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ECONOMICS AND MARKETING

Effects of Defoliation Timing and Desiccation on Net Revenues from Ultra-Narrow-Row Cotton

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ABSTRACT

Criteria for profitable timing of cotton (*Gossypium hirsutum* L.) defoliation have not been determined for ultra-narrow-row cotton (UNRC). This study evaluated the effects of alternative defoliation timing and desiccation treatments on net revenues for UNRC. Cotton cv. PM 1218 BG/RR was planted in 25.4-cm rows at Milan, TN, in 2001, 2002, and 2003. Two defoliation timing criteria using heat-unit accumulation after node above white flower (NAWF) were evaluated. Main plot treatments were the standard defoliation criterion of NAWF = 5 plus 472 degree-days (DD) (base 15.6 °C) and a later defoliation criterion of NAWF = 2 plus 472 DD. Three desiccation treatments (paraquat, sodium chlorate, or no desiccant) were the subplot treatments and were applied 14 ± 1 d after each defoliation. Plots were harvested with a finger-type stripper 8 ± 1 d after each desiccation treatment. Price differences for fiber quality were calculated using fiber quality data measured from the experiment and North Delta spot price quotations. Net revenues were estimated using lint yields, price differences, and desiccation costs. Across years and desiccation treatments, delaying defoliation until NAWF = 2 plus 472 DD increased lint yield and net revenue by 9% relative to the standard NAWF = 5 plus 472 DD criterion. Applying a desiccant after defoliation did not adversely affect lint yield, price difference or net revenue, but desiccation slightly increased gin turnout, which may be an economic benefit to the ginner. Paraquat did not differ from sodium chlorate in effects on lint price differences and revenue. There were no significant timing-by-desiccation effects. Since seedcotton samples were not put into modules, these desiccation results may not apply to cotton stored in modules.

Timeliness of decisions made during production may be the most significant factor influencing the profitability of cotton (*Gossypium hirsutum* L.) (Brooking, 1997). Researchers have found that cotton crop termination can be scheduled on the basis of heat-unit accumulation after physiological cutout (cessation of effective flowering) or after the last effective bloom date for a given location (Stringer et al., 1989; Bourland et al., 1992; Bourland et al., 1997). Cutout establishes the last effective boll (LEB) population that significantly contributes to yield (Bourland et al., 1992). In studies used to develop cotton termination rules for wide-row cotton, yields began to stabilize at 472 degree-days (base 15.6 ºC) after cutout (Stringer et al., 1989; Bourland et al., 1992; Bourland et al., 1997).

The COTMAN Expert System uses degree-day (DD) accumulation after cutout to schedule cotton fields for defoliation (Cochran et al., 1998), which can help producers plan crop termination and harvest operations as early as mid-season. Late season crop management with the COTMAN model is based on identifying the LEB population that contributes to harvestable yields and ultimately to net revenues for a farmer. The model assumes that LEB is set either at five nodes above white flower (NAWF = 5), or the last effective bloom date based on historical weather for a location, whichever event occurs first. Research that established NAWF = 5 as the LEB was conducted in wide-row cotton (Bourland et al., 1992). Bourland et al. (1997) suggested that 472 DD should be accumulated after the last effective flowering date prior to defoliation.

Larson et al. (2002) found that defoliation between 472 and 528 DD after NAWF = 5 produced the largest net revenues for wide-row cotton under growing conditions in Tennessee. Their results indicate that additional yields and net revenues may

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be achieved by delaying defoliation to 528 DD after cutout. Terminating the crop earlier than 472 DD after cutout reduced fiber quality, lint yields, and net revenues. Gwathmey et al. (2004a) found that defoliation at NAWF = 5 plus 472 DD produced the earliest maximum yield in 9 of 16 test environments in the U.S. Cotton Belt.

Timing of harvest aids also may have an important impact on profitability of the production system commonly referred to as ultra-narrow-row cotton (UNRC). The row spacing of UNRC was originally defined as 25.4 cm or less (Atwell, 1996), but contemporary UNRC row spacings range from 19.1 to 38.1 cm (Parvin et al., 2000). Although production statistics are lacking, UNRC appears to occupy a relatively small but stable percentage of cotton area in the mid-South. A common characteristic of UNRC is the use of high plant population densities relative to wide-row cotton (Perkins, 1998; Jones, 2001; Delaney et al., 2002). Because row spacing is narrower and plant population is higher, UNRC plant growth and development differ from wide-row cotton (Gwathmey et al., 1999; Vories and Glover, 2002). Plants in UNRC typically are shorter, have fewer main-stem nodes, fewer bolls per plant, and produce less vegetative growth than plants in wide rows. These differences suggest that NAWF = 5 may not accurately represent the LEB population for the purpose of crop termination decisions in UNRC. Research from a regional UNRC project including Arkansas, Mississippi, North Carolina, Texas, and Tennessee found that the LEB population was set higher on the plant than NAWF = 5 in most environments (Gwathmey et al., 2003; Gwathmey et al., 2004b), so there is a need to develop alternative harvest-aid timing criteria for profitable UNRC production.

