EVALUATION OF HARVEST-AID CHEMICALS FOR EARLY FALL TERMINATION OF COTTON AS A BOLL WEEVIL MANAGEMENT STRATEGY

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Abstract

The boll weevil is the primary insect pest of cotton (*Gossypium hirsutum* L.) in the Texas Rolling Plains. Control of this insect is key to successful cotton production. Uniform planting of cotton during the last half of May is a basic part of recommended boll weevil management practices in the area. When uniform planting is used, boll weevil control with insecticides during the growing season is seldom economical at yield levels <1 bale/acre. Dryland cotton is grown on 90-95% of the acreage, and the average yield level is about 300 lb/acre (12). Alternative methods are needed to control the boll weevil. Effective harvest-aid chemicals used to terminate the crop before early October can reduce the number of boll weevils entering diapause and thus reduce winter survival. This should reduce or eliminate the need for in-season insecticide applications. Ginstar® was used effectively in tests in Hardeman and Wilbarger counties on cotton in the 1994 growing season. Yield and lint grades were not adversely affected when Ginstar was applied in mid- and late September in dryland and in late September in irrigated cotton. In the dryland test in Hardeman County color grade was better in the defoliated cotton than in the freeze terminated cotton that was not harvested until eight to nine weeks after the chemically terminated cotton. Regrowth of the freeze terminated cotton produced 18-20 thousand squares and small bolls/acre and 12-13 thousand bolls/acre with weevil feeding punctures between late September and 16 November when the killing freeze occurred. Ginstar, applied 27 September at 8 and 12 oz/acre rates, was an effective defoliant and did not adversely affect lint grades in dryland 'HS-26' cotton that yielded about 1.3 bales/acre in Wilbarger County. The 12-oz/acre rate of Ginstar was a more effective defoliant than a tank-mix of Prep® and Def® applied 27 September to irrigated 'Stoneville 132' at a rate of 1 pt each per acre. Lint grades were not different for the two defoliants. Ginstar applied to irrigated Deltapine 5409 in late September in Tom Green County resulted in lower micronaire values and yield than the untreated check.

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Introduction

Presently there is only one approach for managing boll weevils during the fall in the Rolling Plains. This is the approach used in the fall diapause control program designed to prevent the westward movement of the boll weevil onto the High Plains and westward into New Mexico. This program has been successfully operated for about 28 years; the status and effectiveness of this program were reviewed by Rummel et al. (11). Additional fall management programs need to be designed to diversify our arsenal of boll weevil management strategies. Such diversification reduces our reliance on insecticides and provides pest managers with broader options to fit differing producer needs.

Bevers and Slosser (4) reported that insecticide treatments for boll weevil control during the growing season were not cost-effective in late May planted cotton unless yields exceeded one bale/acre. Uniform planting of cotton during the last half of May is a basic part of recommended boll weevil management practices in the area. When uniform planting is used, boll weevil control with insecticides during the growing season may not be economical at yield levels < one bale/acre. Yields this high are unusual in dryland cotton, because average yields for the area are about 300-350 lbs. lint/acre (12). In a boll weevil eradication program, an insecticide may be applied throughout the growing season, with perhaps as many as 5-8 applications being required in some fields. Therefore, control measures that are more economical and safer than multiple applications of insecticides are needed. A single application of a crop termination chemical would be more desirable and effective, especially when used over a large geographical area.

The use of early land preparation (6) that facilitates uniform and timely planting, use of adapted varieties, and other best management practices enhance the timely development and maturity of cotton. Avoiding late maturing varieties, especially in dryland cotton, and avoiding irrigation late in the year on irrigated cotton also enhance timely crop maturity, These conditions increase the likelihood of effective use of harvest-aid chemicals.

A high percentage of boll weevils enter diapause during October. Weevils that enter overwintering habitat after the first of October have a higher probability of surviving the winter (Fig. 1). A single application of a crop termination chemical during late September would provide two major benefits. First, it would reduce costs compared to the use of insecticides, and second, it would reduce the size of overwintering boll weevil populations. This second benefit reduces the need for multiple insecticide applications on multiple fields during the following summer.

