of the COTMAN crop monitoring system (Danforth and O’Leary 1998; Oosterhuis and Bourland 2008). Weekly counts of nodes above white flower (NAWF) using COTMAN allows crop managers to determine the flowering date of the last effective boll population, cutout. As those last effective bolls mature, they become less susceptible to particular pests. Heat unit thresholds for the major US cotton insect pests have been developed and validated (Cochran et al 1999, Danforth et al 2004). For Arkansas, crop protection endpoints recommended by the Cooperative Extension Service in the MP144 range from cutout + 250 DD60s for tarnished plant bugs to cutout + 450 DD60s for stink bugs. Other end-of-season heat unit thresholds have been developed for furrow irrigation (cutout + 350 DD60s) (Vories et al 2011) and defoliation (cutout+850 DD60s) (Wells 1991, Benson et al 2000, 2001,).

In this research project, we monitored crop development using COTMAN in irrigated and rainfed management zones over two seasons to examine differences among zones in maturity and timing of cutout. We also assessed tarnished plant bug infestations to determine if pest pressure varied among zones. Late season infestation timing and levels were sufficient for a field validation trial for zone management approach to insect control termination for tarnished plant bugs. Our goal was to determine if crop maturity and corresponding protection requirements were sufficiently different to be worthy of the extra management time and effort required to monitor and manage two zones per field.

Materials and Methods

We compared crop maturity and insect infestations across irrigated and rainfed management zones in 2011 and 2012 in six commercial fields on Wildy Family Farms, located near Leachville in northeast Arkansas. Soils on this farm are classed as a Routon Dundee – Crevasse Complex, ranging from coarse sand to fine sandy loam. Each field was irrigated using a 1/4 mile center pivot sprinkler. Tillage systems were either no-till or low-till with terminated wheat cover crop. Dates of planting, cultivar, acreage, and cutout dates for each field for the two seasons are shown in Table 1.

Sample sites were selected and georeferenced after crop emergence by scouts who had previous crop experience with monitoring and insect sampling in those fields (Figure 1). Plants in the sample location at the time of site selection were considered “high vigor”. We placed tall (6ft) bicycle flags at each designated sample site to expedite our weekly sampling routine. All plant and insect monitoring activities through the season occurred within a 12 row (38 ft) radius of the flag. Each flagged sample circle was divided into quadrants. Scouts shifted their sampling activities to a different quadrant (90 degrees around the flag) each week to limit plant injury from excessive handling of the same plants through the season. For plant monitoring, scouts inspected two sets of five consecutive plants located on adjacent rows using standard COTMAN Squaremap sampling protocol (Danforth and O’Leary 2004). This included weekly measurements of plant height, number of main-stem sympodia, and presence or absence of first position squares and bolls. 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. For insect monitoring, scouts used a drop cloth to take two samples in a transect across 4 adjacent rows per site. Each scout was responsible for both insect and plant monitoring at each sample site. Variation in average number of collected nymphs and adults per drop was analyzed using ANOVA separately for each date. Days to cutout (NAWF = 5) calculations are standard output from the COTMAN software. Yield data were acquired with yield monitors on the cooperating farmer’s cotton pickers and used to evaluate zone productivity.

Figure 1. Irrigated circles and rainfed corners are apparent in Google Map Image. Yellow points shown are the fixed sample sites set in six center pivot irrigated commercial fields in NE Arkansas where COTMAN crop monitoring and tarnished plant bug counts were made through the 2011 and 2012 season -- Wildy Family Farms, Manila, AR.

Table 1. Field designations, harvested field and zone acreage, cultivars, and dates of planting for six commercial fields monitored in zone management evaluations 2011-2012 – Wildy Family Farms, Manila, Arkansas.

Year	Management Zone & Crop Attribute		Field Number 61	15	83	86N	93N	D2
	Harvested Acres[1]	Total field	75.4	69.3	55.7	72.4	74.9	29.8
		Irrigated	65.2	63.6	51.1	63.9	66.2	20.1
		Rainfed	9.6	5.7	4.6	8.5	8.8	9.7
2011	Cultivar		DP 0912	DP 0912	ST 5458	ST 5458	ST 5458	AM 1550
	Date of Planting		11-May	16-May	17-May	18-May	17-May	19-May
2012	Cultivar		AM 1511	DPL 912	ST 5458	ST 5458	ST 5458	AM 1511
	Date of Planting		4-May	26-Apr	30-Apr	2-May	2-May	26-Apr

[1]Fields selected for this study were ca. ½ the total area associated with field groupings irrigated by ¼ mile center pivot sprinklers except for field D2 which was ¼ the circle. Harvested acres (not including turn-rows, ditches, etc) from yield monitor data are listed; per acre lint yield and costs were based on those acreage determinations.

