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CDA/ULV-OIL TECHNOLOGY VERSUS CONVENTIONAL SPRAY TECHNOLOGY FOR GROUND APPLICATION OF SPRAYS FOR BOLLWORM[1] CONTROL IN THE TEXAS ROLLING PLAINS[2]

J. R. C. Robinson,[3] J. E. Slosser,[4] J. K. Walker,[3] and J. R. Price[4]

ABSTRACT

Two insecticide tests were conducted to compare a conventional hydraulic-atomization spraying system and a controlled droplet application (CDA) spraying system for suppression of bollworms, Heliothis zea (Boddie), using a standard rate of pyrethroid. In 1984, no significant differences were found between the two CDA treatments (both using cottonseed oil as a carrier) which were comprised of 80µ and 190µ diameter droplets, respectively. Equivalent suppression was also obtained in 1985 among three CDA treatments (all emmitting 190µ diameter droplets) which employed water, cottonseed oil, and an equal mixture of water/oil as carriers for the insecticide. No significant differences in bollworm control or yield were found in either year between any of the CDA treatments and the conventional treatment, which used water as a carrier.

Two studies were conducted comparing the penetration and deposition of the above treatments (excluding insecticide) in a canopy of cotton foliage. In the 1984 canopy penetration test, the conventional water treatment deposited more spray droplets on sample leaves, squares and bolls at all levels of the canopy than did the CDA treatments. Deposition within all treatments tended to progressively decrease from upper to lower canopy levels.

The canopy penetration test in 1985 revealed a few significant differences between spray deposition from the conventional water treatment and the CDA treatments. No differences were found among the CDA treatments. It appeared that the conventional system had a lower recovery rate relative to the CDA system at lower points in the canopy.

INTRODUCTION

ULV-oil insecticide application is a novel and potentially more effective method for controlling Heliothis spp. with synthetic pyrethroids and other insecticides. Since 1981 this practice has become established in some parts of the U.S. Cottonbelt (Reid 1981, Perantoni 1983), with Texas being one of the areas of stongest interest (Kepple 1985).

The purported advantages of applying pyrethroids with the ULV-oil technique over conventional methods include better accuracy, canopy penetration, and retention of sprays, with less carrier evaporation and

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[3] Department of Entomology, Texas A&M University, College Station, TX 77843

[4] Texas Agricultural Experiment Station, P. O. Box 1658, Vernon, TX 76384

downwind drift (Clower et al. 1982, Crumby 1984, Moore 1983). Applicators have employed the ULV-oil technique from ground equipment using controlled droplet application (CDA) spraying systems (Anonymous 1983, Pigg 1984). This is probably due to the availability of commercial CDA rotary-type atomizers which are suitable for adapting conventional ground sprayers for ULV-oil application.

At present there exists a relatively small amount of published data to evaluate the effectiveness of ULV-oil application and/or CDA spraying systems in the field. The following experiments were conducted to compare conventionally applied, emulsified spray treatments with CDA/ULV-oil spray treatments (both applied from a ground sprayer) for control of bollworms, Heliothis zea (Boddie), in irrigated cotton in the Texas Rolling Plains. The relative effectiveness of the spraying systems was evaluated on the basis of: (1) efficacy of bollworm control using a common rate of insecticide applied through both systems; and (2) relative spray deposition from the two systems at different levels within the cotton canopy.

MATERIALS AND METHODS

Experiments were conducted at the Texas A&M University Vegetable Research Station at Munday, Texas during July and August in 1984 and 1985.

Basic Equipment. Applications were made with a John Deere 6000 Hi-Cycle ground sprayer. The conventional, water-based, higher volume treatments were applied through the sprayer's original system, which utilized a high-volume centrifugal pump and TX4 hollow cone nozzles. Three nozzles per row were arranged with one nozzle over the center of each row and a double-headed drop nozzle between rows.

The center nozzle was positioned 15 cm above the plant canopy during spraying. The boom covered six rows spaced 1.02 m (40 in) apart. At 2814.8 g/cm^2 (40 psi), this system delivered about 88.8 L/ha (9.5 gal/acre) in 1984, and 81.3 L/ha (8.7 gpa) in 1985.