Late-season crop termination is a tactic that has received little attention in dryland production in the southwestern

U.S., yet this strategy offers great potential for reducing or eliminating diapausing boll weevil populations. Adkisson (1) showed that chemical defoliants and desiccants could be used to reduce the number of diapausing pink bollworm larvae by 90%. Additional work with crop termination chemicals for control of diapausing pink bollworms has been conducted and shown to be effective in irrigated cotton in Arizona (2,3). More recently, ethephon has been used to reduce boll weevil populations in irrigated and dryland cotton in the southwest (7,10). Timing of chemical application during the fall is critical for effective termination of cotton fruiting (9); and when environmental conditions are not favorable, other harvest aids, in addition to a defoliant, may be necessary (5).

Hopkins and Moore (8) reported that thidiazuron applied in South Carolina as a preconditioning treatment followed by a full defoliation treatment resulted in removal of significantly more leaves, squares, and bolls, and less regrowth, compared to plots treated with a standard defoliant or untreated check plots. There also were fewer boll weevils and bollworms found in thidiazuron treated plots. They stated that thidiazuron was an effective defoliant and prevented regrowth of cotton, which deprived the boll weevil of feeding and oviposition sites. They concluded that this characteristic should make it a valuable aid in a fall diapause control program by reducing or eliminating the need for insecticide applications.

Thidiazuron is not recommended in areas where nighttime temperatures are expected to fall below 60°F at the time of application. Based on average temperatures from 1971 through 1990, the mean minimum temperature falls to 60°F or below by 21 September in the Northern Rolling Plains of Texas. This makes the use of thidiazuron questionable, and it has not been used extensively in this area.

In the Texas Rolling Plains, dryland cotton is normally terminated by the first killing freeze, which occurs about 10 November. Yet, most effective fruit set has occurred by early September. In many fields, cotton has opened long before the first freeze, and cotton lint is beginning to fall from the plant. There is a need to determine the practicality of harvest-aid chemicals in dryland production, from both a yield and quality standpoint, and to determine their potential for reducing the food supply available to fall populations of diapausing boll weevils.

Arsenic acid, previously the most common cotton harvest-aid chemical in the Texas Rolling Plains, as well as the rest of the state, is no longer available for use by cotton producers because of environmental constraints. Recent preliminary work has identified Ginstar® as an effective defoliant that has the potential to replace arsenic acid, and it is more effective and safer than arsenic acid in terminating fruiting of cotton in the fall. Ginstar is a mixture of thidiazuron and diuron in a solvent system, and has been the most effective defoliant of several materials evaluated. A further advantage is that it suppresses re-growth like thidiazuron.

The objectives of this study were to 1) determine the effect of harvest-aid chemicals on the availability of squares and small bolls to diapausing boll weevils and 2) determine the impact of early termination of cotton on yield, fiber quality, and value of the crop.

Materials and Methods

A study was conducted at the Texas Agricultural Experiment Station at Chillicothe, Hardeman County, Texas (34.1° N, 99.3° W, elev. 1406 ft). Soil type at the test site is an Abilene clay loam (fine, mixed, thermic Pachic Arguistoll) with a slope of about 0.2% with and across plot row direction. Soils of this type typically have low to very low levels of N, low to moderate levels of P, and high levels of K; Ca and Mg are high to very high, and organic matter is < 1%.

Cotton was grown on the test site two years prior to establishing the study. A split-plot design with four replications was used. Main plots were the varieties 'CAB-CS' and HS-26. Sub-plots were an untreated check and two harvest-aid treatments using Ginstar, one applied at 60% open bolls and the other in late September. Each individual plot was 12, 40-in. rows wide and 100 ft long with 20 ft turn rows between replications (blocks). A listing of land preparation and cultural operations is presented in Table 1. Cotton was planted 24 May with a Nodet Gougis Pneumasem II planter with a vacuum seed distribution system and with double disk openers.

The two cotton varieties were selected to represent differences in maturity and ease of defoliation typically found in the Texas Rolling Plains. The variety HS-26 normally matures later and characteristically is more difficult to defoliate than CAB-CS.

Phenological data, consisting of nodes above the highest white flower (NAWF) and percent open bolls, were obtained during the growing season. Beginning in September, numbers of squares, soft bolls, and amount of boll weevil feeding damage to these fruiting forms were determined once each week until a killing freeze occurred on 16 November.

