2244 Alternative Cotton Harvest Preparation

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Abstract

Organic production practices, urban encroachment and the presence of certain protected crops on adjacent fields presently restrict the use of defoliant chemicals in some cotton acreage. New legislation or stricter interpretation of existing environmental regulations may greatly increase the amount of cotton acreage where organophosphate defoliants are prohibited. The US cotton industry is preparing to meet this possible challenge by developing crop termination technology that uses heat instead of chemicals. An experimental thermal defoliator was operated in California, New Mexico and Texas in 2002. A larger prototype unit was used from 2003 to 2006 for extensive trials in a variety of field conditions and cultivars. This paper summarizes physiological studies showing the efficacy of thermal defoliation and its impact on yield and harvest timing, fiber quality studies indicating no damage to lint value and entomological studies demonstrating reduced late season pest populations.

Introduction

The purpose of this paper is to summarize the results of thermal defoliation trials conducted from 2002 through 2006 at multiple locations in the Western United States. Each trial had a distinct objective, but all used both heat and conventional defoliant chemical treatments to prepare cotton for harvest. These multiple trials answer most of the basic questions about thermal defoliation: does it work; how long until the crop is ready for harvest; what impact does thermal treatment have on yield; do any fiber properties change; and what becomes of insect pests? Because all of these trials were conducted with a research two-row prototype apparatus it was not possible to accurately measure the economics that potentially might be attained with a commercial apparatus- research to answer that question is planned for 2007-2008.

To explain why cotton is defoliated, “Harvest aid chemicals, including defoliants, desiccants and boll openers, help to manage harvest timing and reduce harvest costs. Defoliation reduces field maintenance requirements by drying plant juices that otherwise would gum up picker spindles. Furthermore, spindle picker harvest efficiencies increase when foliage does not impede the spindles’ access to the cotton. Boll openers, such as ethephon, have been developed that are mixed into, and applied with, defoliant chemicals to open the bolls while the leaves are dropping off, facilitating once-over picking. In 90% of US cotton acreage, defoliation mixes eliminate the need for a second harvest some weeks later to pick cotton that was still inside closed bolls during the first harvest. Defoliation also facilitates air circulation and light penetration, reducing boll rot in cotton grown in damp climates. Together these harvest aids increase yields, improve quality, and lower capital and operating costs, as fewer pickers are required for a given area.” (Funk, 2004).

History

The practice of cotton defoliation by artificial means emerged in the United States as cotton harvest was mechanized during the 1950's and 1960's. While certain production areas, favored by a killing frost at the right time of year, may not always require chemical defoliation, untreated acreage has become rare. Producers are under increasing pressure to achieve good leaf grades, avoid late season insect and weather damage, and make economical use of harvest labor and equipment.

Thermal defoliation of cotton was first patented in 1950 (Nisbet and Nisbet). A second patent and successful field trial reports came out of Oklahoma State University in the late 1960's (Kent and Porterfield, 1967, Porterfield and Batchelder, 1969, Batchelder et al., 1971). However, thermal defoliation failed to spread at that time because the existing field machine was considered too slow.

New Technology

Concerns over increasingly stringent air quality regulations revived interest in an alternative to chemical defoliation. To increase the area that could be treated in a given amount of time the USDA-ARS-Southwestern Cotton Ginning Research Laboratory developed a new heat treatment principle. Forcing air through the cotton canopy at over 12 $m\cdot s^{-1}$ (2400 $ft\cdot min^{-1}$) increases convective heat transfer, reducing the time required to heat the leaves (Funk et al., 2002). An experimental machine that could treat 0.09 $ha\cdot h^{-1}$ (0.23 $acre\cdot h^{-1}$) was built to prove the concept and identify the optimal temperature and exposure time.

