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INTERACTIONS OF WATER DEFICIT STRESS AND TARNISHED PLANT BUG INDUCED INJURY IN MIDSOUTH COTTON

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Abstract

Cotton research efforts in Arkansas recently have been focused on refinement of the COTMAN™ crop monitoring system to incorporate plant-based decision guides for managing an array of abiotic and biotic stress factors. In this field study conducted in 2003 and 2004 in NE Arkansas, we examined response of non-stressed plants and plants under pre-flower water deficit stress to square loss following feeding by tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois). Water stress was induced by delaying irrigation initiation, and insect induced injury was manipulated by augmenting natural field populations of plant bugs with lab reared nymphs and by application of insecticides. Treatments were terminated at 1st flowers, and all plots received similar irrigation and insecticide applications the remainder of the season. Standardized crop monitoring procedures in the COTMAN system were used to document changes in sympodia development and square and boll retention from 1st squares through cutout. Temperature and rainfall patterns in 2003 were favorable in creating pre-flower water deficits; there were milder temperatures and more abundant rainfall in 2004. There were clear differences in plant structure between irrigated and non-irrigated plants by 1st flowers in 2003, but not 2004. At 1st flowers, no. of sympodia per plant ranged from 4 to 11 depending on irrigation scheduling and year. Number of squaring sympodia per plant (squaring nodes) was not affected by plant bug induced square shed until after the onset of flowering. First position square shed at 1st flowers ranged from over 60% where plant bugs had been released during the 1st week of squaring to lows of less than 2% where insecticides had been applied. Mean no. 1st position squares retained per plant at 1st flowers ranged from 8.5 down to 1.5 depending on plant bug and irrigation treatment. Where square retention levels had been high, there was an abrupt decline in the production of new sympodia after 1st flowers, measured as counts of NAWF (nodes above white flower) – plants were setting and loading bolls, not increasing terminal growth. Where retention was low, the decline in NAWF values was delayed – terminal growth continued as plants added more sympodia. Early irrigation increased yields in 2003 but not in 2004. Plant bug induced injury resulted in delayed crop maturity, but not always reductions in yield. Plants without water stress were able to tolerate and/or recover from moderate levels of insect injury in 2003; yields produced were similar to those produced in cotton receiving weekly applications of insecticide. In 2004, yields from non-infested plants were greater than in similar 2003 treatments, and differences between infested and non-infested plants were significant. To maximize the crop's capacity to tolerate and also recover from early season insect attack, crop managers must make management choices that do not decrease the plant's compensation capacity.

Introduction

Arkansas research focused on refinement of plant based decision guides for incorporation into the COTMAN™ crop monitoring system (Danforth and O'Leary 1998) includes work to establish crop stress indices and new plant-based action levels for insect pest management. Additional research is needed to evaluate and quantify crop response and recovery to an array of abiotic and biotic stress factors. In this experiment we examined response of plants subjected to water stress and to square loss associated with insect feeding prior to 1st flowers. We conducted field studies in 2003 and 2004 with the objectives: 1) to compare crop response with and without pre-flower water deficits coupled with square loss resulting from plant bug feeding and 2) to assess plant responses with standardized COTMAN procedures.

Materials and Methods

The experiment was conducted at Wildy Farms, a commercial farm located in Northeast Arkansas near Leachville. Standard grower practices for fertility, weed control, plant growth regulator application and defoliation were followed through the season; only irrigation and insecticide inputs were varied for the study. The cultivar Stoneville 4892 was seeded on 27 May 2003 and 8 May 2004. The very late planting date in 2003 resulted after wet, cold weather reduced stand of the original April planting. The soil was a Routon-Dundee-Crevasse Complex (sand). Plant population density was ca. 3 plants/ft of row.

The experiment was arranged as a RCBD with 3 replications in a split-plot design with irrigation as main plots and plant bug feeding injury as sub-plots. Treatments were re-randomized in the 2nd year. Plots were 12 rows wide, 30 ft long with 6 row buffers and 10 ft alleys separating plots. Two center rows were selected in each plot for plant bug treatments. In the Early Irrigation treatment plants were irrigated as needed full season. In the Delay Irrigation treatment initiation was delayed until after 1st flowers. Early (full season) irrigated treatments received 2 furrow flood irrigations pre-flower in both 2003 and 2004; thereafter all main plot treatments, early and delayed, were irrigated weekly as needed. The early irrigation was initiated if the crop was squaring and there had been no rainfall in the previous 7 days.

For bug injury subplot treatments, plants were inoculated with tarnished plant bug nymphs to induce different levels of square shed prior to 1st flowers. Plant bug treatments were 1) Bugs 1&2 – plant bug nymphs applied in week 1 and 2 of squaring; 2) Bugs 3 - nymphs applied during the 3rd week of squaring (in 2004 bugs were applied in week 3 and 4 of squaring); 3) Natural – not treated with bugs or insecticide, natural population only; 4) Sprayed - weekly sprays during squaring with Trimax insecticide (imidacloprid 0.047 lb ai/ac). For each infestation, 3rd and 4th instar nymphs were released at densities of 3 to 5 bugs per plant. Plant bug release dates in 2003 were 2 and 9 July (36 and 43 days after planting (DAP)) in Bugs 1&2 treatment and 16 July (50 DAP) in Bugs 3 treatment. In 2004, bugs were released 11 and 18 June (35 and 42 DAP) in Bugs 1&2 and 25 June and 2 July (49 and 56 DAP) in Bugs 3&4. Imidacloprid was applied to sprayed plots on 3, 10 and 16 July in 2003; and on 11, 18, 22 and 30 June in 2004. Insecticide was applied in the sprayed treatment using a tractor mounted sprayer with 4 row boom in 2003 and with a back sprayer equipped with 4 row boom in 2004. Beginning the week of 1st flowers, all plots (Bugs 1&2, Bugs 3&4, natural, and sprayed) received blanket insecticide applications - 25 July and 11 Aug in 2003, 8 and 13 July 2004.

Nymphs were obtained from eggs laid by TPB adults collected from wild plant hosts in NE Arkansas and held on artificial diet (Cohen 2000). For release, TPB nymphs were allowed to walk onto uppermost leaves from shredded strips of white copy paper. These 1/4 inch wide and 11 inch long strips are used to line the bottom of rearing boxes, and the bugs rest on them after feeding. Rearing boxes were carried to the field, and a single paper strip pulled from the box with TPB nymphs clinging to the paper. Excess bugs were brushed off, and the paper strips laid across leaves on the top of the plant. Bugs were released during the cool periods of the morning just after dew had dried.