Another important issue with the harvest-aid decision for UNRC is the potential for a reduction in lint quality due to harvest method. A common practice in UNRC is the use of a finger-type stripper harvester instead of a spindle picker. Finger-stripping cotton may result in more leaf and bark content in the lint than spindle picking, because the stripper harvests more of these extraneous plant parts, and they are not completely removed during lint cleaning (Valco et al., 2001). Higher plant population densities in UNRC were associated with larger price discounts for lint quality (Larson et al., 2004). Fiber discounts at higher plant population densities were mainly due to higher leaf grade and lower micronaire values. More leaf trash in the lint was associated with leaves observed to be remaining on plants at harvest. Juvenile leaves in plant terminals were desiccated by harvest aids but did not fall from the plants prior to harvest, which contributed leaf trash proportionally to plant population density. The occurrence of bark discounts did not vary with plant population density but did vary with growing seasons.

Cotton intended for stripper harvesting is often prepared for harvest in a two-step sequence in which a desiccant is applied after a defoliant and boll opener (Supak and Banks, 2001; Hayes and Gwathmey, 2001). Desiccation is mainly intended to reduce moisture content of seedcotton to minimize the possibility of heat damage during module storage (Supak and Banks, 2001). The rate and extent of desiccation depend on the products used, weather, and crop condition (Crawford et al., 2001). Common desiccants include paraquat and sodium chlorate. Paraquat reacts with oxygen to form free radicals that disrupt cell membranes, causing rapid moisture loss, whereas sodium chlorate is an oxidizing agent that acts as a desiccant at high concentration (Cothren et al., 2001). Sodium chlorate usually desiccates the crop more slowly than paraquat (Hayes and Gwathmey, 2001). The manufacturer specifies 7 d until harvest after sodium chlorate (Drexel Chemical Co., 2004) versus 3 d to harvest after paraquat application (Syngenta Crop Protection, 2004). While the benefits of desiccation of stripper-harvested cotton for module storage are well documented (Supak and Banks, 2001), little information has been published on the direct effects on fiber quality of desiccant application after boll opening.

Given the potential for different growth and development with UNRC than in wide-row cotton, and the need for clean, dry cotton for UNRC harvest, different criteria for timing harvest-aid application may be required for profitable UNRC. The general objective of this study was to determine profitable harvest-aid strategies for UNRC in short-season environments, such as Tennessee. Specific objectives were to determine if UNRC lint yields, fiber quality, and net revenues improved by timing defoliation by heat-units after NAWF = 2 instead of NAWF = 5. Other objectives were to determine if UNRC fiber properties and lint prices are altered by application of a desiccant prior to harvest and to determine if sodium chlorate is more cost-effective than paraquat in desiccating UNRC.

MATERIALS AND METHODS

Cotton yield data. Lint yield and fiber quality data were taken from a UNRC harvest-aid study conducted from 2001 through 2003 at the University of Tennessee Agricultural Experiment Station at Milan, TN. The cotton cv. PM 1218 BG/RR was planted on 4 May 2001, 7 May 2002, and 13 May 2003 into a non-irrigated Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) for this study. This cultivar was used because it was planted on 54 to 74% of Tennessee cotton acreage in the three years of the study (USDA-AMS, 2001-2003). Cotton was planted in 25.4-cm rows using a Kinze tandem planter (Kinze Manufacturing, Inc.; Williamsburg, IA) with no-tillage each year. Plant population densities averaged 239,000 plants ha^{-1} in 2001, 205,000 plants ha^{-1} in 2002, and 312,000 plants ha^{-1} in 2003. Standard no-tillage production and pest control practices for BG/RR cotton in Tennessee were followed (Tenn-AES, 2001).

Crop progress was monitored using the COTMAN Expert System 5.0 computer program (Cochran et al., 1998). Data on nodes above the highest first-position white flower (NAWF) were collected from 80 flowering plants at eight sites during flowering, 60 to 90 d after planting. Two defoliation timing criteria using heat units accumulated after the two NAWF thresholds were evaluated. The standard criterion for timing defoliation of NAWF = 5 plus 472 DD (base 15.6 °C) was compared with a later threshold of NAWF = 2 plus 472 DD. The standard cutout (NAWF = 5) dates occurred on 16 Jul 2001, 14 Jul 2002, and 21 Jul 2003. The later cutout (NAWF = 2) dates were 28 Jul 2001, 22 Jul 2002, and 27 Jul 2003. All of these cutout dates preceded the last effective bloom date of 8 August for Jackson, TN (Bourland et al., 1997), so crop-based termination rules were used to determine defoliation dates using the two degree-day cutout criteria each year. Daily maximum and minimum air temperatures were measured in a standard U.S. Weather Service instrument shelter at the Milan Experiment Station. Cumulative degree-days were calculated as described by Bourland et al. (1997).

Plots were arranged in a randomized complete block split-plot design with defoliation timing treatments assigned to main plots and desiccation treatments applied to sub-plots. Plots were re-randomized and each treatment combination was replicated four times each year.

