HAND REMOVAL OF UPPER-CANOPY SQUARES AT NAWF=5 PLUS 250,350, OR 450 HEAT UNITS AS A MODEL FOR SIMULATING INSECT DAMAGE: HOW ARE YIELD AND QUALITY AFFECTED?

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RESEARCH PROBLEM

Cotton is a perennial with an indeterminate growth habit and will continue to produce fruit as long as the season persists. However, these late-season bolls are often small in size, low in fiber quality, costly to protect, and provide a good food source for insects. COTMAN, a crop- monitoring program for cotton, uses the concept of 350 heat units after anthesis of the last effective flower population at NAWF=5 for termination of insecticide applications. At this time in the cotton-growing season, insects can feed on fruit above NAWF=5 without decreasing yields. This allows growers to save money by eliminating costly end-of-season insecticide applications without the fear of decreased yields. This ongoing study was designed to confirm the hypothesis that insect damage to upper-canopy (above NAWF=5) squares results in improved partitioning of carbon to lower developing bolls which may increase cotton yields and quality.

BACKGROUND INFORMATION

In most crop monitoring programs, such as COTMAN (Danforth and O'Leary, 1998), a major aim is to identify the last effective boll population and project a date for insecticide termination. Bagwell (1995) showed that bollworm *Helicoverpa zea* (Boddie) and boll weevil *Anthonomus grandis* Boheman damage to cotton bolls decreases dramatically at about 350 heat units after anthesis. This finding was supported by Kim (1998), who showed increased resistance of the boll wall to penetration at NAWF=5 plus about 350 heat units. This phenomenon is made use of in COTMAN for decisions about late-season termination of insecticide applications at 350 heat units after NAWF=5. Research and field observations have indicated that terminating insecticide use at 350

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heat units after physiological cutout (NAWF=5) results in a higher yield than when terminating earlier or later than 350 heat units, however, more research is needed to confirm this. The ongoing objective of this five-year study was to investigate the effect of different times of upper-canopy square removal after NAWF=5 on subsequent first-position boll weights at the NAWF=5 main-stem node, lint yields, and quality. A second objective was to determine the amount of carbohydrates trans1ocated to lower bolls following upper canopy fruit removal.

RESEARCH DESCRIPTION

Field experiments were conducted at Clarkedale in northeast Arkansas from 1998 to 2001 to test the effects of late-season fruit removal. Cotton (*Gossypium hirsutum* L.) cultivar Suregrow 125 was planted into a Dubbs-Dundee silt loam during early May each year. Rows were spaced 0.9 m apart and plots were 4 rows wide with a plant density of 10 plants per meter. All plots received fertilizer and pesticide applications following the cotton production recommendations for Arkansas and were furrow irrigated as needed. The experiment was arranged in a randomized complete block design with four treatments and four to six replications depending on the year. Treatments consisted of: 1) control with no fruit removal, 2) hand removal of all fruit above NAWF=5 at NAWF=5 plus 250 H.U., 3) hand removal of all fruit above NAWF=5 at NAWF=5 plus 350 H.U., and 4) hand removal of all fruit above NAWF=5 at NAWF=5 plus 450 H.U.

Taggings of 20 to 30 white flowers per plot were made at the first-fruiting position of the main-stem node at NAWF=5. Treatments were applied when sufficient heat units were accumulated after physiological cutout for the various treatments. Three days following fruit removal, ^{14}C was used to label upper-canopy leaves for determining the amount of carbon eventually translocated to the first-position bolls at NAWF=5. At final harvest, 10 tagged bolls at NAWF=5 were collected in order to determine boll weight and fiber quality. Lint yields were determined from mechanical harvest assuming a standard gin turnout of 38%.

RESULTS

The following four-year field study has investigated the impact that fruit removal at varying heat units after physiological cutout had on yield, boll development, and quality of cotton in Arkansas. One growth chamber study in 1998 and two field studies in 2000 and 2001 were also conducted to determine the amount of carbohydrate partitioned to lower developing bolls following removal of fruit at the different treatment times. The data in this paper will summarize the yield and boll data from the 2001 season with an accompanying four-year average of yield and average boll weight. Results from the 1998 growth chamber study and the 2000 field study evaluating ^{14}C-carbohydrate partitioning will also be discussed. The carbohydrate partitioning data from the 2001 field study is currently being analyzed and will not be included in this paper.