The CDA system consisted of an independent, electrically driven pump and hose line connected to six Micromax/DR-4 rotary atomizers mounted to the right spray boom and pointing straight down. Each atomizer was situated 45 cm directly above one row. The low-volume output from this system was about 9.3 L/ha (4.5 qt/acre) at 915.2 g/cm^2 (13 psi). This sytem was used to deliver treatments with water, oil, and a 50:50 mixture of oil and water as carriers. Once-refined cottonseed oil was used.

1984 Insecticide Test. The cotton variety 'Lockett 77' was planted 20 May 1984 on 1.8 ha (4.4 acres) of Altus fine sandy loam soil. Standard crop cultivation practices were used throughout the season. The cotton was furrow-irrigated three times at bi-weekly intervals beginning in mid-July.

Four insecticide treatments were arranged in a randomized complete block design with four replications. The individual plots were 18.4 m (18 rows) wide and 32.6 m (108.7 ft) long, but only the middle 12 rows were sprayed. The treatments were: (1) conventional spraying system using water as a carrier, (2) CDA system with rotary speed at 2000 rpm (CDA/Oil/2000) to produce droplets ca. 190 µ in diameter, (3) CDA system with rotary speed at 5000 rpm (CDA/Oil/5000) to produce droplets ca. 80 µ in diameter, and (4) untreated check. Both CDA treatments used cottonseed oil as a carrier. Cypermethrin (Ammo 2.5 EC), a pyrethroid, was applied at 39 g/ha (.04 lbs/acre) in the first three treatments.

Plots were sampled semiweekly from 26 July to 16 August. Sampling consisted of whole-plant examinations for bollworm larvae. Two meters of row were examined at two randomly selected points in each plot. Treatments were applied after average bollworm densities exceeded the treatment threshold of 5000 larvae/acre (12,350 larvae/ha) (Boring et al.

1984). Treatments were applied only once on 27 July when most larvae were ≤ 1.3 cm in length. Oviposition continued in the plots for several days after application. However, a second larval population cycle probably did not occur because the cotton senesced in late August and became an unsuitable host for bollworms.

Cotton yield data were obtained 30 November by hand-picking two, 2 m lengths of row in each plot and weighing the harvested cotton. About 95% of the bolls were open in all plots.

1985 Insecticide Test. The variety 'Lockett 77' was planted in a 1.8 ha (4.4 acre) field of Altus loamy fine sand soil. The first planting was on 21 May 1985, but severe soil crusting caused an inadequate stand; and all cotton was replanted on 30 May. Cultural practices were similar to those in 1984. Cotton was furrow-irrigated on 3-4 June, 20-21 June, and 18-19 July.

Five insecticide treatments were arranged in a randomized complete block design with three replications. Each plot was 18.3 m (18 rows) wide and 24.2 m (80.6 ft) long, but only the middle 12 rows in each plot were treated.

The treatments were: (1) conventional spraying system using water as a carrier, (2) CDA with rotary speed set at 2000 rpm using water as a carrier (CDA/Water/2000), (3) CDA with rotary speed set at 2000 rpm using cottonseed oil as a carrier (CDA/Oil/2000), (4) CDA with rotary speed at 2000 rpm using a mixture of 50% oil and 50% water as a carrier (CDA/Mix/2000), and (5) an untreated check. The rotation speed of the Micromax units produced droplets ca. 190 µ in diameter. Cypermethrin was again used in Treatments 1-4 at the rate of 39 g/ha. Treatments were applied 2 August.

The plots were sampled semiweekly from 1 August through 12 August. Sampling procedures were similar to those in the 1984 study, except that sample sizes were doubled. Two, 4 m lengths of row were examined in each plot. As in 1984, bollworms were the only pests of economic significance in the test plots.

Cotton yield was obtained using the same procedure as in 1984. Samples of seed lint were picked on 7 November after 95% of the bolls were open in all plots. Data from the 1984 and 1985 studies were subjected to analysis of variance and multiple mean comparison procedures (Duncan 1955).

1984 Canopy Penetration Study. A canopy penetration test was conducted in 1984 in a 1.4 ha (3.5 acres) field of irrigated cotton separate from the insecticide study. The cotton was planted on 20 May, and this field received crop management similar to that described for the insecticide tests. The individual plots were 44.9 m (44 rows) wide and 12.8 m (42.6 ft) long. The rows ran approximately perpendicular to the prevailing southerly winds.