Insect Control Termination Trial

Low level infestations of tarnished plant bugs were observed through 2011, but in 2012, numbers increased in late season and exceeded Extension recommended action threshold (3 plant bugs per drop cloth sample) in one of our six sample fields. The COTMAN report on 1 August from zone monitoring in Field 61 indicated that the irrigated plants had reached physiological cutout on 28 July, and the last effective boll population had accumulated 110 DD60s (Table 2). In the rainfed zones of Field 61, the crop reached cutout on 5 July, and by 1 August, the last effective boll population had accumulated 653 DD60s. Any new infestation of plant bugs in the rainfed zone on 1 August would have occurred well after the final stage of crop susceptibility for tarnished plant bug. These conditions in Field 61 presented a research opportunity to validate COTMAN termination recommendations as well as evaluate a zone management approach to late season insect control, and we initiated an insect control termination trial.

Table 2. Crop maturity differences among irrigation management zones were apparent in output from the COTMAN FIELD REPORT for 1 August 2012 for WFF field 61.

Phenological stage and Termination thresholds	Management zone	
	Rainfed	Irrigated
Date of physiological cutout (NAWF = 5)	5-Jul	28-Jul
Days from planting to NAWF = 5	62	85
Heat unit total (to date 08/01) calculated from NAWF=5	650	113
350 DD60s - Heat unit threshold: Actual *(Projected)*	20-Jul	*(14-Aug)*
850 DD60s - Heat unit threshold: Actual *(Projected)*	*(12-Aug)*	*(12-Sep)*

For this replicated strip 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 length of the field (1/2 mile). There were three replications. 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. Spray patterns in the zone treatment were changed simply by the operator manually turning the sprayer on and off as he drove through the tall irrigated plants and short rainfed plants.

Scouts made pre and post application insect and plant evaluations to assess insecticide efficacy. Counts of tarnished plant bug nymphs and adults were made using drop cloths as described above. Two georeferenced sample sites were designated in each irrigation zone per strip. Samples were made one day prior to application and 4, 9 and 16 days after spray. Final, end-of-season plant mapping was performed prior to defoliation using COTMAP (Bourland and Watson 1990). Scouts examined 10 plants in one row per site for node number of first (lowest) sympodial branch on the main axis, number of monopodia, and number of bolls on sympodia arising from monopodia. Bolls located on main stem sympodia (1st and 2nd position) were recorded, as well as outside bolls, which were bolls located on the outer positions on sympodial nodes (>2nd position). The highest sympodium with 2 nodal positions and number of bolls on sympodia located on secondary axillary positions also were noted. Plant height was measured as distance from soil to apex. Defoliants were applied 10 September. Harvest was completed on 4 October with a John Deere 7760 cotton picker with JD yield monitor. Lint yield estimates representing the equivalent of two harvester passes within the center of each treatment strip were used to evaluate treatment effects. Yield from plants in the irrigated circle was calculated separately from yield of plants in rainfed corners in each strip. In addition small sub-samples representing 2 harvest swaths, 50 ft long, two swaths wide, were calculated for yields of plants from plant/insect monitoring sample sites.

Results

Summer weather was hot and dry in both 2011 and 2012 and conducive for water deficit stress in rainfed plants. Different crop growth patterns in irrigated and rainfed management zones were apparent in the COTMAN growth curves for the six fields in both years (Figures 4, 5). Plants in the rainfed zones produced fewer mean no. squaring nodes by first flowers compared to irrigated plants. The non-irrigated plants reached physiological cutout (NAWF=5) earlier than irrigated plants in every field in both years, ranging from 7 to 23 days earlier in rainfed compared to irrigated cotton (Table 3). Overall, rainfed plants reached physiological cutout two weeks earlier than irrigated plants (Figure 6). Yields were significantly higher for irrigated compared to rainfed cotton in both 2011 and 2012 (Fig 7). No significant yield effects were observed for tillage (No-till vs. wheat cover crop), and there were no significant interactions with year, tillage, or irrigation.

