CHEMICAL AND PHYSICAL REMOVAL OF COTTON FRUIT AT INSECTICIDE TERMINATION TO IMPROVE YIELDS AND CONTROL BOLL WEEVILS

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Abstract

Increasing yields in cotton (*Gossypium hirsutum L.*) is an ongoing concern for many researchers. It has been shown that removal of upper-canopy squares at nodes above white flower five plus 350 heat units (NAWF=5+350 H.U.) may divert carbohydrates to developing bolls with a resulting yield advantage. This study evaluated different chemical and physical methods of removing late-season upper-canopy squares to potentially increase seedcotton yields and help control boll weevils (*Anthonomus grandis*). The research was performed in northeast and southeast Arkansas on an early-maturing Deltapine DP20B cultivar. To allow for any potential problems in the research due to weather and to provide two growth patterns, two planting dates were included in the study (early and mid May). The treatments for the 1999 season included a hand-square-removal and a mechanical topping treatment (physical removal), cyclanilide (Finish), ethephon (Prep), chlormequat (CCC), maleic hydrazide (M-H 30) (chemical removal) and a control with no fruit removal. The cotton products cyclanilide and ethephon were the most effective at removing unwanted upper-canopy fruit above NAWF=5 and helping to control boll weevils by limiting their late-season food sources. However, weight and fiber quality of first position bolls at NAWF=5 were decreased ($P \leq 0.05$) in plots treated with cyclanilide. The largest bolls were observed from the hand-square-removal and control treatments. No differences ($P \leq 0.05$) occurred with respect to increasing seedcotton yields, but the control unfortunately gave the highest numerical yields due to favorable late-season growing condition and maturation of upper bolls not removed by the control treatment.

Introduction

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 with increasing insect pressure, and provide a food source for insects. Nodes above white flower (NAWF) is an integral concept used in the COTMAN crop monitoring program for basing end-of-season decisions. In COTMAN, a major aim is to identify the last effective boll population and project a date for insecticide termination (Cochran et al., 1998). Bagwell (1995) showed that bollworm (*Helicoverpa zea*) and boll weevil (*Anthonomus grandis*) 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. Oosterhuis et al. (1996) reported that terminating insecticides at 350 heat units after physiological cutout (NAWF=5) results in a higher yield than when terminating before or after this time. It is hypothesized that insect damage to upper-canopy (above NAWF=5) squares results in improved partitioning of carbon to lower developing bolls (Kim and Oosterhuis, 1998). The first objective of the current study was to evaluate the efficiency of various chemicals to remove fruit above NAWF=5. The second objective was to determine if removing upper-canopy fruit increased the weight and fiber quality of first position bolls at the NAWF=5 main-stem node, and total seedcotton yields. This research project also has implications in better control of boll weevils by removing their late-season food sources.

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Materials and Methods

The 1999 season was the third year for this square removal study. The 1997 season served only as a preliminary screening year to determine the most effective rates of chemicals to be used for the next two seasons. The past two years have involved a more in-depth study in which we determined the effects of fruit removal on yield parameters, fiber quality, regrowth, weevil feeding and carbohydrate partitioning. The trials were conducted at two Arkansas locations: Southeast Branch Research Station at Rohwer, and the Delta Branch Station at Clarkedale. In 1999, the study was reduced to a single early-maturing Deltapine DP20B culivar. To allow for any potential problems in the research due to weather and to provide two growth patterns, two planting dates were included in the study (early and mid May).

