INFLUENCE OF TILLAGE SYSTEM AND IRRIGATION INITIATION TIMING ON SUSCEPTIBILITY OF THREE COTTON CULTIVARS TO TARNISHED PLANT BUG

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Abstract

Cotton production practices that negatively affect crop earliness could diminish advantages of utilizing host plant resistance (HPR) as a cultural control management tactic for tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)). Two field experiments were conducted in 2013 in northeast Arkansas to examine performance of three cultivars with relatively high, medium and low HPR levels when grown using production practices that impact crop maturity – conservation tillage and irrigation initiation timing. Each experiment was arranged in a split-split plot design with main plots of either irrigation or tillage and sub-plots of cultivar (Stoneville 5288 B2RF, Deltapine 0912 B2RF or Phytogen 375 WRF) and crop protection (insecticidal control prior to cutout compared to untreated). In the tillage trial, there were three systems: conventional, no-till or terminated wheat cover crop with conservation tillage. For the irrigation initiation trial there were two start times for initiation of furrow irrigation – early start (36 days after planting (DAP) - first week of squaring), or delayed start (55 DAP, ca. 5 days prior to first flowers).

In both trials, fewer plant bugs were observed in the more resistant Stoneville 5288 and Deltapine 0912 cultivars compared to the susceptible Phytogen 375. Infestation levels rose above action thresholds earlier and for longer periods during the season for Phytogen 375. Among the resistant cultivars, HPR levels were not impacted by tillage practices. With moderate infestation levels observed in 2013, the resistant Stoneville 5288 did not require protection with insecticides to produce highest yields. Maturity delays, documented using plant monitoring with COTMAN, were observed if susceptible Phytogen 375 was not protected from plant bugs in mid-season. In both trials, plant response to production practices was confounded by cloudy, rainy weather during weeks 2, 3 and 4 of flowering. These conditions likely resulted in non-insect induced small boll shed. For the Phytogen 375, a delay in irrigation initiation resulted in delayed maturity. Delayed irrigation initiation appeared to have a negative impact on HPR of Stoneville 5288. Additional field studies are needed. Expanded understanding of how production practices affect HPR tolerance and resistance mechanisms will enable crop managers to make more efficient use of this important cultural control tactic within the framework of an integrated pest management system.

Introduction

Cotton production practices that impact pace of square production in early season and/or prolong availability of squares in late season will affect feeding and ovipositional preferences by adult tarnished plant bugs. In 2013, we were interested in how late season maturity delays brought on by tillage practices or by pre-flower water deficit stress would affect cultivars exhibiting host plant resistance (HPR) to plant bugs. We conducted two field experiments to examine performance of three early maturing cultivars grown with and without mid-season chemical control using foliar applied insecticides. Cultivars Stoneville 5288 B2RF, Deltapine 0912 B2RF and Phytogen 375 WRF, with high, medium and low HPR ratings, respectively, were selected for use based on results from previous field and laboratory evaluations in an on-going HPR research program in Arkansas (Bourland 2004, Bourland and Jones 2008; Teague and Bourland 2009, Studebaker and Lancaster 2011, Teague and Neely 2012). Stoneville 5288 B2RF, Deltapine 0912 B2RF and Phytogen 375 WRF were grown in different tillage systems or with different irrigation initiation timings. The tillage experiment was carried out in association with a field study first established in fall 2007 to assess agronomic and environmental impacts of conservation tillage systems. Treatments included conventional system, a conservation tillage system with terminated winter cover crop and a no-till system. In previous seasons, in studies with just one cultivar, crop delay had been observed with both cover crop and with the no-till treatment plots compared to conventional tillage practices (Teague et al. 2010; 2012). Delayed maturity also is one negative consequence when pre-flower water deficit stress is followed at first flowers by rains or a late start time of irrigation (Teague et al 2011; 2013). Our aim in the 2013 irrigation initiation study was to trigger a late season maturity delay by inducing pre-flower water deficit stress with late irrigation start time. We compared infestation levels, plant injury and crop damage among the three cotton cultivars with delayed compared to early start irrigation initiation timing with early maturity as the goal.

Materials and Methods

Both experiments were conducted on the Judd Hill Foundation Research Farm near Trumann in northeast Arkansas. The small plot studies were positioned in adjacent field areas on the 35 acre research farm. Soil at the site is classified as Dundee silt loam.

Tillage System: The experiment was arranged as a 3*3*2 factorial (tillage*cultivar*protection) in a split-split plot design with 3 replications. Tillage treatments were considered main plots and were 1) conventional, 2) no-till, and 3) terminated winter wheat cover crop with conservation tillage. The three cultivars, considered subplots, were either unprotected (untreated check) or sprayed with insecticides in mid-season. We applied insecticides in the protected treatment when field population densities in any treatment group exceeded an action threshold of 3 plant bugs/3 ft. of row sampled using drop cloths.

Tillage practices in the conventional and cover crop treatments consisted of using disk bedders in fall to re-form beds following the 2012 cotton crop. Wheat was broadcast planted in the cover crop treatment mainplots (10 lb seed/ac) in mid-October. In March 2013, a broadcase application of the herbicide glyphosate was made by air across the entire experiment to“burndown” winter weeds in no-till as well as terminate the winter cover crop. Production practices were similar across all tillage treatments with the following exceptions used only in conventional tillage treatment: disk bedders were used to re-form beds (14 May), tops of beds were flattened with a field cultivator prior to planting on 16 May, and row middles (water furrows) cleared with sweep plows on 26 June. No cultivations were made in any treatment. Cruiser treated (thiamethoxam) seeds were planted on 16 May at 3 to 4 seeds/ft on raised beds spaced at 38 inches. A no-till planter was employed, and planter settings were adjusted for each tillage treatment to ensure uniform seed depth and good soil-seed contact. The field was furrow irrigated weekly as needed with early irrigation initiation to avoid pre-flower water deficit stress. Sub-plots were 16 rows wide, 55 ft long with 10 ft alleys. Rows 8 through 12 were used for plant and pest monitoring, and rows 5 and 6 were used for final end-of-season plant mapping and yield assessments. Additional timing of practices and pesticide applications rates are sumarized in Table 1.

Table 1. Tillage*HPR trial production details including dates of planting and irrigation, application dates for insecticide, plant growth regulator and harvest aids, and harvest date – 2013, Judd Hill, AR.

Operation	Date	Days after planting
Date of planting	16-May	
Insecticide (ground)[1]	16 & 29 July	61, 74
Insecticide (aerial)[2]	7 & 15 August	83, 91
Irrigation	21 & 28 June, 10 & 17 July	36, 43, 55, 62
Mepiquat chloride[3]	27 June, 17 & 31 July, 15 August	42, 61, 76, 91
Defoliation/boll opener	26 September & 4 October	133, 141
Harvest	23 October	160

[1]Insecticide applied by ground to protected treatments only, 1.5 oz/ac Transform 50WG (sulfoxaflor)

[2]Insecticides applied by air (a.i./acre): acephate (.67 lb) + bifenthrin (0.075 lb) followed by dicrotophos (.5 lb) + bifenthrin (0.075 lb). Rains precluded ground applications, and the aerial application was necessary to control potentially damaging population densities of plant bugs across an array of experiments on the Judd Hill station.