Lint Yields

Results from 1998 to 2001 have shown no clear trends for significantly increasing lint yields from the removal of late-season fruit (Table 1). However, the data support COTMAN and show that yields are not significantly reduced and possibly even sometimes are increased from the removal of upper-canopy fruit above NAWF=5 once physiological cutout (Oosterhuis et al., 1999) occurs. In 2001, lint yields were numerically the highest in the control plots where upper-canopy fruit (above NAWF=5) was not removed (Table 1). Despite the control, the NAWF=5 plus 350 heat-unit treatment represented the highest lint yields of the three fruit-removal treatments tested. These results support concepts presented in COTMAN about insecticide termination at NAWF=5 plus 350 heat units and help support the data from the 1998 field study in which fruit removal at NAWF=5 plus 350 heat units significantly improved lint yields compared to the control. Removing ftuit earlier than 350 heat units probably increased the total amount of carbohydrate partitioned to lower bolls without the concern of insects harming the bolls at NAWF=5, which would typically not be completely developed yet.

Boll Weights at NAWF=5

In 2001, all fruit removal treatments resulted in a greater weight of first-position NAWF=5 bolls compared to the control with the NAWF=5 plus 250 heat-unit treatment resulting in a significant increase (Table 2). No significant differences occurred between treatments for increasing first-position boll weight at NAWF=5 when averaged over the four-season span from 1998 to 2001 (Table 2). However, all ftuit-removal treatments resulted in numerically higher boll weights than the control treatment where no fruit was removed. The control resulted in the lowest boll weights at NAWF=5 because, in theory, carbohydrates were used to fill the unwanted upper-canopy fruit instead of being translocated to lower harvestable bolls still developing. Boll weight at NAWF=5 was increased the most where upper-canopy fruit was removed at NAWF=5 plus 350 and 450 heat units (Table 2). These boll data support the results from past research by Kim and Oosterhuis (1998), which indicates that boll weight at NAWF=5 was increased the most when fruit was removed at 350 heat units after NAWF=5.

Fiber Quality

No significant differences were noticed with respect to improved length, strength, length uniformity, or micronaire of cotton fiber from first position NAWF=5 bolls (Table 3). Fiber length and strength are usually determined more by genetics than the environment, and therefore no drastic changes were anticipated following the late-season fruit removal treatments. However, micronaire could have been slightly impacted from the removal of upper-canopy ftuit and eventual translocation of additional sugars. The 250, 350, and 450 heat-unit treatments did show numerically higher micronaire values than the control treatment with no fruit removal, but this difference was not significant (Table 3). Removal of upper-canopy fruit at 250 heat units past physiological cutout represented the treatment with the best fiber quality. All measured fiber parameters were numerically increased when fruit was removed at 250 heat units compared to the other treatments.

^{14}C Translocation

In 1998, a growth chamber study was conducted in Fayetteville, AR, to determine the amount of carbohydrate translocated to the developing boll load following fruit removal at different heat units after physiological cutout (NAWF=5). Those data indicated that a greater amount of ^{14}C was translocated to the boll at NAWF=5 when fruit was removed at 350 heat units (Table 4). This movement of ^{14}C helps clarify why lower bolls are larger if upper-canopy fruit is removed, which consequently was observed from this study. A similar technique was used in the field in 2000 at Clarkedale to provide additional information on carbon movement to lower bolls following fruit removal after NAWF=5. Results from this study indicated that of the CO_2 fixed by the leaf, a numerically higher percent of ^{14}C-assimilate was translocated to the boll when fruit was removed at NAWF=5 + 350 H.U. compared to the control with no fruit removal (Table 5). Of this assimilate translocated to the first position boll at NAWF=5, a significantly greater amount was stored in the boll wall for the 350 heat-unit treatment (Table 5). The 2001 study was conducted in both Fayetteville and Clarkedale to repeat the last year's measurements. Due to adverse weather in Clarkedale, no measurements were possible. However, we successfully carried out the experiment in Fayetteville and the data are currently being analyzed for carbon fixation and translocation.

PRACTICAL APPLICATION

Overall, the field experiments conducted from 1998 to 2001 have shown evidence of increased boll weight of NAWF=5 bolls, however there has not been a clear yield trend. Yield results from the 2001 field data at Clarkedale were inconsistent with the field data from the 1998 season, but supported the COTMAN concept of insecticide termination at 350 heat units after NAWF=5. However, the results still indicated that removing late-season fruit did not significantly lower lint yields and lint quality was not affected either. In 2001, boll weight of first-position bolls was increased ($P \leq 0.05$) when fruit was removed at NAWF=5 plus 250 heat units, with boll weight being numerically increased by all fruit removal treatments in comparison to the control where no fruit was removed. This can be explained by improved translocation of carbohydrates from upper-canopy leaves where fruit was removed to lower developing bolls below the area of fruit removal. Previous field and growth-chamber studies have indicated that removing fruit, especially at 350 heat units after NAWF=5 is reached, can increase the amount of carbohydrate to lower bolls. It can be concluded that removing upper-canopy fruit increases translocation to lower developing bolls and will increase the size of the last effective boll population. However, more research is needed to determine if yields can be consistently enhanced by removal of this fruit.