The treatments in 1999 included a hand-square-removal and a mechanical topping treatment (physical removal), cyclanilide (Finish) @ 0.1lba.i./acre, ethephon (Prep) @ 0.2lba.i./acre, chlormequat (CCC) @ 8oz/acre, and maleic hydrazide (M-H 30) @ 2lb/acre (chemical removal) and a control with no square removal. The experimental design was a randomized complete block with four replications. At the NAWF=5 stage, 20-30 first position white flowers were tagged in the center two rows of each 4-row plot. Daily heat units [(max+min temp./2)-60^{0}F] were accumulated from white flower until 350 heat units were reached. At this time (NAWF=5 + 350 heat units) the six square removal treatments were applied. One week after applying treatments, first position square shed was determined for the 5 nodes above and below the tagged NAWF=5, as well as for the tagged NAWF=5 position. Two weeks after applying treatments, weevil damaged fruit (egg and feeding punctures) above the tagged NAWF=5 main-stem nodal position were recorded. At harvest, weight and quality of first position bolls at the NAWF=5 main-stem node, and total seedcotton yields were determined.

Results and Discussion

This past 1999 season was the third year of our study in which we evaluated the effects of removing late-season upper-canopy fruit. Results of the 1997 and 1998 seasons are published in the 1999 Beltwide Proceedings (Brown et al., 1999). The following results are from our field study in 1999 at two Arkansas locations, Clarkedale and Rohwer.

Efficiency of Square Removal

Clarkedale. Cyclanilide was the most effective chemical at removing upper-canopy fruit, removing more fruit ($P \leq 0.05$) than the other chemical treatments for both planting dates (Table 1). All chemical treatments outperformed ($P \leq 0.05$) the control at removing upper-canopy fruit for both planting dates, however, chlormequat and maleic hydrazide were the least effective chemicals for removing late-season fruit. None of the chemical treatments were able to remove as much upper-canopy fruit ($P \leq 0.05$) as the physical methods of removing fruit, which removed 100% of the fruit above NAWF=5 (Table 1). It was hoped that removal of upper-canopy, nonproductive fruit (above NAWF=5) would be possible without shedding fruit at NAWF=5 and below. Unfortunately this was not achieved from the removal of upper-canopy cotton fruit. The hand-square-removal and mechanical topping treatments increased fruit shed at NAWF=5 for the first planting date, with cyclanilide giving the lowest fruit shed of first position fruit at NAWF=5 (Table 1). For the second planting date, chlormequat numerically increased fruit shed of first position boll at NAWF=5, whereas cyclanilide, ethephon, maleic hydrazide, and the mechanical topping treatments all retained a higher percentage of bolls at that position. For the five nodes below the tagged NAWF=5 position, the hand-square-removal treatment provided the highest degree of retention of first position fruit compared to the other treatments for both planting dates (Table 1). The control, ethephon and cyclanilide treatments retained the least amount of first position fruit below NAWF=5.

Rohwer. The data for upper-canopy square shed from Rohwer was very similar to the Clarkedale location. Cyclanilide removed the most upper-canopy first position fruit and was significantly different ($P \leq 0.05$) from all other chemical treatments in efficiency at effectively removing unwanted fruit (Table 2). However, the highest shed percentages were observed from the physical removal treatments, which were higher ($P \leq 0.05$) than any of the chemical treatments or control. The control treatment removed a lower percentage of first position fruit above NAWF=5 than any other treatments for either planting date. There were no significant differences between treatments at the first planting date with respect to the amount of first position fruit shed at NAWF=5 (Table 2). However, the cyclanilide and control treatments retained the least amount of first position fruit and maleic hydrazide retained the most. For the second planting date ethephon retained more fruit at NAWF=5 than any other treatment. The two physical removal treatments, along with cyclanilide and maleic hydrazide caused the most fruit shed. Mechanical topping caused the highest fruit shed of first position bolls lower in the canopy (below NAWF=5), compared to the other treatments for the first planting date (Table 2). Chlormequat, on the other hand, was able to numerically retain more fruit below the tagged NAWF=5 position than the other treatments. For the second planting date, there were no differences ($P \leq 0.05$) between treatments in first position fruit shed below NAWF=5.

Seedcotton Yields

Clarkedale. There were no differences ($P \leq 0.05$) between treatments with respect to increasing seedcotton yields for the first planting date (Figure 1). However, ethephon gave the lowest numerical yield and the control treatment gave the highest yield, which is difficult to explain, but may be related to the release of ethylene in that particular square removal treatment. The second planting was just the opposite in which the control had the lowest yield and the hand-square-removal treatment had the highest numerical yield.