[3]Mepiquat chloride applied by air at 12, 16, 16, 8 oz/acre, respectively

Plant stand density was determined by counting plants per 3 ft in two transects across 4 rows in two different sections of each sub-plot. Stand counts were made on 30 May and 4 and 12 June (14, 19 and 27 days after planting (DAP)). Insect monitoring began at crop emergence with weekly visual inspections. Thrips infestation levels were quantified three weeks after planting using whole plant “thrips washes”. Plants were cut at the soil level and immediately placed in sealed plastic bags, placed in coolers with ice packs and taken back to the laboratory. Plants were washed in a 70% alcohol solution in glass beakers. The plant wash solution for each 10 plant sample was poured through coffee filters to separate thrips and other debris from alcohol. Using a dissecting microscope, we counted thrips adults and larvae for each filtered sample.

Crop monitoring with COTMAN (Danforth and O'Leary 2004, Oosterhuis and Bourland 2008) as well as plant bug monitoring using drop cloths were performed each week from first squares through the latest possible cutout date - seasonal cutout (11 August). Scouts inspected two sets of five consecutive plants located on adjacent rows using standard COTMAN Squaremap sampling protocol. By the second week of flowering, scouts also began recording nodes above white flower (NAWF). Ten plants with first position white flowers were selected in the two sample rows weekly, and numbers of main stem squaring nodes determined. Days to cutout (mean NAWF = 5) calculations were derived from standard output using the COTMAN software. For tarnished plant bug monitoring, scouts used a drop cloth to sample 2 adjacent rows per plot. Average number of collected nymphs and adults per drop cloth sample was analyzed using PROC GLM (SAS Institute Inc., Cary, NC) separately for each date. Insecticide was applied to appropriate treatment plots using a high clearance, tractor mounted sprayer with 8-row boom. Yield determinations were made using a 2-row research cotton picker. Seedcotton "grab" samples collected from picker basket) in each treatment plot were ginned with a laboratory gin and sent to the Texas Tech Fiber and Biopolymer Research Institute for HVI evaluations.

Irrigation: The irrigation initiation * HPR experiment was arranged in a split-split plot design as 2*3*2 factorial with 3 replications. Main plots were irrigation start time: 1) Early (an early start time; first week of squaring - 36 DAP), and 2) Delayed start (one week prior to first flowers – 55 DAP). Sub-plot treatments were cultivars and protection as described above for the tillage trial. Plots were 40ft long, 8 rows wide with 10 ft alleys. Rows 3 and 4 were used for plant and pest monitoring and rows 5 and 6 were used for final end-of-season plant mapping and yield assessments. Crop monitoring with COTMAN as well as insect monitoring using drop cloths were performed as described above as harvest. Additional information on timing of practices plus rates of pesticide applications are sumarized in Table 2.

Table 2. Irrigation initiation trial dates of planting and irrigation, application dates for insecticide, plant growth regulator and harvest aid, and harvest date for 2013 tillage*HPR trial – Judd Hill, AR.

Operation	**Date**	**Days after planting**
Date of planting	16-May	
Insecticide (ground)[1]	16 & 29 July	61, 74
Insecticide (aerial)[2]	7 & 15 August	83, 91
Irrigation- Early start treatment	21 & 28 June, 10 & 17 July	36, 43, 55, 62
Irrigation- Late start treatment	10 & 17 July	55, 62
Mepiquat chloride[3]	27 June, 17 & 31 July, 15 August	42, 61, 76, 91
Defoliation/Boll Opener	26 September & 4 October	133, 141
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[3]Mepiquat chloride applied by air at 12, 16, 16, 8 oz/acre, respectively

Results

Rainy weather conditions were prevalent during much of the 2013 production season (Table 2). Planting was delayed until mid-May because of spring rains. August rainfall and associated cloudy conditions affected late season crop development in both trials.

Tillage: .Plant stand density was lowest in no-till compared to the conventional and cover crop systems ($P<0.05$) (Figure 1). Plants were slower to emerge in the no-till main plots, and after emergence there were higher levels of seedling mortality. Stand densities at the last sample date, 27 DAP, ranged from 6.8 to plants per ft for the DP 0912 in no-till system compared to 11.4 plants for Stoneville 5288 in the conventional tillage treatment. Generally, highest plant population density was observed for the Stoneville 5288.