Ginstar, the harvest-aid chemical used in this study, was applied with a four-row tractor-mounted sprayer. The spray boom was mounted to the side of the sprayer to permit application of the chemical without driving through the test-plot area. Eight center rows of the 12-row plots were sprayed, and cotton was harvested with a two-row batt-brush, tractor-mounted stripper from the four middle rows of the 12-row plots. Harvested samples were ginned on a laboratory-scale gin, and lint yield per acre was determined for each plot. Fiber data were obtained from the International Textile Center, Texas Tech University, Lubbock, Texas.

During harvest, green bolls were collected in the green-boll box on the stripper when each plot was harvested. These were forced to open by drying in forced air and subsequently ginned. Gin turnout and lint yield were determined as an estimate of lint loss associated with termination of the cotton with Ginstar.

All data were analyzed using the split-plot routine of the MSTAT-C, FACTOR program, and treatment means were separated with the RANGE program (LSD, $\alpha = 0.05$). Analysis of variance and LSD mean separations of data were done to provide a basis of evaluating main effects, due to variety and harvest-aid treatment, and interactions between the main effects.

Supporting studies were conducted with producer cooperators in Wilbarger County, near Vernon in the northern Rolling Plains, and in Tom Green County, near the Wall community in the southern Rolling Plains. Ginstar was applied aerially on 5-10 acre blocks in late September. The cotton variety 'Deltapine 5409' was used in irrigated production in Tom Green County. The variety HS-26 was used in dryland and Stoneville 132 was used in irrigated production in Wilbarger County.

Results and Discussion

Cotton was moisture stressed during much of the year. Annual precipitation was slightly above average, but distribution was not favorable. A major factor contributing to stress was a period of extremely high temperatures beginning in late June when cotton was in the early square development stage. The average maximum temperature for the period 23 June through 4 July was 103.8 ºF, and a maximum of 118 ºF occurred 28 June. This caused shedding of the lowest squares and loss of the early production. Cotton apparently never recovered adequately from this shock.

Objective 1. Determine the effect of harvest-aid chemicals on the availability of squares and small bolls to diapausing boll weevils.

Effectiveness of Harvest-Aid Treatments on Boll Weevil Food Supply

Squares $\geq$ 1/8 in. diameter, soft bolls, and boll weevil damage were deter-mined at weekly intervals from 6 September to 17 November (Fig. 2). Pretreatment counts obtained on 6 and 13 September indicated there were no differences between treatments. The first Ginstar treatment was applied on 14 September. Although differences were not statistically significant, this application reduced square and boll numbers on 20 September by 68% as compared to numbers in the untreated check. Boll weevil damage was reduced by 61%. The HA-60% plots were harvested 28 September and cotton stalks were destroyed, so there were no squares or bolls in these plots beginning in October.

The second Ginstar treatment was applied on 29 September. Post-treatment counts on 4 October indicated there were no significant differences between this treatment and the untreated check. However, this late September treatment reduced square and boll numbers by 70% as compared to numbers remaining in the untreated check plots, and boll weevil damage was reduced by 68%. These plots were harvested 6 October, and the cotton stalks were destroyed, eliminating squares and bolls in these plots.

Because the cotton was stressed throughout the summer, there were few squares and soft bolls on the plants during September. These low numbers made the harvest-aid treatments appear ineffective. However, the timing of both Ginstar treatments enabled us to harvest the crop by or before early October. The data in Fig. 1 show that boll weevil populations enter diapause in high numbers during October. To enter diapause and successfully over-winter, boll weevils require a food supply during October. Both chemical termination treatments eliminated the squares and bolls by early October. Square and soft boll numbers increased to 14,000 - 23,000 per acre by mid-October in the untreated check plots, and there was an average of 11,800 squares and soft bolls in the untreated check plots from mid-October to mid-November (Fig. 2). These squares and soft bolls would have provided the food source needed by boll weevils for successful overwintering as indicated by the number of fruit forms with weevil feeding punctures in the check treatment (Fig.3). Thus, the timing of both Ginstar treatments did successfully eliminate the food supply by the critical time period of 1 October. Cotton in the untreated check plots remained in the field and was harvested 30 November, after the first killing freeze on 16 November. This is the most common approach to harvesting cotton in the Texas Rolling Plains. The untreated cotton provided abundant food for boll weevils entering diapause.