Rohwer. For the first planting date, the control treatment resulted in the highest seedcotton yields while cyclanilide and maleic hydrazide gave lower ($P \leq 0.05$) yields (Figure 2). There were no treatment differences for the second planting date with respect to seedcotton yield. However, chlormequat numerically yielded the highest with the mechanical topping treatment reducing yields the most.

Boll Weights at NAWF=5

Clarkedale. The largest boll weights were observed in the control, ethephon, and hand removal of fruit treatments for the first planting date (Figure 3). Conversely, the cyclanilide treatment lowered ($P \leq 0.05$) boll weights compared to the control treatment. The second planting date resulted in no significant changes in the weight of bolls at NAWF=5. However, the hand-square-removal treatment showed the highest numerical weight of bolls at NAWF=5 with the cyclanilide and chlormequat treatments having the lowest boll weights. There appeared to be a trend between boll weight and seedcotton yield for both planting dates. At each planting date, the treatments with the highest boll weight at NAWF=5 had the highest yield and treatments with lower boll weights had lower yields.

Rohwer. At the early planting date, there were only subtle differences among treatments to increase boll weight at NAWF=5 although the cyclanilide treatment did decrease ($P\leq 0.05$) boll weight compared to other treatments (Figure 4). For the later planting date at Rohwer, the hand-square-removal treatment resulted in the largest boll weight at NAWF=5 and the mechanical topping treatment gave the lowest boll weight at NAWF=5 (Figure 4).

Fiber Quality

Clarkedale. Fiber length was the longest for the mechanical topping and maleic hydrazide treatments and the shortest for the ethephon treatment at the first planting date (Table 3). At the second planting date, cyclanilide treated plots showed the shortest fiber length with the hand-square-removal treatment giving the longest fibers. Fiber strength was reduced ($P\leq 0.05$) by the ethephon and cyclanilide treatments for the early planting date (Table 3). For the second planting date, fiber strength was significantly increased ($P\leq 0.05$) by maleic hydrazide in comparison to the control. Uniformity was the lowest for the cyclanilide treatment for both planting dates and significantly lower ($P\leq 0.05$) than the control at the first planting date (Table 3). Micronaire values were significantly reduced ($P\leq 0.05$) for both planting dates by the cyclanilide treatment (Table 3). The hand-square-removal treatment gave the highest numerical micronaire value at both planting dates which was significantly higher than the other treatments for the later planting date.

Rohwer. For the first planting date, fiber length was the greatest for the ethephon treatment and shortest for the cyclanilide treatment (Table 4). The second planting date resulted in no significant differences among treatments for increasing fiber length. No significant differences ($P\leq 0.05$) in fiber strength were observed for either planting date at Rohwer. When compared to the control treatment, cyclanilide decreased ($P\leq 0.05$) uniformity for the first planting date as did mechanical topping for the second planting date. Micronaire values were significantly lower ($P\leq 0.05$) than the control for the mechanical topping and cyclanilide treatments at the earlier planting date. At the second planting date, ethephon showed the highest numerical micronaire values with cyclanilide and mechanical topping giving the lowest values. Overall the cyclanilide treatment caused the lowest fiber quality of first position NAWF=5 bolls. Mechanical topping was also a treatment which caused decreased fiber quality, particularly in reducing micronaire and length uniformity. The control and maleic hydrazide treatments represented the best fiber quality values.