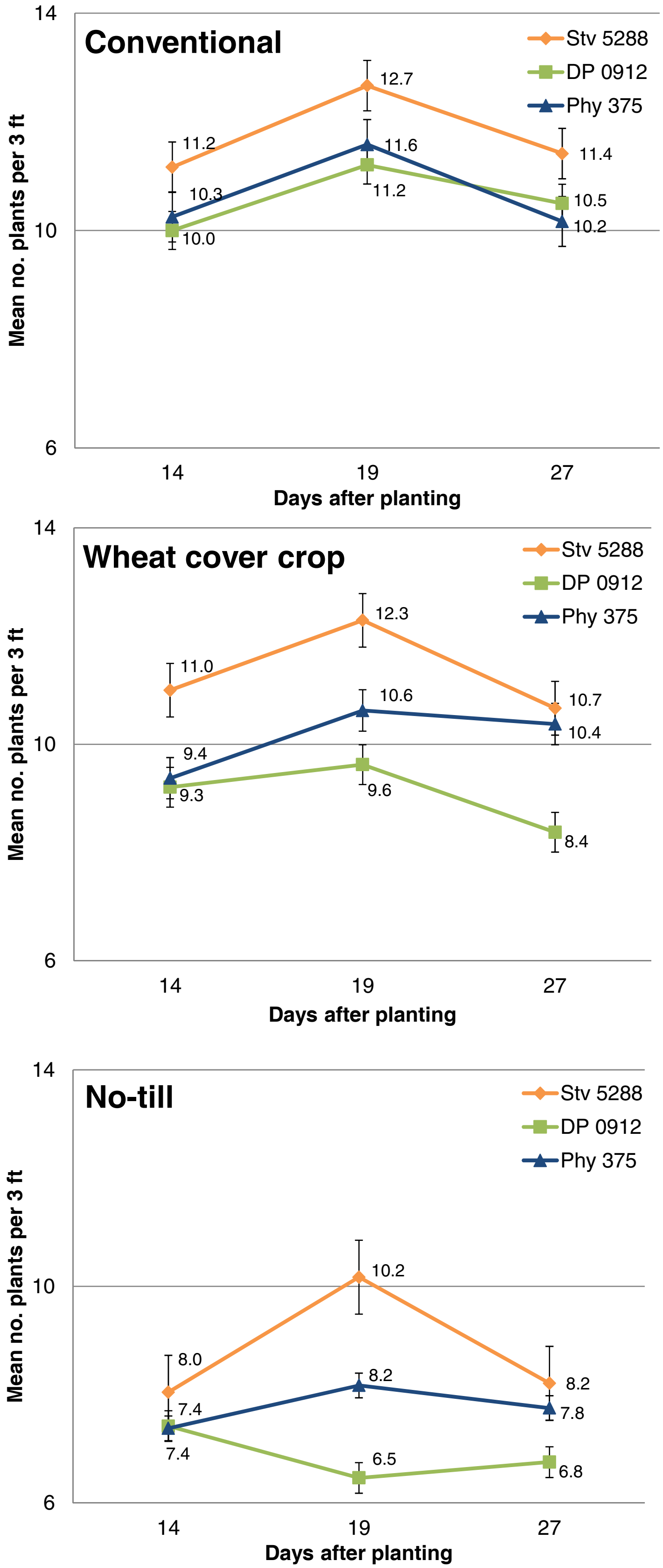

Figure 1. Mean (±SEM) no. plants per 3 ft over three dates for conventional, wheat cover crop and no-till main plot treatments in 2013 tillage*HPR trial - Judd Hill, AR.

Highest numbers of thrips were associated with the plant bug susceptible cultivar, Phytogen 375 (P=0.02) (Figure 2). A significant tillage effect was also observed with fewest numbers of thrips were associated with the wheat cover crop (P=0.03). There were no significant interations. Thrips numbers were generally below threshold with very low levels of injury; however, apparent differences in thrips suceptibility among cultivars merits closer attention in future work. Tobacco thrips was the dominant species in 2013.

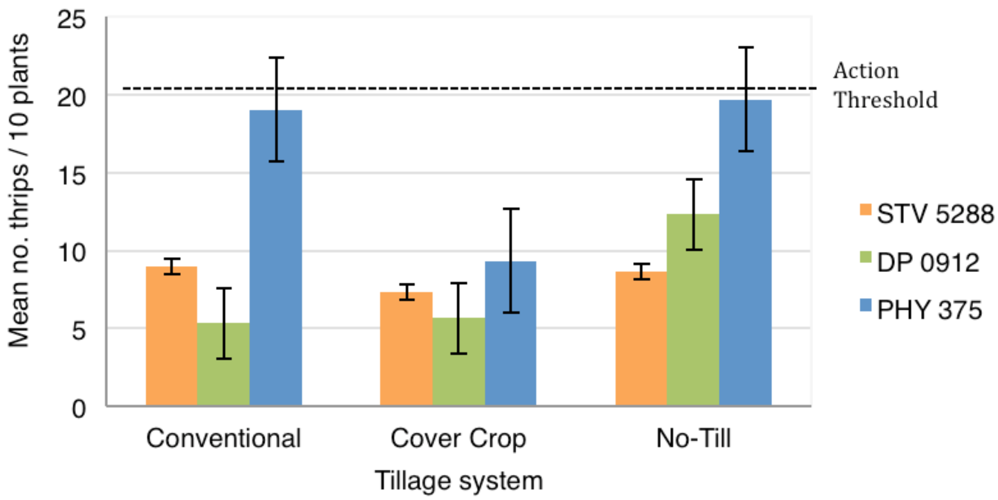

Figure 2. Mean (±SEM) no. thrips per 10 plants observed in seedlings of three cotton cultivars collected 21 days after planting in the Judd Hill tillage*HPR trial.

COTMAN growth curves for plants in the tillage trial show that main stem nodal development for all cultivars in the three tillage systems was on target through first flowers (ca. 60 DAP). Maturity delays became apparent from that growth stage forward. Plant response to pre-flower square shed resulting from insect induced injury typically will not affect slope of COTMAN growth curves until *after* first flowers. A growth curve with “flat” slope after first flowers, in comparison to the target development curve, indicates continued addition of new squaring nodes at a greater than expected pace. As lower canopy squares mature and flower, physiological stress from boll development will slow the production of new terminal squaring nodes. If there are few bolls and low levels of boll loading stress, healthy plants with adequate moisture and nutrients will continue producing squaring nodes at a higher rate relative to the standard curve.

Maturity delay indicated by post flower growth curves in the tillage trial likely was related to both insect and non-insect related shed of fruiting forms. Plants that were not protected from plant bug feeding had higher levels of pre-flower square shed (Figure 4). Square retention at the 1st position on mainstem squaring nodes was reduced to < 85% in most treatments by 60 DAP triggering insecticide application in protected treatments. Pre-flower square shed exceeded 15% by first flowers in the susceptible Phytogen. Infestation levels of plant bugs were moderately high for the NE Arkansas region in the 2013 production year. Plant bug population densities tended to reach action threshold in the susceptible Phytogen 375 earlier compared to the other more resistant cultivars (Figure 4). Mean plant bug numbers were slightly higher with cover crop at 70 DAP, but these levels were not statistically significant. Plant bug numbers in protected treatment plots were reduced to sub-threshold levels following insecticide applications at 61 and 74 DAP. The excessive rains during August precluded additional ground applications of insecticides. Aerial applications across the entire research station were made on 83 and 91 DAP.

Cloudy, rainy weather conditions likely contributed to non-insect induced small boll shed during the effective flowering period (first 4 weeks of flower) in late July and early August. Differences among cultivars to the insect and non-insect induced loss of all first position fruiting forms (squares and bolls) is apparent in comparisons of total sheds from plant monitoring on 60, 74 and 90 DAP (Figure 5). No mainplot tillage differences were observed, there

there were signigicant cultivar * protection interactions (P=0.02). Mean % total shed of first position squares and bolls was significantly lower in protected Stoneville 5288 than in all other treatment combinations.

Table 2. Monthly precipitation totals from the Judd Hill Research Station for the crop production seasons 2008 through 2013. Rainfall for August 2013 was +4 inches above the average of the previous 5 years.

	Rain (inches)					
Month	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
April	6.9	9.5	3.7	7.9	1.5	5.9
May	4.0	9.8	7.1	8.8	0.0	11.6
June	1.4	4.6	0.6	1.8	0.0	3.2
July	1.8	8.3	7.0	0.8	1.2	3.5
August	0.6	3.8	0.3	3.5	1.6	6.4
September	3.2	4.8	0.8	1.5	5.2	2.6
October	2.9	12.4	0.4	2.3	3.4	3.6
Total	20.8	53.2	19.9	26.6	12.9	36.7

The days to cutout calcultaions from NAWF sampling reflect crop delay among all treatments (Table 3) with no treatments reaching physiological cutout by 80 DAP. There were no significant main effects of tillage system on mean no. days to cutout (P=0.40); however, there were significant interactions associated with tillage*cultivar (P=0.02) and protection * cultivar (P=0.10). The latest maturity was noted with unprotected Phytogen 375 grown in the no-till system. In conventional tillage mainplots, the Stoneville 5288 reached cutout by 87 DAP compared to 93 DAP for Phytogen 375.

