# Defoliation of California Pima and Upland cotton

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## ABSTRACT

*Growers need defoliants with different modes of action to insure continued best results under a variety of environmental and crop conditions. However, it also is important to consider the importance of prevailing environmental and crop conditions in determining a cost-effective approach for each field. Primary defoliant materials are generally limited to the organophosphates (OP) defoliants (Tribufos) or sodium chlorate and thidiazuron + diuron. Over 10 years of our research in cotton grown in the San Joaquin Valley of California has shown the organophosphates in combination with ethephon have provided the most consistent performance. Thidiazuron + diuron combinations, particularly when combined with ethephon have provided the second best performance. Rates of sodium chlorate and thidiazuron + diuron must be adjusted to achieve acceptable performance and to prevent leaves from sticking on the plants. Usually sodium chlorate has its best fit as a low cost second application to desiccate remaining leaves before harvest. Several defoliant enhancers such as endothall, cacodylic acid, dimethipin, paraquat, were evaluated. Under some conditions- rank growth, poor boll set, excessive moisture and/or nitrogen- these enhancers have increased efficacy when used in combination with thidiazuron + diuron or tribufos. Results in these studies demonstrate the strong influence of prevailing air temperatures and crop vigor at harvest aid application timing, but still indicate which materials consistently promote acceptable defoliation and desiccation in Acala and Pima cotton varieties typically grown in the San Joaquin Valley of California.*


## Introduction

Although it is one of the last management decisions in the cotton production cycle, defoliation timing and application are critical to producing a profitable crop. Improper timing will compromise both seed cotton yield and quality. In light of the premiums and discounts for fiber quality brought about with High Volume Instrumentation (HVI) measurements, proper choice and timing of harvest aid chemicals are of paramount importance. Ideally, the proper harvest aid materials should defoliate the entire plant within 14 days after application with minimal desiccation. However, plant maturity, moisture status, nitrogen status and environmental conditions dictate this response. The tight economics of cotton production today dictate that grower's do all that is possible to properly set up the crop for effective, reduced-cost defoliation that still protects lint quality and price. The best conditions for effective defoliation include the following: 1) Air temperatures from moderate to high (day time - >26.8 °C and night time - >10 °C; 2) Relatively low plant and soil nitrogen levels; 3) Moderate soil water levels (plants can't be water stressed); 4) Uniform crop development with crop at cutout; 5) Weeds, insect and disease under control; 6) Complete defoliant coverage with good penetration within the canopy.

## Types of California cotton

Types of cotton and sometimes even varieties must also be considered before making defoliation decisions. In 2002 California planted 281,000 hectares of cotton. Approved Acala comprised 59 percent, Pima was 36 percent, and non-Acala Upland was 5 percent of total hectares. Total Acala and non-Acala Upland hectares were 43% glyphosate-tolerant (Roundup Ready) cotton and about 6% bromoxynil-resistant (BXN) cotton. In the late 1990's and early 2000's, cotton lint yields in most commercial fields ranged from about 1100 to over 2200 kg per ha. Types of cotton widely grown in the San Joaquin Valley have been divided into three basic categories, which will be discussed in the following sections.

### Acala Upland

The exceptional fiber quality of approved Acalas and the environmental conditions of the San Joaquin Valley have, to some degree, "insulated" the California cotton crop from costly fiber quality penalties associated with too-early applications of harvest applications. Cotton merchants in today's markets may not be as forgiving with lower quality fibers. Most of the Acala defoliation studies have been conducted using the Acala variety "Maxxa". The mix of varieties which constitute the "Approved Acala" varieties from the San Joaquin Valley Cotton Board's testing program increasingly represent a range of growth types and leaf characteristics, so some differences in ease of defoliation can be expected across cotton represented in the Approved Acalas.