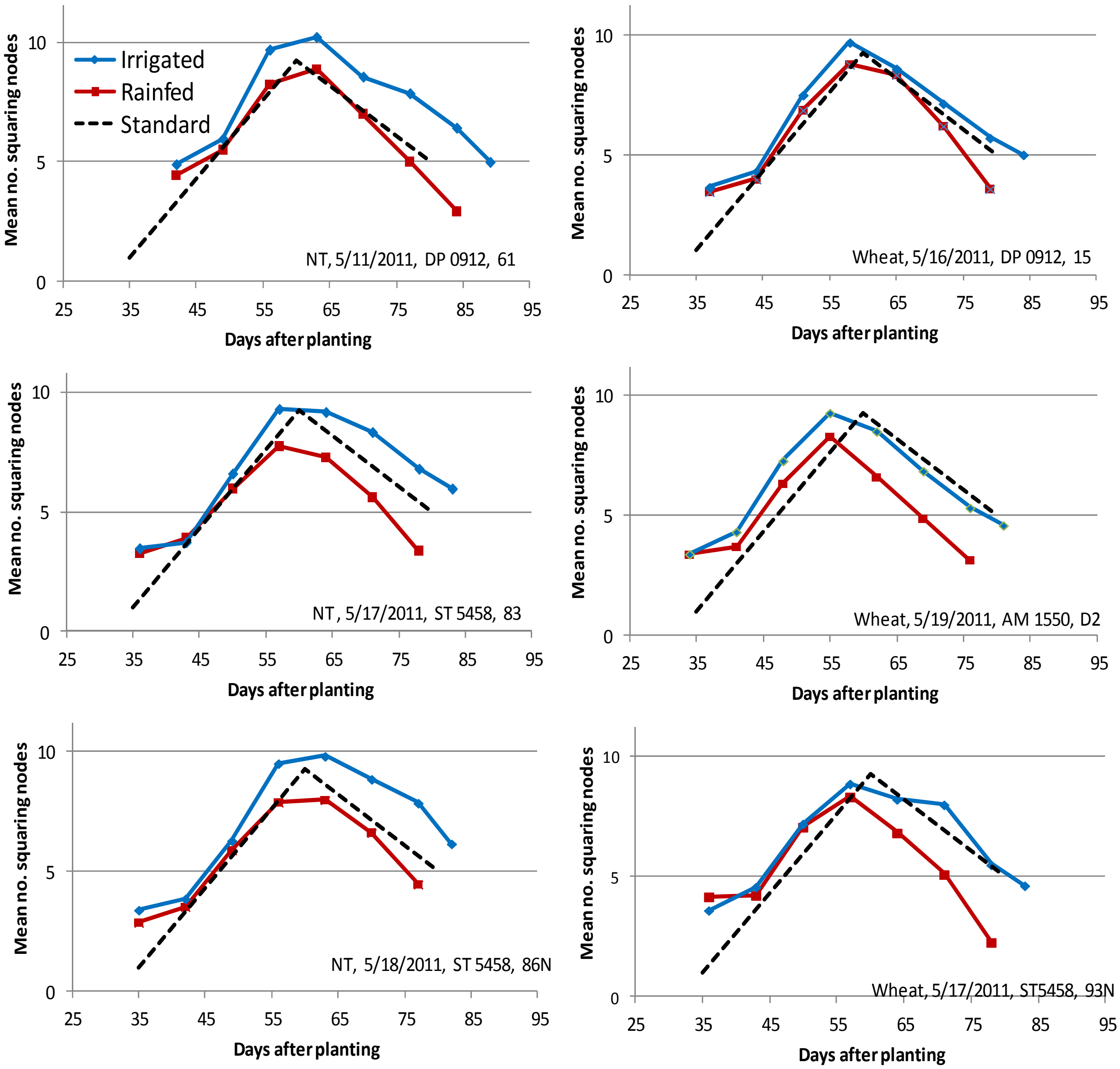

Figure 2. COTMAN growth curves along with the standard target development curve for six commercial fields on Wildy Family Farms in 2011. Plant monitoring sites included two management zones per field - irrigated and rainfed. Fields were either no till (NT) or planted into a wheat cover crop (Wheat). Date of planting, cultivar and farm field number are indicated along the X-axis of each growth curve.