Table 3. Tillage system*HPR trial plant maturity measurements - days from planting to physiological cutout (NAWF=5) for the three cultivars either protected or unprotected with insecticides during the first four weeks of flowering – Judd Hill, AR, 2013

	Protected			**Unprotected**		
Tillage treatment	Stv 5288	DP 0912	Phy 375	Stv 5288	DP 0912	Phy 375
Conventional	87	88	93	87	93	93
No-Till	93	94	94	87	87	97
Cover Crop	91	86	88	90	84	89

Tillage and cultivar significantly impacted yield in 2013 (P= 0.02 and 0.005, respectively). Lowest yields were associated with the no-till system compared to conventional and cover crop system (Figure 6). The cultivar Phytogen 375 had lower lint yield compared to Stoneville 5288 and Deltapine 0912. Midseason insecticide sprays did not significantly affect yield, but there was a cultivar*protection interaction (P=0.10) with the lint production of the susceptible cultivar similar to resistant cultivars only if sprayed with insecticide to prevent mid-season damage. All cultivars produced lower yields in the no-till system. In the six years of the tillage study, yields in the no-till generally have been lower compared to the cover crop and conventional treatments. Factors reducing no-till yield in previous years have not been insect related. Fiber quality assessments were not completed in time for this report.

Irrigation: Our protocol for irrigation timing in the early start treatment was to initiate irrigation after the plants began squaring, if there was one week without rain. Weekly irrigation applications were made if there was no measureable rain. Early start mainplots received irrigated at 41 and 47 DAP (Figure 7). Both early and delayed treatments were irrigated 55 and 62 DAP. First flowers were observed at 61 DAP. With above average rainfall from mid-season through cutout no further irrigations were applied.

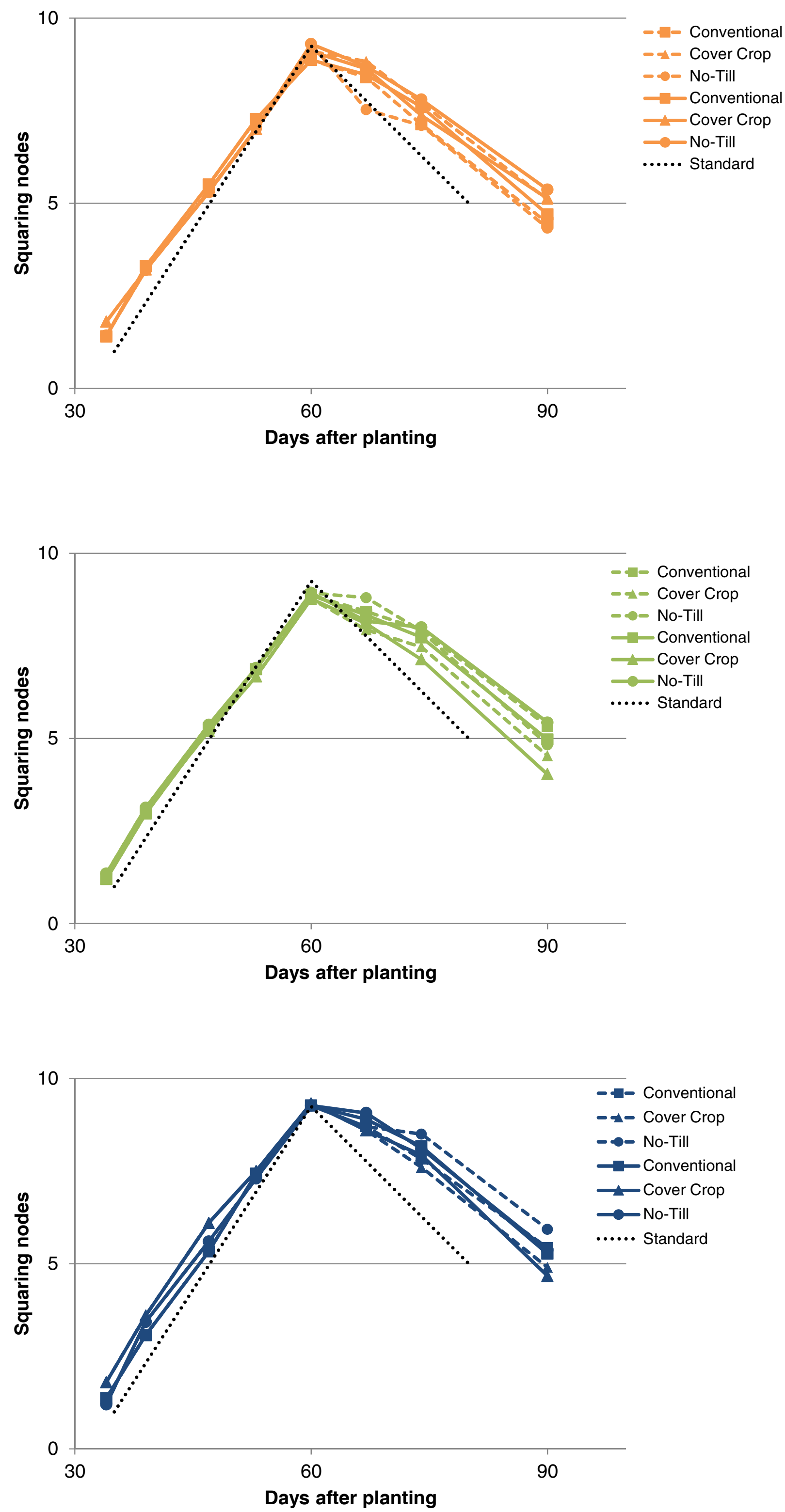

Figure 3. COTMAN growth curves for 2013 tillage*HPR trial for three cultivars, protected or unprotected from mid-season infestations of tarnished plant bug - 2013 Judd Hill, AR.