Plants were monitored in each plot from the early squaring period through seasonal cutout using the COTMAN Squaremap procedure. In all sampling activities, plant mappers touched the plants as little as possible to minimize thigmonastic effects. Five consecutive plants in 2 treatment rows were monitored weekly. Sampling included measurement of plant height, number of sympodia, and presence or absence of first position fruiting forms.

Final plant mapping was performed following defoliation using COTMAP (Bourland and Watson 1990). Ten plants in one row per plot were examined 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 were also noted. Plant height was measured as distance from soil to apex.

Plots were hand harvested over 3 dates (8, 27 Oct and 5 Nov) in 2003 and 5 dates (13, 20, 27 Sep and 4, 13 Oct) in 2004. Harvest aid chemicals for defoliation and boll opening were applied 15 Oct 2003 and 22 Sep 2004. All crop monitoring and yield data were analyzed using AOV with mean separation using LSD.

Results

Delaying irrigation initiation and augmenting natural field populations of plant bug allowed us to examine crop response to pre-flower water stress and square injury and loss resulting from plant bug feeding. Changes in crop development in response to injury and delayed irrigation are apparent in COTMAN based growth curves for both years (Fig. 1) Squares appeared for all treatments in both years by the target date of 35 days after planting (Fig 1).

Flowers were first observed in weekly sampling in 2003 at 55 DAP in sprayed treatments and all treatment plots by 62 DAP; flowers in 2004 were observed in all treatments by 66 DAP.

In the time from 1st squares until 1st flowers, no. of sympodia produced per plant varied with irrigation treatment and year. There was an average of 2.7 fewer sympodia per plant by the time of 1st flowers in 2003 when irrigation was delayed rather than initiated early. Temperatures and rainfall patterns were more conducive to plant growth in 2004, and effects of water stress from delayed irrigation were less pronounced (Fig 1).

Native plant bug population densities were low in both years, and 1st position square shed recorded in unsprayed, non-inoculated plots was less than 5% for the entire pre-flower period (Fig 2). Square shed levels were not affected by irrigation delay in the non-inoculated natural or sprayed treatments prior to flowering. In these treatments after flowers, some small boll and small square shed was observed, but these fruiting form losses were related to physiological shedding and were not associated with insect infestations. Growth curves for non-infested plants in the absence of pre-flower water stress generally followed the pattern of the COTMAN target development curve (Fig.1).

For plants inoculated with plant bug nymphs, square shed increased rapidly following infestations, and by 1st flowers mean square shed levels in those plots had risen to over 50% (Fig. 2). Significant differences in 1st position square shed among bug injury treatments were observed in every post-infestation sample.

Mean no. of retained 1st position squares per plant by 1st flowers ranged from 8.5 down to 1.5 depending on plant bug and irrigation treatment (Fig 3). No. of sympodia per plant ranged from 4 to 11 depending on irrigation scheduling and year (Fig. 1). This variability in square retention and plant stature (no. of sympodia at 1st flowers) resulted in dramatic differences in post-flower plant growth among treatments. Post-flower terminal growth was gauged using counts of NAWF (nodes above white flower) (Bourland et al 2000). There was an abrupt decline in the production of new sympodia after 1st flowers in non-infested and non-water stressed plants. Where plant bugs had caused squares to shed, there were few bolls to induce boll loading stress, and pace of nodal development slowed very little – plant terminals continued to grow with new sympodia produced. In 2003 water stressed treatments, boll loading stress was less severe because of poor structure (fewer sympodia) at 1st flowers. After irrigation was finally initiated, terminal growth resumed and NAWF values increased as new sympodia were produced (Fig 1).

The latest possible cutout date for NE Arkansas is 8 Aug (date at which there is a 50% probability of accruing 850 additional DD60s). With the late date of planting in 2003, no treatments reached physiological cutout (mean NAWF=5) prior to 8 Aug. In 2004, plant bug infested treatments did not reach physiological cutout by 8 Aug.

Results from end-of-season plant mapping show significant irrigation and plant bug effects on final plant stature and structure (Tables 1 to 4; Figs.4 & 5). In 2003 timing of irrigation initiation significantly affected no. of effective sympodia, highest no. of sympodia with 2nd position bolls, no. of sympodia, no. sympodia with 1st position bolls, % bolls in outer positions, % total bolls on monopodia, % early boll retention, and total nodes/plant (Table 2), but only no. of sympodia with 1st position bolls was significantly impacted by irrigation in 2004. In both years, injury by TPB affected no. of effective sympodia, no. sympodia with 1st position bolls, no. sympodia with 2nd position bolls, % total bolls in 1st position, and internode length. In both years plants infested with bugs produced greater no. of sympodia and no. of effective sympodia (Fig. 5). Plants receiving pre-flower insecticide applications had higher no. of sympodia with 1st and 2nd position bolls, but there was no significant difference in mean total bolls/plant.

Irrigation delay reduced mean boll weight in 2003, but not 2004 (Fig 6.) Boll weight was not significantly affected by bug injury or bug*irrigation effects in either year, but mean weights were higher in 2004 compared to 2003.

Cumulative yield data over 3 to 5 dates of hand picking in both years show that high pre-flower square sheds and irrigation delays resulted in crop maturity delays (Fig. 7), but plant bug induced injury and square loss did not always result in reductions in final yield. In 2003, irrigation timing significantly affected final yields, but not in 2004 (Table 5). Final yields in 2003 were surprisingly high considering the late date of planting (Fig.8). Non-water stressed plants were able to tolerate and/or recover from moderate levels of insect injury in 2003; yields produced were similar to those produced in cotton receiving weekly applications of insecticide. Yields in non-infested plants were 30% higher in 2004 compared to 2003. Early boll retention in 2004 in non-infested plants was higher than in similar treatments in 2003.

Late season crop development in 2004 was limited by cool temperatures in August. In 2003, DD60 accumulation from 8 Aug until application of defoliants on 15 Oct was 778. In 2004, only 625 DD60s were accrued from 8 Aug until defoliants were applied on 22 Sept.

Discussion

Delayed irrigation initiation can lead to pre-flower water deficits, and the subsequent water stress effects on plant growth can be documented with plant monitoring using COTMAN (Teague et al 2000; Barrentine et al. 2001). Plant injury, square shed and recovery from tarnished plant bug feeding also can be documented with COTMAN (Teague et al. 2001, 2002, 2004; Coy et al. 2003). Using standardized plant monitoring procedures in this study, we were able to document changes in sympodia development and square shed in a systematic manner through the season and determine the effects of pre-flower stresses on final crop structure, crop delay and yield.