Objective 2. Determine the impact of early termination of cotton on yield, fiber quality, and value of the crop.

Termination of the Crop

Cotton plants averaged four nodes above white flowers (NAWF) on 4 August, and cotton was at least 60% open by 13 September (Fig. 4). The predicated date for harvest-aid application based on date of occurrence of 4 NAWF+850 DD60 was 10 September. The earliest harvest-aid application was made 14 September when CAB-CS and HS-26 had 70% and 69% open bolls, respectively, (Fig. 4). The variety CAB-CS was 99 to 100% open and HS-26 was 97% open on 4 October.

Lint Yield

Mean lint yield for the test was 213 lb/acre, reflecting the stressed condition of the crop. There were no significant effects on yield attributable to varieties or termination treatments (Table 2), and there was no significant variety x termination date interaction. HS-26 had a higher gin turnout (23%) than CAB-CS (20%), but there was no termination date, or variety x termination date interaction effect on gin turnout.

Grade Factors, Price, and Value of Cotton

Color grade, fiber length (staple), leaf content of the lint, micronaire, and fiber strength (g/tex) are the factors that determine price per lb of lint cotton. Price per lb was determined for each treatment and replication, and value per acre was determined by price per lb multiplied by yield per acre. Each factor affecting grade and price was statistically analyzed. Price per lb and value per acre, containing the variability of all the determining factors, also were analyzed.

Color grade was 31 for all the treatments that were terminated with the harvest-aid chemical (Table 3). Grades for the cotton from the check treat-ment that was freeze terminated 16 November and harvested 30 November were 41 for CAB-CS and 51 for HS-26.

Mean fiber length was not significantly different for either variety or for any of the termination treatments (Table 3). Mean leaf index was higher for HS-26 than for CAB-CS. CAB-CS had a leaf index value of 2 from all three termination treatments, and HS-26 had a value of 3 from two of the three termination treatments.

Varieties had a significant effect on micronaire; CAB-CS was lower than HS-26 (Table 3). Harvest-aid treatments had no significant effect on micronaire, and there was no significant interaction of varieties and treatments. Micronaire did not affect the price per lb of either variety.

Fiber strength was greater for HS-26 than for CAB-CS (Table 3), but there was no significant harvest-aid treatment effect or interaction. Mean fiber strength had a major effect on price of the lint from HS-26, contributing 105 points ($0.0150) per lb for each of the termination treatments.

Price per lb, determined from all grade factors (fiber characteristics), differed among varieties and treatments. The harvest-aid treatment applied at 60% open bolls resulted in the highest price, $0.4785 and $0.4803 per lb, for CAB-CS and HS-26, respectively (Table 2). The harvest-aid treatment applied to HS- 26 in late September resulted in a price of $0.4790, not different from those above, but higher than the prices for the two varieties in the check treatment. This was largely due to the lower color grades for the two varieties that remained in the field longer before harvest (check treatment).

Value of lint per acre was not significantly different (statistically) among any of the variety-treatment combinations (Table 2). The accumulative variability associated with yield and grade factors determining price per lb resulted in a high CV. Thus, large differences in value per acre were not measurably different in this test.

Cost of Ginstar established by AgrEvo in 1994 was $10.50 per acre for 0.5 pint per acre, the rate used in this test. The local application cost was $3.50 per acre, giving a total cost of $14.00 per acre. This amount was subtracted from return per acre for harvest-aid treatments (Table 2), and the resulting value of cotton over harvest-aid cost was analyzed statistically. The results showed no statistically significant treatment main effects (Table 2), and there was no significant interaction effect.

Lint loss from Green Bolls

Mean lint yield from the green bolls was 5 lb per acre (Table 4). The main effect for variety and the variety x termination date interaction were not significant. Termination date produced a significant effect on lint from green bolls. This was attributable primarily to the later maturing variety, HS-26, which had the greatest loss to green bolls. Cotton that was terminated 14 September at 60% open bolls had a mean loss of 8 lb per acre compared to 2 lb per acre from that terminated on the predetermined date of 28 September (late September). However, the check treatment that was not harvested until after it was terminated by a freeze, did not yield significantly more than the chemically terminated cotton (Table 2).