### California Upland

The cotton varieties that have been given the "CA Upland" designation are all Upland type cottons. Although these varieties are of the same genus and species (*Gossypium hirsutum*) of our California-origin Acalas, they represent a much broader range of genetic material and plant type. It may be important to be aware of the effects of defoliation on fiber quality when preparing some potentially lower quality cottons for harvest. Significant mistakes (such as early pre-treatment or defoliant applications) made on an Upland variety with some borderline quality characteristics could significantly affect the value of that fiber. Experiences through 2000 suggest that the California Uplands are

much easier to defoliate than Pima and in general, significantly easier and cheaper to defoliate than the approved Acala varieties. As more research and field experience is obtained, growers and consultants should be able to have more confidence regarding use of lower chemical application rates, less need for sequential applications, and an overall lower input cost approach in defoliating California Uplands. Figure 1 shows the defoliation differences between varieties Acala, Uplands and Pima with the verticillum wilt resistant Acalas and Pima being more difficult to defoliate than the Uplands.

### Pima

Because of its more indeterminate growth characteristics, Pima *(Gossypium barbadense)* cottons are more difficult and costly to defoliate than all California-grown upland varieties. Higher rates and sequential applications of harvest aid materials are usually needed to thoroughly desiccate remaining leaves. Some European mills have reported the presence of arsenic in Pima samples from the San Joaquin Valley due to excessive rates of cacodylic acid. A single application of cacodylic acid at label rates should avoid this problem or use alternative materials. Most of these Pima defoliation studies were conducted using the Pima S-7 variety.

## Experimental procedure

The primary objective of these studies is to define the most appropriate conditions for ideal defoliation and crop termination. An additional objective was to evaluate efficacy of alternative or new materials as harvest aids, including an evaluation of impacts of their use on fiber quality. Uniform fields of Acala variety "Maxxa" and Pima variety "S-7" were planted in April of each planting year on a 101.6 centimeters bed spacing which was divided into four row plots. Experimental design was four replications of 11 to 25 treatments utilizing a randomized complete block design. Standard cultural practices for San Joaquin Valley Acala and Pima varieties were used throughout the growing season. Defoliation treatments were applied starting in September each year, with the sequential treatments applied 14 days later. Treatment applications were made to Acala at 4 nodes above cracked boll (NACB), and Pima at 3 NACB. All preconditioning, defoliation and sequential treatments were applied with a Hagie High Cycle sprayer using TXVS-10 cone jet nozzles delivering a volume of 187 liters per hectare at 50 psi. Defoliation, desiccation, open boll, and regrowth were evaluated on a visual basis at 7, 14, and 21 days after treatment (DAT). Table 1 lists harvest aid materials evaluated in these studies.

## Results and Discussions

### Acala harvest aid trials - research (1996-2000)

Primary defoliant materials are generally limited to the organophosphate (OP) defoliants (tribufos), or sodium chlorate, thidiazuron + diuron and thidiazuron. Despite ongoing discussions about restricting the use of organophosphate (OP) defoliants in cotton, these studies have shown these materials provide some of the most consistent results year after year. Long-term University of California studies, however, have identified some specific conditions, which influence the performance of some materials versus others. With OP's, best results are usually obtained when they're applied in combination with ethephon. Thidiazuron when used alone has been more inconsistent in performance, especially with Acala Upland varieties. Sodium chlorate and thidiazuron + diuron, when applied at high rates in combination with warm to hot temperatures, can cause leaves to freeze or desiccate on the plant. Sequential applications of sodium chlorate can be used effectively for defoliation under some conditions, but it is most often used as a second application following an OP to desiccate remaining leaves before harvest. There are several defoliant enhancers, such as endothall, cacodylic acid, dimethipin and paraquat. Under some situations – rank growth, poor boll set, excessive moisture and/or nitrogen - these enhancers will increase efficacy when used in combination with thidiazuron or organophosphate.

