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ENGINEERING & GINNING

Assessing the Effectiveness of Air-assisted and Hydraulic Sprayers in Cotton Via Leaf Bioassay

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INTERPRETIVE SUMMARY

Pesticides applied to control specific cotton insects need to be deposited at the place or places within the plant canopy where the insects feed. Most insects that cause damage during their larval stage begin feeding on new foliage and fruiting parts in terminals and blooms of cotton plants, while pests such as aphids, spider mites, and whiteflies usually feed on the underside of leaves and down into the plant canopy. Compared with conventional over-the-top sprayers, the air-assisted and drop-nozzle sprayers developed in recent years should provide improved pesticide penetration and coverage within the plant canopy and on the undersides of cotton leaves.

The effectiveness of three sprayer configurations, air-assisted, over-top, and drop-nozzle sprayers, was evaluated using Tracer insecticide to control insect larvae in cotton. Laboratory bioassay tests with beet armyworm larvae feeding on cotton leaves picked from the top, middle, and bottom of treated plants indicated that all three sprayers, when adjusted properly, could provide acceptable leaf coverage, as indicated by insect mortality, in the top of cotton plants where protection from insects is critical.

At the bottom of cotton plant canopies, though, air-assisted and drop-nozzle sprayers had better insect mortality than did the over-the-top sprayer. Air-assisted and drop-nozzle sprayers provided good insect mortality on leaves in the middle of plants and some insect mortality toward the bottom of plants. The air-assisted sprayer provided the best insect mortality throughout the plant, while the over-top sprayer had the poorest insect mortality in the bottom of the plant. Both air-assisted and drop-nozzle sprayers had good insect mortality in the middle of the plant.

This evaluation indicated that all three sprayers have effective leaf coverage in the top of cotton plants but only the drop-nozzle and air-assisted sprayers would be effective in controlling insect pests within the plant canopy.

ABSTRACT

Compared with conventional over-the-top sprayers, air-assisted and drop-nozzle sprayers should provide improved pesticide penetration and coverage within the plant canopy where the insects feed. This study compared the effectiveness of the insecticide Tracer, a natural insecticide produced by the actinomycete *Saccharopolyspora spinosa*, (Dow Agrosciences, Indianapolis, IN) applied by these three sprayers within the canopy of cotton (*Gossypium hirsutum* L.). Leaves from the top, middle, and bottom of cotton plants were used in a bioassay as an indicator of insecticide deposition within the canopy. The test measured the mortality of beet armyworm (*Spodoptera exigua,* Hübner) larvae feeding on the sampled leaves. All three sprayers provided adequate coverage for good insect control in the top of the cotton canopy. The air-assisted sprayer provided the best insect mortality throughout the canopy, while the over-the-top sprayer had the poorest insect mortality in the bottom. Air-assisted and drop-nozzle sprayers provided good insect mortality in the middle of plants.

The success of the boll weevil, *Anthonomus grandis*, eradication program in the U.S. Southeast has reduced the amount of conventional insecticides used in cotton. However, lepidopterous insects can still cause substantial losses in cotton across the South, and use of conventional insecticides to control them may be severely curtailed due to environmental concerns and the failure of

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insecticide manufacturers to re-register these products for use in cotton. Lack of registered conventional insecticides and/or development of insecticide resistance could lead to crop loss when outbreaks of lepidopterous pests occur.

Industry has developed commercial formulations of several pathogenic organisms for use in insect control. Examples of these are the viruses, Gemstar[1] (Thermo Trilogy Corp., Columbia, MD), the fungi, Naturalis-L (Troy Biosciences), and the bacteria, Dipel DF (Abbott Labs, Chicago, IL) that have promise for use in managing lepidopterous insects. These biological/biorational insecticides could provide alternatives to conventional insecticides for cotton pest management and, theoretically, could reduce lepidopterous pest populations below economic damaging levels while protecting beneficial insect populations.

A need exists to develop and evaluate methods to effectively apply these insecticides to cotton. Placing more active ingredient on the target in an effective manner could enhance product performance, prolong the effective activity, and provide greater economic returns. Improved performance would result in wider acceptance of biological/biorational insecticides by growers.

Application technology has been developed in recent years to improve pesticide deposition and leaf coverage. Mulrooney and Skjoldager (1997) found that air-assisted application of insecticides significantly enhanced the efficacy of boll weevil and beet armyworm control in cotton. Compared with over-the-top and drop-nozzle sprayers, the air-assisted sprayer provided greater canopy penetration and deposit of fluorescent dyes/markers on Mylar sheets and water-sensitive papers in cotton (Womac et al.,1992); plus, it also increased deposition of bifenthrin on leaves and squares within the canopy. Howard et al. (1994) reported that three air-assisted sprayers deposited more bifenthrin on both the upper and under-sides of leaves in the middle of the cotton canopy and had a higher percent coverage than conventional over-the-top hydraulic sprayers. Therefore, the improved canopy penetration and leaf coverage available with air-assisted sprayers should improve the performance of biological/biorational insecticides, which require direct contact or ingestion for effective control.