Late-Season Weevil Punctured Fruit and Upper-Canopy Growth

Clarkedale. Plant height above the tagged NAWF=5 position was not reduced ($P\leq 0.05$) by any of the chemical treatments for either planting date. However, the mechanical topping treatment had a lower ($P\leq 0.05$) plant height due to the intentional topping of all plant biomass above the tag at NAWF=5 for both planting dates (Table 5). Of all the chemical treatments, chlormequat treated plots had the fewest nodes above NAWF=5 for the first planting date. Chlormequat (CCC) is a growth retardant designed to reduce plant height and lodging. As expected, the mechanical topping treatment had the lowest ($P\leq 0.05$) number of nodes above the NAWF=5 position of all treatments since the plant was intentionally topped above the main-stem NAWF=5 position.

The total number of boll weevil punctured fruit (feeding and egg punctures) were counted per plant above the tagged NAWF=5 position to estimate possible reductions in weevil feeding and oviposition habits as affected by fruit removal. We hypothesized that less fruit would be damaged due to a less available food source. The control had a higher number ($P\leq 0.05$) of weevil punctured fruit than that of the other treatments for the first planting date (Table 5). Cyclanilide had a lower ($P\leq 0.05$) number of weevil punctures than the control or any of the other chemical treatments at both planting dates. This occurred because cyclanilide was the most effective chemical at removing upper-canopy fruit leaving less cotton fruit available for weevils to damage. However, the two physical fruit removal treatments (hand-square-removal and mechanical topping) had the lowest number ($P\leq 0.05$) of weevil punctures for both planting dates. These two treatments were the lowest because all fruit above the tagged NAWF=5 position had been removed earlier.

Rohwer. Plant height above NAWF=5 was reduced ($P\leq 0.05$) for the mechanical topping treatment for the first planting date, however, no significant differences were observed between the chemical treatments (Table 6). For the later planting date, chlormequat had the greatest height above NAWF=5 with ethephon being the chemical with the lowest height above the tagged NAWF=5 position. However, the mechanical topping treatment had the lowest ($P\leq 0.05$) height, which was zero. Of the chemical treatments, chlormequat had the least number of effective nodes above NAWF=5 for the early planting date, and the hand-square-removal treatment had the most. The mechanical topping treatment had the lowest ($P\leq 0.05$) number of nodes above the tag for both planting dates. With the exception of mechanical topping, no significant differences occurred between treatments at changing node number for the later planting date.

For the first planting date, the control had a higher number of weevil damaged fruit than any of the other treatments with cyclanilide having significantly fewer ($P<0.05$) than the control (Table 6). There were no significant differences between chemical treatments at the later planting date in regard to weevil damaged upper-canopy fruit. For both planting dates the least amount of weevil damage occurred for the physical removal of fruit treatments where all fruit was removed.

Since boll weevil eradication has only been proposed and not yet adopted for northeast Arkansas, more research is needed to determine possible late-season methods for their control. We have documented several ways to effectively remove late-season fruit which could potentially help to control late-season weevil infestations. However, more field verification is needed to insure their control without reducing yields.

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Table 1. First position fruit shed percentages at the tagged NAWF=5 position, as well as, the five nodes above and below the tag one week after application of treatments. Clarkedale, Arkansas, 1999.

	Planting Date 1			Planting Date 2		
Treatment	Tagged NAWF5	Above NAWF5	Below NAWF5	Tagged NAWF5	Above NAWF5	Below NAWF5
	---------Shed %---------			---------Shed %-----------		
Control	27.5ab[1]	61.5d	27.0abc	10.0ab	56.5c	29.0a
Hand sq rem	35.0a	100.0a	18.5c	10.0ab	100.0a	14.5b
Mech. Top.	35.0a	100.0a	22.5bc	5.0b	100.0a	20.5ab
Chlormequat	22.5abc	73.5c	24.0bc	22.5a	62.0c	23.5ab
Maleic Hyd.	17.5bc	73.5c	23.0bc	7.5b	62.5c	25.5a
Ethephon	22.5abc	80.0c	29.0ab	5.0b	63.0c	30.5a
Cyclanilide	12.5c	90.0b	35.0a	5.0b	82.5b	25.5a

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

Table 2. First position fruit shed percentages at the tagged NAWF=5 position, as well as, the five nodes above and below the tag one week after application of treatments. Rohwer, Arkansas, 1999.

