USE AND VALIDATION OF COTMAN TO TERMINATEINSECTICIDE APPLICATIONS IN SOUTH TEXAS

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Abstract

The decision to terminate insecticide treatments at the end of the growing season is one of the most perplexing management decisions that cotton growers and their consultants face. Recently research data has shown the level of boll maturity required for bolls to be safe from injury by boll weevil and bollworm/tobacco budworm. This maturity is measured in heat units (HUs) accumulated on a daily basis. Knowledge of boll maturity and susceptibility to insect injury, combined with recent advances in plant monitoring have made it possible to identify the last harvestable boll population and thus determine when it is safe to terminate insecticide treatments.

The objectives of the studies reported here were to validate: (1) the level of boll resistance to boll weevil and bollworm/tobacco budworm used in COTMAN to decide when to terminate insecticide applications at the end of the season; and (2) the effect on yield of using the COTMAN plant monitoring methods and rules used to terminate insecticide treatments for boll weevil and bollworm/tobacco budworm.

Results of the boll resistance study showed that as bolls matured they became more resistant to injury from boll weevils and bollworms. The percent penetration of the carpal wall by these insects declined dramatically by 16 days, or about 400 HU after bloom. Percent penetration by boll weevil adults declined to <4%, and bollworm (third- and fourth-instars) to <40% at 400 HUs of boll development.

The results of studies validating the use of COTMAN rules to terminate all insecticide applications for boll weevil and bollworm/budworm applications (at 350 to 450 HUs after crop physiological cut-out), demonstrated yield usually peaked at this time. These data suggest that terminating insecticide applications at 350 to 450 HUs after cut-out can be a useful guide post and practice in insect management of boll weevil and bollworm/tobacco budworm on cotton. Combining cotton crop monitoring with insect management may offer crop consultants and growers opportunities to improve total crop management and minimize production risks.

Introduction

The decision to terminate insecticide treatment at the end of the season has long been recognized as one of the most perplexing management decisions that cotton growers face. High insect control costs, insecticide induced outbreaks of insect pests, and development of insect resistance to insecticides must be balanced with the desire to protect bolls that may be harvestable. Recent advances in using plant monitoring to identify the last harvestable boll population (Bourland et al. 1992) have great potential to accurately guide when harvestable bolls have reached a level of physiological maturity where they are no longer susceptible to boll weevil and bollworm/tobacco budworm damage (Bagwell and Tugwell 1992).

A foundation of these plant monitoring techniques is the number of mainstem nodes above the uppermost white bloom at the first position fruiting site. This measure is referred to as the Nodes Above White Flower (NAWF) count. Decision rules have been developed in Arkansas that suggest that the last harvestable boll population corresponds to those bolls associated with a NAWF count equal to 5 and that after these bolls have accumulated 350 heat units they are mature enough to sustain a low probability of insect damage. Additional insect treatments after this date are uneconomical since they do not protect harvestable bolls and increase yields. An expert system, COTMAN, has been developed to facilitate the implementation of these decision rules (Zhang et al. 1993). Nevertheless, there remains a need to validate and standardize these rules in cotton regions other than Arkansas. At last year's Beltwide Cotton Research Conference, Cochran et al. (1996) and O'Leary et al. (1996) reported on the results of a beltwide COTMAN validation effort. Here we report specifically on South Texas results from two studies to validate components of COTMAN in South Texas. Our objectives were as follows:

1. Conduct studies to validate the age of bolls when they are resistant to bollworm and boll weevil injury using heat-unit accumulation from flowering (similar to R. Bagwell and P. Tugwell 1992, and R. Bagwell 1994).
2. Validate the effect on yield of using COTMAN rules and plant monitoring to guide insecticide termination in south Texas, in small research plots.

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Materials and Methods

Objective 1, Validation of boll age on resistance to boll weevil and bollworm. All experiments were conducted with Delta Pine 50 in the field at Texas A&M Agric. Res. and Ext. Center, Corpus Christi, TX. Insects evaluated were the boll weevil and third-instar bollworm. Adult boll weevils were obtained from the USDA, ARS, Insect Rearing Research Unit, Mississippi State, MS. Bollworm larvae were obtained from the USDA, ARS Rearing Facility, Stoneville, MS and from naturally infested field plots.