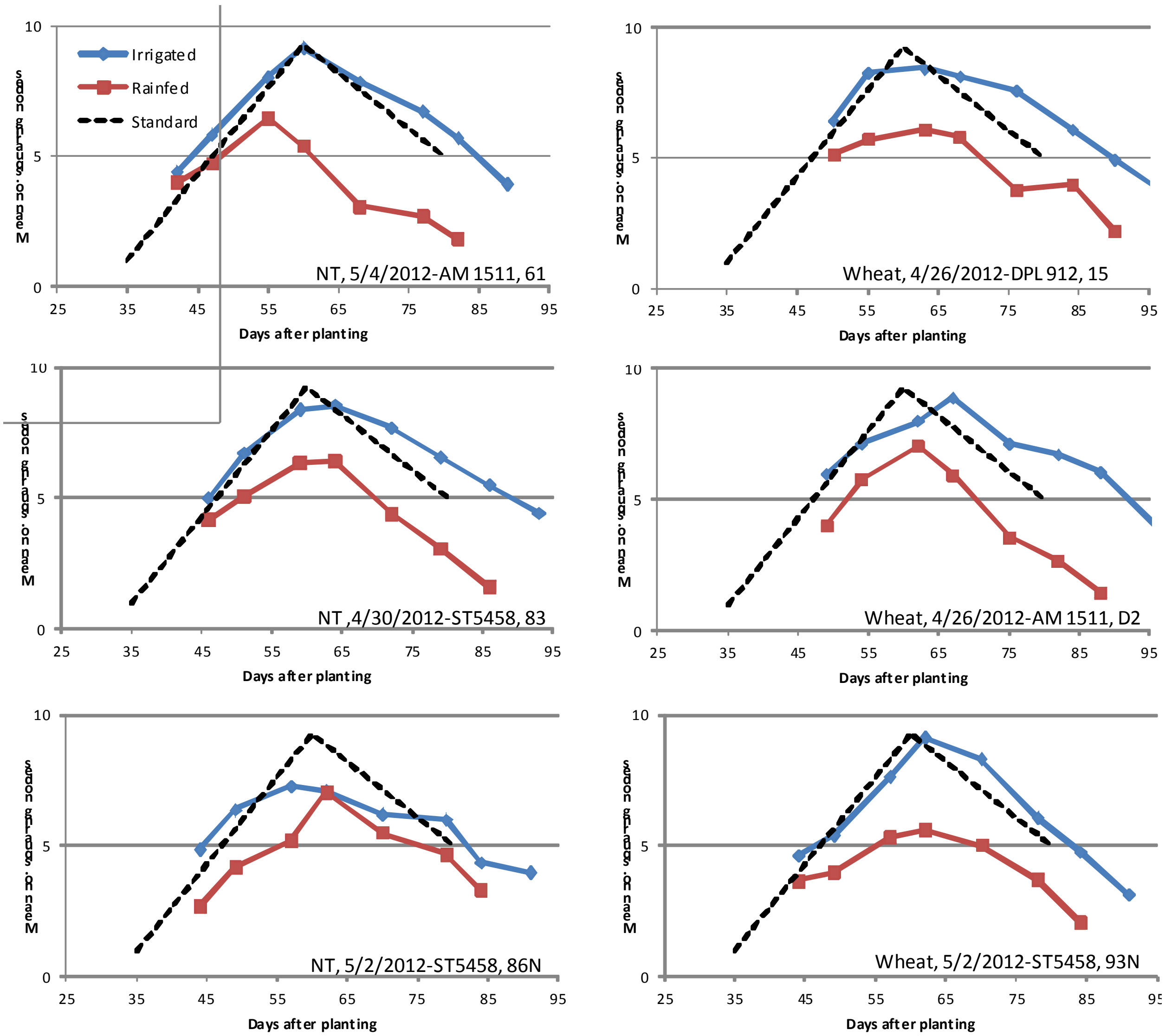

Figure 3. COTMAN growth curves along with the standard target development curve for six commercial fields on Wildy Farms in 2012.

Table 3. Lint yield and mean dates of physiological cutout (NAWF=5) and days from planting to cutout for six commercial fields monitored in zone management evaluations 2011-2012 – Wildy Family Farms, Manila, Arkansas.