	Planting Date 1			Planting Date 2		
Treatment	Tagged NAWF5	Above NAWF5	Below NAWF5	Tagged NAWF5	Above NAWF5	Below NAWF5
	---------Shed %---------			---------Shed %----------		
Control	50.0a[1]	70.0d	23.5ab	22.5ab	65.5d	28.5a
Hand sq rem	45.0a	100.0a	23.5ab	27.5a	100.0a	27.0a
Mech. Top.	37.5a	100.0a	29.0a	30.0a	100.0a	28.5a
Chlormequat	45.0a	74.5cd	19.5b	20.0ab	70.5cd	28.0a
Maleic Hyd.	45.0a	70.0d	27.0ab	30.0a	67.0cd	26.0a
Ethephon	47.5a	80.5bc	23.0ab	5.0b	73.5c	30.5a
Cyclanilide	50.0a	86.0b	23.5ab	32.5a	80.5b	30.0a

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

Table 3. Effect of chemical and physical fruit removal on cotton fiber quality (length, strength, length uniformity and micronaire) of first position NAWF=5 bolls. Clarkedale, Arkansas, 1999.

	Planting Date 1				Planting Date 2_			
Treatment	Len.	Stren.	Unif.	Mic.	Len.	Stren.	Unif.	Mic.
	in.	g/tex	%		in.	g/tex	%	
Control	1.17ab[1]	30.2a	86.0ab	4.7a	1.14ab	27.7b	84.6ab	4.7ab
Hand sq rem	1.16ab	30.2a	85.5ab	4.7a	1.16a	28.2ab	85.3ab	5.0a
Mech. Top.	1.18a	30.1a	85.3b	4.2b	1.15ab	28.5ab	85.4a	4.6b
Chlormequat	1.17ab	29.9a	85.4ab	4.6a	1.14ab	29.4ab	85.5a	4.5b
Maleic Hyd.	1.18a	30.2a	86.1a	4.6a	1.14ab	30.1a	85.3ab	4.7ab
Ethephon	1.15b	28.9b	85.3bc	4.6a	1.14ab	29.8ab	85.4ab	4.6b
Cyclanilide	1.17ab	28.4b	84.6c	3.3c	1.12b	28.2ab	84.2b	4.0c

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

Table 4. Effect of chemical and physical fruit removal on cotton fiber quality (length, strength, length uniformity and micronaire) of first position NAWF=5 bolls. Rohwer, Arkansas, 1999.

	Planting Date 1				Planting Date 2			
Treatment	**Len.**	**Stren.**	**Unif.**	**Mic.**	**Len.**	**Stren.**	**Unif.**	**Mic.**
	in.	g/tex	%		in.	g/tex	%	
Control	1.13ab[1]	30.0a	85.6a	5.5a	1.15a	30.9ab	86.6a	5.2ab
Hand sq rem	1.13ab	30.0a	85.3ab	5.4ab	1.14a	29.8b	85.8ab	5.3ab
Mech. Top.	1.13ab	29.3a	85.4ab	5.2c	1.14a	30.6ab	85.4b	5.0b
Chlormequat	1.13ab	30.0a	85.3ab	5.3abc	1.15a	30.3ab	85.6ab	5.2ab
Maleic Hyd.	1.12ab	29.6a	85.6a	5.5ab	1.15a	30.0ab	85.6ab	5.3ab
Ethephon	1.14a	29.2a	85.7a	5.3bc	1.15a	31.2a	85.7ab	5.4a
Cyclanilide	1.11b	29.2a	84.7b	4.9d	1.14a	30.3ab	86.0ab	5.0b

[1]Treatment means within a column followed by the same letter are not significantly different (P≤0.05).

Table 5. Effect of chemical and physical fruit removal on height, number of nodes and weevil punctures (egg and feeding) above NAWF=5 two weeks after applying treatments. Clarkedale, Arkansas, 1999.