The objective of this study was to compare the application effect of three sprayer methods (air-assisted, over-the-top, and drop-nozzle) on the effectiveness of Tracer for mortality of lepidopterous insect pests in cotton.

MATERIALS AND METHODS

Application of Insecticides

Field tests were conducted in plots eight rows wide by 15.2 m long planted to cotton, cv. DPL5415 (Delta and Pineland, Scotts, MS) at the Coastal Plain Experiment Station, Tifton, GA, during 1998 and 1999. Application methods were (Fig. 1):

- Air-assisted (Berthoud row crop sprayer that delivered air at 54 m s^{-1}) equipped with two 15/10 blue spray nozzles per row that have 1.5 mm diam. orifices and operated at 103 kPa to deliver 187 L ha^{-1} of spray solution (Berthoud Sprayers, South Haven, MI).

- Over-the-top with two TX-6 hydraulic nozzles per row that operated at 414 kPa and delivered 78 L ha^{-1} (Spraying Systems Co., Wheaton, IL).

- Hydraulic drop nozzles with one TX-10 hydraulic nozzle on each side (38-cm drops) and one over-the-top of the row that operated at 552 kPa and delivered 136 L ha^{-1} .

These sprayers were operated as recommended by their manufacturer or as generally used by spray applicators in cotton. The sprayers differed in spray droplet size, spray rate, and spray coverage throughout the cotton canopy. The insecticide evaluated was Tracer 4SC, applied at 70.1 g ai ha^{-1} with each sprayer. The effectiveness of each sprayer in getting Tracer 4SC to leaves in the top, middle, and bottom of plants was determined by a bioassay of leaf samples, described below. An untreated control was included as a check.

All plots were over-sprayed in 1998 with a blanket treatment of Karate, Lambda-cyhalothrin (Zeneca, Wilmington, DE) applied at 22.4 g ai ha^{-1} on 9, 15, and 21 July using the over-the-top sprayer

[1] Mention of a proprietary product does not imply an endorsement or a recommendation for its use by USDA or the University of Georgia.

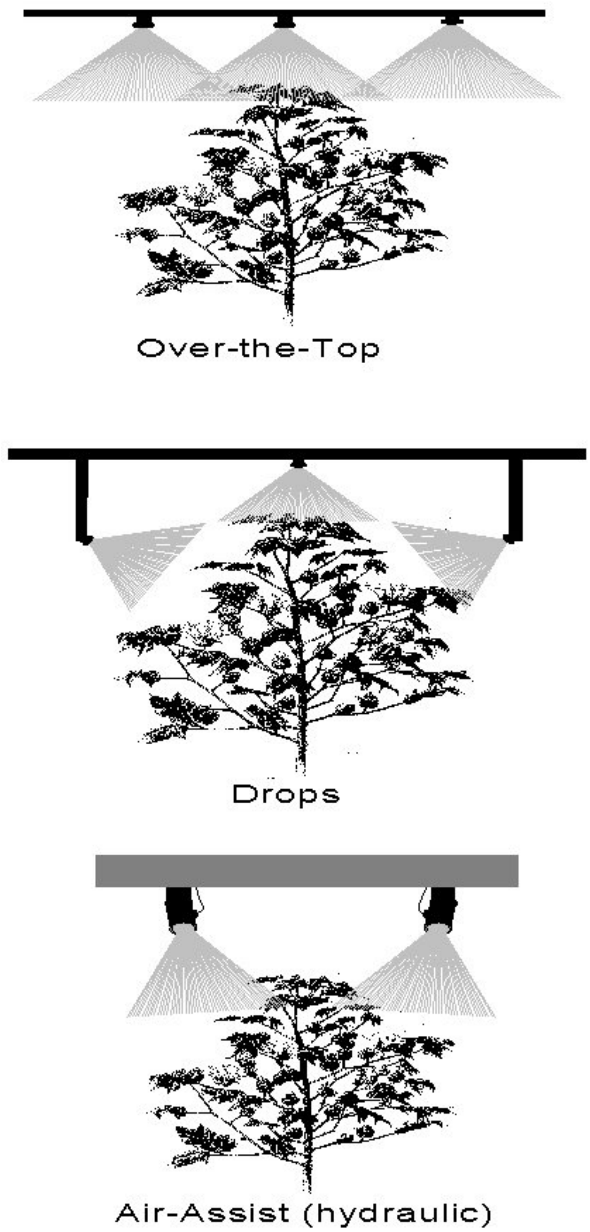

Fig. 1. Schematics of the configurations of the three types of sprayers used in this study to analyze which gives the best overall penetration of the cotton leaf canopy.

treatment. Tracer treatments were applied on 28 July; on 4, 11, 18, 25 August; and 1 September. In 1999 no blanket treatments were applied, and Tracer plots were treated on 20, 27 July; and on 2 and 10 August.