Year	Maturity & Lint yield	Management Zone	Field Number 61	15	83	86N	93N	D2
2011	Date of Cutout	Irrigated	8-Aug	8-Aug	13-Aug	12-Aug	8-Aug	8-Aug
		Rainfed	27-Jul	30-Jul	29-Jul	31-Jul	28-Jul	27-Jul
	Days to Cutout	Irrigated	89	84	88	86	83	81
		Rainfed	77	75	73	74	72	69
	Yield (lb/ac)	Irrigated	1185	1152	1206	1161	1056	1294
		Rainfed	901	971	718	601	628	731
2012	Date of Cutout	Irrigated	28-Jul	25-Jul	29-Jul	24-Jul	24-Jul	28-Jul
		Rainfed	5-Jul	7-Jul	9-Jul	17-Jul	12-Jul	7-Jul
	Days to Cutout	Irrigated	85	90	90	83	83	92
		Rainfed	62	72	70	76	71	71
	Yield (lb/ac)	Irrigated	1458	1224	1189	1280	1138	1150
		Rainfed	974	760	740	690	390	753

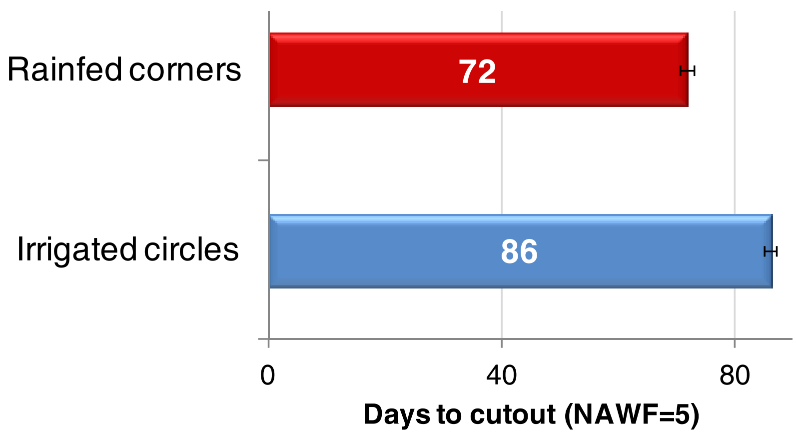

Figure 4. Mean no. days to physiological cutout for plants in the six sample fields for the 2011 and 2012 seasons (P=0001; LSD=3.4).

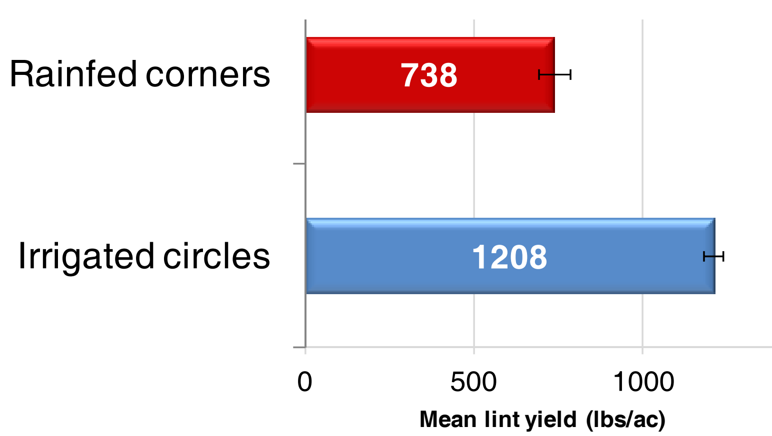

Figure 5. Mean lint yield for irrigated cotton was higher than for rainfed cotton for the six sample fields over the two year study (P=0.001; LSD_{05}=86.8).

Insect Control Termination Trial

Tarnished plant bug numbers remained at low levels and below threshold season-long in 2011 and much of 2012 (Figure 8). Numbers of bugs in 2012 were similar between zones until late season around cutout, when nymph population densities generally were higher in irrigated compared to rainfed zones. Among the two management zones in early August, irrigated plants had squares, and most rainfed plants did not. Movement of adult plant bugs between and within fields is affected by availability of squares. Around the time of cutout, as bolls mature and there are fewer squares, adults will move to find more attractive and nutritious host plants. 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.