White flowers were tagged with date of bloom. Boll age was defined for each boll by the accumulated heat units from flowering. Heat units were calculated using the formula: HU = ((daily max. temp. °F + min. temp. °F) / 2) - 60. Bolls from 200 to 600 HU, in 100 HU increments, were infested by caging two boll weevils or one bollworm on each boll evaluated. Thus, treatments were bolls infested at (1) 200, (2) 300, (3) 400, (4) 500, and (5) 600 HU. A minimum of 40 bolls per treatment were evaluated. Treatments were single row plots replicated 4 times with 10 bolls/plot of the correct age infested with each insect. Bolls at the first position on branches 2-6 were tagged on the day of bloom (beginning just after first bloom) and HUs accumulated starting on that day. In each plot 10 bolls of the correct HUs were required for each insect, therefore at least 20 blooms were tagged per plot to insure sufficient number of correct aged bolls for infestation. Cage, boll and insect were removed three days after the insects were initially placed on the boll.

After removal, the carpel of each boll was examined for: (1) the number of feeding scars on the epicarp (i.e., outer epidermal layer) and the mesocarp (i.e., those penetrations up to, but not penetrating the endocarp); and (2) the number of penetrations through the endocarp (i.e., layer of lignified cells surrounding the lint).

Bolls were classified as either having the endocarp penetrated or not having the endocarp penetrated. Bolls with the endocarp penetrated were considered injured. Percent penetration of the endocarp was calculated as a proportion of the total feeding scars.

Objective 2, Validation of use of COTMAN insecticide termination on yields in small field plots. The following treatments were replicated 4 to 6 times in a randomized complete block design, in small plot field experiments, to test the hypothesis that the cotton yield response to late season insecticide applications would plateau after the last effective boll population had received sufficient heat accumulations to mature:

1. All insecticide applications terminated at NAWF=5
2. All insecticide applications terminated at NAWF=5 + 200 HU
3. All insecticide applications terminated at NAWF=5 + 350 HU
4. All insecticide applications terminated at NAWF=5 + 500 HU
5. All insecticide applications terminated at NAWF=5 + 650 HU

The following data were recorded for each plot beginning at the NAWF=5. However previous to NAWF=5 the following data under 1.c. were collected from treatments 1 and 5 beginning at first square.

1. Plant data and insect infestation and damage data. Plants were not injured nor were flower buds or bolls removed.
   a. Examined 25 randomly selected terminals (top 4" = top 3-4 nodes) for bollworm/tobacco budworm eggs and larvae for each plot. Recorded number of eggs and larvae.
   b. Examined 25 randomly selected flower buds from the top ⅓ of the plants. Recorded number of bollworm/tobacco budworm damaged squares, number of larvae, and number of boll weevil injured buds.
   c. Began mapping squares using SQUAREMAP in COTMAN at about 35 days* after planting and terminated SQUAREMAP at cutout + 850 HU. (*Begin SQUAREMAP NAWF <5 when pinhead squares reach an average of one per plant.)
   d. Just before defoliation we examined 3 meters of row per plot for (1) total harvestable bolls, (2) total caterpillar damaged bolls, and (3) total open bolls.
2. Counted nodes above white flower (NAWF) from first bloom to defoliation. Used COTMAN to record data. Initiated when there were at least 3 white flowers per 30 ft. of row. Sampled by examining 5 consecutive plants in row 4, then turned 180 degrees and examined 5 consecutive plants in row 5. Terminated NAWF counts sometime after NAWF < 5.
3. Recorded daily maximum and minimum temperatures (° F) from first bloom to defoliation, and calculated accumulated Day Degrees (=HU), at least weekly.
4. Recorded the irrigation dates and amounts.
5. Recorded the fertilization dates and amounts.
6. Recorded the insecticide application dates and amounts. These are reported in Tables 4 and 5.
7. Recorded the general observations on insect damage following insecticide termination.

8. Yields were taken by hand harvesting the middle 2 rows of each plot. Yields were taken in a stratified harvest, with first harvest at 50% open bolls in the earliest treatment. Defoliation was based on COTMAN rule of CUTOUT + 850 HU. CUTOUT is NAWF=5 for Type I plants.

Results and Discussion

Objective 1, Validation of boll age on resistance to boll weevil and bollworm. The change in resistance of bolls to injury from adult boll weevils and third- fourth-instar bollworms was evaluated at 200, 300, 400, 500 and 600 HU after bloom. These heat units represent approximately 8, 12, 16, 20 and 24 days after bloom, respectively. The results are reported in Table 1.