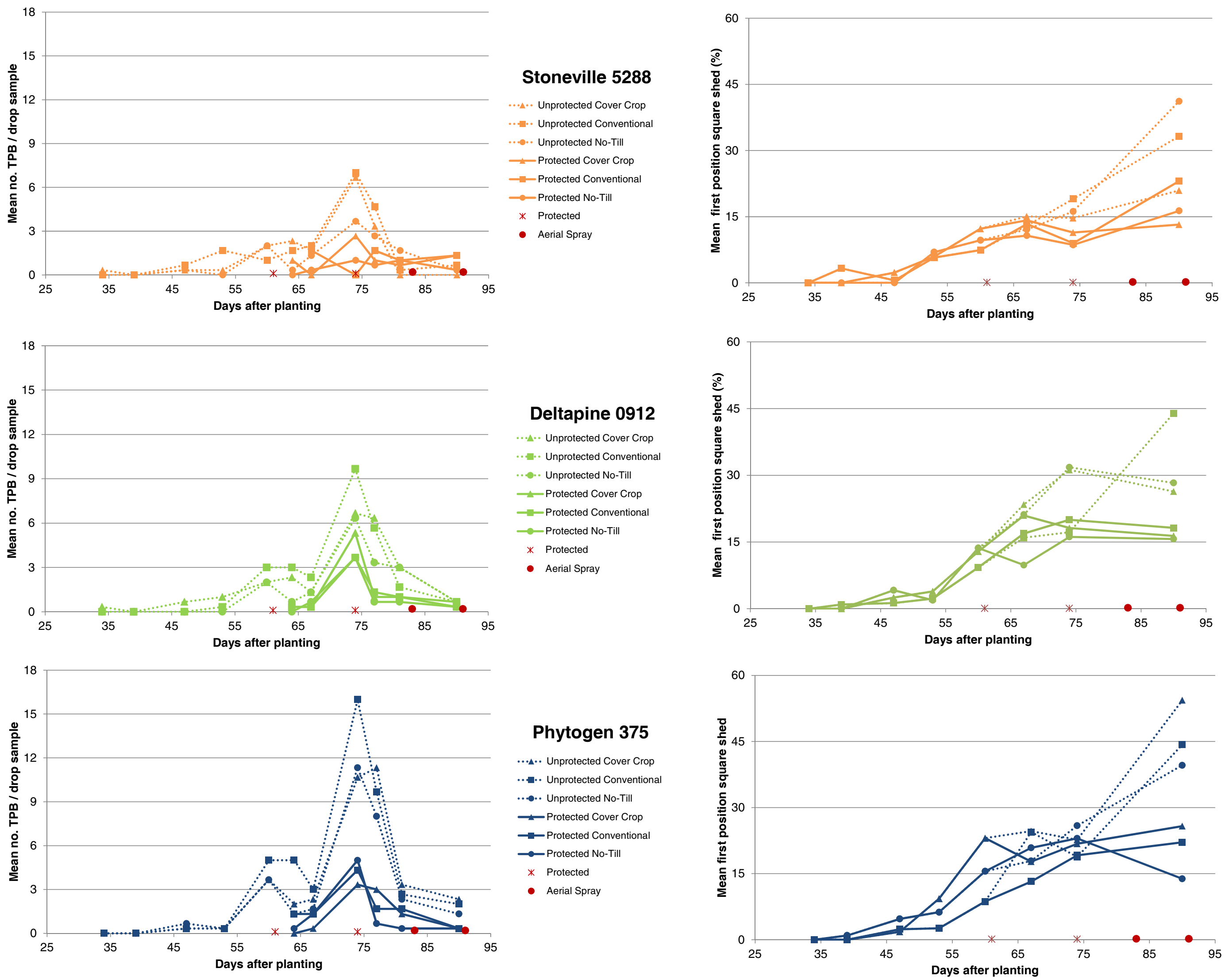

Figure 4. Mean no tarnished plant bugs per drop cloth sample (3 ft of row) (left) and mean first position square shed (right) in 2013 tillage*HPR trial with three cultivars either protected with mid-season insecticide sprays or unprotected in 2013 tillage trial – Judd Hill, AR.

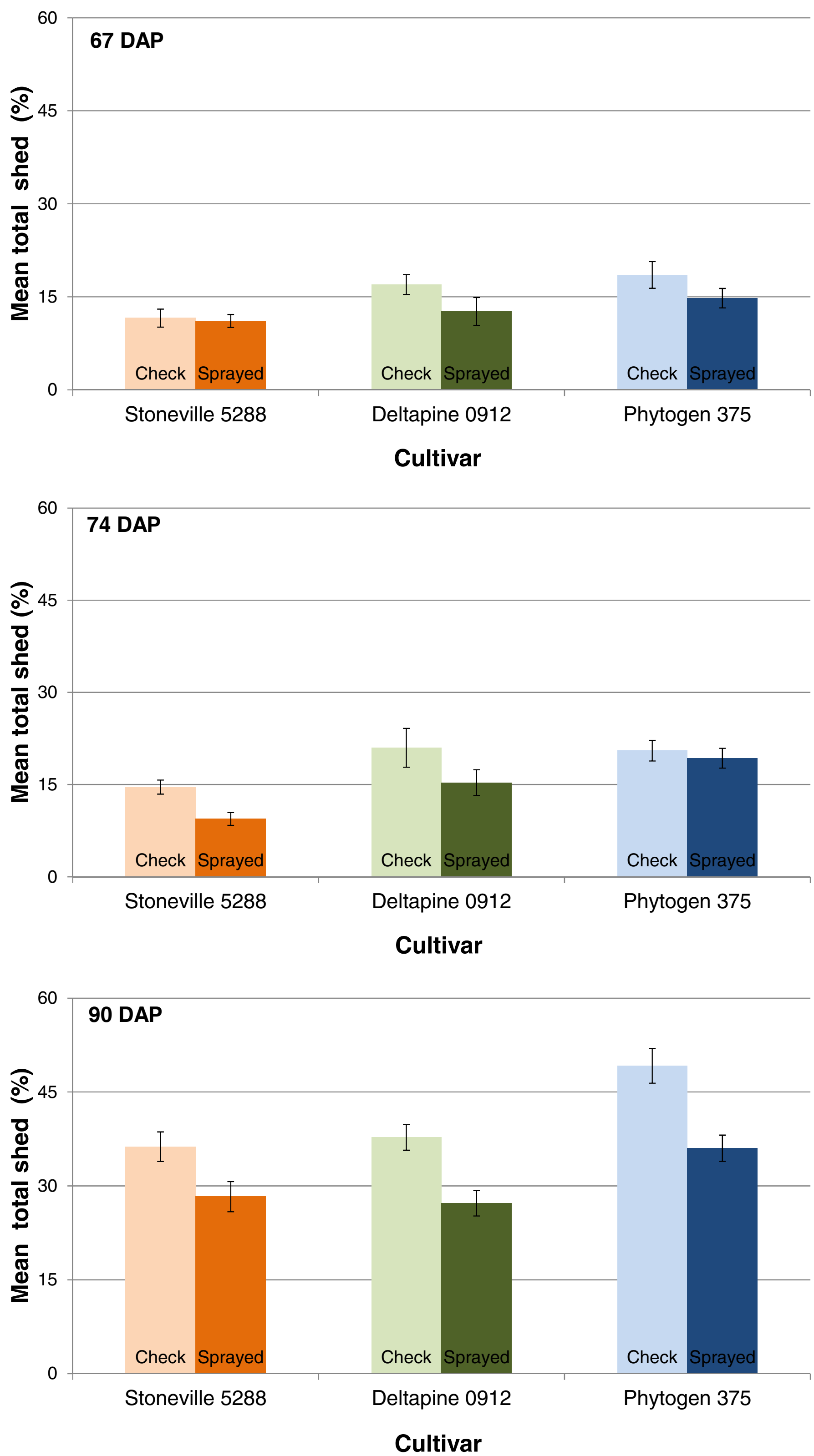

Figure 5. Mean shed (±SEM) of first position fruiting forms (squaring and boll nodes) 2013 tillage*HPR trial at 67, 74 and 90 DAP for the three cultivars either unprotected (check) or protected (sprayed) with insecticide at 61 and 74 DAP.