Table 2 summarizes over 20 trials conducted in a Panoche clay loam soil at the University of California West Side Research and Extension Center (WSR&ES) in western Fresno County between 1996-2000, ranking the overall performance at 21 days after treatment for Acala defoliation and desiccation. The table also lists harvest aid material prices for 2002. This table can also be used to illustrate the difference that each season has on performance of preharvest aids. The field conditions that produced the results in 1997 are more representative of condition 1 (see summary) whereas the conditions that produced the results in 1996 and 1998 are more representative of condition 2. In 1996 the pretreatments combination provided the most effective defoliation. A grower must select a treatment that will perform the best under his or her field conditions. Material cost, efficacy, local and plant back restrictions will determine which treatment to use. Table 3 shows the regrowth ratings from 1993 to 1999 demonstrating the regrowth control with glyphosate and thidiazuron + diuron. Table 5 lists the advantages and disadvantages of the most common harvest aid treatments.

### Pima harvest aid trials - research summary (1995-2000)

Pima, because of its more indeterminate growth characteristics, is more difficult and costly to defoliate than Upland varieties. Higher chemical application rates and sequential applications are usually needed to thoroughly desiccate remaining leaves. Several treatments were evaluated at the University of California West Side

Research and Extension Center (Fresno County) on Pima S-7 between 1995 and 2000. It should be understood that performance of some materials may be somewhat different at other locations with different soil types, plant vigor, depth of crop rooting, and end-of-season soil water and nutrient levels. However, the WSR&EC location is representative of responses seen with Pima cotton under strong growth, high yield conditions, so should give a good relative indication of likely harvest aid performance. Table 4 lists the treatments that provided the most consistent defoliation/desiccation performance 14 – 21 days after treatment to Pima cotton (variety S-7) at a clay loam soil site located at the WSR&EC during the years 1995 though 2000. Cost of materials applied on a dollar cost per hectare basis only reflect material cost (not total application costs), and were based upon a phone survey of product retailers done in summer of 2000.

## Factors to consider when selecting a defoliation strategy for Acala and Pima

Defoliation decisions will have to be made on a field-by-field basis, due to the wide range of maturities. Whatever the situation; defoliation applications are based on the crop maturity. Fields that progress quite evenly into vegetative cutout and have a good boll load will be much easier to defoliate. There are at least a couple scenarios where treatments would be most likely to be cost effective based on field tests and observations. The following are two general situations.

**Condition 1. Fields with uniform boll load, abrupt cutout, and little vegetative growth**

- Under this condition lower labeled rates of most defoliants are effective.
- There is less potential for regrowth, thus less need for early glyphosate applications unless preharvest weed control is needed.
- Thidiazuron + diuron or tribufos treatments often give effective single shot defoliation.
- Ethephon treatments for boll opening are less critical, however, ethephon tank mixes will be useful in areas with aphids or whiteflies for faster leaf drop.
- If a second treatment is needed, sodium chlorate or paraquat applied alone or in combination will be very effective.

**Condition 2. Late plantings, low boll retention, rank growth in Upland and Pima**

- Under these conditions defoliants perform poorly. Regrowth and boll opening are a concern.
- Higher rates and sequential applications will be required to defoliate or desiccate remaining leaves.
- Pre-treatments with thidiazuron + diuron, thidiazuron, glyphosate, will enhance defoliation and reduce regrowth.
- Ethephon tank-mixes will help defoliation and boll opening.

The following web site (http://cottoninfo.ucdavis.edu) can be accessed for additional details of harvest aid performance under California conditions.