Supporting Studies

Ginstar was applied to irrigated Deltapine 5409 at the late September date (28 September) in Tom Green County when cotton had about 60% open bolls and eight nodes above cracked bolls (NACB). The yield level in this study was about two bales/acre. The late September application resulted in lower micronaire and yield compared to cotton that was treated with two applica-tions of Cyclone® on 6 October (6 oz/acre) and again on 16 October (16 oz/acre) when >65% of the bolls were open and there were four NACB.

Ginstar was applied to both dryland and irrigated cotton in Wilbarger County on 27 September. In the dryland field, 8 oz and 12 oz rates of Ginstar were compared on 5-acre strips and a freeze terminated check was used. There was no difference in effectiveness between the two rates. A 12 oz rate was used on a 10-acre strip in the irrigated cotton and compared with Prep® and Def® applied in a tank mix at 1-pt/acre each. Ginstar provided better defoliation than the combination treatment. Lint grades were not different in the dryland or the irrigated test. The dryland HS-26 yielded about 1.3 bales/acre, and the irrigated Stoneville 132 yielded about 3.2 bales/acre.

Table 1. Date and description of operations for the 1994 test of harvest-aid chemical treatment for boll weevil management at the Chillicothe Research Station, Hardeman County, TX.

Date of operation	Operation
1. After 1993 harvest	Shredded cotton stalks.
2. Early January	Subsoiled twice at 90 degrees from each other.
3. 26 January	Disked to level land before applying and incorporating herbicide.
4. 25 March	Applied and simultaneously incorporated 2 pt (1.0 lb a.i. per acre) trifluralin (Treflan 4E).
5. 28 March	Reincorporated herbicide with sweep cultivator.
6. 30 March	Established beds with sweep-disk bedder.
7. 23 May	Applied 30 lb N and 30 lb P_2O_5 per acre in 20-inch bands into sides of beds.
8. 24 May	Planted cotton: 4.2 seed per foot of row.
9. 13 June	Cultivated cotton.
10. 15 July	Cultivated cotton.
11. 14 September	Applied 1/2 pt/acre Ginstar to 60% open bolls treatment.
12. 28 September	Applied 1/2 pt/acre Ginstar to late September treatment.
13. 29 September	Harvested 60% open boll treatment.
14. 7 October	Harvested late September treatment.
15. 30 November	Harvested freeze terminated cotton treatment.

Table 2. Yield and value of cotton from a study evaluating harvest-aid chemicals as a boll weevil management strategy at Chillicothe, Hardeman County, TX, 1994.

Variety	Treatment [1/]	lb/acre	$/lb	harvest-aid $/acre	$/acre less cost
CAB-CS	Check	182	0.4478	81.49	83.47
	HA, LS	169	0.4559	77.04	63.83
	HA, 60% OB	209	0.4785	100.01	86.09
HS-26	Check	262	0.4465	116.98	117.72
	HA, LS	231	0.4790	110.65	97.05
	HA, 60% OB	222	0.4803	106.62	93.24
LSD 0.05		ns	0.0294	ns	ns
CV %		15.4	4.1	17.2	19.0

1/ Check: Cotton freeze terminated.
HA, LS: Harvest-aid applied late September.
HA, 60% OB: Harvest-aid applied at ≥60% open bolls.

Table 3. Grade factors affecting price of cotton from a boll weevil management study at Chillicothe, Hardeman County, TX, 1994.

Var.	Trt.	Color grade	Fiber length	leaf	mic	Strength g/tex
CAB-CS	Check	41	31	2	3.5	24
	HA, LS	31	31	2	3.5	24
	HA, 60%	31	32	2	3.5	26
HS-26	Check	51	31	3	4.4	31
	HA, LS	31	31	2	4.3	33
	HA, 60%	31	31	3	4.2	33

1/ Check: Cotton freeze terminated.
HA, LS: Harvest-aid applied late September.
HA, 60%: Harvest-aid applied at ≥60% open bolls.