A tank mixture of thidiazuron (Dropp 50WP, Bayer Crop Science; Research Triangle Park, NC), tribufos (Def 6EC, Bayer Crop Science; Research Triangle Park, NC), and ethephon (Prep 6SL, Bayer Crop Science; Research Triangle Park, NC) was used for both defoliation timing treatments. Defoliation at NAWF = 5 plus 472 DD occurred on 28 Aug 2001, 27 Aug 2002, and 8 Sep 2003. Application dates for the NAWF = 2 plus 472 DD criterion were 12 Sep 2001, 5 Sep 2002, and 17 Sep 2003. Tribufos rates were 0.32 kg ha^{-1} in 2001 and 2002, and 0.53 kg ha^{-1} in 2003. Thidiazuron was applied at a rate of 0.056 kg ha^{-1} and ethephon was applied at a rate of 1.68 kg ha^{-1} in all years of the study. Tank mixtures were applied in 168 or 187 L ha^{-1} aqueous solution by a self-propelled high-clearance sprayer operating at 276 kPa hydraulic pressure.

Three desiccation treatments were applied 14 ± 1 d after the two defoliation timing treatments. Paraquat dichloride (Gramoxone Max, Syngenta Crop Protection; Greensboro, NC) was applied at 0.56 kg ha^{-1} using a 0.25% v/v nonionic surfactant. Sodium chlorate (Defol 6SL, Drexel Chemical Company; Memphis, TN) was applied at a rate of 6.72 kg ha^{-1}. The third treatment was no desiccant. Desiccation treatments following the standard NAWF = 5 plus 472 DD defoliation were applied on 12 Sep 2001, 10 Sep 2002, and 23 Sep 2003. Desiccation treatments following the NAWF = 2 plus 472 DD defoliation were applied on 26 Sep 2001, 18 Sep 2002, and 1 Oct 2003. Desiccants were applied in 146 or 173 L ha^{-1} aqueous solution through a spray boom pressurized to 276 kPa by CO_2, attached to a self-propelled high-clearance sprayer.

Each plot was harvested with a John Deere 7450 harvester (Deere & Company; Moline, IL) equipped with a 3-m finger-type header and bur extractor. Harvest dates for the early harvest-aid application plots were 21 Sep 2001, 18 Sep 2002, and 30 Sep 2003. The later harvest-aid application plots were harvested on 3 Oct 2001, 25 Sep 2002, and 8 Oct 2003. All harvests occurred after solar noon each day to minimize moisture in the harvested cotton. Seedcotton harvested from each plot was weighed at harvest, and a grab sample was taken from each plot, weighed, and air-dried before ginning. Seedcotton samples were ginned with a 20-saw gin (Continental Gin Company; Prattville, AL) equipped with a stick machine, dual incline cleaners, and two lint cleaners located at the West Tennessee Experiment Station, Jackson TN. Processes of this gin assembly resemble those of a commercial gin. Lint was weighed to calculate gin turnout, and a subsample of lint was analyzed by high volume instrument (HVI) testing and hand-classing procedures at the USDA Agricultural Marketing Service Cotton Classing Office in Memphis, TN (USDA-AMS, 1995).

Cotton price data. Quotations collected by the USDA, Agricultural Marketing Service were used to estimate premiums and discounts for UNRC fiber quality measured for each defoliation timing and desiccation treatment. Relevant quotations for Tennessee are from the North Delta market, which includes Northeast Arkansas, Missouri, and West Tennessee. Lint price differences for fiber quality associated with the base quality price of \$1.07 kg^{-1} for the 2002/2003 marketing year were used to evaluate UNRC price differences and net revenues as influenced by harvest aid treatment (USDA-AMS, 02003). Price differences for the 2002/2003 marketing year were assumed to be representative of the price differences faced by farmers growing UNRC.

The equation used to estimate lint prices differences for UNRC fiber quality as influenced by defoliation timing and desiccation treatment using North Delta market spot price data was as follows:

$$LPD_{ijt} = CLS_{ijt} + M_{ijt} + S_{ijt} + U_{ijt} + E_{ijt}, \qquad \text{[Eq. 1]}$$

where *LPD* was the total lint price difference for each harvest aid treatment *i* in the j^{th} experimental block from the base price of cotton (\$ kg^{-1}) for fiber quality obtained in year *t* of the experiment, *CLS* was the price difference for the combination of color grade, leaf grade, and staple (\$ kg^{-1}); *M* was the price difference for micronaire (\$ kg^{-1}); *S* was the price difference for strength (\$ kg^{-1}); *U* was the price difference for length uniformity (\$ kg^{-1}), and *E* was the price difference for extraneous matter (\$ kg^{-1}).

Net revenues. The net impacts of defoliation timing and desiccation treatment on lint yields, lint prices adjusted for fiber quality, and production costs were evaluated using partial budgeting techniques (Dillon, 1993; Dillon, 1994). With partial budgeting, only the cost and revenue items that change because of a decision were considered in the analysis. Cost and revenue items that do not change with the decision were ignored. The following partial budgeting equation was used to estimate net revenues (*NR*) for each defoliation timing and desiccation treatment *i* as follows:

$$NR_{ijt} = (BLP + LPD_{ijt}) \times LY_{ijt} - DC_{i}, \qquad \text{[Eq. 2]}$$

where *BLP* was North Delta base quality lint price (\$ kg^{-1}), *LPD* was the total price difference for each treatment that was defined previously (\$ kg^{-1}), *LY* was lint yield measured for each treatment (kg ha^{-1}), and *DC* was the desiccation materials and application costs for each treatment (\$ ha^{-1}). The value of cottonseed was assumed to cover the costs of ginning and handling. The cost of materials for the thidiazuron-tribufos-ethephon tank mixture was the same for the two defoliation timing treatments and was not included in the calculation of net revenues. The other harvest and production costs do not change with the defoliation timing and desiccation treatments and also were not included in the calculation of net revenues.