The two CDA oil treatments and the conventional water treatment (described previously in the 1984 insecticide test) were compared in a randomized complete block design with six replications. "Saturn Yellow" or "Blaze Orange" fluorescent pigments (Day-Glo Color Corp., Series D) were used with the treatments as a tracer. A wetting agent (Wex®) was included with the pigment in each spray formulation; however, no insecticide was used.

Six rows were sprayed in each plot on 15 August. After spraying, a whole plant was randomly selected from each replication and removed from the plot. Squares, bolls and leaves were collected from the upper-1/3, the middle-1/3, and the lower-1/3 of each sampled plant. However, an equal number of squares and bolls could not be obtained from all strata. Squares and bolls were placed in individual bags, and leaves were placed in a plant press. The material was transported to the laboratory.

The leaves and fruiting parts were examined for spray deposition under longwave UV light (366 µm). Numbers of spray droplets per fruit (including the bracts) were counted, or numbers were estimated when counts exceeded 200 droplets/fruit. For analysis, droplet counts were ranked as follows: 1 = 0-9 droplets per fruit, 2 = 10-29, 3 = 30-69, 4 = 70-149, 5 = 150-309, 6 = 310-630, and 7 = >630. Leaves were also examined under UV light, and numbers of droplets/cm^2 were counted.

Readings on leaves were made by counting deposited droplets in four, 1 cm^2 areas on the topside and underside of each leaf. To reduce variability, the four sampling areas were fixed, and they included two lateral areas, one medial and one apical area.

1985 Canopy Penetration Study. Following the experience gained in 1984, a methodology for quantitatively measuring spray deposition was sought which would yield more precise data with less tedium. Carlton et al. (1981) developed a method for measuring the percent spray coverage of fungicide on soybean leaves. Their methodology employed fluorescent pigments similar to those described previously, and the spray deposits were assessed directly from leaf surfaces. The canopy penetration study in 1985 followed procedures slightly modified from those presented by Carlton et al. (1981, 1983).

Following the cessation of insect sampling in the 1985 insecticide plots (previously described), these same plots were used for the 1985 canopy penetration study. These plots contained a fairly tall stand of cotton in which to evaluate spray penetration and deposition. Plants averaged 77.8 cm (2.6 ft) tall with an average of 16.5 mainstem nodes. Treatments included the CDA/Oil, CDA/Water, CDA/Mix, and conventional water sprays used in the 1985 insecticide study. These were compared in a randomized block design with three replications. A fluorescent tracer (Day-Glo, Series AX, Blaze Orange) was used at a rate of 3 g/L of carrier. A wetting agent (Wex) was used in all treatments, but insecticide was excluded.

Treatments were applied on 19 August to six rows in each treatment plot. To avoid interfering with plot yield data, the six rows chosen for deposition testing did not include the rows treated in the insecticide test.

After the completion of spraying, various plant parts were sampled for evaluation of spray deposit. Sampling was restricted to the middle two rows of the six that were sprayed. Seven leaves were picked from each of the upper-1/3, middle-1/3, and lower-1/3 of the plant canopy for a total of 21 leaves per plot. The leaves were stored in individual plastic bags and kept in a cooler until they could be transported to the laboratory. Likewise, ten fruiting forms (squares and bolls) were picked from the three canopy levels and stored in plastic bags.

The collected plant parts were refrigerated in the laboratory to prevent deterioration. Care was maintained in handling to avoid contamination or smearing of pigment deposits on the samples. In general the pigment deposits adhered fairly well to plant surfaces.

The leaf samples were measured for deposited spray using a modified Turner Fluorometer Model 111. The fluorometer is an instrument which gives a quantitative reading of the fluorescence of objects held in its sampling rack. This particular instrument was modified to take readings from a 2 cm^2 area of a flat object (e.g. a leaf). Initial readings from both surfaces of unsprayed cotton leaves collected prior to this experiment showed no measurable fluorescence. Leaves sprayed with water or cottonseed oil only (no tracers) showed no measurable fluorescence. This indicated that the fluorometer readings could be used to evaluate leaves for deposition of sprays containing fluorescent tracers.