Boll weevil. The percent penetration of the endocarp was highest when bolls were youngest and decreased as bolls matured (Table 1). The percent penetration of carpel walls by boll weevils was 72.7% at 200 HUs after bloom (approximately 8 days), whereas at 400 HUs, percent penetration declined to 3.4% (approximately 16 days). Percent penetration continued to decline to 1.1 at 600 HUs. The R^2 for the regression was 0.75 and highly significant, $P<0.0001$. These results agree well with Dr. Bagwell's (1994) using the same variety, DPL50. We conclude that bolls are well protected from boll weevil injury at 400 HUs and greater, and that insecticides for control of boll weevil can be terminated at 400 HUs after NAWF=5. Keep in mind that insecticide residues are active for 3 to 5 days after application, and thus termination at NAWF-5+ 400 HUs will provide insecticidal protection of bolls until about 500 HUs.

Bollworm. Bollworm third-instars were reared from eggs supplied by the USDA, Stoneville laboratory, and used in the 200 and 300 HU evaluations (Table 1). However, because of extremely high mortality of these lab reared bollworms at 300 HUs (17% survival after 72 hours) we decided to switch to field collected bollworms for the 400 thru 600 HU evaluations. Because many of these field collected third-instars molted to fourth-instar during their 3-day confinement in the cage, these penetration data are for combined third- and fourth-instar bollworm.

The percent penetration of the carpel wall was high at 300 HUs, 63%, however at 400 HUs penetration significantly declined to 40%. Penetration continued to drop as HUs increased to 600 HUs, but never below 22% penetration. This is higher than what Bagwell (1994) found. He averaged only 8.2% penetration after 350 HUs, using lab reared third-instars from the USDA Stoneville laboratory. Keep in mind that the larvae in our study were late third- and fourth-instars. Earlier instars (i.e., first and second) appear less capable of chewing through the carpel wall of bolls that have accumulated 350 HUs. These data suggest bolls between 350 and 600 HUs of age are somewhat more susceptible to injury from bollworm third- and fourth-instars than they are to boll weevil adults.

Objective 2, Validation of use of COTMAN—insecticide termination in small plots. Cutout as determined by COTMAN, and verified by visual inspection of the field, occurred at 83 to 87 days after planting regardless of planting dates or irrigation. Daily heat units accumulated rapidly due to high daily maximum and minimum temperatures in June, July, and August. Heat units ranged from 19 to 30 HU per day, typically accumulating 100 HUs every 4 days.

Boll weevil pressure was quite high at both test sites (Tables 6 and 7). The yields were numerically higher when insecticides were terminated at between 200 to 500 HU accumulated after cutout (Tables 2 and 3). The best yields tended to occur when insecticides were terminated between 350 and 500 HU. Based on these small plot studies the maximum yield occurred at between 200 and 350 HU after cutout. Surprisingly yields were numerically lower when boll weevil insecticide sprays were terminated after about 450 HU. We wonder why spraying later than 450 tends to reduce yield? Terminating insecticide at 350-450 HU appeared to increase yield by 30 to 50 lbs lint/AC compared to terminating earlier or later (i.e., < 200 HU or > 500 HU). The findings are similar to results from other states (Cochran et al. 1996). However, more data are needed to confirm these results for south Texas.

Fiber properties showed little effect from terminating insecticide at different HU accumulations. Whereas, percent lint was significantly affected by the time of insecticide termination but a consistent, predictable pattern could not be observed.

In summary, the benefits of using the COTMAN plant monitoring and insecticide/crop termination rules may have a number of benefits for the grower. These benefits are: (1) To identify problems with cotton insects, plant growth, fertility, irrigation and etc. The mapping program helps identify plant management problems that cannot be easily observed by a weekly visual observation. (2) Determining the optimum time to terminate all insecticide applications for bollworm/tobacco budworms and boll weevils to obtain maximum yield and economic benefit from using the insecticide. (3) Determining the optimum time to defoliate each field. (4) Determining the optimum time to harvest each field; and (5) Scheduling of all fields on the farm for defoliation and harvest. These benefits may be valued at more than $50/acre. A manual on use of cotton crop monitoring and management of insect pests has been developed by Landivar et al. (1996) and copies can be obtained from Juan Landivar or John Benedict, Texas A&M University, AREC, Corpus Christi. Also, copies of the COTMAN program can be obtained from the University of Arkansas, Agricultural Extension Service, Fayetteville, Arkansas.

Acknowledgments

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Table 1. Percent penetrations of different aged bolls, based on HU after bloom, by boll weevil and bollworm (third- and fourth-instar) confined to the boll for 72 hrs.

	% penetrations			
HU	(*n*)	Boll weevil	(*n*)	Bollworm
200	37	72.7 a	28	60.7 a
300	39	61.3 b	5	63.3 a
400	41	3.4 c	37	39.7 b
500	39	1.6 c	30	25.3 b
600	34	1.1 c	36	22.1 b
(P)		(0.0001)		(0.0001)

Means in columns followed by different letters are significantly different (α = 0.05), DNMR.

