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THERMAL DEFOLIATION

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Abstract

An apparatus designed to defoliate cotton with hot air was tested in two varieties and two field conditions. Cotton defoliation using hot air was as effective as defoliation using typical chemicals under some conditions. Aphid populations were eliminated by the thermal treatment, reducing the risk of producing sticky cotton. The trash content of cotton defoliated by thermal and conventional means were similar. Fiber properties were the same when compared to either chemical defoliation or no defoliation. Seed germination rates were also unchanged.

Background

Defoliation of cotton by thermal energy was first attempted as early as 1963 (Kent and Porterfield, 1967). Hot air treatment using an oven-like device transported through the field resulted in 80% defoliation (Porterfield and Batchelder, 1969). Experiments with thermal defoliation were not continued because it was difficult to achieve a reasonable ground speed without scorching the fiber (higher speeds required higher temperatures). Recent experiments using steam attempted to reduce scorching but resulted in inadequate leaf drop (Funk et al., 2001).

Research Objectives

The overall project goal is to develop an alternative defoliation method for organic production. The objective of this study was to compare defoliation (leaf drop) using a new thermal defoliator to defoliation resulting from a conventional tank mix of desiccant, defoliant and boll opener and to no treatment (green picked) in two varieties and two soil types. Insect mortality and seed and fiber properties for each treatment were also contrasted.

Materials and Methods

Preliminary Study

Seedlings donated by the Animal and Plant Health Inspection Service were raised under artificial light in the laboratory until attaining an average height of 18 inches. Plants were randomly selected and assigned to treatment levels corresponding to a central composite design with three parameters (temperature, time and air velocity) each at five levels. A scale model of a crop canopy tunnel was constructed in the laboratory and the seedlings were exposed to hot air at temperatures from 215 to 485 F and velocities from 650 to 7400 ft/min and then removed after from 3.5 to 8.5 seconds. Total percent defoliation (leaf drop counted 14 days after thermal treatment) was found to be a linear function increasing with temperature, almost independent of dwell time and air velocity.

Apparatus Design

Addressing earlier problems (temperature being a function of ground speed) the new defoliator has a long treatment chamber and high air velocity, improving both convective heat transfer and canopy penetration. The single-row defoliator was constructed such that its 10 foot long towed passageway supported an air handling system. A separate trailer carried a 1,000-gallon propane tank (Figure 1). A 2.5 million BTU/hr propane burner provided heat and a 9,000 cfm fan powered by a 15 hp hydraulic motor forced the heated air into the crop canopy through 572 one inch diameter nozzles at 2450 ft/min. Air was recirculated to reduce fuel consumption (Figure 2).

Treatment Design

Two levels of thermal treatment were realized by operating at two ground speeds (1.8 and 1.1 mph). Both thermal treatments had the same burner set point temperature (430 F) resulting in a mean crop canopy temperature of 307 F as measured by thermocouples mounted throughout the system. Hot air entered the crop canopy first from one side and then the other. The crop was in the defoliator's tunnel for an exposure time of either 4.0 (low) or 6.6 (high) seconds. Two control treatments were also used to gage defoliation effectiveness, both green pick (no treatment) and chemical defoliation (applied by ground rig) with a typical tank mix of desiccant, defoliant and boll opener.

Experiment Design

Two varieties (Deltapine 565 and Acala 1517-99) were planted in four row plots with three skip-rows between each. The skip rows provided a passageway for the tractor pulling the prototype defoliator and the trailer carrying the propane fuel tank. Normal cultural practices for the Mesilla Valley were followed on an irrigated field adjacent to the Rio Grande River. Boll weevil eradication required Baythroid treatments. One treatment of growth regulator and an insecticide to control pink bollworm were also applied. Ample vegetative growth occurred at one end of the field where the soil was heavier clay. Lighter sandy soil dominated the other end of the field, producing short plants. In both cases yields were excellent (3 - 4 bales/acre).