Most sample leaves were too large to fit in the fluorometer sampling door, so individual leaves were carefully cut in half down the midvein. One leaf half was then measured on the topside, and the other half was measured on the underside. To reduce variability, the same general area on the lateral lobe of each leaf half was used as the 2 cm^2 sampling area for all the readings.

Squares and/or bolls were examined under longwave UV light, and the numbers of fluorescing droplets were counted as in the 1984 study. In order to obtain actual counts of the droplets present on the fruit (instead of estimates), the bracts were removed and not included in the droplet counting procedure.

Data from the 1984 canopy penetration test (square and boll samples) were analyzed by the non-parametric Kruskal-Wallis test because droplet counts were ranked, and because unequal sample sizes were obtained (Ott 1984). Data from the 1984 canopy penetration tests (leaf samples) and the 1985 canopy penetration test were analyzed by analysis of variance as a split split-plot design; spray treatments, canopy levels, and sides of the leaves constituted the main plots, subplots and sub-subplots, respectively (Snedecor and Cochran 1980, Ray 1982). Means were then compared by multiple comparison procedures (Duncan 1955).

The fluorometer data from the 1985 study were left in the form of readings on the primary scale (1X) of the fluorometer for analysis. The conversion to percent spray coverage described by Carlton et al. (1981) could not be accomplished in this study. Although these readings represent quantitative assessments of the spray deposits, they are expressed in terms of the dial reading on the fluorometer.

RESULTS AND DISCUSSION

1984 Insecticide Test. The bollworm suppression data from the 1984 study illustrate the general suppressive effect of the pyrethroid on bollworm populations (Table 1). Significantly fewer bollworm larvae were counted in the insecticide treated plots as compared to the untreated check plots. However, no significant differences were found between the two CDA/Oil treatments or between either CDA/Oil treatment and the conventional water-based treatment. This pattern was exhibited on most sampling dates and in the season-long posttreatment average.

The only significant differences in cotton yield occurred between the conventional water treatment, which produced the highest yield, and the untreated check, which produced the lowest yield (Table 1). Yields in both CDA/Oil treatments were intermediate. The yield data, however, do not adequately reflect the differences between the three insecticide treatments and the untreated check. The normal freeze date in the northern Rolling Plains occurs 11 November; but in 1984, first freeze occurred about three weeks later. The extended growing season apparently allowed regrowth and refruiting in the untreated check plot, producing additional yield. Yields could have been taken at least one month earlier in the three insecticide plots, because fruit formation and growth had ceased following the setting of an early crop. The untreated check plot continued to set fruit later into the fall, and the delayed frost allowed many of these late bolls to mature and open.

The results of this study were obtained in plots infested with more than sufficient levels of *H. zea* for the purposes of this test. The bollworm populations encountered in 1984 were exceptional in both number and duration for the location. In this context, the three different insecticide treatments all gave equivalent suppression of bollworms. There were differences in the degree of suppression among the treatments, but these differences had no statistical significance. For example, the average posttreatment values for the two CDA/Oil treatments represented slightly higher percent reductions from their respective pretreatment levels as compared to the percent reduction obtained with the conventional water treatment.

Table 1. Average Number of Bollworm Larvae Per Four Meters of Row in a Test of Controlled Droplet Application (CDA) vs. Conventional Application, Munday, TX 1984.

Treatment[a]	Pre-treatment[b]	Posttreatment[b]						$\bar{X}$[c]	%[d]	Yield
	26 Jul	30 Jul	3 Aug	6 Aug	9 Aug	13 Aug	16 Aug			(kg lint/ha)
CDA/Oil/2000	5.25a	2.25a	1.75a	3.50a	2.25a	1.50a	1.75a	2.17a	-58.7	858.6ab
CDA/Oil/5000	8.00a	3.75a	3.50a	4.25a	2.50a	2.00a	0.62a	2.77a	-65.4	832.9ab
Conventional Water	5.50a	3.75a	3.00a	5.50a	4.25a	2.00a	1.25a	3.29a	-40.2	909.4b
Untreated Check	5.50a	15.50b	14.00b	12.50b	9.00b	5.75b	2.00a	9.79b	+78.0	661.2a

[a] Includes 39.0 gm cypermethrin/ha in all treatments except for Untreated Check.
[b] Means in a column followed by a common letter are not significant at the P=0.05 level (Duncan's multiple range test).
[c] Season average of all posttreatment values.
[d] Percent change from pretreatment to average posttreatment levels.