Bioassay of Applied Insecticide Residue

Leaf bioassays were conducted on 4, 18, and 25 August 1998, and on 20, and 27 July and 2 and 10 August 1999 using foliage from the Tracer-treated and check plots. The experiment design was a randomized complete block with four replications where treatments were arranged in a 3-by-4 factorial to evaluate efficacy by plant location and application method for both years.

On the treatment day, after the spray solution had dried on the leaves, five leaves each were sampled randomly from the top, middle, and bottom of the cotton plants (15 leaves per plant) in each plot treated with Tracer and the untreated check plots. Leaves were trimmed to fit into 100 mm diameter sterile petri dishes containing a 75 mm diameter filter paper disk that had been moistened with distilled water to prevent premature leaf desiccation. Ten 5-d-old beet armyworm larvae obtained from the USDA-ARS-IBPMRL insect rearing facility in Tifton, GA were placed on each leaf sample. Five petri dishes were used for each plant location in the plots. Petri dishes were held in an environmental chamber at 24 °C at 50 % RH and 12:12 light-dark photophase. The larvae in each dish were examined 72 h after test initiation, and the number of live larvae recorded.

Table 1. Beet armyworm mortality on leaves from three locations within the canopy of Georgia cotton plants treated with Tracer insecticide applied by three sprayer types on three dates in 1998.

Sprayer method, location sampled within canopy	Beet armyworm mortality			
	4 August	18 August	25 August	Means†
	%			
Air-assisted, top	81 ab‡,y	84 ab,y	54 b,y	73 b,y
Air-assisted, middle	92 a,y	91 a,x	87 a,x	90 a,x
Air-assisted, bottom	76 b,x	74 b,x	83 a,x	78 ab,x
Over-top, top	92 a,y	79 a,y	89 a,x	87 a,y
Over-top, middle	75 b,y	64 b,y	63 b,y	68 b,y
Over-top, bottom	55 c,y	28 c,y	39 c,y	41 c,y
Drops, top	87 a,y	92 a,y	82 a,x	87 a,y
Drops, middle	86 a,y	90 a,x	89 a,x	88 a,x
Drops, bottom	60 b,xy	48 b,y	53 b,y	54 b,y
Untreated, top	12 a,z	2 a,z	1 a,z	5 a,z
Untreated, middle	13 a,z	2 a,z	1 a,z	6 a,z
Untreated, bottom	19 a,z	2 a,z	1 a,z	8 a,z
LSD (sprayer method)	14	15	24	13
LSD (canopy location)	20	24	24	17

† Means are the average of the three sample dates. LSD is the weighted average of the three sampled LSD, Steel and Torrie, 1960.

‡ Mean values in columns with common letters (a,b,c, for leaf location within sprayer method, x,y,z, for sprayer method within leaf location) are not significantly different by Fishers LSD test (*P* = 0.05).

Then SAS Proc Mixed procedures (SAS Institute Inc., 1989) were conducted on mortality data for application methods and leaf position. Means were separated by Fishers LSD (P = 0.05).

RESULTS

Bioassay 1998

There was a significant application method-by-canopy location interaction for the laboratory bioassay for each of the three sample dates. All leaves treated with Tracer, regardless of application method and location on the plants, had significantly higher beet armyworm mortality than did leaves from untreated plots. Leaves from untreated plots had higher beet armyworm mortality on 4 August than on 18 and 25 August, possibly indicating some residual carryover of Karate from the blanket treatments on leaves collected on 4 August (Table 1).

Leaves subjected to air-assisted spray had as high or higher beet armyworm mortality in the middle than in the top of plants; but on 25 August mortality from the top leaves was significantly lower than for the middle and bottom leaves. Our inability to lift the nozzles of the tractor-mounted air-assisted sprayer above the canopy in 1999, as in 1998, probably resulted in spray materials being blown or directed past the plant tops during application. The air-assisted sprayer had lower beet armyworm mortality on leaves in the top and higher beet armyworm mortality on leaves in the bottom of the plant than did over-the-top and drop-nozzle sprayers.