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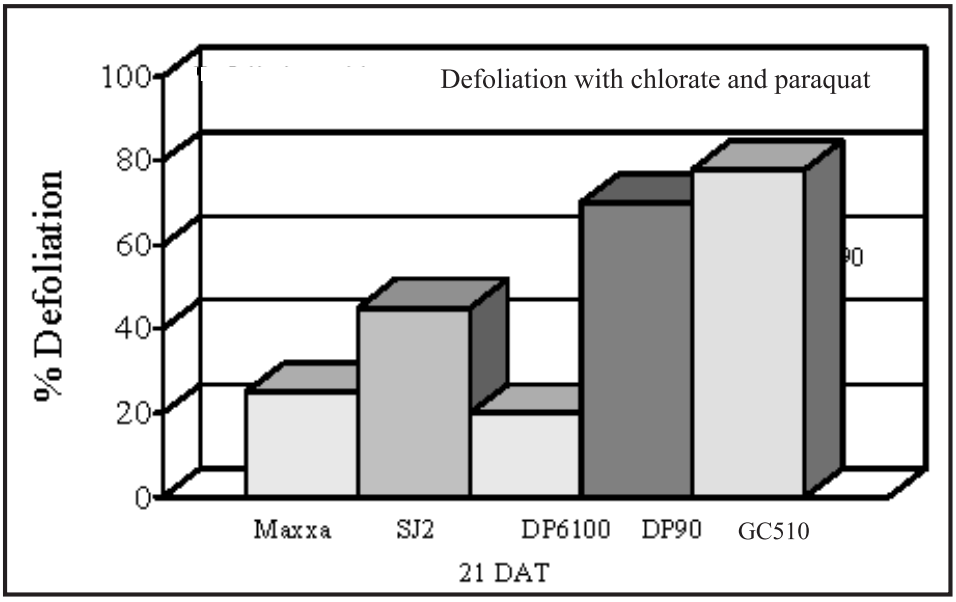


***Figure 1.*** *Variety x defoliation – 1992. Varieties differ with the Verticillium-tolerant Acala varieties (Maxxa, SJ-2, GC-510) being more difficult to defoliate than non-Acala Uplands (DP-6100 and DP-90 above).*

***Table 1.*** *Harvest aids tested in university of California studies.*

| Brand Name | Common chemical name/Formulation | Company |
|---|---|---|
| Agridex | *Crop Oil Concentrate* | Helena |
| Aim/Shark* | 40 DF *carfentrazone-ethyl* | FMC |
| AMS | *Ammonium Sulfate* | Monterey |
| Cotton-Aid | 3.25 lb/ G *cacodylic acid* | Monterey |
| Cotton Quik | 2.25 lb/G *ethephon & AMADS* | Griffin |
| Def 6 | 6 lb/G *tribufos* | Bayer |
| Defol 6 | 6 lb/G *sodium chlorate* | Monterey/Drexel |
| Dropp | 50 WP *thidiazuron* | Bayer |
| ET-751* | 0.2 EC *pyraflufen-ethyl* | Nihon Nohyaku |
| Finish | 6 lb/G *ethephon & cyclanilide* | Bayer |
| Folex | 6 lb/G *tribufos* | Amvac |
| Ginstar | 1.5 EC *thidiazuron & diuron* | Bayer |
| Gramoxone Max | 3 lb/G *paraquat* | Syngenta |
| Harvade 5F | 5 lb/G *dimethipin* | Crompton Uniroyal |
| Harvade 25F* | 2 lb/G *dimethipin* | Crompton Uniroyal |
| HM2047* | Adjuvant | Helena |
| Lint plus* | 2 lb/G *dimethipin* | Crompton Uniroyal |
| Prep | 6 lb/G *ethephon* | Bayer |
| Rocket | *d-Limonene* | Monterey |
| TADS 14806* | 6 lb/G *ethephon & cyclanilide* | Bayer |
| TADS 14782* | 6 lb/G *ethephon & cyclanilide* | Bayer |