Table 2. Average Number of Bollworm Larvae Per Four Meters of Row in a Test of Controlled Droplet Application (CDA) vs. Conventional Application, Munday, TX 1985.

Treatment[a]	Pre-treatment[b]	Posttreatment[b]			$\bar{X}$[c]	%[d]	Yield
	1 Aug	5 Aug	8 Aug	12 Aug			(Kg lint/ha)
CDA/Oil/2000	5.50a	4.17a	5.83a	0.00a	3.33ab	-39.4	450.8a
CDA/Water/2000	4.50a	5.33a	3.17a	0.00a	2.83a	-37.1	453.1a
CDA/Mix/2000	5.67a	5.67a	3.33a	0.67a	3.22ab	-43.2	505.6a
Conventional Water	4.33a	5.17a	3.17a	0.50a	2.95a	-31.9	452.7a
Untreated Check	4.17a	8.67b	4.83a	1.83b	5.11b	+22.5	443.5a

[a] Includes 39.0 gm cypermethrin/ha in all treatments except for Untreated Check.
[b] Means in a column followed by a common letter are not significant at the P=0.05 level (Duncan's multiple range test).
[c] Season average of all posttreatment values.
[d] Percent change from pretreatment to average posttreatment levels.

1985 Insecticide Test. There were no significant differences in counts of bollworm larvae in 1985 among any of the insecticide treated plots on any of the individual sampling dates (Table 2). The percent reductions in larval numbers from the pretreatment values in the insecticide treated plots ranged from 32% to 43%. The untreated check plot had significantly higher numbers of bollworms than were noted in any of the insecticide treated plots on 5 and 12 August. The average post treatment count in the untreated check plot was significantly higher than counts recorded for the CDA/Water/2000 and for the conventional water values, but not for the CDA/Oil/2000 or for the CDA/Mix/2000.

The results from the first posttreatment sampling date were unexpected. Rather than showing a decline, bollworm numbers in two of the insecticide plots slightly increased from the pretreatment level, while one insecticide plot showed a decline in bollworms and one plot maintained the same number. However, the numbers of bollworms in the untreated check plot doubled during the same time interval, perhaps demonstrating that the treatments with insecticide curtailed an otherwise increasing population.

Counts on the second posttreatment date showed the more anticipated decline in bollworm numbers in the insecticide treated plots, with the exception of the CDA/Oil/2000 plot. On the last sampling date, populations declined to minimal levels in all plots.

The yield data (Table 2) did not reveal any significant differences among the treatments. The CDA/Mix/2000 treatment had the highest yield and the untreated check had the lowest yield. The three remaining insecticide treatments were intermediate.

In both 1984 and 1985, all insecticide treatments gave equivalent control of bollworms regardless of carrier or application technology. The results of the insecticide tests did not demonstrate the effect of any superior efficiency on the part of the CDA technology. No effect could be seen due to the use of cottonseed oil, oil/water mixtures or water as carriers.

Apparently, the choice between conventional application technology and CDA technology is immaterial for the purpose of suppressing bollworms in the Rolling Plains environment. This conjecture is based on the generally fragile nature of bollworm populations in the Rolling Plains, as typified by the fairly short-lived bollworm population in 1985. Perhaps differences in biological effectiveness between these spraying systems could be measured in areas where bollworm populations are present for extended periods. Differences in effectiveness might also be realized by using a rate of cypermethrin lower than that applied in this study.

1984 Canopy Penetration Study. Results from the canopy penetration study, as measured by numbers of fluorescent droplets on squares and bolls, were used to compare the three spray treatments within individual canopy levels (Table 3). The Kruskal-Wallis procedure indicated the presence of significant differences within the CDA/Oil/5000 treatment, and also within each canopy level. The conventional water treatment tended to deposit higher (though not necessarily statistically higher) numbers of fluorescent spray droplets on squares or bolls at all three canopy levels than were deposited by either CDA/Oil treatment. Likewise, the CDA/Oil/5000 treatment also tended to deposit more spray droplets on squares or bolls at the upper and middle canopy levels.