Materials costs for the paraquat dichloride (\$19.60 ha^{-1}) and sodium chlorate (\$12.11 ha^{-1}) desiccation treatments were calculated using prices from the Tennessee Farmers Cooperative suggested retail price list (Tennessee Farmers Cooperative; LaVergne, TN). Prices were multiplied by the application rate for each treatment. Machinery and labor expenses of \$8.99 ha^{-1} for a 14.2 m self-propelled boom sprayer to apply the paraquat and sodium chlorate desiccation treatments were included in the calculation of treatment costs (Gerloff, 2004).

Analysis. Statistical analyses of lint yields and fiber quality attributes, along with price differences and net revenues, were performed using the mixed model procedure in SAS (release 9.1, SAS Institute, Inc.; Cary, NC) (Littell et al., 1996). The mixed procedure provides Type III *F* statistical values but does not provide mean square values for each element within the analysis or the error terms for mean separation, so a macro for converting mean separation output to letter groupings with the mixed model procedure was used to evaluate mean separation among treatments through a series of protected pair-wise contrasts (Saxton, 1998). A probability level of 0.05 was used for the mean separation comparisons. Statistical analysis results are reported for the main plot (defoliation timing) and subplot (desiccation treatment) effects estimated with the mixed model. Because both individual year and multiyear comparisons can provide useful information for harvest aid decision making in UNRC, mean separation results were evaluated for each year of the experiment and were also summarized for the 3 yr of the experiment.

RESULTS AND DISCUSSION

Lint yield and gin turnout. Defoliation timing significantly influenced lint yields (*P* = 0.004) and gin turnout (*P* = 0.007) in the 3-yr study, but there were significant year-by-timing interaction effects on yield (*P* = 0.039) and gin turnout (*P* = 0.001). Desiccation treatments did not significantly affect lint yields, but they did affect gin turnout (*P* = 0.021). There was also a significant desiccation-by-year interaction for gin turnout (*P* = 0.003). There were no significant defoliation timing-by-desiccation interactions for any responses measured in the study.

In 2001, delaying defoliation until NAWF = 2 plus 472 DD increased lint yields 19% (232 kg ha^{-1}) relative to the standard NAWF = 5 plus 472 DD criterion (Fig. 1). A significantly lower gin turnout contributed to the lower lint yields observed with earlier defoliation (Fig. 1). Gin turnout in 2001 averaged 31.7% for cotton defoliated at the earlier NAWF=5 plus 472 DD compared with 36.0% for cotton defoliated later at NAWF=2 plus 472 DD.

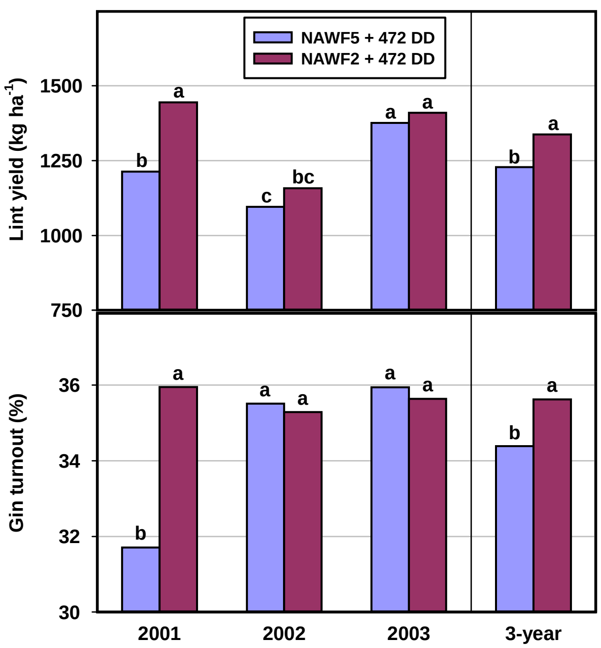

Figure 1. Defoliation timing effects on lint yield and gin turnout of ultra-narrow-row cotton averaged across desiccation treatments in 2001, 2002, and 2003, and 3-yr means. Within yearly data and 3-yr data, bars topped by the same letter are not significantly different (*P* = 0.05) according to paired comparisons.

Neither lint yield nor gin turnout was significantly influenced by defoliation timing in the 2002 and 2003 growing seasons, but defoliating at the later NAWF = 2 plus 472 DD date did produce a 3-yr lint yield mean that was 9% (109 kg ha^{-1}) larger than the mean yields obtained using the standard NAWF = 5 plus 472 DD criterion. In each year of the experiment, defoliating at NAWF = 2 plus 472 DD provided similar or higher lint yields than the standard NAWF = 5 plus 472 DD criterion, depending on the growing season. Over the 3 yr of the experiment, gin turnout averaged 35.6% when UNRC was defoliated later, which was significantly higher than the 34.4% gin turnout obtained using the standard defoliation timing criterion. These UNRC lint yield results are consistent with Larson et al. (2002), who found that delaying termination of wide-row cotton later than NAWF = 5 plus 472 DD increased lint yields.