Lint yield from plants with highest levels of plant bug induced square shed was improved in both years by initiating irrigation during the squaring period rather than delaying irrigation initiation until after 1st flowers. When plants were not subjected to pre-flower water stress, pace of sympodia development and crop growth were not slowed or interrupted. Plants with better structure at 1st flowers (more sympodia) were better able to tolerate feeding by high numbers of tarnished plant bugs and then later compensate for plant bug induced square loss. These plants had higher numbers of squares/plant at 1st flowers. With equivalent numbers of bugs released in each plot, those smaller plants suffered greater damage than larger plants. With more squares there was a buffering capacity for tolerating attack and with more sympodia, there were more potential fruiting sites on which outside bolls could be set. Compensation was achieved by bug damaged plants by increasing number of sympodia produced post-flower, and by retaining a higher percentage of outside bolls (Fig 4 & 5).

Hearn and Room (1979) listed 2 types of time-dependent compensatory responses to loss of fruiting structures: 1) ***time dependent tolerance*** - when fruiting structures that would have shed physiologically replace those previously damaged or 2) ***time-dependent compensation*** – when loss of fruiting structures delays metabolic stress from boll loading stress therefore lengthening the time of squaring and allowing some of the additional squares to set bolls. We observed both types of compensatory response in 2003 and 2004; however compensation was not sufficient in 2003 for water stressed plants or in 2004 for plant bug damaged plants when both time and extent of compensation were limited. Production areas in the northern extremes of the US Cotton Belt typically have less time for compensation; thus growers in these regions must be concerned with management practices or pests that result in crop delay. Management decisions for tarnished plant bug and irrigation both are important factors in managing crop earliness.

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Table 1. Results from final end-of-season plant mapping following defoliation using COTMAP[1] – plant bug subplot main effects – 2003.

	Mean per plant for each treatment					
Category	**Bugs 1&2**	**Bugs 3**	**Natural**	**Sprayed**	***Pr>F***	***LSD$_{05}$***
1st Sympodial Node	7.2	7.2	6.9	7.0	*0.7*	
No. Monopodia	2.1	1.8	1.7	1.6	*0.21*	
Highest Sympodia with 2 nodes	11.6	10.5	8.7	8.3	*0.01*	*1.98*
Plant Height (inches)	44.3	44.3	41.2	40.2	*0.45*	
No. Effective Sympodia	10.9	10.4	8.8	8.2	*0.04*	*2.05*
No. Sympodia	15.7	14.9	13.6	13.1	*0.01*	*1.61*
No. Sympodia with 1st Position Bolls	3.1	4.7	4.8	4.1	*0.003*	*0.62*
No. Sympodia with 2nd Position Bolls	1.7	1.8	1.4	1.5	*0.52*	
No. Sympodia with 1st & 2nd Bolls	1.0	0.9	1.0	1.2	*0.86*	
Total Bolls/Plant	9.4	10.3	9.5	9.2	*0.82*	
% Total Bolls in 1st Position	44.1	54.7	61.6	58.5	*0.001*	*7.5*
% Total Bolls in 2nd Position	29.0	26.0	24.9	28.1	*0.26*	
% Total Bolls in Outer Position	9.1	9.6	3.8	2.3	*0.005*	*4.22*
% Total Bolls on Monopodia	17.3	9.2	9.6	10.0	*0.1*	
% Total Bolls on Extra – Axillary	0.5	0.6	0.2	1.0	*0.75*	
% Boll Retention – 1st Position	26.2	37.7	42.2	40.1	*0.002*	*5.6*
% Boll Retention – 2nd Position	23.1	25.5	26.9	31.4	*0.15*	
% Early Boll Retention	12.3	31.3	50.5	49.8	*0.001*	*8.18*
Total Nodes/Plant	21.9	21.1	19.6	19.1	*0.03*	*1.99*
Internode Length (inches)	2.0	2.1	2.1	2.1	*0.66*	

[1] means of 10 plants per plot

Table 2. Results from final end-of-season plant mapping following defoliation using COTMAP[1]—irrigation main effects -- 2003.

Category	Mean per plant for each treatment: Early irrigation	Delayed irrigation	*P>F*	*LSD_{05}*
1st Sympodial Node	7.2	7.0	*0.10*	
No. Monopodia	1.8	1.9	*0.77*	
Highest Sympodia with 2 nodes	9.2	10.4	*0.15*	
Plant Height (inches)	43.8	41.2	*0.22*	
No. Effective Sympodia	9.7	9.5	*0.29*	
No. Sympodia	13.9	14.8	*0.09*	
No. Sympodia with 1st Position Bolls	4.7	3.6	*0.03*	*0.95*
No. Sympodia with 2nd Position Bolls	1.3	1.9	*0.009*	*0.25*
No. Sympodia with 1st & 2nd Bolls	1.0	1.0	*0.92*	
Total Bolls/Plant	9.4	9.7	*0.68*	
% Total Bolls in 1st Position	61.4	48.0	*0.04*	*12.4*
% Total Bolls in 2nd Position	24.0	29.9	*0.13*	
% Total Bolls in Outer Position	4.3	8.0	*0.188*	
% Total Bolls on Monopodia	9.4	13.6	*0.29*	
% Total Bolls on Extra – Axillary	0.8	0.4	*0.46*	
% Boll Retention – 1st Position	41.7	31.4	*0.02*	*7.2*
% Boll Retention – 2nd Position	25.1	28.3	*0.44*	
% Early Boll Retention	36.8	35.2	*0.43*	
Total Nodes/Plant	20.0	20.8	*0.17*	
Internode Length (inches)	2.2	2.0	*0.02*	*0.2*

[1] means of 10 plants per plot

Table 3. Results from final end-of-season plant mapping following defoliation using COTMAP[1] – plant bug subplot main effects – 2004.

Category	Mean per plant for each treatment: Bugs 1&2	Bugs 3&4	Natural	Sprayed	*P>F*	*LSD_{05}*
1st Sympodial Node	5.8	5.8	5.7	5.9	*0.17*	
No. Monopodia	0.9	1.3	0.8	0.8	*0.04*	*0.21*
Highest Sympodia with 2 nodes	12.8	11.5	8.3	8.9	*0.008*	*1.43*
Plant Height (inches)	39.4	31.7	29.7	32.2	*0.06*	*6.90*
No. Effective Sympodia	11.2	10.7	8.0	8.8	*0.001*	*1.15*
No. Sympodia	16.3	15.0	12.3	12.8	*0.007*	*1.94*
No. Sympodia with 1st Position Bolls	3.5	3.1	4.1	4.6	*0.03*	*0.92*
No. Sympodia with 2nd Position Bolls	1.1	0.7	0.8	0.8	*0.37*	
No. Sympodia with 1st & 2nd Bolls	0.7	0.7	1.8	2.1	*0.006*	*0.48*
Total Bolls/Plant	7.7	7.3	9.1	10.5	*0.002*	*1.11*
% Total Bolls in 1st Position	55.1	54.1	64.9	64.9	*0.06*	
% Total Bolls in 2nd Position	22.8	19.4	27.3	27.8	*0.24*	
% Total Bolls in Outer Position	14.6	10.0	2.9	2.8	*0.002*	*4.82*
% Total Bolls on Monopodia	7.1	15.3	4.9	4.6	*0.07*	
% Total Bolls on Extra – Axillary	0.4	1.2	0.0	0.0	*0.49*	
% Boll Retention – 1st Position	25.9	26.0	47.2	52.6	*0.001*	*6.54*
% Boll Retention – 2nd Position	13.6	12.3	29.8	32.7	*0.001*	*6.80*
% Early Boll Retention	20.3	8.5	52.0	58.2	*0.001*	*8.41*
Total Nodes/Plant	21.1	19.7	17.0	17.7	*0.005*	*1.81*
Internode Length (inches)	1.9	1.6	1.8	1.8	*0.20*	