	Planting Date 1			Planting Date 2		
Treatment	**Height**	**Nodes**	**Weevil punc.**	**Height**	**Nodes**	**Weevil punc.**
	cm	#	#	cm	#	#
Control	29.4a[1]	6.6abc	1.8a	29.6a	6.8a	2.5a
Hand sq rem	29.9a	6.7ab	0.0d	29.1a	6.9a	0.0c
Mech. Top.	0.00b	0.0d	0.0d	0.0b	0.0b	0.0c
Chlormequat	27.8a	6.2c	1.3ab	28.4a	6.8a	2.5a
Maleic Hyd.	29.3a	6.5abc	1.2b	28.9a	6.9a	2.6a
Ethephon	30.3a	6.8a	0.8bc	28.6a	6.7a	2.1a
Cyclanilide	29.1a	6.3bc	0.5c	28.4a	6.8a	1.1b

[1]Treatment means within a column followed by the same letter are not significantly different (P≤0.05).

Table 6 Effect of chemical and physical fruit removal on height, number of nodes and weevil punctures (egg and feeding) above NAWF=5 two weeks after applying treatments. Rohwer, Arkansas, 1999.

	Planting Date 1			Planting Date 2		
Treatment	**Height**	**Nodes**	**Weevil punc.**	**Height**	**Nodes**	**Weevil punc.**
	cm	#	#	cm	#	#
Control	32.1a[1]	7.5abc	1.8a	30.2ab	7.2a	2.6a
Hand sq rem	32.7a	8.0a	0.0c	29.3ab	7.2a	0.0b
Mech. Top.	0.00b	0.0d	0.0c	0.0c	0.0b	0.0b
Chlormequat	31.0a	7.2c	1.6ab	32.3a	7.3a	2.5a
Maleic Hyd.	32.7a	7.3bc	1.4ab	28.3ab	7.0a	2.2a
Ethephon	32.2a	7.9ab	1.4ab	27.6b	6.7a	1.7a
Cyclanilide	32.1a	7.9ab	1.2b	30.4ab	7.1a	2.0a

[1]Treatment means within a column followed by the same letter are not significantly different (P≤0.05).

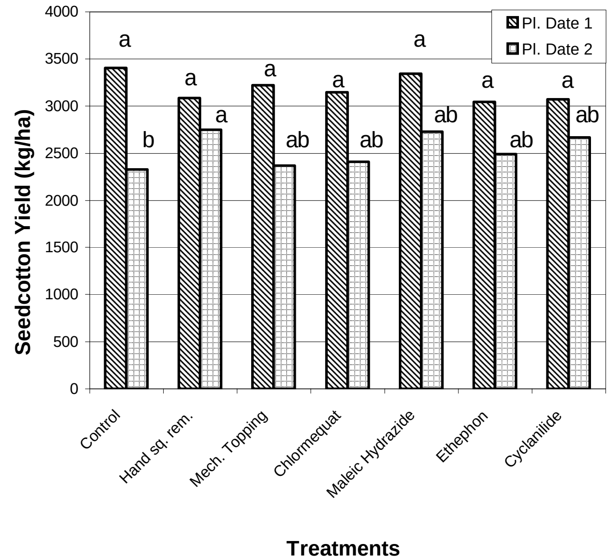

Figure 1. Effect of upper-canopy fruit removal on seedcotton yields. Clarkedale, Arkansas, 1999. Bars with the same letter are not significantly different (P≤0.05).