Although desiccation treatments did not affect lint yields, application of desiccants significantly increased gin turnout relative to no desiccation (Fig. 2). In 2002, application of paraquat and sodium chlorate resulted in gin turnouts of 36.4% and 35.6% gin turnout, respectively. Cotton receiving no desiccant in 2002 had 34.2% gin turnout. Gin turnout was not significantly influenced by desiccation treatments in 2001 or 2003. Over the 3 yr of the experiment, applying a desiccant provided significantly higher gin turnouts over no desiccant (35.3%, 35.2%, and 34.5% for paraquat, sodium chloride, and no desic-

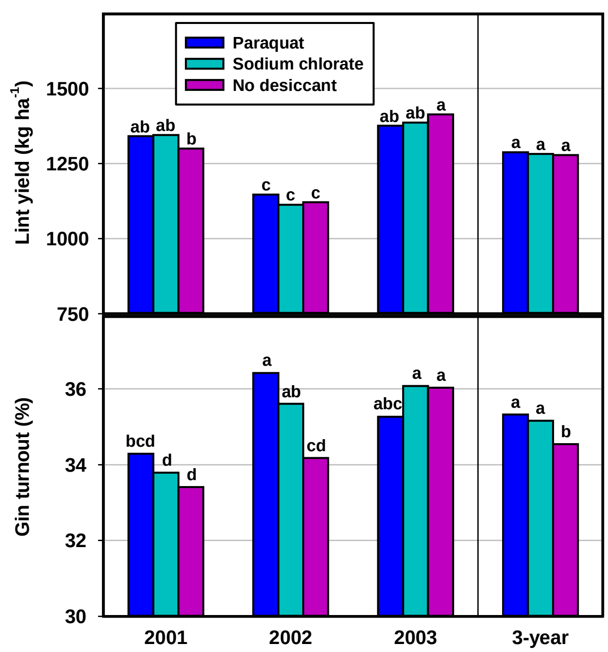

Figure 2. Desiccation treatment effects on lint yield and gin turnout of ultra-narrow-row cotton averaged across timing treatments in 2001, 2002, and 2003, and 3-yr means. Within yearly data and 3-yr data, bars topped by the same letter are not significantly different (*P* = 0.05) according to paired comparisons.

cant, respectively). Results indicate that, while there may be no additional yield benefits from using a desiccant in UNRC production, there may be a benefit to ginning efficiency. These results generally are consistent with Brashears et al. (1995), who worked with a brush-type stripper harvester equipped with a field cleaner.

Fiber quality. Defoliation timing and choice of desiccant did not impact the fiber strength, staple length, length uniformity, or extraneous matter content of UNRC (not shown). Over the 3-yr study, fiber strength averaged 284 kN m kg^{-1}, staple length averaged 26.7 mm, and length uniformity index averaged 82%. Defoliation timing had a consistent impact on micronaire. Delaying defoliation until NAWF = 2 plus 472 DD significantly increased micronaire values relative to the standard NAWF = 5 plus 472 DD criterion in each year of the experiment (Table 1). Over the 3 yr, micronaire averaged 47 for cotton defoliated at NAWF = 2 plus 472 DD, compared with 43 for cotton defoliated at NAWF = 5 plus 472 DD. In 2002, micronaire values for both defoliation timing criteria fell within the upper discount range (≥50) (USDA-AMS, 1995). The differences in micronaire price discounts for the two defoliation timing criteria will be discussed in the next section. These results are consistent with Larson et al. (2002) and Gwathmey et al. (2004a), who found that delaying defoliation later than NAWF = 5 plus 472 DD usually increased micronaire of wide-row cotton.

Desiccation treatment significantly influenced micronaire in only one of the three years of this study (Table 2). In 2003, desiccation with paraquat significantly reduced micronaire relative to no desiccation, but desiccating with sodium chloride did not produce significantly different micronaire than paraquat or no desiccant.

Defoliation timing and desiccation treatments had relatively inconsistent effects on trash and leaf grade from year to year in this study. The standard NAWF = 5 plus 472 DD timing criterion produced significantly higher HVI trash content and leaf grades in 2001 than the later defoliation treatment (Table 1). Incomplete defoliation was observed following the standard NAWF = 5 plus 472 DD application in 2001, which may explain the higher trash content and leaf grade values. In addition, poor defoliation with earlier termination was also associated with the lower gin turnout observed in 2001 (Fig. 1). In 2002 and 2003, HVI trash and leaf grade values for the standard defoliation criterion were not significantly different from the values observed for later defoliation.

Defoliation timing had a small but significant impact on the HVI trash content for the 3 yr (Table 1). Delaying defoliation from NAWF = 5 plus 472 DD to NAWF = 2 plus 472 DD lowered mean HVI trash from 0.64% to 0.49%. The corresponding difference in mean leaf grades were not statistically significance (P = 0.071). Few leaf grades exceeded the base quality leaf grade of 4.