A second machine was built following the same principles. This research two-row prototype apparatus was capable of treating 0.4 $ha\cdot h^{-1}$ (1 $acre\cdot h^{-1}$). It was self propelled and carried enough propane to operate for a day before refueling (Funk et al., 2004). The platform used to support the prototype thermal defoliator was initially a corn detasseling unit. It came equipped with an open tilt cab, two-wheel steering, four-wheel hydrostatic drive, auxiliary hydraulic power and a six cylinder gasoline engine. The platform had nearly two meters (six feet) of ground clearance, providing ample room for the defoliation apparatus (Funk et al., 2005). Figure 1 depicts the prototype machine.

The engine was converted to burn propane fuel from the same pair of 303 liter (80 gallon) tanks that supplied the burner. As well as the two propane fuel tanks, two electric vaporizers, a gas train with meter, a regulator, pilot, safety and control valves, and a 50 kW generator were also added to the platform. The defoliation apparatus was suspended beneath the platform. It could be raised with hydraulic cylinders to facilitate maneuvering in the field and self-loading for transporting. A framework of rectangular steel tubing supported crop dividers, treatment tunnels, fans, a burner, and distribution and return air duct work. The prototype thermal defoliator auxiliary hydraulic pump powered a 22.4 kW (30 Hp) motor turning two centripetal fans. The fans supplied 9,970 $l\cdot s^{-1}$ (21,130 $ft^3\cdot min^{-1}$) of air to a 732 kW (2,500,000 $BTU\cdot hr^{-1}$) propane burner where it was heated to 193 C (380 F). Hot air from the burner was forced through cotton plants passing through a pair of 4.57m (15 ft) long treatment tunnels. Figure 2 depicts the nozzles lining the treatment tunnel. Roughly 66% of the treatment air was recirculated to conserve energy. Estimated burner emissions were 70 ppm NOx and 300 ppm CO.

Test Locations and Objectives

Figure 3 is a map of field locations showing the year and location where experiments took place. Table 1 lists the year, location and objectives of each experiment. For the 2003 experiments in California and the 2006 experiments in Weslaco,TX, insecticides were included with the mix of desiccant and defoliant chemicals sprayed on the control plots, to measure their potential to reduce lint stickiness from late-season sucking insects. Otherwise all experiments were direct comparisons between thermal defoliation and treatment with the chemical defoliation tank mix most commonly used in the area where the trial took place. Some of the plots in Lubbock in 2004 were treated with a boll opening chemical (Ethephon) before thermal defoliation. Otherwise, all thermal treatments were chemical-free.

Findings

Ginning results (Funk et al., 2003)

Early work with the experimental (one row) thermal defoliator examined desiccation and defoliation responses for low, <93.5 $l \cdot ha^{-1}$ (<10 $gal \cdot ac^{-1}$), medium, 93.5-140, $l \cdot ha^{-1}$ (10-15 $gal \cdot ac^{-1}$), and high, >140 $l \cdot ha^{-1}$ (>15 $gal \cdot ac^{-1}$) propane use at Las Cruces. Comparisons were also made between thermal and chemical defoliation in stripper harvested cotton at Lubbock. An interesting finding was that though the leaf material in seedcotton was higher with thermal defoliation, leaf material in baled lint was less. It appeared easy for gin cleaning machinery to remove dry, crumbly thermally desiccated leaf matter.

Fiber and yarn properties (Funk et al., 2004a)

Follow-on research with the new prototype (two-row) thermal defoliator confirmed significantly better leaf and color grades and loan values when using more than 93.5 $l \cdot ha^{-1}$ (10 $gal \cdot ac^{-1}$) propane for heat treatments compared to conventional chemical defoliation. Other fiber quality properties measured by the USDA-AMS Classing Office High Volume Instrument (HVI) were unchanged. There were fewer thicks as well as a slight decrease in irregularities with yarn made from thermally defoliated cotton. All other spinning and yarn quality measures were not statistically different.