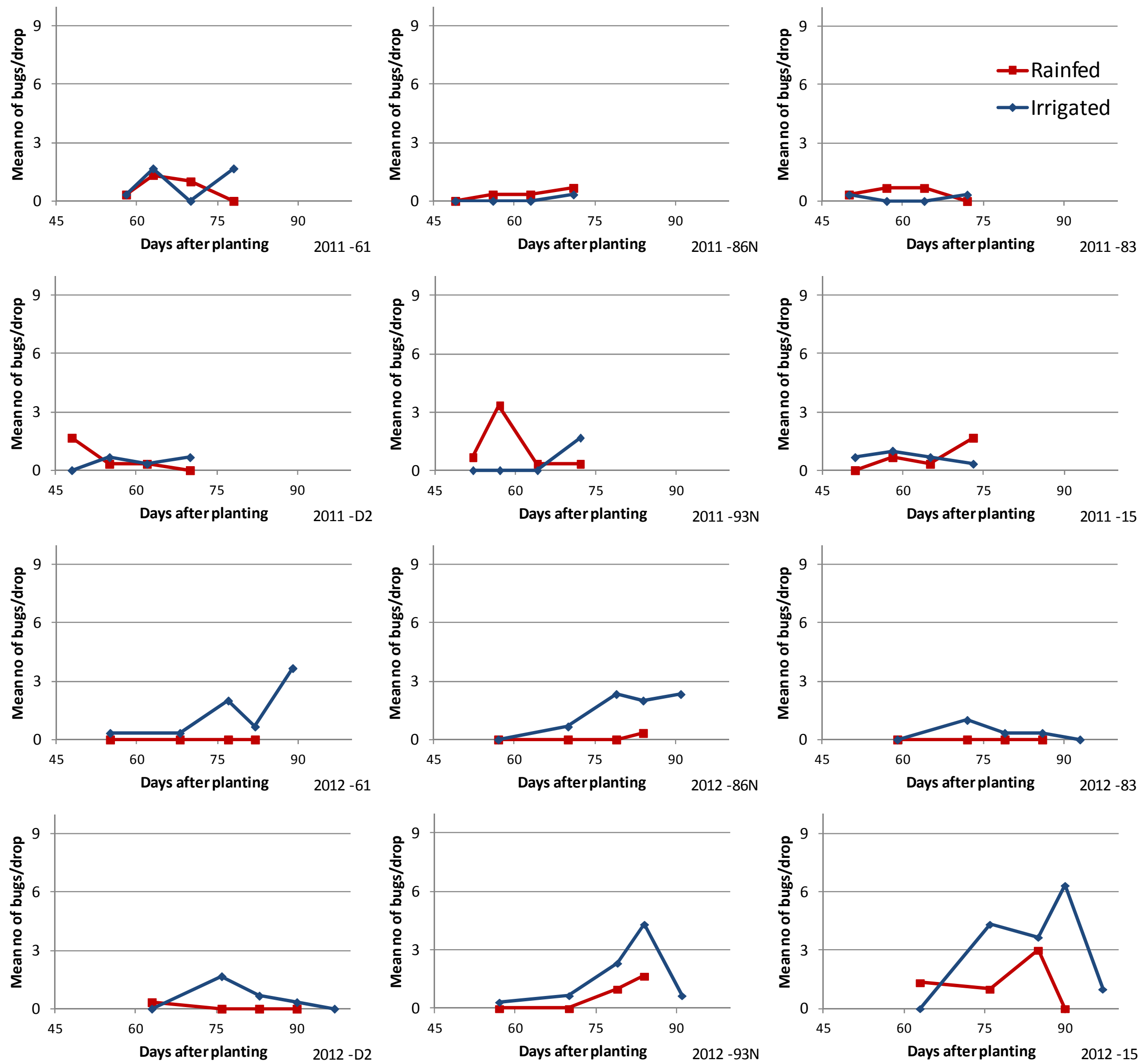

Figure 6. Mean no tarnished plant bug adults and nymphs per drop (3 ft of row) for each of the six monitored fields for 2011 and 2012 in irrigated and rainfed zones.

Tarnished plant bug response to irrigation was evident in late season increase in the unsprayed irrigated cotton treatment strips in the Field 61 termination trial. Significantly fewer tarnished plant bugs were observed in rainfed compared to irrigated cotton in each sample ($P<0.01$) (Table 4). In irrigated cotton, the insecticide application reduced tarnished plant bug numbers to below threshold by 6 August. Numbers remained relatively low in sprayed strips relative to the untreated check. By 11 August, 9 days after application, numbers of tarnished plant bug nymphs increased dramatically in the irrigated, unprotected check plants.