Table 1. Effects of defoliation timing on micronaire, trash content, classer's leaf grade, reflectance (Rd) and yellowness (+b) of lint averaged across desiccation treatments for 2001, 2002, and 2003, and 3-yr means

Year	Defoliation timing[x]	Micronaire	HVI trash (%)	Leaf grade	Color Rd (%)	Color +b[y]
2001	NAWF5 + 472DD	37 e[z]	0.83 a	4.4 a	77.1 b	8.2 cd
2001	NAWF2 + 472DD	44 c	0.45 c	3.8 bc	79.8 a	8.0 d
2002	NAWF5 + 472DD	51 b	0.48 bc	3.3 c	75.6 c	8.5 abc
2002	NAWF2 + 472DD	53 a	0.45 c	3.4 c	74.5 d	8.6 ab
2003	NAWF5 + 472DD	41 d	0.63 c	4.0 ab	79.1 a	8.6 a
2003	NAWF2 + 472DD	43 c	0.58 bc	4.0 ab	79.7 a	8.3 bcd
3 yr	NAWF5 + 472DD	43 b	0.64 a	3.9 a	77.3 b	8.4 a
3 yr	NAWF2 + 472DD	47 a	0.49 b	3.7 a	78.0 a	8.3 a

[x] NAWF5 + 472DD = defoliation at 5 nodes above white flower plus 472 degree-days (base 15.6 °C) on 28 Aug. 2001, 27 Aug. 2002, and 8 Sept. 2003. NAWF2 + 472DD = defoliation at 2 nodes above white flower plus 472 degree-days (base 15.6 °C) on 12 Sept. 2001, 5 Sept. 2002, and 17 Sept. 2003.

[y] Due to the rounding of color +b (yellowness) values to the nearest tenth, mean separation letters may be inconsistent but accurately reflect the results of the analysis.

[z] Within yearly data and 3-yr data, means within a column followed by the same letter are not significantly different (P = 0.05) according to paired comparisons (Saxton, 1998).

Desiccation treatment did not have a consistent year-to-year impact on HVI trash (Table 2). In 2003, paraquat produced a significantly larger HVI trash content (0.70%) compared with the sodium chloride (0.51%) but not when compared to no desiccant (0.59%). This difference was not reflected in classer's leaf grades. In 2001, leaf grades of cotton treated with sodium chlorate averaged 4.4, which was significantly higher than those from paraquat (3.9) or no desiccant (4.0). In 2002, none of the desiccation treatments differed significantly in HVI trash or leaf grade. Averaged over the 3 yr of the experiment, desiccation did not have a significant impact on HVI trash or leaf grade.

The color grade of cotton fiber is determined by the degree of reflectance and yellowness (USDA-AMS, 1995). Reflectance indicates the brightness or dullness the cotton lint, while yellowness indicates the degree of color pigmentation. Timing of crop defoliation had a significant but inconsistent impact on UNRC reflectance values in 2001 and 2002 (Table 1). Delaying defoliation from NAWF = 5 to NAWF = 2 plus 472 DD increased reflectance in 2001, but decreased reflectance in 2002. In 2003, defoliation timing did not affect reflectance, but the later defoliation decreased yellowness. Averaged across the 3-yr study, reflectance was increased by delaying defoliation to NAWF = 2 plus 472 DD, but yellowness was not affected.

Over the three years of the study, there was a slight improvement in the number of samples that received a color grade of 21 (strict middling) with the later defoliation criterion. Of cotton defoliated at NAWF = 2 plus 472 DD, 31% of samples received a color grade of 21, 47% received a color grade of 31 (middling), 3% received a color grade of 32 (light spotted strict middling) and 19% received a color grade of 41 (strict low middling). Of cotton defoliated at the standard NAWF = 5 plus 472 DD, 19% of samples received a color grade of 21, 64% received a color grade of 31, and 17% received a 41 color grade.

Desiccation treatment had a significant effect on the reflectance and yellowness values of cotton lint in one of 3 yr of the experiment (Table 2). For the 2002 growing season, both paraquat and sodium chloride produced significantly brighter fiber (higher reflectance values) than not applying a desiccant. Averaged over the 3 yr, desiccation with paraquat produced larger reflectance values than either sodium chlorate or not using a desiccant. In 2003, sodium chlorate reduced yellowness relative to paraquat, but was not significantly different from the no-desiccation treatment. None of the desiccation treatments produced significantly different yellowness values when averaged over the three years of the experiment.

Table 2. Effects of desiccation treatments on micronaire, trash content, classer's leaf grade, reflectance (Rd) and yellowness (+b) of lint averaged across timing treatments for 2001, 2002, and 2003, and 3-yr means

Year	Desiccation treatment	Micronaire	HVI trash (%)	Leaf grade	Color Rd (%)	Color +b[y]
2001	Paraquat	40 cd [z]	0.63 ab	3.9 bc	78.8 abc	8.1 d
2001	Sodium chlorate	40 d	0.69 a	4.4 a	78.1 c	8.1 cd
2001	No desiccant	40 cd	0.60 abc	4.0 b	78.4 bc	8.1 cd
2002	Paraquat	52 a	0.46 bc	3.3 d	75.6 d	8.6 ab
2002	Sodium chlorate	52 a	0.45 c	3.4 d	75.1 d	8.5 ab
2002	No desiccant	52 a	0.49 bc	3.5 cd	74.4 e	8.5 abc
2003	Paraquat	41 cd	0.70 a	4.0 ab	79.6 a	8.7 a
2003	Sodium chlorate	42 bc	0.51 bc	4.0 ab	79.3 ab	8.3 bcd
2003	No desiccant	43 b	0.59 abc	4.0 ab	79.3 ab	8.5 abc
3 yr	Paraquat	45 a	0.60 a	3.7 a	78.0 a	8.4 a
3 yr	Sodium chlorate	44 a	0.55 a	3.9 a	77.5 b	8.3 a
3 yr	No desiccant	45 a	0.56 a	3.8 a	77.3 b	8.3 a

[y] Due to the rounding of color +b (yellowness) values to the nearest tenth, mean separation letters may be inconsistent but accurately reflect the results of the analysis.