Mortality of beet armyworm on leaves from plots sprayed with the over-the-top sprayer was significantly lower for leaves from top to middle to bottom of the plant canopy. Plots sprayed with the drop-nozzle sprayer had significantly lower beet armyworm mortality on leaves from the bottom of the plant canopy than on those from the top and middle of the plant. Beet armyworm mortality was not significantly different between top and middle of plants for the drop-nozzle sprayer. The over-the-top sprayer had the lowest beet armyworm mortality of all sprayers for leaves from the middle of the plants.

Bioassay 1999

There was a significant application method-by-canopy location interaction for each of the four sample dates in 1999. All leaves treated with Tracer, regardless of application method and location in the plants, had significantly higher beet armyworm mortality than did leaves from untreated plots. Leaves from untreated plots had similar beet armyworm mortality for all four collection dates indicating that there was no pesticide overlap or drift from other treatments (Table 2). The air-assisted sprayed leaves from the middle of the canopy had as high or significantly higher beet armyworm mortality than leaves from the top of plants on all four collection dates. Also, mortality was as high on leaves from the bottom as from the middle of the plants, except on 10 August, when limitations for sprayer height above the canopy, mentioned above, probably resulted in less-effective spray patterns on the top of plants. With the air-assisted sprayer, mortality of the beet armyworm was lower on leaves from the top and higher on leaves from the bottom of the plant than was seen with the over-the-top sprayer.

Table 2. Beet armyworm mortality on leaves from three locations within the canopy of Georgia cotton plants treated with Tracer insecticide applied by three sprayer types on four dates in 1999.

Sprayer method, location sampled within canopy	Beet armyworm mortality				
	20 July	27 July	3 August	10 August	Means †
	%				
Air-assisted, top	60 b‡,y	44 b,y	91 a,y	78 ab,y	68 b,y
Air-assisted, middle	84 a,y	87 a,y	96 a,x	93 a,y	90 a,xy
Air-assisted, bottom	74 ab,y	90 a,y	91 a,x	60 b,x	79 b,x
Over-top, top	83 a,x	99 a,w	89 a,y	94 a,y	91 a,x
Over-top, middle	83 a,y	95 a,y	73 b,y	78 a,y	82 a,y
Over-top, bottom	16 b,z	79 b,y	74 b,y	35 b,y	54 b,y
Drops, top	82 a,xy	70 b,x	80 b,y	80 a,y	78 b,y
Drops, middle	91 a,y	96 a,y	94 a,x	97 a,y	94 a,x
Drops, bottom	84 a,y	81 b,y	89 ab,x	44 b,xy	74 b,x
Untreated, Top	1 a,z	2 a,z	2 a,z	2 a,z	2 a,z
Untreated, Middle	4 a,z	1 a,z	2 a,z	2 a,z	2 a,z
Untreated, Bottom	5 a,z	3 a,z	2 a,z	0 a,z	2 a,z
LSD (sprayer method)	24	13	11	23	11
LSD (canopy location)	24	13	13	23	12

† Means are the average of the four sample dates. LSD is the weighted average of the four sampled LSD, Steel and Torrie, 1960.

‡ Mean values in columns with common letters (a,b,c, for leaf location within sprayer method, w,x,y,z, for sprayer method within leaf location) are not significantly different by Fishers LSD test (P = 0.05).

Mortality of beet armyworm on leaves from plots sprayed with the over-the-top sprayer was significantly lower for leaves from top and middle than for the bottom of the plant canopy. Plots sprayed with the drop-nozzle sprayer had significantly lower beet armyworm mortality on leaves from the bottom and the top of the plant than on those from the middle of the plant. Beet armyworm mortality was not significantly different between top and bottom of plants for drop-nozzle sprayer. When compared with the other sprayers, the over-the-top sprayer had the lowest beet armyworm mortality on leaves at the bottom of the plants.

SUMMARY

Bioassays for insecticidal activity against the beet armyworm indicated that air-assisted sprayers can distribute spray materials throughout the canopies of cotton plants to provide leaf coverage for good insect mortality to most leaves in the middle and bottom of plants. The air-assisted and drop-nozzle sprayers had better insect mortality than did over-the-top sprayers in the bottom of cotton plants. Air-assisted and drop-nozzle sprayers provided good insect mortality on leaves in the middle of plants and some insect mortality toward the bottom of plants. All three sprayers, when adjusted properly, provide acceptable insect mortality to squares and bolls in the top of cotton plants, where insect protection is critical. However, the air-assisted sprayer attachment to the tractor should be redesigned to provide air and liquid discharge above the cotton canopy.

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