* Experimental materials

***Table 2.*** *Acala defoliation summary (1996-2000).*

| | UCCE, WSR&EC Percent Defoliation (21 DAT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | Ave. 1996 - 2000 | Material U.S. Cost/ha |
| Treatment | | | | | | | |
| Tribufos (2.24 kg) + ethephon (2.24 kg) B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | 86 | 88 | 92 | 75 | -- | 85 | $42 |
| Ethephon (2.24 kg) + tribufos (2.24 kg) + paraquat (0.7 kg) B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | -- | 88 | 78 | 73 | -- | 80 | $37 |
| Thidiazuron + diuron (0.42 kg) B. Thidiazuron + diuron (0.56 kg) | 74 | 95 | 62 | -- | -- | 77 | $24 |
| Dimethipin (0.56 kg) + tribufos (2.24 kg) B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | -- | 83 | 80 | -- | 68 | 77 | $32 |
| Tribufos (2.24 kg) + ethephon (2.24 kg) + C.O.C (1.12 kg) | 87 | 55 | 79 | 77 | 79 | 75 | $30 |
| Tribufos (2.24 kg) + paraquat (0.7 kg) B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | -- | 87 | 74 | 73 | 63 | 74 | $24 |
| Thidiazuron + diuron (0.7 kg) | 37 | 70 | 50 | 75 | 74 | 60 | $18 |
| Thidiazuron + diuron (0.56 kg) $NaCLO_3$ (9.35 L) + paraquat (0.77 kg) B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | 36 / 26 | 68 / 87 | 20 / 12 | 82 / 65 | 71 / 71 | 55 / 52 | $12 / $23 |
| Tribufos (2.24 kg) + C.O.C (1.12 kg) | 55 | 52 | 33 | 55 | -- | 49 | $15 |

B. Treatments are secondary treatments applied 7 days after the initial treatment.

***Table 3.*** *Acala regrowth control (1993-1999).*

| | Percent regrowth control |
|---|---|
| Treatments with glyphosate (2.24 - 4.448 kg) | 80-92 |
| Tribufos (2.24 kg) + thidiazuron (.336 kg) + C.O.C (2.24 kg) | 65-87 |
| Thidiazuron + diuron (0.63 kg), thidiazuron + diuron (0.63 kg) + endothall (1.68 kg) or cacodylic acid (2.24 kg) | 55-80 |

***Table 4.*** *Pima defoliation summary (1995–2000).*

| | Defoliation Ratings (14 to 21 DAT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment (or combination of treatments) | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Avg. 1995-2000 | Material U.S. Cost/ha |
| Thidiazuron + diuron (0.7 kg) + ethephon (2.24 kg)<br>B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | 70 | 34 | 80 | 49 | 35 | 49 | 55 | $51 |
| Ethephon (2.24 kg) + thidiazuron (0.336 kg)<br>B. Thidiazuron + diuron (0.7 kg)<br>• $NaCLO_3$ (9.35 L) + paraquat (1.47 kg)<br>• $NaCLO_3$ (9.35 L) + tribufos (2.24 kg)<br>• $NaCLO_3$ (9.35 L) + cacodylic acid (1.46 kg) | 63 | 40 | 70 | 54 | 44 | -- | 54 | $43 – 56 |
| Thidiazuron + diuron (0.42 kg)<br>B. Thidiazuron + diuron (0.7 kg) | 61 | 39 | 73 | 41 | 57 | 46 | 53 | $25 |
| Dimethipin (0.56 kg) + thidiazuron + diuron (0.56 kg)<br>B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | -- | -- | 72 | 60 | 37 | 42 | 53 | $32 |
| Thidiazuron + diuron (0.91 kg) | 58 | 38 | 77 | 48 | 43 | 48 | 52 | $23 |
| Ethephon + AMADS (1.75 qt) + thidiazuron + diuron (0.7 kg) | -- | -- | -- | 50 | 55 | 41 | 49 | $48 |
| Thidiazuron + diuron (0.91 kg) + ethephon (2.24 kg) | -- | 19 | 73 | 48 | 32 | 48 | 44 | $29 |
| Ethephon (2.24 kg) + tribufos (2.24 kg)<br>B. $NaCLO_3$ (9.35 L) + paraquat (1.47 kg) | -- | 19 | 60 | 40 | 60 | 41 | 44 | $42 |

B. Treatments are secondary treatments applied 7 days after the initial treatment.

***Table 5.*** *Advantages and disadvantages of treatments.*

| Treatment | Advantages | Disadvantages |
|---|---|---|
| Thidiazuron + diuron | Very effective, no odor, regrowth control | Crop rotation restrictions |
| Tribufos + ethephon | Very effective, warm & cool weather performance | Odor, spray restrictions |
| Sodium chlorate + paraquat | Less effective cheap, warm-cool weather performance | Salts |