[z] Within yearly data and 3-yr data, means within a column followed by the same letter are not significantly different (P = 0.05) according to paired comparisons (Saxton, 1998).

Weather conditions during the desiccation periods may have influenced efficacy of desiccation treatments. Table 3 shows average daily weather conditions at the test location during the periods of desiccation treatment each year compared to historical averages for the same periods. Relative humidity data were not available for this location. With one exception (18 through 25 Sept. 2002), average daily evaporation exceeded precipitation during these periods, that suggest that drying conditions prevailed. Except for the same period (18 through 25 Sept. 2002), precipitation amounts were below historical averages. No killing freeze occurred before or during these periods. Some weather conditions generally favored crop desiccation regardless of treatment, potential differences between plots treated with a desiccant and no desiccant may have been reduced.

Lint price differences. Total lint price differences due to fiber quality were not significantly affected by defoliation timing in any year, or across the years of this study (Fig. 3). In 2001 and 2003, the total lint price differences averaged less than $0.05 kg^{-1}. In 2002, net price discounts of $0.087 and $0.131 kg^{-1} for defoliation at NAWF = 5 and NAWF = 2 plus 472 DD, respectively, were mainly attributable to high micronaire values >50 (Table 1). The micronaire price discount of −$0.097 kg^{-1} for later defoliation in 2002 was significantly larger than the −$0.056 kg^{-1} price discount received for the standard NAWF = 5 plus 472 DD criterion. Averaged over the 3-yr study, the later defoliation criterion produced an average micronaire price discount of −$0.031 kg^{-1} compared with −$0.019 kg^{-1} for cotton defoliated at NAWF = 5 plus 472 DD.

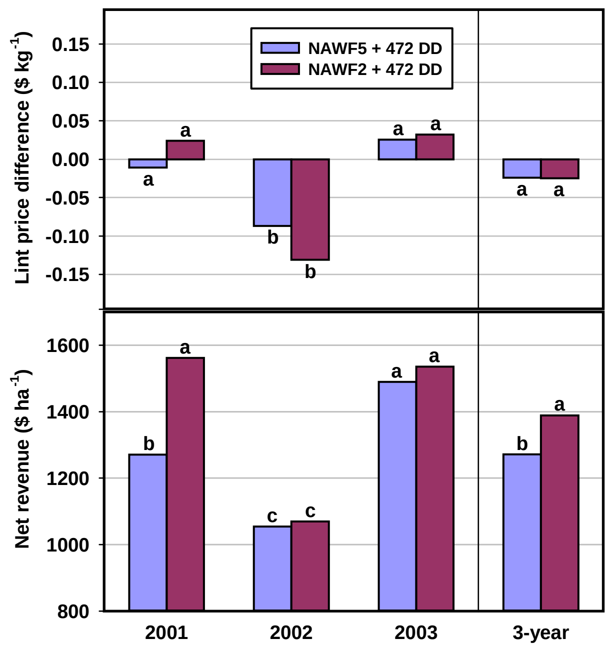

Figure 3. Defoliation timing effects on lint price differences and net revenues of ultra-narrow-row cotton averaged across desiccation treatments in 2001, 2002, and 2003, and 3-yr means. Within yearly data and 3-yr data, bars topped by the same letter are not significantly different (*P* = 0.05) according to paired comparisons.

Table 3. Average daily weather conditions at the Milan Experiment Station, Milan TN, during periods of desiccation periods in 2001, 2002, and 2003 compared to historical averages for the same periods

Year	Defoliation timing[y]	Desiccation period[z]	Ave. daily precip. (mm)	Ave. daily evap. (mm)	Ave. daily max. temp. (°C)	Ave. daily min. temp. (°C)
2001	1	12-21 Sept.	2.3	4.0	29.0	12.4
	2	26 Sept.- 3 Oct.	0.0	3.6	23.8	4.9
1984-2000		12-21 Sept.	3.6	4.5	29.4	13.3
		26 Sept.- 3 Oct.	3.5	3.9	26.4	10.2
2002	1	10-18 Sept.	2.9	4.2	30.9	17.6
	2	18-25 Sept.	9.5	3.9	27.2	15.2
1984-2000		10-18 Sept.	3.1	4.4	29.5	14.2
		18-25 Sept.	3.7	4.2	27.6	11.7
2003	1	23-30 Sept.	0.0	3.8	24.9	9.0
	2	1-8 Oct.	0.9	3.5	21.4	6.3
1984-2000		23-30 Sep.	3.9	3.9	26.3	10.7
		1-8 Oct.	2.8	3.6	24.7	8.3

[y] **1 = defoliation at NAWF = 5 plus 472 DD; 2 = defoliation at NAWF = 2 plus 472 DD.**

[z] **Historical data for desiccation periods from the National Climatic Data Center (NCDC, 2004).**

Total lint price differences were significantly affected by desiccation treatments in two of the 3 yr of the study (Fig. 4). In 2001, cotton desiccated with sodium chlorate incurred a small discount (−\$0.014 kg^{-1}) that was mainly attributable to leaf grades >4 (Table 2). In contrast, small premiums were recorded for cotton desiccated with paraquat (\$0.015 kg^{-1}) or no desiccation (\$0.019 kg^{-1}) in 2001 (Fig. 4). In 2002, sodium chlorate provided a lower total price discount of –\$0.087 kg^{-1} compared to -\$0.129 kg^{-1} for paraquat. Micronaire price differences were not influenced by choice of desiccant (not shown). Averaged across the 3-yr study, overall lint price differences due to desiccation were relatively small and were not significantly different.