Impact on fiber value and yarn quality (Funk et al., 2004b)

Although no differences were measured in leaf grade, color grades were still significantly better with thermally defoliated cotton compared to chemically defoliated cotton, all other classing office measures of fiber value remaining the same for both treatments. Advanced Fiber Information System measures of fiber quality confirmed the HVI findings. Open-end spinning tests saw slight improvements (reductions) in opening/ cleaning waste and ends down with thermal defoliation, depending on variety. White specks and thicks were fewer in yarn spun from thermally defoliated cotton. All other measures of yarn quality were unchanged between chemical and thermal treatments.

Boll opener with heat (Funk et al., 2005)
This study compared thermal, chemical and frost defoliation with thermal defoliation following an application of a boll opener. While standard chemical defoliation, thermal defoliation alone and untreated control plots all experienced open boll counts that increased from about 60% to about 83% after 19 days, an application of 1.53 $l \cdot ha^{-1}$ ethephon combined with thermal defoliation 6 days later resulted in open bolls increasing from 63% to 99% over 19 days- a significant aid.

Insect mortality and stickiness mitigation (Bancroft et al., 2006)
Cotton from plots treated with a combination of defoliants and insecticide were compared to thermal and conventional chemical (defoliant alone) to see if stickiness could be reduced by reducing late season sucking insect populations. Data from high speed stickiness detector analysis was mined using sophisticated algorithms. Because lint stickiness is highly variable, and was at low levels the two years tested, differences were difficult to quantify.

Physiology of thermal defoliation (Showler et al., 2006)
Comparing leaf kill and leaf drop in thermal and chemical treatments in three fields over two years showed a fairly consistent pattern: thermal defoliation resulted in near-complete desiccation within 24 hours, where chemical defoliants required 7-10 days to approach that level of leaf kill. Leaf drop in thermally defoliated plots progressed slowly, usually by the fifth or sixth day chemical defoliation leaf drop exceeded thermal levels. Leaf drop from chemical treatments could reach 80-90% in 7 to 10 days, while thermal treatment leaf drop was approximately 60-65% at the end of two weeks. Killing the leaf with heat also appears to kill the abscission layer, sticking the leaves to the stalk. However, there were no differences in fiber value or seed quality. And thermal defoliation makes it possible to harvest in advance of adverse weather (like a hurricane).

Insect mortality (Bundy et al., 2006 and Bundy et al., 2007)
Some late-season sucking insects (whiteflies) survived thermal treatment (about 2% in upper leaves, 11% in lower leaves) but vanished completely within one to three days in the field. The heat (integrated area on a plot of temperature over time) required to kill all stages of insects is slightly greater than that required to cook cotton leaves. However, because thermal defoliation completely desiccates the leaf there is no food for whiteflies (or aphids) that may survive, and they either leave or starve.

Harvest timing (Funk et al., 2006)
Early harvest had been advocated as a method to increase harvest labor and equipment utilization or prevent significant losses from expected storms. Analysis of 138 plots from five locations over two years indicated no difference in yield, fiber value or gross return per hectare (acre) when comparing thermal defoliation with chemical defoliation. The same was true when comparing early harvest (two days after thermal treatment) with chemical defoliation harvested the usual two weeks after treatment. Though there was still a lack of statistical significance, slight yield differences were observed between early and normal harvest of thermally defoliated plots. An extra 12 days in the field added on the average 43$kg \cdot ha^{-1}$ (38 $lb \cdot ac^{-1}$) or \$60 ha^{-1} (\$24 ac^{-1}).

Remote sensing (Fletcher et al., 2007)
Color infrared photos taken six days after treatment from fixed-wing aircraft 500 m (1500 feet) above fields where thermal and chemical defoliation were being compared were scanned for digital comparison of pixel counts. This form of remote sensing resulted in desiccation and defoliation estimates that agreed with leaf counts made by trained observers on the ground. Remote sensing was validated as a potential tool for monitoring the effectiveness of thermal treatment.