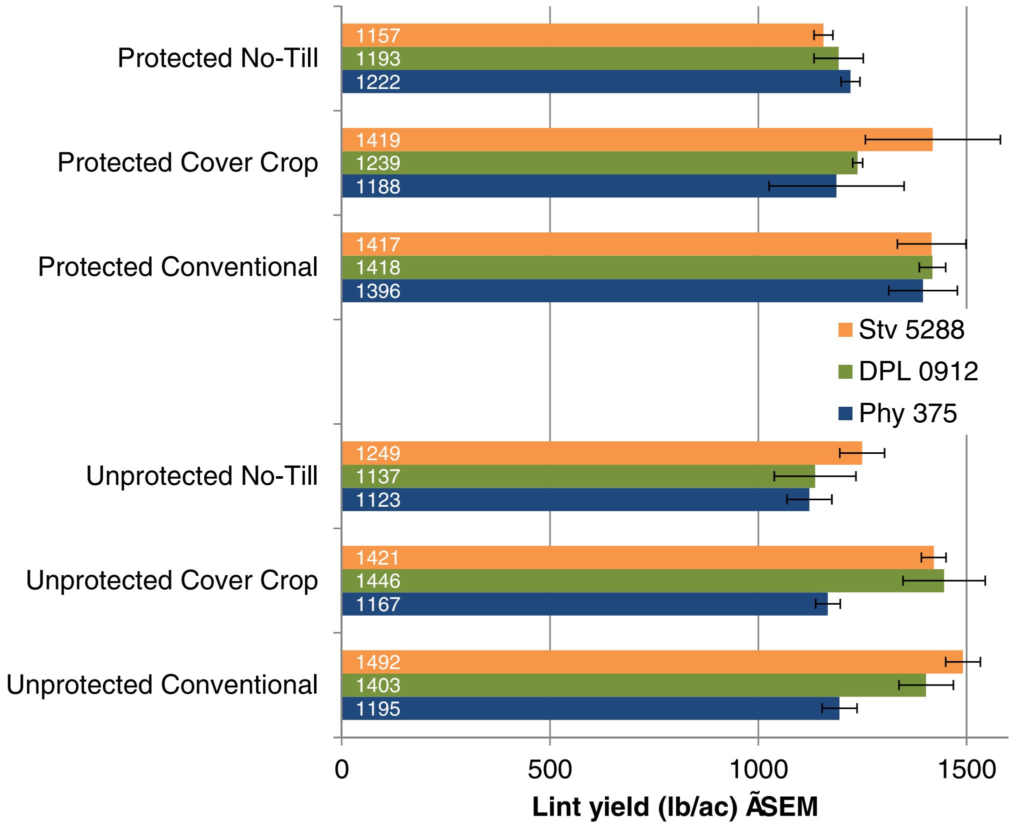

Figure 6. Mean (±SEM) lint yield (lbs/ac) in 2013 tillage*HPR trial at Judd Hill, AR.

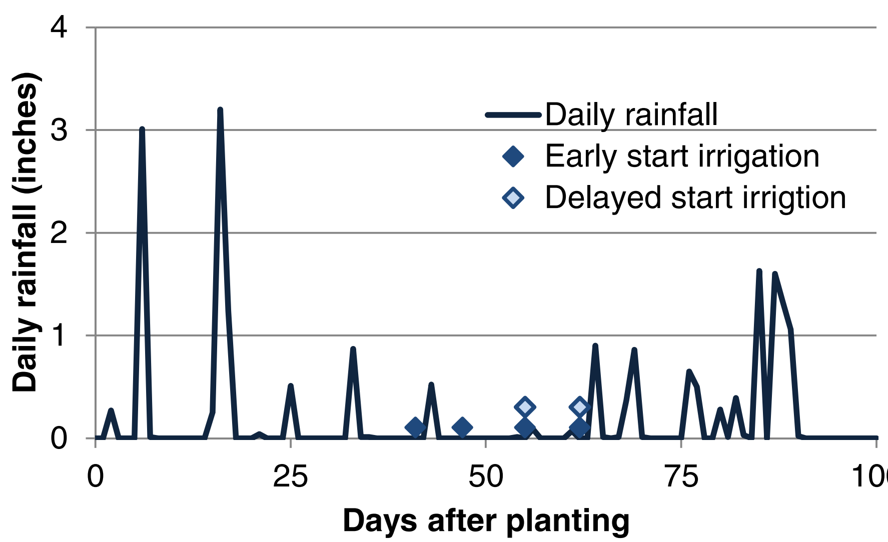

Figure 7. Daily rainfall (inches) and irrigation timing for the early and delayed starts for the 2013 irrigation initiation * HPR trial at Judd Hill. Date of planting was 16 May.

COTMAN growth curves for plants in the irrigation trial indicate that plant nodal development was similar among all treatments and was on target through first flowers (Figure 8). Rain events undermined our efforts to manipulate plants to produce wide ranges in late season maturity. COTMAN plant monitoring provided an efficient means to document plant response to irrigation even in the unusually wet year. Variation in nodal development, fruit retention and crop maturity were observed with delayed compared to early start irrigation. After first flowers, COTMAN growth curves for delayed start irrigation treatments did not follow the target development curves; instead of a smooth decent toward cutout, slope of curves flattened, indicating a maturity delay. This was particularly evident for Phytogen 375 where physiological cutout was significantly later compared to the more resistant cultivars (P=0.001) (Table 4). Days to cutout ranged from 83 to 86 DAP for Stoneville 5288. Protected, early irrigated treatments of Phytogen 375 reached cutout by 84 DAP, but if irrigation was delayed and/or the plants were not protected from injury by plant bug, physiological cutout was delayed from 93 to 97 DAP.

Table 4. Irrigation initiation*HPR trial plant maturity measurements - days from planting to physiological cutout (NAWF=5) for the three cultivars with either early or delayed irrigation initiation timing and protected or unprotected with insecticides during the first four weeks of flowering – Judd Hill, AR, 2013.

Irrigation Initiation Treatment[1]	Protected			Unprotected		
	Stv 5288	DP 0912	Phy 375	Stv 5288	DP 0912	Phy 375
Early Start	84	85	84	83	86	93
Delayed Start	86	87	97	83	90	97

[1]No significant main effects of irrigation initiation on plant maturity were observed in 2013 (P=0.42); there was a significant difference in days to cutout associated with cultivar (P=0.001) and for protection*cultivar interaction (P=0.10).