[1] means of 10 plants per plot

Table 4. Results from final end-of-season plant mapping following defoliation using COTMAP[1]—irrigation main effects -- 2004.

Category	Mean per plant for each treatment			
	Early irrigation	**Delayed irrigation**	***Pr>F***	***LSD_{05}***
1st Sympodial Node	5.8	5.8	*0.79*	
No. Monopodia	1.0	0.9	*0.64*	
Highest Sympodia with 2 nodes	10.6	10.2	*0.63*	
Plant Height (inches)	34.5	31.9	*0.37*	
No. Effective Sympodia	10.0	9.3	*0.22*	
No. Sympodia	14.1	14.0	*0.88*	
No. Sympodia with 1st Position Bolls	4.1	3.6	*0.002*	*0.2*
No. Sympodia with 2nd Position Bolls	0.8	0.8	*0.81*	
No. Sympodia with 1st & 2nd Bolls	1.2	1.4	*0.56*	
Total Bolls/Plant	8.5	8.7	*0.85*	
% Total Bolls in 1st Position	61.5	57.9	*0.07*	
% Total Bolls in 2nd Position	23.6	25.1	*0.27*	
% Total Bolls in Outer Position	6.2	9.0	*0.41*	
% Total Bolls on Monopodia	8.7	7.2	*0.49*	
% Total Bolls on Extra – Axillary	0.0	0.8	*0.22*	
% Boll Retention – 1st Position	38.8	37.1	*0.52*	
% Boll Retention – 2nd Position	20.6	23.6	*0.27*	
% Early Boll Retention	34.2	35.3	*0.75*	
Total Nodes/Plant	18.9	18.8	*0.90*	
Internode Length (inches)	1.8	1.7	*0.09*	

[1] means of 10 plants per plot

Table 5. Statistical *F* test significance for effects of irrigation timing and plant bug injury on final lint yield.

Year	Variable	P>F
2003	Irrigation initiation (I)	0.03
	Bug induced injury (B)	0.05
	I*B	0.76
2004	Irrigation initiation (I)	0.91
	Bug induced injury (B)	0.04
	I*B	0.36

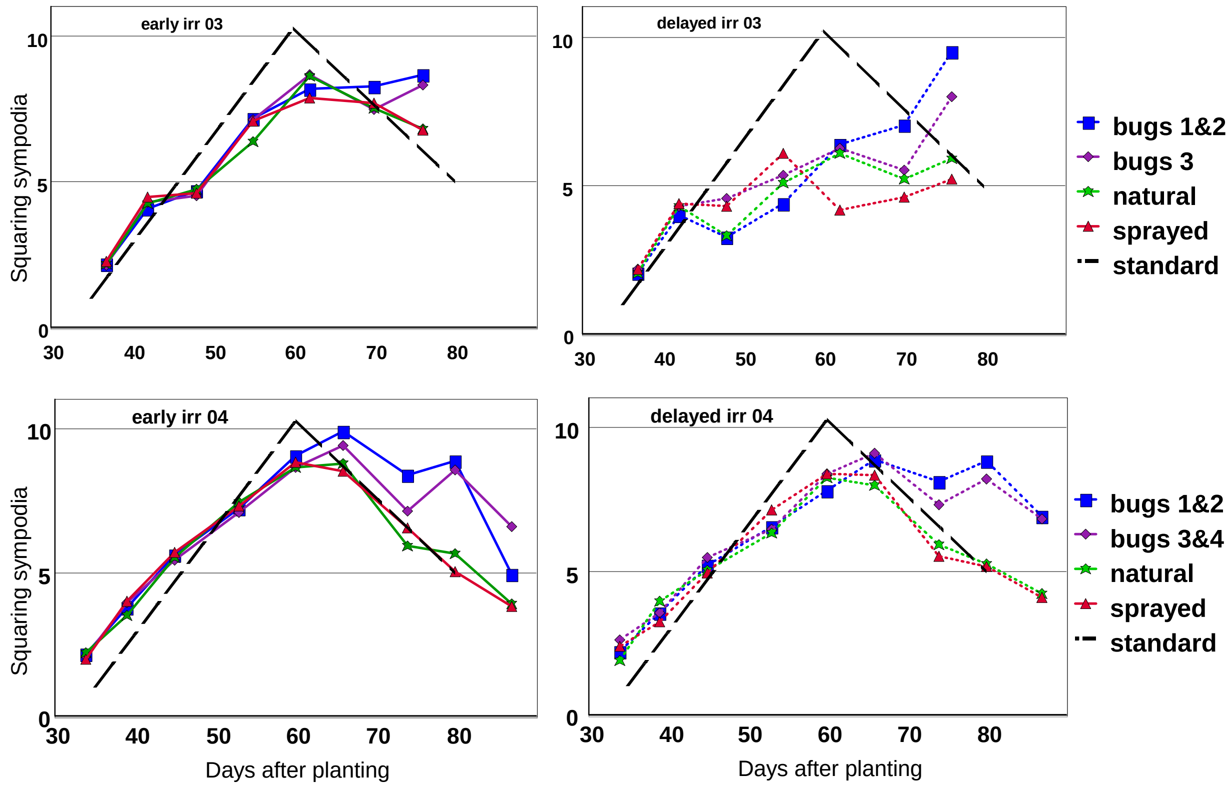

Figure 1. COTMAN based growth curves depicting mean no. of squaring sympodial nodes of plants in 2003 and 2004 either irrigated full season (early) or irrigated only post flower (delayed), and either exposed to 3 to 5 tarnished plant bug nymph/wk during the 1st two weeks of squaring (bugs 1&2) or during the 3rd week of squaring (bugs 3) (in 2004 bugs 3&4), or untreated plants (natural) or plants protected with insecticide pre-flower (sprayed).