Pesticide replacement (Liu, T.X. and R.E. McGee, unpublished)
Sweetpotato whitefly (Bemisia tabaci) adults were counted, using the leaf turn method, on the third leaf from the main terminal of 10 plants in each plot while nymphs counts were made from the fifth leaf of 10 plants in each plot. Cotton aphid (Aphis gossypii) were counted from the terminals of 10 plants in each plot and boll weevil (Anthonomus grandis) were sampled by picking up all dropped squares/bolls in a 3 m (10 ft) length of row within the treatment plot and counting adults, larvae and pupae. Three 'standard' chemical treatments (Dropp SC, Dropp SC +Def, and Ginstar) were compared to thermal defoliation and untreated (green) plots. Adult whitefly counts per plant were 15-42 with chemical treatment, 0-6 with thermal defoliation and 120-130 untreated. Whitefly nymphs per leaf averaged 10-15 with chemical treatment, 4-5 with thermal, and 100-110 green. Boll weevil damage in 3 m (10 ft) averaged 0.3-1.3 squares with chemical and 4.7 squares with thermal. As observed elsewhere, boll weevils are protected from heat inside the boll, so normal eradication measures are still required. (Showler et al., 2006).

Conclusion

The advantages of using heat to prepare cotton for harvest include:

- No fiber damage- bale value and yarn quality are the same with thermal defoliation as they are with conventional chemical defoliation.
- Equivalent treatment costs- Propane and defoliant chemicals have long cost approximately the same per acre as both rise and fall with crude oil prices.
- Heat treated cotton is ready to pick in two days- Producers can improve harvest equipment utilization as well as bring in their crop in advance of a storm.
- Weather independent- Treatment is possible on a windy day, before a rain, or when nights are colder. And treatment is independent of flight restrictions.
- Once is enough- Even Pima cotton is ready for harvest after just one treatment.
- Thermal defoliation is environmentally sound- There is no chemical drift to contaminate dwelling places, wildlife habitat, waterways, or nearby crops.
- There is no chemical residue- Thermal defoliation is approved for organic production, and thermal defoliation makes it possible to sell gin trash as feed.
- Kills bugs dead- 24 hours after thermal defoliation late season sucking insects are completely gone, killed outright or starved off, for "NO STICKY COTTON!!!"

References

Bancroft, J.S., R. Hutmacher, L. Godfrey, P. Goodell, M.R. Mcguire, P.A. Funk and S. Wright. 2006. Comparison of sticky cotton indices and sugar composition. *Journal of Cotton Science*. **10**:97-104.

Batchelder, D.G., J.G. Porterfield and G. McLaughlin. 1971. Thermal defoliation of cotton. In Cotton Defoliation-Physiology Conference, Proceedings of the Beltwide Cotton Production Research Conferences, January 12-13, 1971, Atlanta, GA. National Cotton Council, Memphis, TN, p. 36-37.

Bundy, C.S., P.A. Funk and R.L. Steiner. 2006. Impact of thermal cotton defoliation on late-season insect populations. In: Proceedings of the Beltwide Cotton Conferences, January 3-6, 2006, San Antonio, TX. CDROM, p. 1344-1351.

Bundy, C.S., P.A. Funk, S. Lowry and R.L. Steiner. 2007. Thermal cotton defoliation: impact on late-season whiteflies. In: Proceedings of the Beltwide Cotton Conferences, January 9-12, 2007, New Orleans, LA. CDROM, p. 260-262.

Fletcher, R.S., A. Showler and P.A. Funk. 2007. Surveying thermally-defoliated cotton plots with color-infrared aerial photography. *Crop Management* [online]. Available: http://www.plantmanagementnetwork.org/cm/.

Funk, P.A., C.B. Armijo, B.E. Lewis, R.L. Steiner and D.D. McAlister III. 2002. Thermal defoliation. Proceedings of the Beltwide Cotton Conferences, January 8-12, 2002, Atlanta, GA [CD ROM]. 6 p.