Table 4. Lint loss in green bolls from a harvest-aid chemical/boll weevil management study at Chillicothe, TX, 1994.

Defoliation treatment	Variety: CAB-CS	Variety: HS-26	Mean
	lb lint/acre		
Ginstar, LS	1 b*	2 b	2 B
Ginstar, 60% OB	4 b	11 a	8 A
Mean	3 A	7 A	5

* Means within rows and columns followed by the same lower case letter are not significantly different (P≤0.05); means within row or column followed by the same upper case letter are not significantly different (P ≤ 0.05).

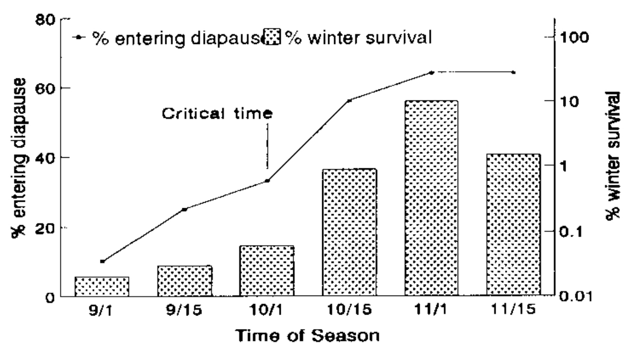

Fig. 1. Percent of boll weevil population entering diapause and percent overwinter survival versus time of entry into habitat.

Data adapted by J. E. Slosser from Bottrell and Almand, 1970; Sterling and Adkisson, 1974; Rummel and Carroll, 1983

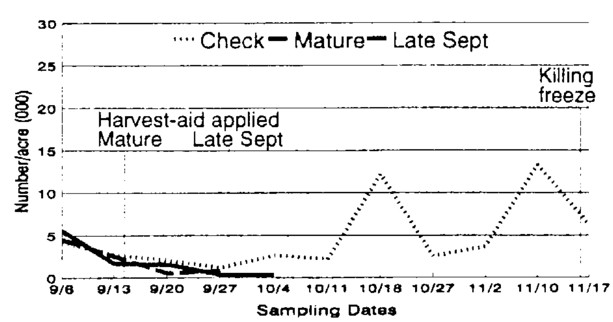

Fig. 3. Harvest-aid treatment effects on number of weevil damaged squares and small bolls in a boll weevil management study at Chillicothe, Hardeman County, Texas, 1994.

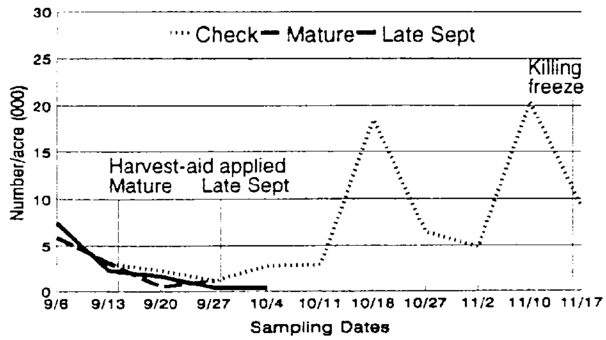

Fig. 2. Effect of harvest-aid chemicals on number of squares and small bolls in a boll weevil management study at Chillicothe, Hardeman County, Texas, 1994.

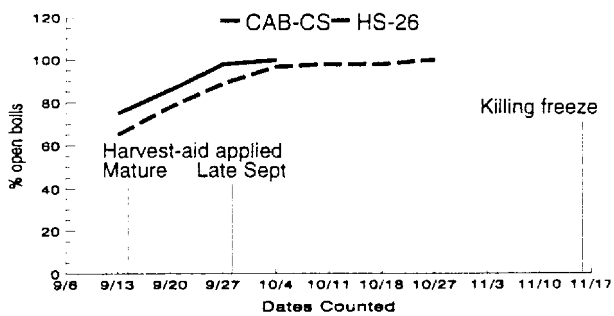

Fig. 4. Percent open bolls versus time on two cotton varieties in a boll weevil management study at Chillicothe, Hardeman County, Texas, 1994.

Acknowledgements

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