The data from spray deposition on leaves provided another comparison of relative deposition between treatments. The number of spray droplets per cm^2 from the conventional water treatment and the CDA/Oil/2000 treatment were compared on the topside and underside of cotton leaves within the different canopy levels (Table 4). (Leaves were sprayed with the CDA/Oil/5000 treatment also, but they dried and deteriorated before

Table 3. Number of Spray Droplets on Cotton Squares and Bolls in a Canopy Penetration Test, Munday, TX 1984.

Treatment	Canopy Level[a/] upper-1/3	middle-1/3	lower-1/3	H-statistic[b/]
CDA/Oil/2000	2.75	2.83	2.17	0.68
CDA/Oil/5000	4.33	3.67	2.00	6.11*
Conventional Water	5.80	6.00	4.67	2.05
H-statistic[c/]	6.02*	10.40*	7.07*	

[a/] Droplet counts ranked from 1-7 where: 1 = 0-9, 2 = 10-29, 3 = 30-69, 4 = 70-149, 5 = 150-309, 6 = 310-629, and 7 = higher than 630 droplets per square or boll.

[b/] Kruskal-Wallis Test comparing droplet counts between canopy levels within each treatment; * = significant at the P=0.05 level.

[c/] Kruskal-Wallis Test comparing droplet counts between treatments within each canopy level; * = significant at the P=0.05 level.

Table 4. Number of Spray Droplets per cm^2 on Topside and Underside Leaf Surfaces in a Canopy Penetration Test, Munday, TX 1984.

Treatment[a/]	Canopy Level[b/] upper-1/3	middle-1/3	lower 1/3
		Leaf topside	
CDA/Oil/2000	7.8aA	4.8aA	1.3aA
Conventional Water	88.2bC	74.8bB	28.1bA
		Leaf underside	
CDA/Oil/2000	1.2aA	0.0aA	0.0aA
Conventional Water	23.1bB	0.9aA	0.1aA

[a/] Includes 3 g "Blaze Orange" fluorescent pigment per liter of carrier in all treatments.

[b/] Values followed by a common lower case letter (for vertical comparisons between treatments) or by a common upper case letter (for horizontal comparisons between canopy levels) are not significant at the P=0.05 level (Duncan's multiple range test). Separate comparisons are made for upper and lower leaf surfaces.

droplet readings could be made.) The relative deposition of the two treatments on topside of leaves followed the pattern observed on squares and bolls: the conventional water treatment deposited a significantly higher number of spray droplets per cm^2 of leaf area than was deposited by the CDA/Oil/2000 treatment at each canopy level. The conventional water treatment also deposited a significantly higher number of spray droplets per cm^2 on the underside of upper canopy leaves than did the CDA/Oil/2000 treatment.

Within each treatment, spray coverage densities were compared among the three canopy levels (Table 4). This test was valid since the sample leaves were approximately the same size and shape throughout the canopy (in contrast to squares and bolls which generally increase in size with a lowering of canopy level). The data for the conventional water and the CDA/Oil/2000 treatments followed the same trend. Spray densities (droplets per cm^2 of leaf area) within each treatment progressively decreased from the upper canopy level to the lower level. Significant differences were found among spray coverage densities in all three canopy levels of the conventional water treatment. Within the CDA/Oil/2000 treatment, the differences in density of spray coverage among canopy levels were not significant.

The density of spray droplet coverage on the underside of leaves was always less than on the corresponding topside. No statistical comparisons were made between leaf sides in Table 4; nevertheless, there were apparent differences between topside and underside values in the case of the conventional water treatment at all three canopy levels.

<u>1985 Canopy Penetration Study</u>. In contrast to the 1984 study, the data for 1985 represent actual counts of droplets on fruiting forms rather than ranked values of droplet numbers. Another difference in methodology was the exclusion of the bracts, which made it possible to count the actual number of fluorescing spray droplets deposited on the square bud or boll.

There were no significant differences in numbers of spray droplets per fruiting form among the four treatments in the upper canopy (Table 5). The conventional water treatment deposited significantly higher numbers of spray droplets per fruiting form than all three CDA treatments at the middle and lower canopy levels. In addition, droplet counts from

Table 5. Number of Spray Droplets on Cotton Squares and Bolls in a Canopy Penetration Test, Munday, TX 1985.