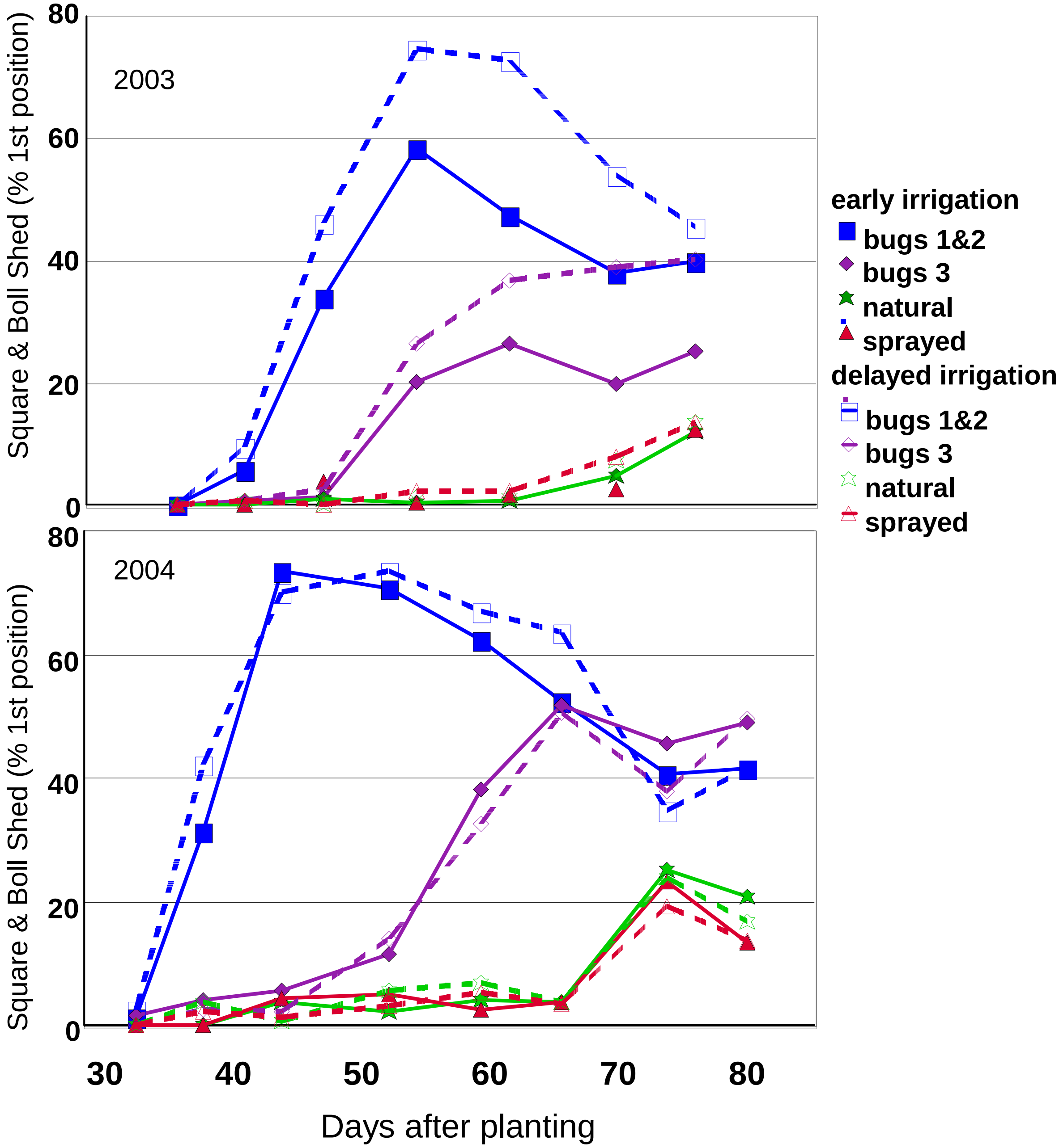

Figure 2. Percent shed of 1st position squares pre-flower and squares and bolls after flower for irrigation * bug treatments 2003 and 2004 – Wildy Farms, Leachville, AR. Bugs were released 36, 43 (bugs 1&2) and 56 (bugs 3) days after planting in 2003 and 35, 42 (bugs 1&2) and 49, 56 (bugs 3&4) days after planting in 2004.