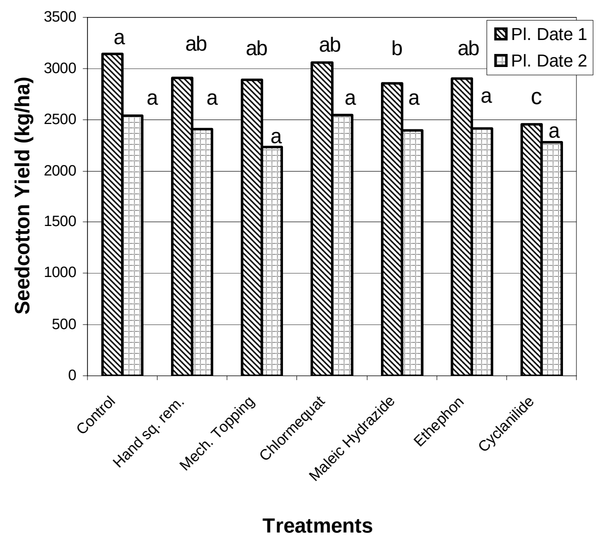

Figure 2. Effect of upper-canopy fruit removal on seedcotton yields. Rohwer, Arkansas, 1999. Bars with the same letter are not significantly different (P≤0.05).

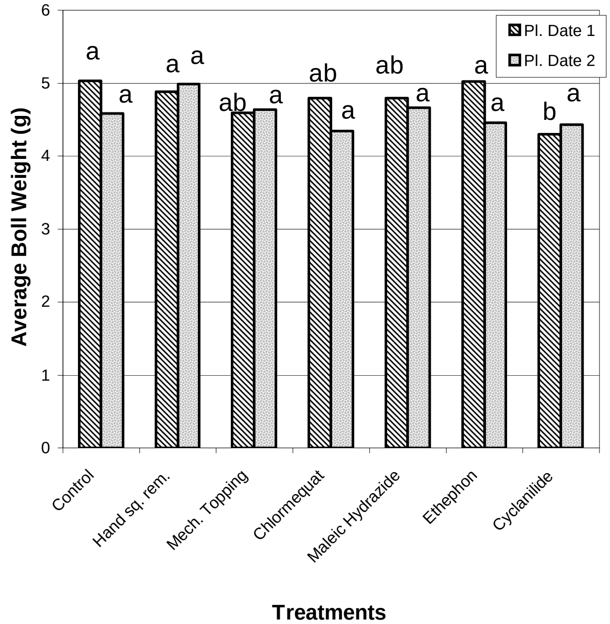

Figure 3. Effect of late-season upper-canopy fruit removal of average weights of first position bolls at NAWF=5. Clarkedale, Arkansas, 1999. Bars with the same letter are not significantly different (P≤0.05).

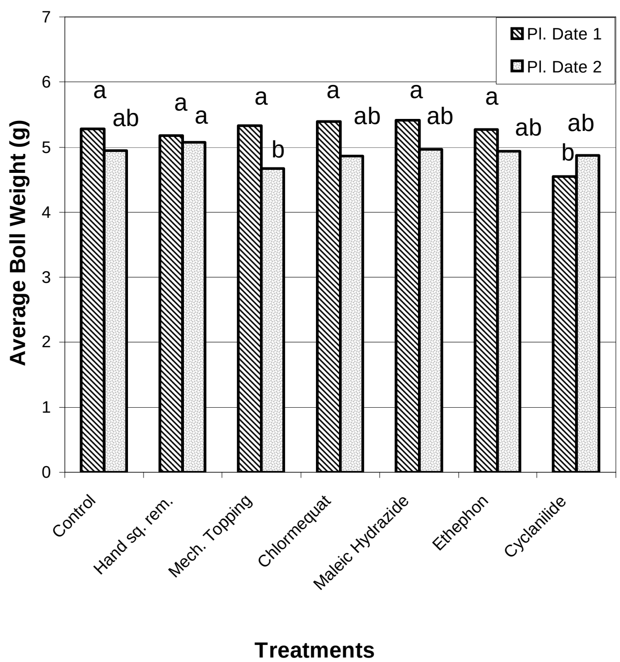

Figure 4. Effect of late-season upper-canopy fruit removal on average weights of first position bolls at NAWF=5. Rohwer, Arkansas, 1999. Bars with the same letter are not significantly different at (P≤0.05).