Funk, P.A., C.B. Armijo, D.D. McAlister, III, A.D. Brashears, J.S. Bancroft, B.A. Roberts and B.E. Lewis. 2003. Thermal defoliation. Proceedings of the Beltwide Cotton Conferences, January 6-10, 2003, Nashville, TN. pp. 2549-2553.

Funk, P.A., C.B. Armijo, D.D. McAlister III, A.D. Brashears, M.R. McGuire, B.E. Lewis, R.B. Hutmacher and B.A. Roberts. 2004a. 2003 Thermal defoliation trials. Proceedings of the Beltwide Cotton Conferences, January 5-9, 2004, San Antonio, TX. pp. 755-759.

Funk, P.A., C.B. Armijo, D.D. McAlister III and B.E. Lewis. 2004b. Experimental thermal defoliator trials. *Journal of Cotton Science*. **8**:230-242.

Funk, P.A. 2004. Thermal defoliation. in Encyclopedia of Agricultural, Food and Biological Engineering. New York. Dekker Publishing, Inc..

Funk, P.A., C.B. Armijo, A.D.Brashears, A.T. Showler, R.S. Fletcher, R.B. Hutmacher, L.D. Godfrey, M.R. McGuire and J.S. Bancroft. 2005. Thermal defoliation in 2004. In: Proceedings of the National Cotton Council, Beltwide Cotton Conferences, January 4-7, 2005, New Orleans, LA. CDROM, p. 648-656.

Funk, P.A., C.B. Armijo, A.T. Showler, R.S. Fletcher, A.D. Brashears and D.D McAlister III. 2006. Cotton harvest preparation using thermal energy. *Transactions of the ASABE*. **49**(3):617-622.

Kent, J.D. and J.G. Porterfield. 1967. Thermal defoliation of cotton. *Transactions of the ASAE* **10**(1), 24-27.

Porterfield, J.G. and D.G. Batchelder. Thermal defoliator. US Patent 3,442,262, May 6, 1969.

Showler, A.T., P.A. Funk and C.B. Armijo. 2006. Effect of thermal defoliator on cotton leaf desiccation, senescence, post-harvest regrowth, and lint quality. *Journal of Cotton Science*. **9**:229-237.

Table 1. Year, location and objective of each experiment.

Year	Location	Objective
2001	Las Cruces, New Mexico	Technical feasibility and fiber quality impact
	Las Cruces, New Mexico	Range of effective temperature and dwell time
2002	Las Cruces, New Mexico	Optimal temperature and dwell time
	Las Cruces, New Mexico	Feasible in chile peppers?
	Shafter, California	Field demonstration
	Five Points, California	Field demonstration
2003	Weslaco, Texas	Test new prototype unit
	Las Cruces, New Mexico	Test in three varieties
	Las Cruces, New Mexico	Fiber quality
	Las Cruces, New Mexico	Chile pepper response
	Shafter, California	Participate in beltwide insecticide study
	Visalia, California	Participate in beltwide insecticide study
	Five Points, California	Participate in beltwide insecticide study
	Lubbock, Texas	Test in stripper cotton varieties
	Lubbock, Texas	Ginning and fiber quality impact
2004	Weslaco, Texas	Physiology of response
	Weslaco, Texas	Remote sensing feasibility
	Shafter, California	Harvest timing study
	Five Points, California	Harvest timing study
	Las Cruces, New Mexico	Harvest timing study
	Las Cruces, New Mexico	Varietal trials
	La Union, New Mexico	Difference in organic Pima
	La Union, New Mexico	Difference in organic upland
	Lubbock, Texas	Harvest timing study
	Lubbock, Texas	Effect with ethephon (boll opener)
2005	Weslaco, Texas	Physiology of response (year 2)
	Weslaco, Texas	Remote sensing feasibility (year 2)
	Las Cruces, New Mexico	Insect mortality
	Las Cruces, New Mexico	Stickiness mitigation
	Las Cruces, New Mexico	Harvest timing study
2006	Mendota, California	Effectiveness in high-quality organic cotton
	Firebaugh, California	Effectiveness in field inaccessible by air
	Dos Palos, California	Effectiveness in urban area
	Weslaco, Texas	Pesticide replacement

Fgure 1. Research prototype machine used from 2003 through 2006.