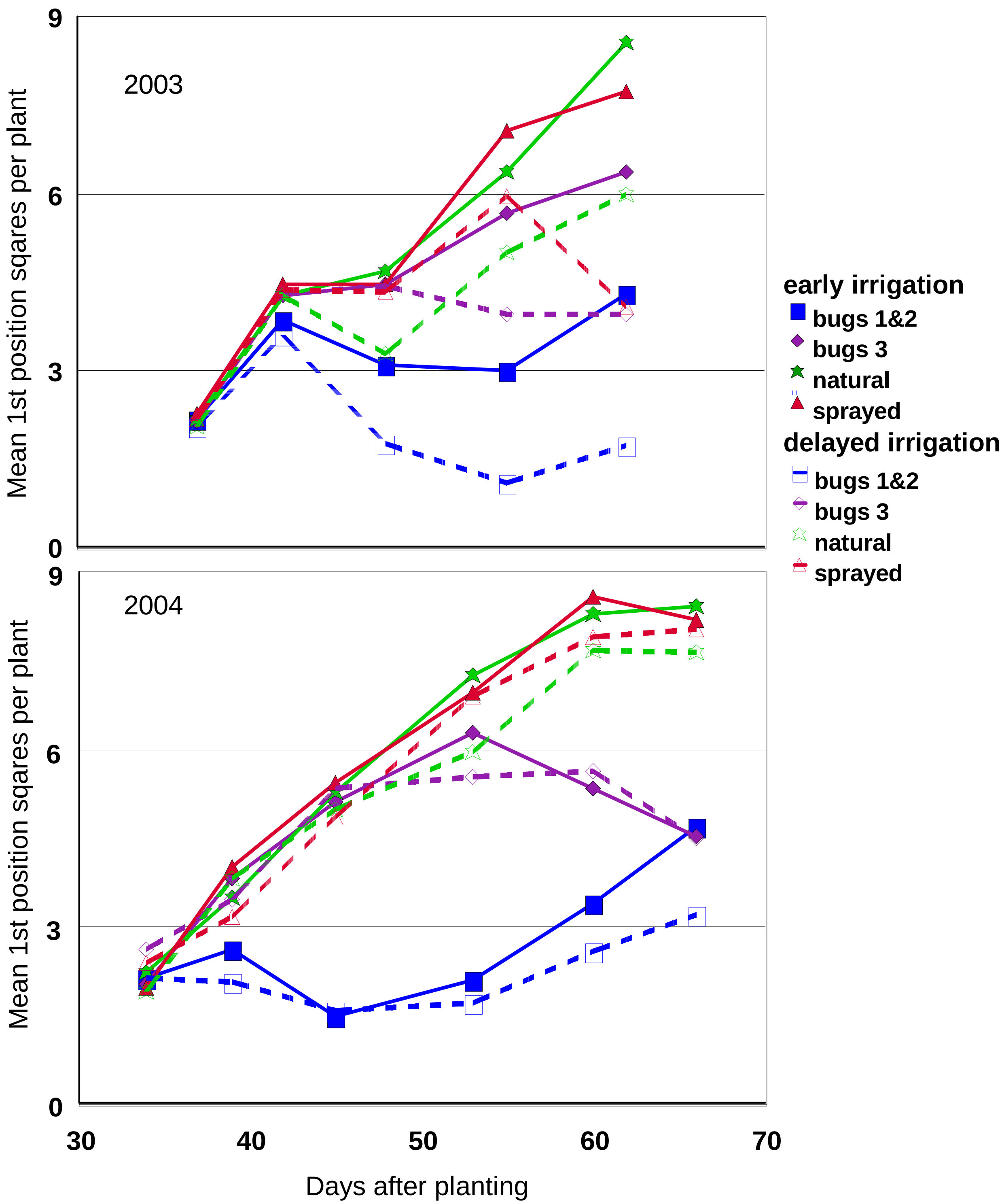

Figure 3. Mean no. retained 1st position squares per plant observed in treatments with delayed irrigation initiation and early initiation exposed to tarnished plant bug nymphs, untreated or sprayed with insecticide pre-flower in 2003 an 2004.

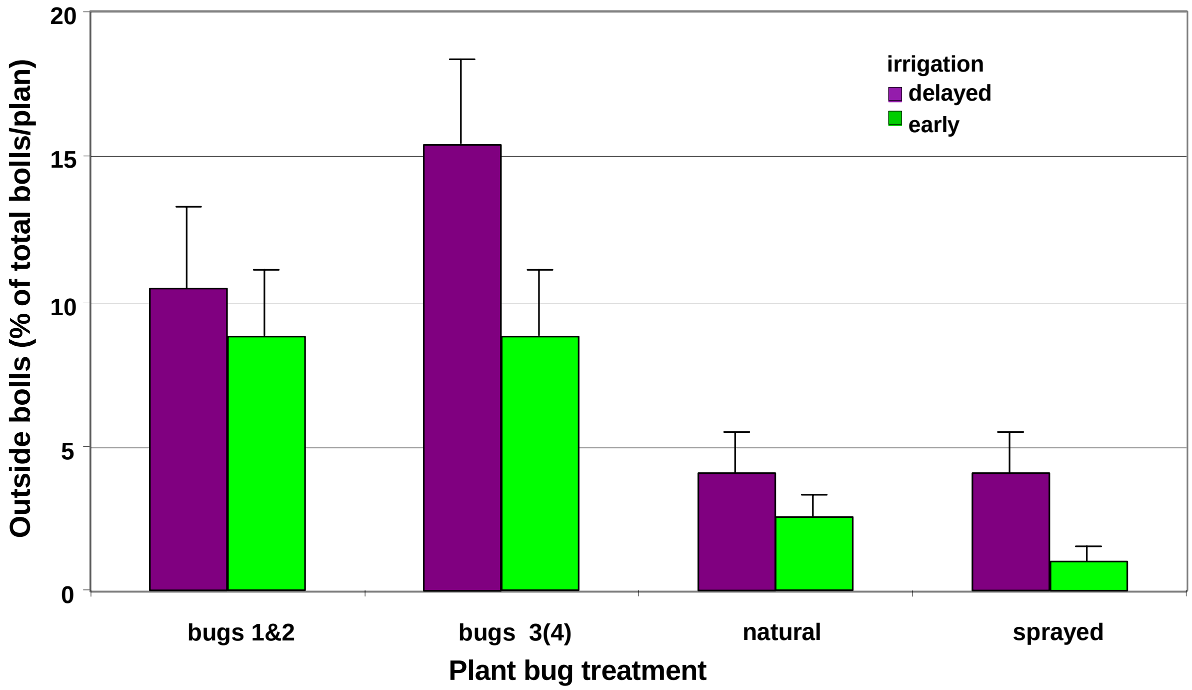

Figure 4. Mean percent of total bolls per plant located in outside positions (3^{rd} position or higher) for bug injury treatments from final end-of-season COTMAP plant mapping (+SE) from combined 2003 and 2004 trials (P>F 0.001; LSD_{05}= 4.7).

