COTTON PESTICIDE DEPOSITION FROM AERIAL ELECTROSTATIC CHARGED SPRAYS

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Abstract

A 1995 season-long aerial electrostatic spray charging program was undertaken to determine the feasibility of controlling whitefly in cotton. Sixty acres of whitefly infested production cotton was made available for the study by the University of Arizona, Maricopa Agricultural Center at Maricopa, AZ. This test area was subdivided into four equal size replicates which were further subdivided into four aerial spray treatment plots. In the four spray treatments formed, we sought to compare three spray charging regimens with that of conventional aerial spraying for whitefly. The season-long control effort consisted of six aerial pesticide applications over the test plots. Intensive pre and post spray sampling of depositing spray was carried out by use of leaf washers. The spray dosage resulting from quantitative analysis of the leaf deposits provided a basis for statistical inference. The large-scale experimental study resulted in many detailed conclusions. However, relative to our objectives, we found some important results. From an overall season perspective, one of the three aerial electrostatic spray charging protocols gave cotton deposition levels that were equal to or significantly higher than that of the conventional protocol applying the same active ingredients. A companion study that dealt with efficacy, referenced in the text, also drew some positive conclusions regarding whitefly control using aerial electrostatic spray charging technology.

Introduction

Previous research has shown that aerial electrostatic spray charging can provide desirable deposition effects. Carlton et al. (1995) showed that electrostatic charging of aerial spray over cotton could enhance deposition by more than four times over identical but uncharged spray. That research also showed that increased canopy penetration was also achieved as well as a plant leaf wrap-around effect that gave higher underleaf coverage. Equally important was the identification of the bipolar spray charging protocol as the one that best achieved those results. From this it can be concluded that the state-of-the-art/science has progressed sufficiently for this methodology to become a part of aerial spraying of the near future. However, there are still related problems that yet remain to be solved. Among them is the lack of spray charging nozzles that can provide suitable atomization, spray flow rate, charge/mass ratio (Q/M) and survive the rigors of a field operational environment over time. This is no small order. Drift studies with electrostatically charged aerial sprays also need to be carried out to determine the extent of this factor. For the present, it is necessary to carry out further field studies that relate to deposition and biological control of an economic pest. It has recently been demonstrated that some plant pest could be controlled by use of charged sprays applied from ground equipment (Gao et al. 1994; and Kabashima et al. 1995). Similar advantages are to be expected from aerial electrostatically charged pesticide sprays. For the challenge to explore this, we have chosen the control of whitefly in cotton. The objectives of our study were: (1) Determine if the state-of-the-art/science of aerial electrostatic spray charging is sufficient to compete with conventional protocol for improving pesticide deposition on cotton. (2) Determine from (1) the limitations/ problems that must be solved to make the methodology/ technology ready for practical use.

Description of the Aerial Spray Equipment Used in the Study

Figure 1 provides a visual description of the assembled boom and spray charging system mounted on the Ag Husky spray aircraft. The system was engineered to provide the large number (82) of spray charging nozzles necessary for 0.5 gal/acre. The nozzles are a recent design for induction charging whose characteristic features are given in Tables 1 and 2. The nozzles (Figure 1) required some clustering and special support for operating in a smooth, laminar, airstream region. Each nozzle body contained its own check value. A 1/4" dia stainless steel rod (buss bar) was positioned/ supported on insulators trailing behind the boom. The buss bars served to distribute power to each of the nozzles. Small wires were provided to electrically connect the nozzle induction charging electrodes to the buss bars. High voltage cable provided power from the interior ends of the buss bars to the (±) power supplies. The remainder of the wiring, electrical equipment, and operational procedure was as previously described by Carlton et al. (1995). The entire boom system was aerodynamically designed to provide low drag and stability against vibration. In operation, it was always necessary for the pilot to use charging voltage settings less than the optimums as indicated in Table 2. This was due to check-valve problems causing wetting and hence shorting/burning of the electrode insulator supports. Thus, the charging system had to be operated at a compromising voltage of ± 5 kV.

Figure 2 is a photograph of the boom setup for the conventional spray applications. This setup also used tubular drops onto which CP nozzles were attached. A total of 32 CP nozzles was used providing an application rate of 5 gal/acre at 28 psi. The same AG Husky aircraft and pilot were used for applying all of the spray treatments.

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Interchanging the two sets of booms permitted appropriate treatment changes.