Table 2. Lint yield and percent lint turnout in the multi-state test of COTMAN insecticide termination rules based on plant monitoring, small plot test, Asgrow Research Farm, West Sinton, Texas (San Patricio Co.).

Treatment (Actual HU)*	% lint turnout	Lint yield lb/ac
1. NAWF = 5 + 0 HU (0)	39.1 a	695.7 b
2. NAWF = 5 + 200 HU (219.5)	38.0 bc	814.8 a
3. NAWF = 5 + 350 HU (350.5)	38.2 abc	757.3 ab
4. NAWF = 5 + 500 HU (567.5)	38.8 ab	734.7 ab
5. NAWF = 5 + 650 HU (740.5)	37.7 c	756.5 ab
LSD (0.05)	0.89	105.3 (NS)
F test (P)	(0.0256)	(0.2385)

Means followed by different letters are significantly different (α=0.05) LSD, except where LSD value is followed by (NS).
* HU for last boll weevil insecticide application.

Table 3. Lint yield and percent lint turnout in the multi-state test of COTMAN insecticide termination rules based on plant monitoring, small plot test, TAES, Corpus Christi, Texas (Nueces Co.), 1995.

Treatment (Actual HU)*	% lint turnout	Lint yield lb/ac
1. NAWF = 5 + 0 HU (117.5)	35.5 a	753.3 a
2. NAWF = 5 + 200 HU (258.0)	35.6 a	768.9 a
3. NAWF = 5 + 350 HU (450.5)	35.7 a	782.0 a
4. NAWF = 5 + 500 HU (642.5)	36.2 a	765.2 a
5. NAWF = 5 + 650 HU (744.0)	36.3 a	736.8 a
LSD (0.05)	0.99 (NS)	96.6 (NS)
F test (P)	(0.3442)	(0.8746)

Means followed by different letters are significantly different (α=0.05) LSD, except where LSD value is followed by (NS).
* HU for last boll weevil insecticide application.

Table 4. Insecticide and harvest aid application records, and date of harvest for the Insecticide Termination Study on the small plots experiment at Asgrow Research Farm, West Sinton, Texas (San Patricio County), 1995.

Application date	Chemical	Rate (oz/A)	Application Method	Purpose
4/25	Temik 15G	75.2	At planting	Sucking insects
5/26	Provado 1.8 + Bidrin 8E	3.0 3.75	Ground	Aphids, leaf miners
5/17	Guthion 2L + Bidrin 8E	16.0 3.0	Ground	Overwinter boll weevil, fleahoppers
5/28	Guthion 2L + Bidrin 8E	16.0 3.0	Ground	Overwinter boll weevil
7/3	Guthion 2L	16.0	Aerial	Boll weevil
7/8	Guthion 2L	16.0	Aerial	Boll weevil
7/15	Guthion 2L	16.0	Aerial	Boll weevil
7/22	Guthion 2L	16.0	Aerial	Boll weevil
7/28	Guthion 2L	16.0	Hand	Boll weevil (Trt 2, 3, 4, 5)
7/31	Guthion 2L	16.0	Hand	Boll weevil (Trt 2, 3, 4, 5)
8/5	Guthion 2L	16.0	Hand	Boll weevil (Trt 3, 4, 5)
8/14	Guthion 2L	16.0	Hand	Boll weevil (Trt 4, 5)
8/21	Guthion 2L	16.0	Hand	Boll weevil (Trt 5)
8/21	DROPP 50 + Prep	6.4 42.7	Ground	Defoliation
8/31	No chemical	—	—	Harvest

Planting date 4/25/95.

Table 5. Insecticide and harvest aid application records, and date of harvest for the Insecticide Termination Study on the small plots experiment at TAES, Corpus Christi, Texas (Nueces County, Texas), 1995.

Application date	Chemical	Rate (oz/A)	Application Method	Purpose
5/5	Orthene 75 WP	8.0	Ground	Aphids, thrips, loopers
5/19	Provado 1.6	3.75	Ground	Aphids
5/4	Vydate C-LV + PIX	8.5 4.0	Ground	Fleahoppers, overwinter boll weevil
5/9	Vydate-CLV	8.5	Ground	Overwinter boll weevil
5/28	Guthion 2L + PIX	16.0 8.0	Ground	Boll weevil
7/07	Vydate-CLV + PIX	16.0 8.0	Ground	Boll weevil
7/13	Guthion 2L	16.0	Hand	Boll weevil (Trt 2, 3, 4, 5)
7/21	Guthion 2L	16.0	Hand	Boll weevil (Trt 3,4,5)
7/28	Guthion 2L	16.0	Hand	Boll weevil (Trt 4, 5)
8/1	Guthion 2L	16.0	Hand	Boll weevil (Trt 5)
8/18	DROPP 50 WP + Prep	6.4 42.7	Ground	Defoliation
8/25	No chemical	—	—	Harvest

Planting date 4/6/95.