Plant bug infestatation levels were lower in the irrigation trial compared to those observed in the tillage trial. Plant bug abundance was not impacted by irrigation timing effects (Figure 9), but there were differences among cultivars. Plant bug numbers did not exceed recommended action in the resistant Stoneville 5288 prior to cutout. As was observed in the tillage trial, bug infestation level were highest in the Phytogen 375. Plant bug population densities reached threshold in the this cultivar earlier compared to the other more resistant cultivars. Square shed levels were similar among irrigation treatments through first flowers, and then were highest in unprotected plants in the susceptible Phytogen 375 (Figure 9).. Significant differences in shed levels were associated with insecticide spray and cultivar subplot effects (P<0.05), but not irrigation main plots. There were no significant interactions.

In the high rainfall, 2013 production season, irrigation timing did not influence lint yield (Figure 10). There were significant differences in lint yields among cultivars (P=0.03). Phytogen 375 produced lower yields compared to Deltapine 0912 and Stoneville 5288. Insecticide protection (P=0.14) tended to increase yields, and there were no significant interactions. Lowest mean yields were observed in unprotected, late start irrigation treatments. Regardless of insecticidal protection, highest yields were observed with the Stoneville 5288 when grown with early start irrigation.

Conclusions

Untangling trends among treatment effects in these 2013 trials was problematic because of confounding effects of cloudy and rainy weather conditions during the effective flowering period. In-season plant monitoring using COTMAN provided an efficient and systematic sampling methodology to document plant response to treatment effects. These included measures of pace of nodal development, fruit retention and a simple gauge of crop maturity, days to cutout. Each are each important plant cues for evaluating cotton HPR to tarnished plant bug. Drop cloths were effective for surveying abundance of plant bug nymphs, but COTMAN measures of square shed in pre-flower cotton allowed us to gauge feeding injury from illusive adult bugs. COTMAN sampling provided a means for post-flower assessments of small boll shed, useful in documenting non-insect induced fruit loss.

When plants were protected in mid-season using chemical control, all cultivars produced comparable yields when grown under conventional tillage and with early irrigation timing. It should be noted that the resistant Stoneville cultivar - without insecticide - performed well in all systems except no-till, if not subjected to pre-flower water deficits. Overall, production system effects did not affect HPR properties of the cultivars tested, although delayed irrigation initiation appeared to have a slight negative impact on HPR on the Stoneville 5288. Expanded understanding of how production practices affect HPR tolerance and resistance mechanisms will enable crop managers to make more efficient use of this important cultural control tactic. A successful integrated pest management (IPM) system will make extensive use of cultural controls, including appropriate cultivar selection and use of production practices that promote early vigor and early maturity. An integrated approach to plant bug management will allow producers to reduce reliance on chemical control. Efficient and ecologically sound IPM is essential for improving cotton sustainability in the Midsouth.

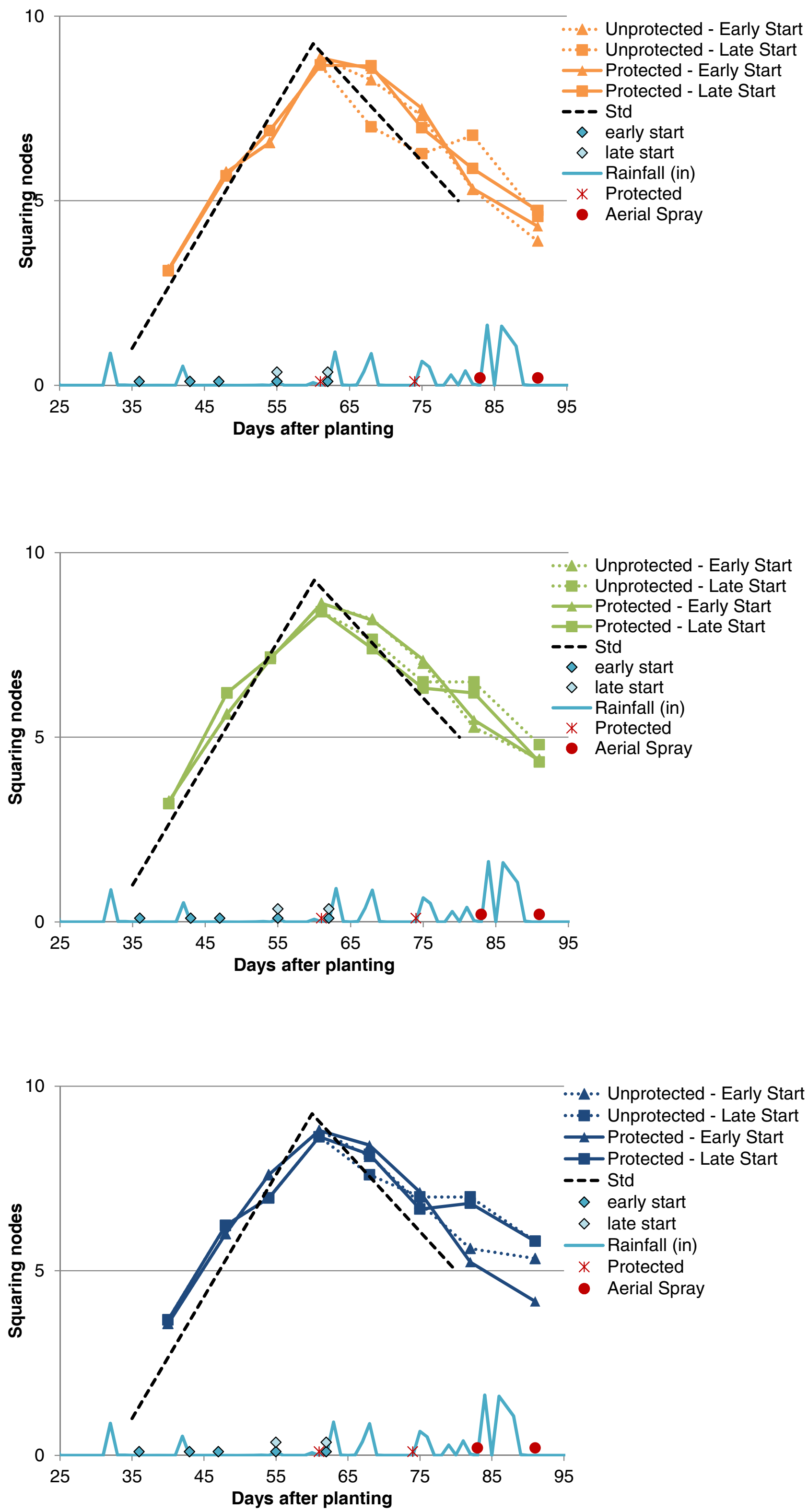

Figure 8. COTMAN growth curves for 2013 irrigation initiation*HPR trial with three cultivars, protected or unprotected from mid-season infestations of tarnished plant bug; rainfall, irrigation and insecticide application timing are also shown -- Judd Hill, AR