Experimental Procedure

Aerial spray treatments that give a good test against the conventional protocol to control whitefly in cotton are given in Table 1. Each treatment incorporated the same insecticide applied at label active ingredient (a.i.) rates except as follows. Treatments' T_1, T_2, and T_3 were always applied at the finished spray rate of 0.5 gal/acre. Additionally, T_3 was selected to apply the insecticide at 1/2 the a.i. rate. Treatment T_4 was designated the conventional one and consequently the spray applications were applied at full a.i. label rates and at 5 gal/acre. A fluorescent spray tracer (Caracid Brilliant Flavine FFN, Carolina Color and Chemical Co., Charlotte, NC) was incorporated into each treatment spray mix. A dye application rate of 10 gm/acre was added for each spray treatment.

A 60 acre field of irrigated production cotton was made available for the test. It was subdivided into four equal size blocks to serve as the spray replicates. Each block was subdivided to provide for each of the 4 randomly assigned treatments. Thus there were 4 treatments and 4 replicates of each treatment for each (6) spray application. All spray applications were applied as the adult whitefly population thresholds (i.e., 5 per leaf) dictated. Cotton plant deposition was sampled both pre and post spraying and in accordance to the protocol previously delineated (Carlton 1992, Carlton et al. 1995). Notes given in Table 1 show that 6 spray applications were made between 7/28/95 and 9/8/95. The insecticide used for each application is also noted. Danitol/Orthene is currently one of the common insecticides for whitefly control and could only be used four times as prescribed by the label. The electrostatic spray nozzle performance characteristics were established (Table 2) by use of this insecticide. Practical operational problems (i.e., drooling/ leaky check values) with the nozzles required operating the charging system at ± 5 kV. Consequently, it was not practical to operate the charging system at a higher and at a more desirable Q/M ratio level (see Tables 1 and 2).

The six spray application dates are given in Table 1. Each of the six indicated dates is those for which leaf spray deposit sampling was done. The treatment deposit means for each of the six applications are tabulated in Table 3. The data of this table was statistically analyzed (SAS, 1987) to compare mean effects among treatments for each application. Season-long deposit means for each treatment (Table 3) were formed to provide comparisons among each treatment (i.e., see bar graph, Figure 3).

Another study was concurrently carried out to evaluate the efficacy of the treatments. Efficacy, or controlling whiteflies in the cotton required getting count data to give a measure of quality of the treatment effect. That independent study was carried out by Latheef et al. (1995). Adult whitefly counts and leaf-borne eggs and nymphs were routinely sampled in the cotton. When adult whitefly counts (using the leaf-turn method) rose to 5/leaf, spraying was initiated.

Results and Discussion

Early in the spraying season it became apparent that plumbing problems due to poor performance of the nozzle check valves would be detrimental. Specifically, poor check valve seating/closure caused nozzle leakage and hence wetting of the insulators supporting the induction charging, cylindrical electrodes. The high-voltages placed upon the electrodes caused immediate shorting/insulator burn-outs. From experience, we found that ± 5 kV charging voltages were marginally acceptable. From Table 2, a 5 kV charging voltage corresponds to a Q/M = 1.15 mC/kg for T_1 and 0.80 mC/kg for T_3. On the basis that a $Q/M < 0.80$ mC/kg will not show enhanced depositional effects (Law and Lane, 1981), we were forced to operate at a marginal Q/M ratio. This situation accounts for the Q/M ratio levels indicated in Table 1. It is important to point out that unless spray charging levels are known to be $\geq$ 0.80 mC/kg, the results from electrostatic charging cannot be expected to enhance spray deposition. Conversely, as the Q/M ratio increases, enhanced deposition will increase. We subsequently used this (Table 1) charging level throughout the duration of the spray program.