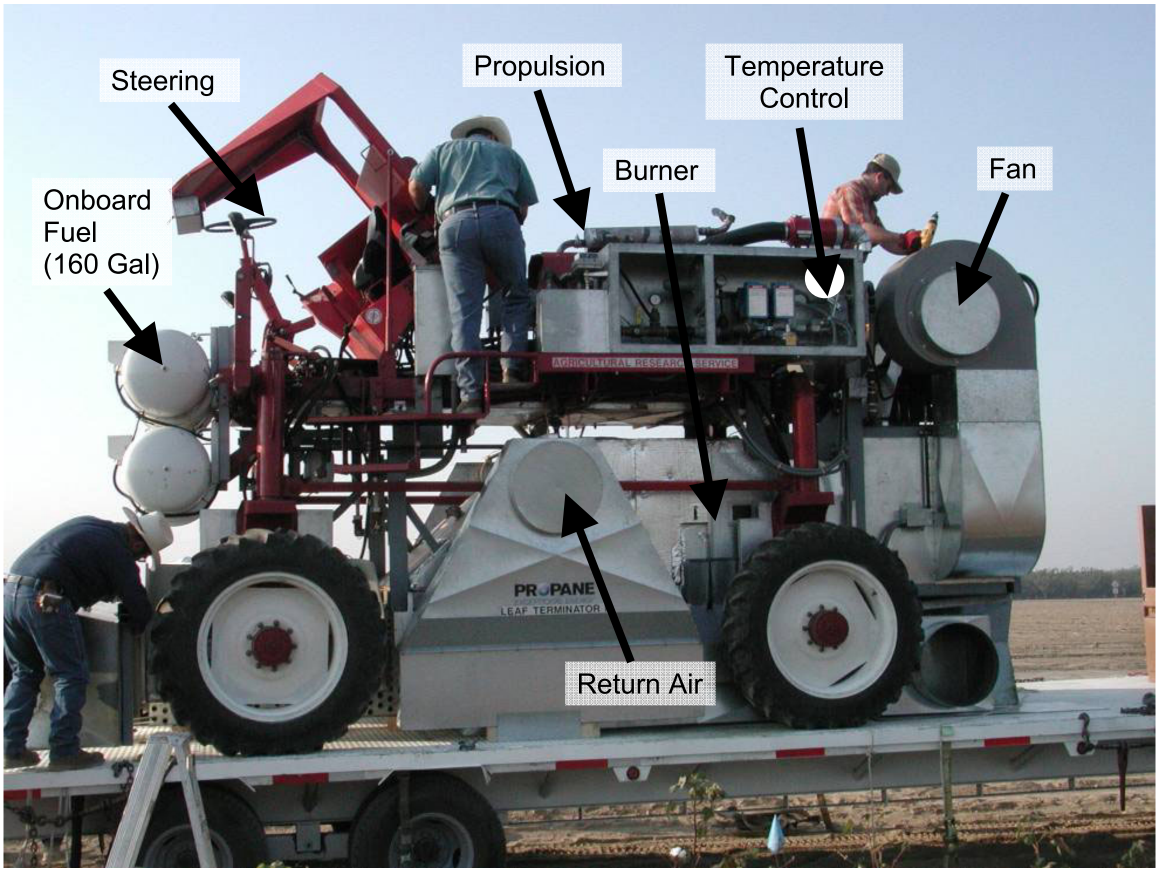

Figure 2. Treatment chamber with nozzles to direct hot air through the cotton canopy.

Figure 3. Map of field locations showing the year and location where experiments took place.