For the defoliation part of the study the two fields were blocked by soil type. For insect mortality and post-harvest tests (germination, trash and fiber properties) the soil type was ignored. Treatments were randomly assigned to two row plots with the exception that chemical treatments were paired on adjacent two row strips to prevent possible cross contamination by drift. Defoliation was quantified by randomly selecting and permanently identifying four plants from each treatment plot and counting the leaves on those specific plants just before, and at 7, 14 and 21 days after treatment (DAT). Defoliation was verified by subjective visual quantification at 12 and 19 DAT.

Insect populations were monitored before, at 12 and at 19 DAT. Twenty-five plants were randomly selected from each plot, one leaf being removed from the lower half of each plant. The total number of motile aphids were counted on each leaf.

Post harvest processing tests included 1) wagon sample fractionation, 2) ginning machinery trash quantification, 3) seed germination, 4) HVI classing and 5) Shirley method trash analysis. Additional tests are planned. For seed production seed viability may be of concern, so two seed sub samples were collected for each of the four replicates per treatment. Four hundred seeds were germinated per sub sample at 20 C /30 C diurnal temperature cycle in incubation chambers and counted after 12 days.

Results

Field Results

Defoliation averages based on four sub samples from each of four plots per treatment are presented in Table 1. Soil type (and plant moisture content and architecture resulting from soil type) influenced plant response to thermal treatment, reducing it slightly in light sandy soil where plant height averaged 32 inches. In clay soil where the plant height averaged 60 inches, both the thermal and chemical treatments were equally effective (Figure 3).

Insect Mortality

In Acala 1517-99 the mean number of aphids per leaf was less than 10 prior to treatment. At 13 DAT populations increased in both chemical and untreated plots to 83 and 108. Mean aphids per leaf remained below 6 in plots with both thermal treatments. Aphid populations continued to climb in both Chemical and Green treatment plots, averaging over 450 per leaf at 20 DAT. In thermal treated plots aphid counts were less than 30.

In Deltapine 565 the before treatment count of motile aphids was also less than 10 per leaf. At 13 DAT aphid populations increased from less than five to over 80 in the chemical and untreated plots. Thermal treatment held aphid populations to below two per leaf. By 20 DAT mean aphid counts per leaf were 520 and 318 per leaf in chemical and untreated plots, and zero in both the low and high thermal treatment plots (Table 2).

Thermal treatment effectively prevented insect populations from growing in both varieties during the last stages of boll opening and maturing. Eliminating aphid populations can help prevent the formation of sticky cotton.

Trash Content

Weights of trash collected from gin machinery indicate all three defoliation methods improve the quality of ginned Acala. Defoliation reduced lint cleaner waste by 20 to 25 percent over green picked cotton (Table 3). Differences followed the same trend for the Delta Pine variety, but were not as large or statistically significant.

Fiber Properties
Length, short fiber content, maturity ratio, nep count, strength, elongation and uniformity were unaffected by the treatments suggesting that a brief exposure to heat did no damage to the fiber. Visible foreign matter by both AFIS and Shirley methods was significantly different (Table 4) indicating trash content reduction is the same for either thermal or chemical defoliation. Classing office data confirmed the benefit of defoliation by either means (Table 5).

Seed Germination
Germination rates were the same for all four treatments. The brief duration of elevated temperatures appears to be insufficient to impact seed viability, and the surrounding fiber possibly provides additional protection. Germination results are presented in Table 6.

Economics
The estimated cost of thermal defoliation is at least twice as much as chemical defoliation. The difference is primarily due to getting a machine through the crop at ground level. Compared to aerial applications ground rig operation is considerably more expensive. Naturally this comparison assumes crop dusting will remain permissible.

Conclusions

Desiccation was effective for all three treatments but the ability of the plant to completely shed its leaves may have been hampered by the weather. No treatment attained greater than 80% defoliation due to cool nighttime and warm daytime temperatures. Both varieties responded to thermal treatment almost as well as to chemical treatment. Soil type influenced plant response to thermal treatment, reducing it slightly in sandy soil. However, for the taller plants in clay soil thermal and chemical treatments were equally effective. Also, moist soil may increase cell turgidity.