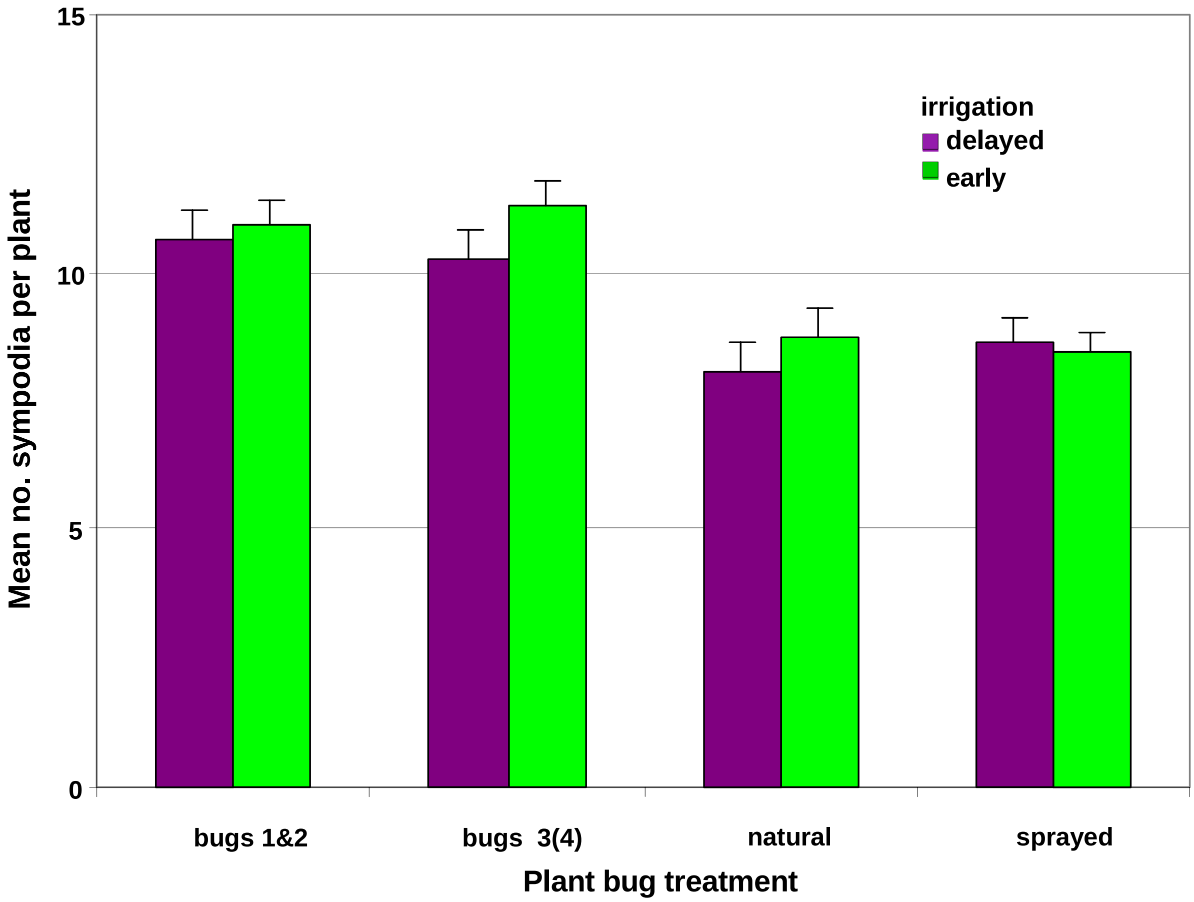

Figure 5. Mean no. of effective sympodia per plant for bug injury treatments from final end-of-season COTMAP plant mapping (+SE) from combined 2003 and 2004 trials (P>F 0.0001; LSD_{05}= 1.12).

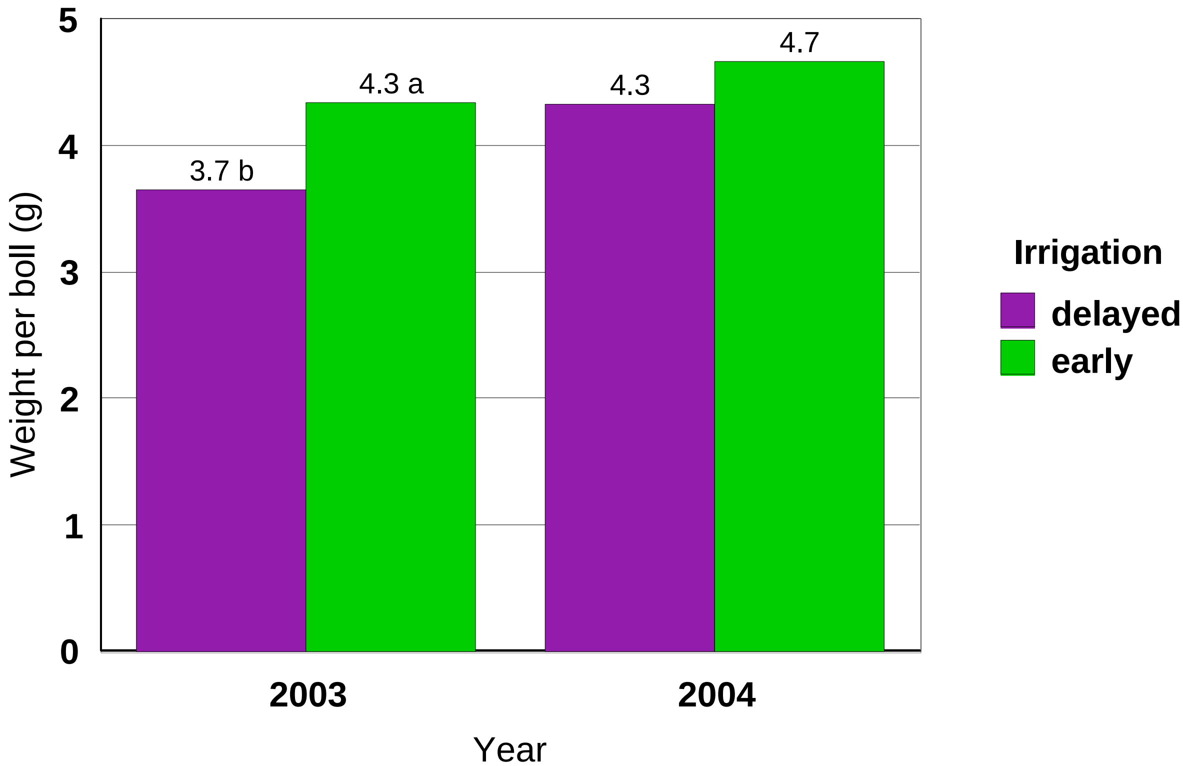

Figure 6. Mean weight per boll (g) determined from 50-boll seed cotton samples collected from consecutive plants and positions in each plot just prior to harvest - irrigation main effects are shown for each year. Significant irrigation effects were observed in 2003 (P>F 0.002; LSD_{05}=0.45) but not in 2004. Bug and irrigation*bug interactions were not significant.