Table 4. Mean no. plant bugs per drop cloth sample in Field 61 in the conventional broadcast, zone application or untreated check. Samples were made on one day prior to and 4, 11 and 18 days after insecticide application on 2 August 2012, Wildy Farms, Manila, AR. Plants in the irrigated cotton reached cutout on 28 August, 85 days after planting (DAP); rainfed plants reached cutout on 5 July, 62 DAP.

Sample date[1]	Days after spray (DAP)	Accumulated Heat Units (DD60s) from Cutout (NA. F=5)		Nymphs and adults per drop cloth sample (3 ft of row)					
				Conventional Broadcast		Zone Application		Untreated Check	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1 Aug	-1 (89)	650	114	0	3.2	0.2	4.1	0.1	2.8
6 Aug	4 (94)	772	235	0	1.2	0.3	1.4	1.3	3.3
11 Aug	9 (99)	866	330	0	3.2	1.0	4.8	0.3	30.5
18 Aug	16 (106)	980	444	0	6.9	1.0	8.2	1.0	25.5

Significant irrigation effects as well as insecticide treatment effects on final plant structure were measured in final, end-of-season plant mapping using COTMAP (Table 5). Irrigation resulted in taller plants, higher numbers of sympodia, effective sympodia, bolls per plant, bolls in outer positions, and bolls on monopodia. Early boll retention was higher in rainfed compared to irrigated plants. Internode length was greater in irrigated plants. Irrigation resulted in significantly higher retention of 2nd position bolls. Such differences in plant structure and retention support differential management practices and the zone management approach. For insecticide effects measured using COTMAP, fewer plants with both 1st and 2nd position mainstem sympodial bolls were observed in unsprayed check compared to protected plants. There were no other significant insecticide effects suggesting that feeding injury by late season tarnished plant bug nymphs was directed at meristematic tissues, squares and small bolls that did not contribute to final yield.

Table 5. Results from PRE-defoliation, final plant mapping using COTMAP for irrigation and spray effects – 2012, Wildy Family Farms, Manila, AR[1]. Plant mapping was completed prior to defoliation and includes counts of small, immature green bolls that did not contribute to final yield; however, these fruiting forms were available as a food source for tarnished plant bug and were protected (or not) with the insecticide application.

	Irrigated			Rainfed			P>F	
Category	**Broad**	**Zone**	**Check**	**Broad**	**Zone**	**Check**	***Irrigation***	***Insecticide***
1st Sympodial Node	5.4	5.5	5.6	5.6	5.5	5.7		
No. of Monopodia	1.5	1.1	1.5	1.2	1.2	1.7		
Highest Sympodia with 2 nodes	14.6	14.6	13.9	12.5	12.4	11.1	*0.001*	
Plant Height (inches)	40.3	40.5	41.2	28.6	27.5	23.1	*0.005*	
No. of Effective Sympodia	12.2	12.2	10.9	8.9	8.1	6.1	*0.01*	
No. of Sympodia	17.1	17.3	16.5	15.4	14.9	14.1	*0.001*	
No. of Symp. with 1st Position Bolls	5.5	4.4	5.3	4.3	3.6	3.4		
No. of Symp. with 2nd Position Bolls	1.5	2.6	1.5	0.9	1.0	0.7	*0.01*	
No. of Sympodia with 1st & 2nd Bolls	2.2	2.8	1.6	1.9	2.0	1.2		*0.05*
Total Bolls/Plant	15.3	15.9	11.7	11.0	10.7	7.7	*0.03*	
% Total Bolls in 1st Position	51.2	45.1	58.8	55.9	52.7	59.8		
% Total Bolls in 2nd Position	24.5	33.5	25.5	25.1	27.8	23.6		
% Total Bolls in Outer Position	13.9	14.5	7.8	6.0	5.1	3.0	*0.05*	
% Total Bolls on Monopodia	8.7	5.2	5.3	12.5	14.1	13.0	*0.05*	
% Total Bolls on Extra – Axillary	1.8	1.6	2.6	0.4	0.4	0.6		
% Boll Retention - 1st Position	44.6	41.5	41.2	40.0	37.4	32.8		
% Boll Retention - 2nd Position	25.0	36.3	21.9	22.1	24.2	16.6		
% Early Boll Retention	48.0	49.5	46.5	62.5	64.0	51.0	*0.05*	
Total Nodes/Plant	21.5	21.8	21.1	20.0	19.3	18.8	*0.001*	
Internode Length (inches)	1.9	1.9	2.0	1.4	1.4	1.2	*0.01*	

[1]Irrigation and insecticide effects were significant (ANOVA) for several mapping categories; however, there were no significant Irrigation*Insecticide interactions. In those cells with no values listed, treatment effects were not significant (P>0.05).