Thermal defoliation by hot air resulted in immediate and continued suppression of aphid populations. Warm fall temperatures otherwise are conducive to rapid aphid population increases that result in sticky cotton.

Lower levels of trash in ginned fiber confirmed the benefits of defoliation in general but ginning machinery waste measurements showed no difference between defoliation method. ARS Spinning Lab and AMS Classing Office fiber property measurements conclude defoliated lint is cleaner and thermal defoliation does not damage the fiber.

References

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Disclaimer

Names are necessary to report factually on available data; however the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may be suitable.

Table 1. Defoliation results 14 Days After Treatment. Percent leaf drop compared to day before treatment based on counting leaves on 4 plants per sample, 4 samples per replicate, 4 replicates per treatment.

	Acala 1517-99		**Deltapine 565**	
Variety Soil	**Heavy**	**Light**	**Heavy**	**Light**
Chemical	81 a	88 a	89 a	87 a
High Thermal	82 a	54 b	84 ab	55 bc
Low Thermal	62 b	61 b	79 b	64 b
Control (Green)	21 c	33 c	43 c	48 c
MSE	129	73	31	91
t Critical	2.18	2.18	2.18	2.18
L.S.D.	17.5	13.2	8.6	14.7

*Means with the same letter are not significantly different.

Table 2. Insect Counts. Mean number of motile aphids per leaf based on average of l leaf per plant, 25 plants per plot, 4 plots per treatment.

	Acala 1517-99			**Deltapine 565**		
Variety Date	**29 Sep Before**	**14 Oct 12DAT**	**21 Oct 19DAT**	**29 Sep Before**	**14 Oct 12DAT**	**21 Oct 19DAT**
Low Thermal	7.2 a	5.17	29.2 b	6.6	1.4 b	0.0 b
High Thermal	3.4 b	0	4.50 b	8.7	0.0 b	0.0 b
Chemical	3.5 b	83.4	488.3 a	8.5	178.0 a	520.3 a
Control (Green)	5.5 ab	108.5	592.9 a	6.8	155.0 a	318.3 a
F-val	3.75	2.48	19.85	0.61	4.24	16.59
OSL	0.0448	0.1173	0.0002	0.7166	0.0264	0.0002
MSE	1.556	3220.5	9107.4	9.66	5236.7	8336.7

*Means with the same letter are not significantly different.

Table 3. Trash Content. Pounds of lint cleaner waste collected per treatment (average of eight replicates per treatment).

Variety	**Acala 1517-99**		**Deltapine 565**	
Lint Cleaner	**LC #1**	**LC #2**	**LC #1**	**LC #2**
Chemical	11.78 b	3.95 b	10.40 a	3.13 a
High Thermal	11.18 b	3.53 b	10.95 a	3.13 a
Low Thermal	12.37 b	4.15 b	10.85 a	3.15 a
Control (Green)	15.10 a	5.13 a	11.22 a	3.50 a
MSE	1.20	0.23	1.33	0.08
Critical Range	1.69	0.74	1.77	0.44

*Means with the same letter are not significantly different.

Table 4. USDA-ARS Cotton Quality Research Station Clemson, SC fiber quality analysis. Mass percent visible foreign matter measured by AFIS and Shirley methods (sixteen replicates per treatment).

	Acala 1517-99		**Deltapine 565**	
Variety Method	**AFIS**	**Shirley**	**AFIS**	**Shirley**
Control (Green)	2.131 a	2.263 a	1.218 a	1.250 a
Low Thermal	1.800 ab	1.913 ab	0.925 a	1.025 b
Chemical	1.578 b	1.688 b	0.945 a	1.075 ab
High Thermal	1.505 b	1.525 b	0.998 a	1.125 ab
MSE	0.102	0.064	0.042	0.016
Critical Range	0.493	0.389	0.315	0.193

*Means with the same letter are not significantly different.

Table 5. USDA-AMS Classing Office Phoenix, AZ. Fiber properties are from HVI analysis (three replicates per treatment).