Treatment[a]	Canopy Level[b] upper-1/3	middle-1/3	lower 1/3
CDA/Oil/2000	1.18aA	20.25aA	5.58aA
CDA/Water/2000	3.95aA	70.45bB	17.85aA
CDA/Mix/2000	1.40aA	24.05aA	7.98aA
Conventional Water	8.40aA	166.25cC	79.98bB

[a]/ Includes 3 g "Blaze Orange" fluorescent pigment per liter of carrier in all treatments.
[b]/ Values followed by a common lower case letter (for vertical comparisons between treatments) or by a common upper case letter (for horizontal comparisons between canopy levels) are not significant at the P=0.05 level (Duncan's multiple range test).

the CDA/Water/2000 treatment were significantly higher than the remaining CDA treatments at the middle canopy level.

The fluorometer readings for upper and lower leaf surfaces provided quantitative measures of spray deposit which were compared among treatments and canopy levels within treatments (Table 6). At the upper and middle canopy levels, the conventional water treatment gave a significantly higher reading of fluorescence on the topside of leaves as compared to all three CDA treatments. There were no differences between the CDA treatments within the three canopy levels. There were also no differences within each CDA treatment for relative fluorescence reading among canopy levels. However, the fluorescence reading of the conventional water treatment was significantly higher at the middle canopy level than the reading from the other two levels, and the reading in the upper level was significantly higher than the reading in the lower level.

Table 6. Fluorometric Reading[a] of Spray Deposits on the Topside and Underside of Cotton Leaves in a Canopy Penetration Test, Munday, TX 1985.

Treatment[b]	Canopy Level[c] upper-1/3	middle-1/3	lower-1/3
		Leaf topside	
CDA/Oil/2000	1.97aA	2.24aA	1.96aA
CDA/Water/2000	4.63aA	3.22aA	3.21aA
CDA/Mix/2000	1.82aA	1.97aA	1.91aA
Conventional Water	10.26bB	16.89bC	4.80aA
		Leaf Underside	
CDA/Oil/2000	1.86aA	0.22aA	0.56aA
CDA/Water/2000	0.75aA	0.52aA	0.09aA
CDA/Mix/2000	2.80aA	0.22aA	0.00aA
Conventional Water	8.58bB	1.56aA	1.22aA

[a] Fluorometer readings made with the 1X scale of a Turner Model 111 fluorometer.

[b] Includes 3 gm "Blaze Orange" fluorescent pigment per liter of carrier in all treatments.

[c] Values followed by a common lower case letter (for vertical comparisons between treatments) or by a common upper case letter (for horizontal comparisons between canopy levels) are not significant at the P=0.05 level (Duncan's multiple range test). Separate comparisons are made for upper and lower leaf surfaces.

Fluorescence readings on the underside of leaves were characteristically lower than the readings on the corresponding upper side. On the underside of leaves in the upper canopy level, the conventional water treatment had a significantly higher fluorescence reading than the three CDA treatments, but there were no significant differences between the CDA treatments. There were no significant differences in fluorescence readings among the four treatments at the middle and lower canopy levels. The only significant difference in fluorescence readings among canopy levels occurred within the conventional water treatment.

The conventional water system emitted ca. 7.8 times more spray/ha than did the CDA system. The same amount of insecticide per ha was applied from both these systems during the insecticide studies. Therefore, the CDA sprays contained ca. 7.8 times the concentration of insecticide (1.4% vol:vol, compared to .18% for the conventional treatment sprays).

Hypothetically, if both spraying systems operated with equal rates of spray efficiency and recovery, one could expect: (1) roughly equal deposition of insecticide between the two spraying systems (not measurable with our methods), (2) roughly equal control efficacy (observed in the insecticide study), and (3) a fairly constant ratio of spray deposit from one spraying system to the other (measured in the 1985 canopy penetration study).

Table 7 presents the ratios of the deposition values (from Table 6) of the conventional water treatment to the CDA treatments. Since the conventional system consistently emitted about 7.8 times as much spray per ha relative to the CDA system, it would be expected that the ratio of conventional spray deposition to CDA spray deposition would be roughly consistent as well, given equal recovery and loss rates between the systems.