LITERATURE CITED

Bagwel1, R.D. 1995. Monitoring the cotton plant for insecticide effects and late-season termination. Ph.D. Dissertation, University of Arkansas, Fayetteville.

Danforth, D.M. and P.F. O'Leary (eds.). 1998. COTMAN expert system. University of Arkansas Agricultural Experiment Station, Fayetteville. Published Cotton Incorporated, Raleigh, NC. 198 pp.

Kim, M. 1998. Changes in the cotton fruit wall in relation to COTMAN insecticide termination rules. M.S. Thesis, Fayetteville, Arkansas.

Kim, M., and D. M. Oosterhuis. 1998. Effect of upper-canopy square removal before and after NAWF=5 plus 350 heat units on carbon partitioning from upper-canopy leaves to bolls lower in the canopy. *In:* D.M. Oosterhuis (ed.). Proc. 1998 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 188:174-176.

Oosterhuis, D.M., F.M. Bourland, and W.R. Robertson. 1999. Cutout defined by crop development. University of Arkansas, Cooperative Extension Service, Little Rock. Cotton Comments 98-7.

Table 1. Effect of upper-canopy fruit removal at varying heat units (H.U.) after physiological cutout on lint yields. Clarkedale, AR.

Treatment	2001 Lint yields	4-year average (98-01)
	---------- (lb/acre) ----------	
Control	1216 a[z]	1236 a
NAWF=5 + 250 H.U.[y]	1180 a	1273 a
NAWF=5 + 350 H.U.	1190 a	1224 a
NAWF=5 + 450 H.U.	1147 a	1245 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 2. Average weight of first-position bolls at NAWF=5 following removal of upper-canopy fruit at different heat units past physiological cutout. Clarkedale, AR.

Treatment	2001 Boll weight	4-year average (98-01)
	---------------------------- (g/boll)	---------------------------
Control	4.63 b[z]	4.34 a
NAWF=5 + 250 H.U.[y]	5.22 a	4.50 a
NAWF=5 + 350 H.U.	5.02 ab	4.61 a
NAWF=5 + 450 H.U.	4.99 ab	4.62 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).
[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 3. Fiber quality of first-position bolls at NAWF=5 following removal of upper-canopy fruit at different heat units past physiological cutout. Clarkedale, AR. 2001.

Treatment	Length	Uniformity	Strength	Micronaire
	(inches)	(%)	(g/tex)	
Control	1.15 a[z]	83.6 ab	30.2 a	3.9 a
NAWF=5 + 250 H.U.[y]	1.17 a	84.4 a	30.5 a	4.2 a
NAWF=5 + 350 H.U.	1.16 a	83.3 b	29.9 a	4.2 a
NAWF=5 + 450 H.U.	1.15 a	83.5 ab	29.8 a	4.1 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).
[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 4. Translocation of ^{14}C from upper-canopy leaves to NAWF=5 bolls following upper-canopy fruit removal. Fayetteville, AR. 1998.

Treatment	Boll weight	^{14}C translocated
	(g)	(%)
Control	3.3[z]	1.8
NAWF=5 + 250 H.U.[y]	3.8	75.4
NAWF=5 + 350 H.U.	2.8	44.4
NAWF=5 + 450 H.U.	0.9	63.2

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).
[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 5. Total $^{14}CO_2$ fixation by main-stem leaves positioned three nodes above the NAWF=5 main-stem node and percent ^{14}C-assimilate translocated into the first-position boll at NAWF=5 two days after leaf labeling. Clarkedale, AR, 2000.

Treatment	Leaf $^{14}CO_2$ fixation	^{14}C-assimilate transported to boll: Boll	Boll wall	Seedcotton
	(dpm mg^{-1} DW)	------------------------- (%)	---------------------	
Control	40.4 a[z]	17.2 a	1.4 b	15.8 a
NAWF=5 + 350 H.U.[y]	19.5 a	21.4 a	3.8 a	17.6 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.