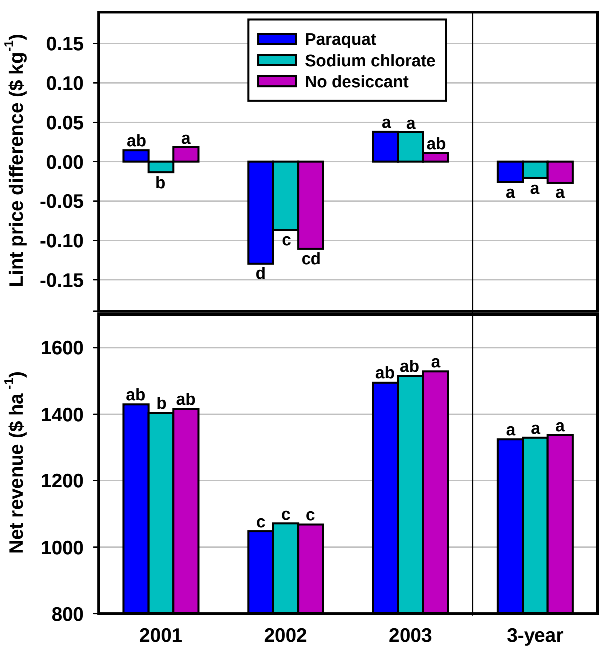

Figure 4. Desiccation treatment effects on lint price differences and net revenues of ultra-narrow-row cotton averaged across timing treatments in 2001, 2002, and 2003, and 3-yr means. Within yearly data and 3-yr data, bars topped by the same letter are not significantly different (*P* = 0.05) according to paired comparisons.

Net revenues. Delaying UNRC defoliation beyond NAWF = 5 plus 472 DD had a significant and positive impact on UNRC net revenues in 2001, and across the 3 yr of the study (Fig. 3). In 2001, defoliating later at NAWF = 2 plus 472 DD increased net revenues 23% (\$291 ha^{-1}) above the lint yields achieved using the standard defoliation criterion. While most of the improvement in net revenues with delayed defoliation came from increased lint yields, an overall lint price premium of \$0.024 kg^{-1} also contributed to the rise in net revenues observed in 2001. In 2002 and 2003, defoliation timing did not significantly influence net revenues. Over the 3 yr of the experiment, defoliating later produced net revenues that averaged 9% (\$169 ha^{-1}) higher than revenues obtained using the standard defoliation timing. Results showed that defoliating at NAWF = 2 plus 472 DD in UNRC was as profitable or more profitable than the standard NAWF = 5 plus 472 DD criterion, depending on the growing season. These findings suggest that delaying defoliation in UNRC may increase net revenues in some years for cotton growers in short season environments, such as Tennessee. These UNRC net revenue results are consistent with Larson et al. (2002), who found that delaying defoliation of wide-row cotton beyond NAWF = 5 plus 472 DD improved net revenues.

Desiccation treatment did not have a significant impact on net revenues in this study (Fig. 4), despite differences in treatment costs. Desiccation with sodium chlorate produced no more net revenue than paraquat. Lint price differences were small relative to yield effects on net revenues. Results indicate that, apart from the documented benefits of desiccation of stripper-harvested cotton for module storage (Supak and Banks, 2001), desiccants do not directly improve lint prices or net revenue in UNRC. Because seedcotton samples were not moduled in this study, these desiccation results may not apply to cotton stored in modules. On the other hand, these results indicate no harmful effects on lint prices and revenues from the use of desiccants.

CONCLUSIONS

The general objective of this study was to determine profitable harvest-aid strategies for UNRC in short-season environments, such as Tennessee. Farmers may be able to achieve significantly higher lint yields and net revenues by using NAWF = 2 plus 472 DD for timing defoliation of UNRC. Yield results support the hypothesis that additional yield may be gained as UNRC crop termination is delayed beyond NAWF = 5 plus 472 DD. While the timing of defoliation affected certain UNRC fiber properties in some years, it did not greatly impact total price differences for fiber quality. Application of desiccants elicited no harmful effects on fiber quality or net revenue. Desiccation with sodium chlorate produced no more net revenue than paraquat, and no direct improvement in net revenues to the producer was found from the application of either paraquat or sodium chlorate after defoliation. The latter result should be viewed with caution since weather conditions in this study may have favored crop desiccation in all treatments, and seedcotton was not moduled. Control of moisture in seedcotton intended for module storage requires an effective harvest-aid program including crop desiccation. In addition, there may be economic benefits to the ginner from improved gin turnout with desiccation.

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