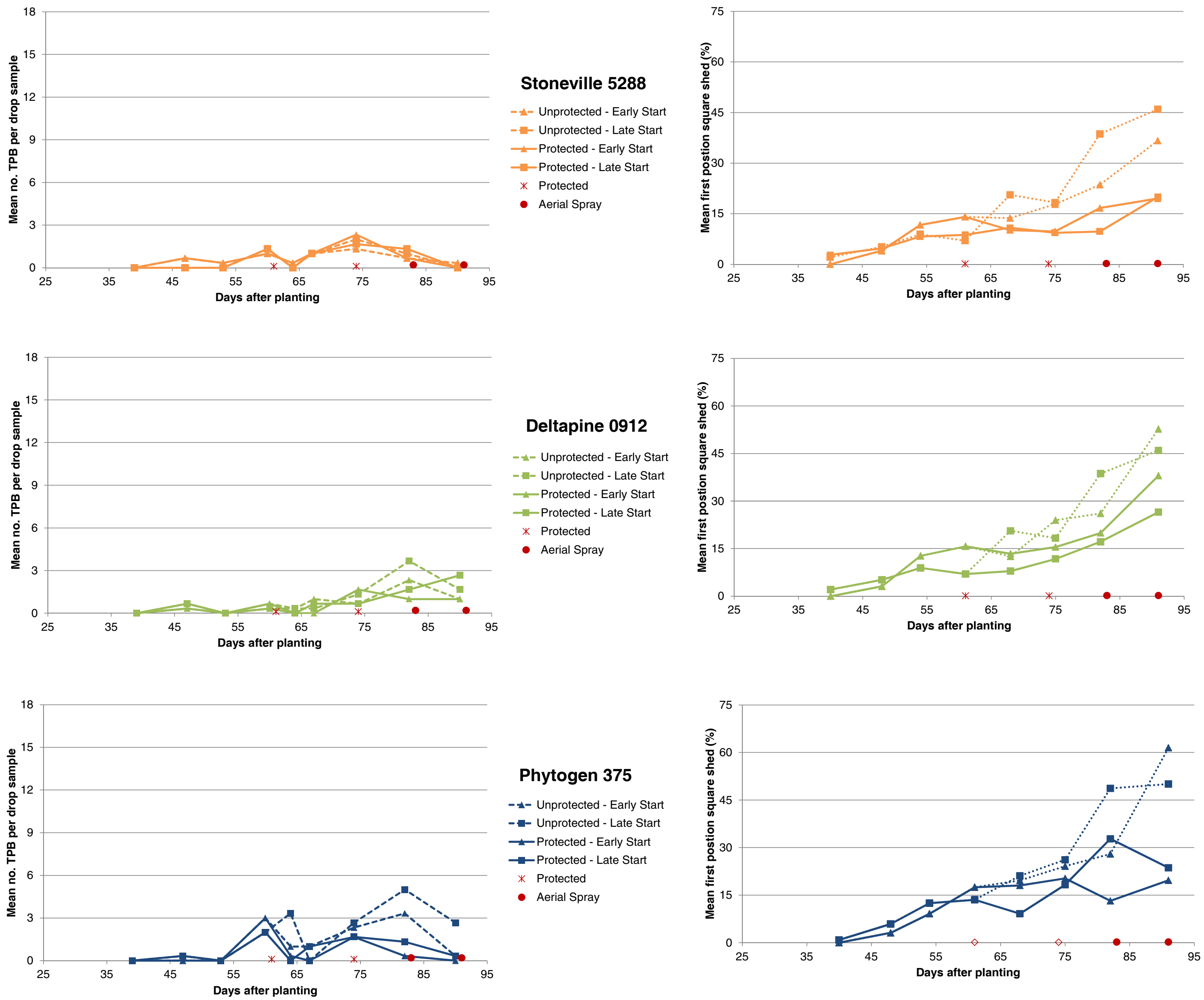

Figure 9. Mean no tarnished plant bugs per drop cloth sample (3 ft of row) (left) and mean first position square shed (right) in 2013 irrigation initiation*HPR trial with three cultivars either protected with mid-season insecticide sprays or unprotected in 2013 tillage trial – Judd Hill, AR.

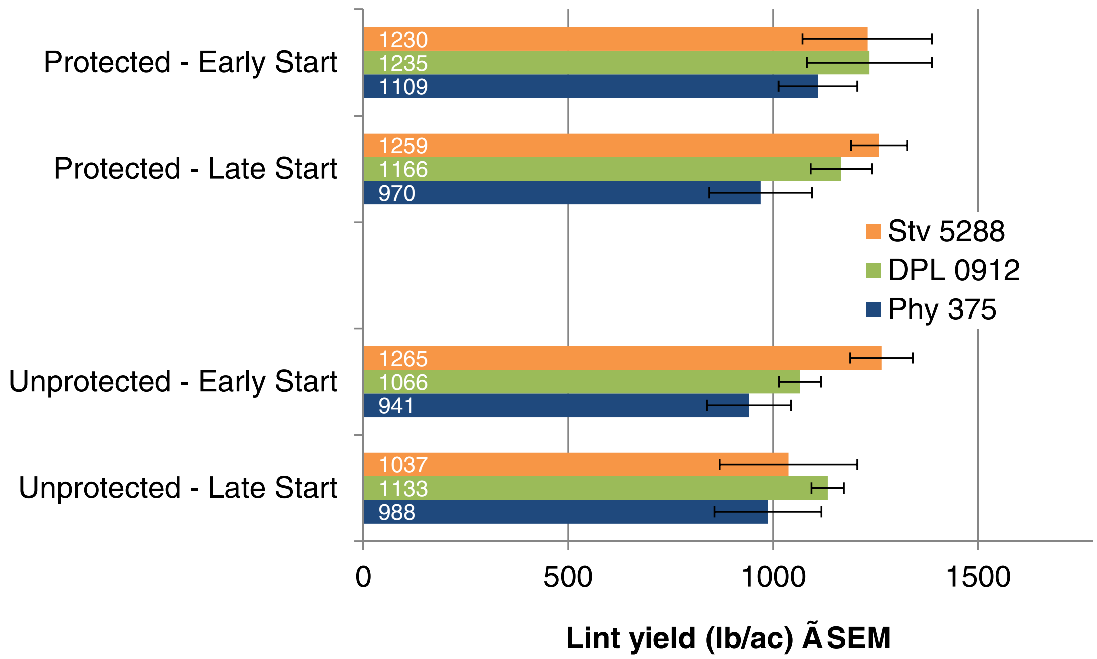

Figure 10. Mean (±SEM) lint yield for irrigation initiation*HPR trial for three cultivars, protected or unprotected from mid-season infestations of tarnished plant bug; - Judd Hill, AR.

Acknowledgements

This project is a part of the cotton sustainability research program supported through Cotton Incorporated, the University of Arkansas Division of Agriculture and Arkansas State University. This project was supported by USDA National Institute of Food and Agriculture (project ARK02355).

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