Irrigated plants produced higher yields than rainfed plants. Tarnished plant bug infestations had no significant impact on yield (Figure 9). Feeding injury from the late season tarnished plant bugs apparently came too late to damage harvestable bolls. The insects appeared after the last effective boll population had surpassed the 250 DD60 heat unit threshold. Irrigated plants reached cutout + 250 DD60s on 7 August. The late season tarnished plant bug surge was observed at cutout + 330DD60s.

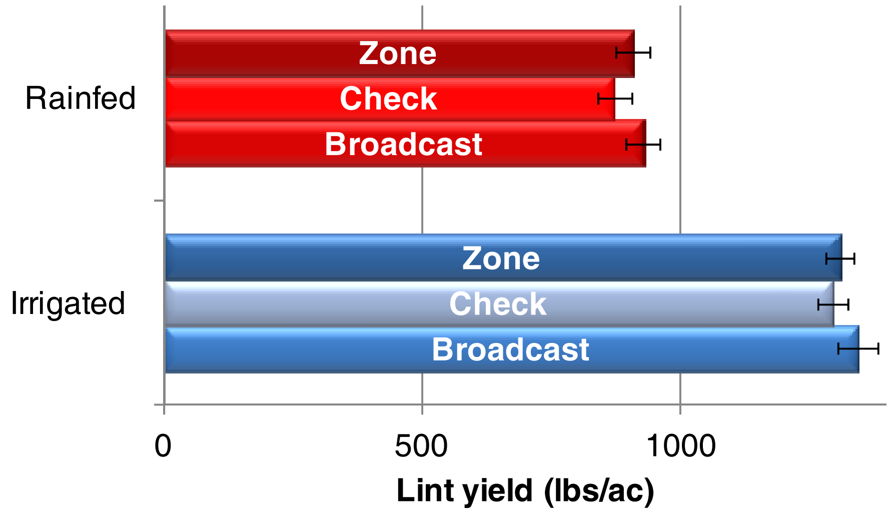

Figure 7. Mean lint yields (±SEM) were significantly (P=0.0001) higher in irrigated compared to rainfed portions of Field 61; lint yields for zone, broadcast or check spray strips were similar within each irrigation zone in insect control termination trial, Wildy Family Farms, Manila, AR, 2012.

Conclusions

Action thresholds for crop protection for tarnished plant bug are static through the season until around two weeks following cutout. Previous research has shown that making protective insecticide applications for control of new infestations of tarnished plant bug after cutout + 250 DD60s is unproductive (Teague et al 2002, 2006, 2008, 2010). Results from this trial support the findings of previous research. Even though late season tarnished plant bug numbers were tenfold the recommended action threshold at cutout + 330 DD60s, there was no yield penalty for terminating insect control. The last effective boll population had reached its final stage of crop susceptibility, and tarnished plant bugs were no longer economically important.

Mid-South cotton producers are expanding use of zone management practices for insect management to improve crop production efficiency. Historically, site specific 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). In a step toward precision IPM, progressive producers have begun shifting from broadcast sprays in late season to site specific sprays. They use COTMAN crop termination guides to save money by eliminating insecticide applications in crop areas to protect mature bolls that are no longer susceptible to feeding damage.

On the 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 field 61 replicated strip trial summarized in this paper, insecticide costs were reduced 14% with a zone approach. Insecticide product cost for the producer was $16.92/acre. Broadcast cost for field 61 (75.4 acres) was $1276. If only the irrigated zone (65.2 acres) was sprayed, insecticide cost was $1103. Reductions in total insecticide use provide economic benefits as well as potential environmental benefits. 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. Site specific management practices such as zone management can further improve input use efficiency in late season crop protection. The COTMAN crop termination rules fit well with irrigation zones and appear to be a worthy investment in management time.

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