Table 6. Percent boll weevil injured squares throughout the season in a multi-state test of insecticide termination rules based on plant monitoring, small plot test, Asgrow Research Farm, West Sinton, TX (San Patricio Co.), 1995.

Treatment (Actual HU)*	Percent injured squares 6/2	6/6	6/15	6/22	6/30
1. NAWF=5+ OHU (0)	0.0a	0.0a	0.0a	0.0a	0.0a
2. NAWF=5+ 200 HU (219.5)	0.0a	0.0a	0.0a	0.0a	1.0a
3. NAWF=5+ 350 HU (350.5)	0.0a	0.0a	0.0a	0.0a	0.0a
4. NAWF=5+ 500 HU (567.5)	0.0a	0.0a	0.0a	0.0a	2.0a
5. NAWF=5+ 650 HU (740.5)	0.0a	0.0a	0.0a	0.0a	0.0a
LSD (0.05)	0	0	0	0	3.2(NS)
F test (P)	0	0	0	0	(0.5767)

Table 6 continued.

Treatment (Actual HU)*	Percent injured squares 7/6	7/14	7/18	7/26
1. NAWF=5+ OHU (0)	3.0a	14.0a	17.0a	12.0a
2. NAWF=5+ 200 HU (219.5)	5.0a	14.0a	21.0a	19.0a
3. NAWF=5+ 350 HU (350.5)	3.0a	16.0a	14.0a	15.0a
4. NAWF=5+ 500 HU (567.5)	5.0a	17.0a	25.0a	15.0a
5. NAWF=5+ 650 HU (740.5)	6.0a	10.0a	13.0a	19.0a
LSD (0.05)	5.8(NS)	8.8(NS)	16.3(NS)	11.1(NS)
F test (P)	(0.7301)	(0.5017)	(0.4988)	(0.6114)

Table 6 continued.

Treatment (Actual HU)*	Percent injured squares 8/4
1. NAWF=5+ O HU (0)	54.0abc
2. NAWF=5+ 200 HU (219.5)	64.0a
3. NAWF=5+ 350 (HU (350.5)	62.0ab
4. NAWF=5+ 500 HU (567.5)	48.0bc
5. NAWF=5+ 650 HU (740.5)	46.0c
LSD (0.05)	15.6(NS)
F test (P)	(0.0951)

Table 7. Percent boll weevil injured squares throughout the season in a multi-state test of insecticide termination rules based on plant monitoring, small plot test, TAES, Corpus Christi, TX (Nueces Co.), 1995.

Treatment (Actual HU)*	Percent injured squares 5/26	6/2	6/8	6/16
1. NAWF=5+ OHU (0)	1.0a	0.0a	1.0a	4.0ab
2. NAWF=5+ 200 HU (219.5)	0.0a	1.0a	0.0a	6.0a
3. NAWF=5+ 350 HU (350.5)	1.0a	0.0a	0.0a	5.0ab
4. NAWF=5+ 500 HU (567.5)	0.0a	0.0a	0.0a	5.0ab
5. NAWF=5+ 650 HU (740.5)	0.0a	1.0a	0.0a	2.0b
LSD (0.05)	(NS)	2.0(NS)	1.4(NS)	3.9(NS)
F test (P)	(0.3125)	(0.6114)	(0.4449)	(0.2898)

Table 7 continued.

Treatment (Actual HU)*	Percent injured squares 6/23	6/30	7/7
1. NAWF=5+ OHU (0)	28.0a	15.0a	39.0a
2. NAWF=5+ 200 HU (219.5)	12.0b	15.0a	27.0a
3. NAWF=5+ 350 HU (350.5)	13.0b	17.0a	20.0a
4. NAWF=5+ 500 HU (567.5)	14.0ab	8.0a	20.0a
5. NAWF=5+ 650 HU (740.5)	14.0ab	14.0a	22.0a
LSD (0.05)	14.1(NS)	10.8(NS)	19.3(NS)
F test (P)	(0.1431)	(0.4658)	(0.2295)