Table 7. Ratio of Fluorometric Reading of Conventional Water Spray Deposits with each CDA Spray Deposit, Munday, TX 1985.

Treatment	Canopy level upper-1/3	 middle-1/3	 lower-1/3
		Leaf topside	
CDA/Oil/2000	2.2 : 1	5.2 : 1	1.5 : 1
CDA/Water/2000	5.2 : 1	7.5 : 1	2.4 : 1
CDA/Mix/2000	5.6 : 1	8.6 : 1	2.5 : 1
		Leaf underside	
CDA/Oil/2000	4.6 : 1	7.1 : 1	2.2 : 1
CDA/Water/2000	11.4 : 1	3.0 : 1	13.5 : 1
CDA/Mix/2000	3.1 : 1	4.3 : 1	---

The ratios of conventional system spray deposits to CDA treatment spray deposits were not constant among canopy levels or corresponding leaf surfaces (Table 7). The conventional treatment spray deposits on the topside of leaves decreased relative to the CDA treatments from the middle canopy level to the upper level, and from the upper canopy level to the lower canopy level. In addition, the ratio of conventional treatment spray deposits to CDA treatment deposits also declined from the topside to the underside of middle canopy leaves.

These results indicate a change in relative spray recovery between the two systems at different sites in the canopy. The effectiveness of the deposition of conventional treatment sprays appears to decline at the lowest canopy level relative to the deposition from the CDA treatments.

The conventional water treatment consistently delivered a higher measure of spray deposit than the CDA treatments, regardless of the inconsistent ratio of deposits between the two systems. The denser spray droplet coverage and the higher fluorometric readings from the conventional water treatment are probably due to a number of factors. First, the higher amounts of spray deposited from the conventional system relative to the CDA treatments occurred largely because of the higher volume output of the conventional system. It is reasonable that a spraying system with a higher volume output of spray per ha would deposit more spray on a given target (assuming that the spray was deposited with a reasonable degree of accuracy).

Second, the relative differences between the systems in spray deposition within certain levels of the cotton canopy may have been influenced by the different nozzle arrangements and emission patterns of the two systems. The overhead nozzle of the conventional system probably enhanced the deposition of spray on cotton terminals directly below, while output from the drop nozzles might explain the higher deposition of conventional treatment sprays on leaves and fruiting forms in the middle canopy level. The CDA units emit droplets in a lateral, radial pattern, with a dependence on mild crosswind currents for lateral movement of droplets into the canopy. The typical field conditions under which these treatments were applied might not have been optimum for the proper movement and deposition of the CDA sprays in the two lower canopy levels.

Third, the different carriers used might have had an effect on the relative deposition. The conventional system consistently used water as a carrier. Interestingly, within the 1985 CDA treatments, the water-only carrier treatment had the highest readings of spray deposition at all three canopy levels on fruiting forms (Table 5) and on the topside of leaves (Table 6). These differences were only significant in one instance. Nevertheless, this trend might indicate some physical advantage of water-based sprays over cottonseed oil-based sprays for deposition on cotton plants.

Finally, the unevenness of deposition by the conventional spraying system apparently had no bearing on the results of the insecticide test. One explanation is that the smallest deposits of spray from the conventional system may have been adequate for control with the insecticide rate that was used. In this case, the larger deposits would represent a wasteful overkill, but would not be differentiated as such in an evaluation of control efficacy.

On a practical level, no differences in control of bollworms were found between the conventional application technology and the CDA technology in the areas investigated. The two systems exhibited comparable effectiveness in applying insecticide sprays for insect suppression in cotton. The CDA system appeared to be slightly more effective in depositing spray evenly throughout the canopy than the conventional system. Robinson (1986) reported that the CDA system also produced spray drift to a shorter distance than the conventional system under certain conditions, and no differences between spraying systems were noted in the suppression of beneficial insects in the bollworm control tests.

Practical assessments of these application technologies should probably focus more on the relative economics and convenience of these systems for use in the field. Such evaluations should consider the cost and availability of CDA equipment compared with conventional spraying equipment and the cost and physical inconvenience of using vegetable oil carriers.

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