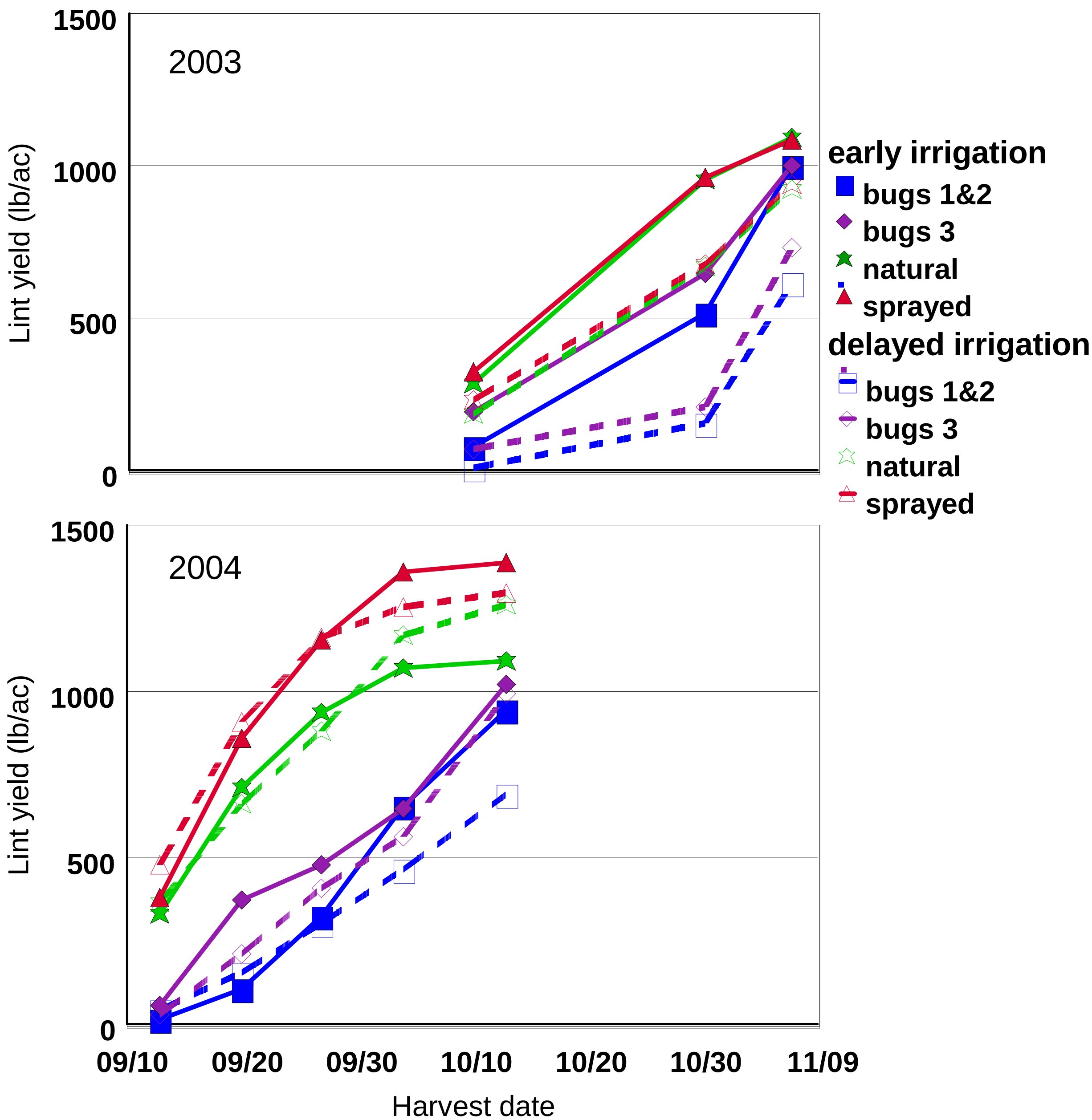

Figure 7. Mean cumulative lint yield of treatment plots over 3 hand picked harvests in 2003 and 5 harvests in 2004 – lint percent calculated at 33%.

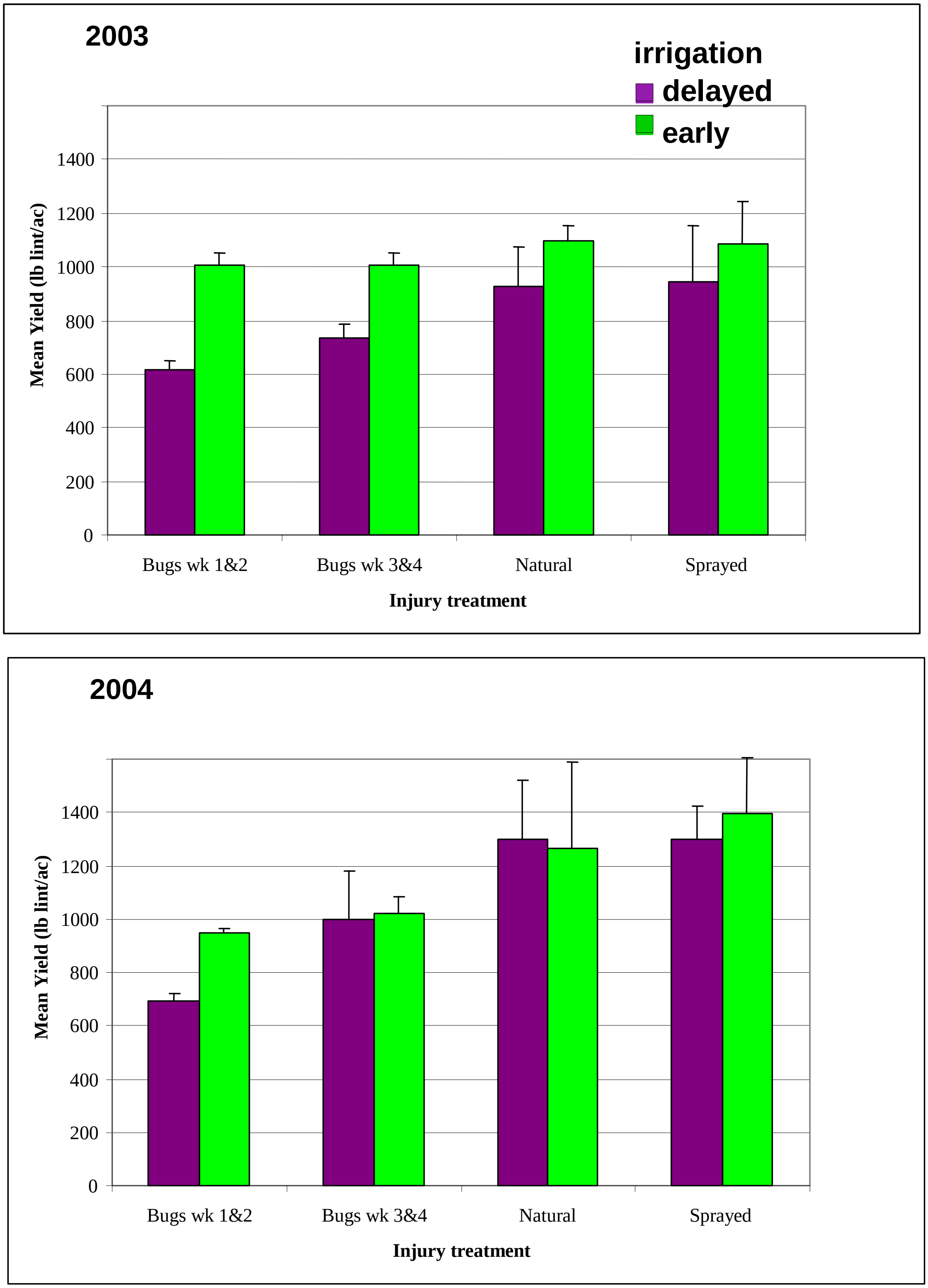

Figure 8. Effects of plant bug injury and pre-flower irrigation on final lint yield (+SE) in 2003 and 2004 – turnout from hand harvested seed cotton was calculated at 33% .