Variety	Acala 1517-99		Deltapine-565	
Measure	**HVI Trash**	**Color +b**	**HVI Trash**	**Color +b**
Control (Green)	2.50 a	9.29 a	1.50 a	8.03 a
Low Thermal	2.00 ab	8.88 b	1.13 b	7.91 a
Chemical	2.13 ab	8.78 b	1.13 b	7.84 a
High Thermal	1.50 b	8.70 b	1.13 b	7.70 a
MSE	0.266	0.689	0.047	1.01
Critical Range	0.794	0.404	0.334	0.491

*Means with the same letter are not significantly different.

Table 6. Seed Germination. Percent viable seeds, 400 seeds per sample, 2 samples per replicate, eight replicates per treatment.

Variety	Acala 1517-99	Deltapine 565
Control (Green)	80.0 a	76.9 a
Low Thermal	80.4 a	78.5 a
Chemical	82.0 a	79.8 a
High Thermal	82.4 a	78.3 a
MSE	7.4	7.4
Critical Range	2.8	2.8

*Means with the same letter are not significantly different.

Figure 1. Apparatus built to apply hot air to the cotton canopy. The hydraulic cylinder (on tractor toolbar) positions the device over the inner or outer row.

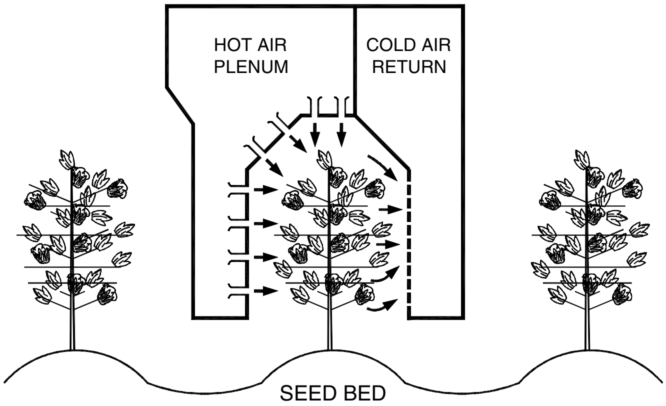

Figure 2. Section through treatment tunnel containing cotton canopy.

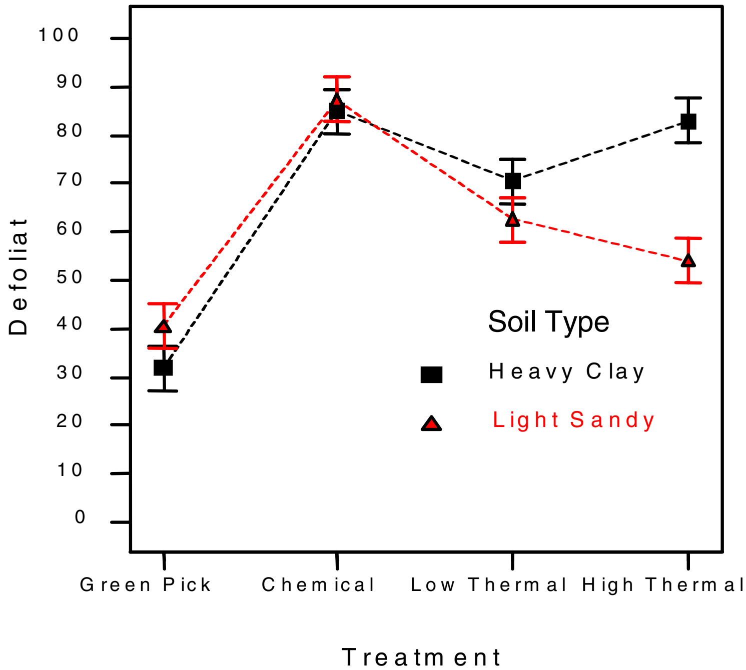

Figure 3. Interaction. Response to thermal treatment varied by soil type (average of both varieties). Whisker bars signify the 95% confidence interval for a particular average value. Overlapping bars are not significantly different.