From the nozzle performance data of Table 2, it was to be expected from the outset that the deposition from T_1 would be greater than that of T_3. The season-long deposition data (Table 3) shows that this was the case for all of the means. The differences were not all significant, however. From the table, Appl. 2 shows that T_1 had a significantly higher mean than any of the others. T_3 and T_4 were not different, and T_2 was lowest of all. The true effect of charging can be seen in comparing the T_1 mean with that of T_2 (i.e., 2:1). Other conclusions from the applications can be similarly drawn. Some of the treatment effects change with the application number. For example, for Appl. 3 and 4, T_1, T_3 and T_4 are not significantly different. There are season-long trends and these are more readily observed from the bar graph of Figure 3. This portrayal shows that T_1 had significantly higher deposition than that of all others. The next largest deposit mean was that of T_4 but it was not statistically different from that of T_3. Finally, T_2 had the lowest deposition level among all treatments. In conclusion, when comparing the treatments T_1, T_2, and T_3 with the conventional T_4: (1) T_1 is as good as that of T_4. (2) T_2 is not as good as T_4. (3) T_3 shows promise in reducing the amount of a.i. but could not be currently recommended because of its low Q/M ratio. Specifically, it is not clear if the reported low efficacy performance (Latheef et al. 1995) is due to low deposition from a low Q/M ratio (or) that due to the 1/2 a.i. rate, (or) both. It will be necessary to repeat a test with T_3 after the nozzle problem has been solved.

The data of Table 2 shows that the current spray charging nozzle does have the capability, under more ideal conditions, to perform at a higher level of spray charging efficiency than was practical in the field of study. The check valves were seen as the primary source that created the secondary, and detrimental voltage breakdown problems. The basic nozzle performance is otherwise considered satisfactory. The other spray formulations used in the season-long effort were found to be sufficiently electrically conductive to be chargeable by the nozzle. Modification of the charging electrode support is needed to partially solve the primary problem. Improved deposition results by T_1 and equivalent efficacy results (i.e., T_1 (vs.) T_4), show that electrostatic aerial spray charging is similar to that of conventional aerial application.

The operational protocol of the cotton production farm provided an opportunity to continue the spraying and deposition studies through an induced drought-stress period. In the early exploratory studies of plant leaf retention phenomenon of agricultural liquid formulations, (Carlton, 1995) observed several unreported effects. An immersion cell (Carlton, USDA/ARS, 1994) was used to identify and measure a change in the effect of interfacial forces that bond the formulation to plant leaves. For cotton leaves, an observation was made that these bonding forces apparently changed as the plant underwent physical stresses from temperature/drought effects. It was suspected at that time that such an effect would be involved in changing the bonding effect in actual spray applications. The induced drought-stress in the cotton provided an ideal opportunity to obtain further information about the phenomena on a large scale basis. It is to be noted that the effects are, or, can-be formulation sensitive. Specifically, the formulation(s) must be fixed throughout a test. From Tables 1 and 3, applications 3-6 contained formulations of Danitol/Orthene only. Consequently only deposition data for these applications is considered. The results of this portion of the overall experiment are given in Table 3. Beginning with each treatment (Appl. 3) and continuing, a considerable increase in deposit occurred on Appl. 6. Means of this data were subsequently combined and statistically analyzed (Figure 4). This bar graph shows the mean deposit effects by date and the date of the last surface irrigation (8/19/95). The statistical analysis shows that the mean deposition was not statistically different until the spray test on 8/31-9/1/95. It is considered to be remarkable in itself that Appl. 3, 4, and 5 were not statistically different. It certainly attests to the overall quality of our field protocol. The same trends seen in Figure 4 were also observed from the raw experimental data. Specifically, the same results are seen from observing only; (1) the top plant canopy data, (2) the mid canopy data, (3) the tops of leaf surface data, or (4) the leaf bottom data. Similar results of the converse of this effect were established by Carlton et al. (1994). In that deposition study, one of the 3 replicates was found to be statistically significant, i. e. lower deposit levels. This rep was irrigated the day before the aerial spray application. These two independent studies provide documentation that ties the earlier retention measurements to a diverse array of aerial spray treatment depositions.

There are several points to be made regarding the retention discoveries. The increases in deposition are not related to electrostatic charging. All (4) spray treatments showed the effect. It was also independent of the 3 different spray formulations, as well as, the respective atomizations. It is quite clear from the results that by spraying when the cotton was drought-stressed, the overall deposition was increased (Figure 4) by: $(32.7-22.13)/22.13 \times 100 = 48\%$. This means that if control was being achieved at the lower deposition rates (i.e. Appl. 3, 4, and 5), then $\approx$ 33% of the chemical collecting on the cotton on Appl. 6 was not needed. This obviously has economic implications for the producer and should infuse some prudence about the environment.

Acknowledgments

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Table 1. Aerial spray treatments/parameter identification.

A. Cessna Ag Husky spray aircraft application parameters.
  1. Speed: 120 M/H.
  2. Elevation: ≈ 5 ft. boom above cotton.
  3. Nozzles for T_1, T_2, T_3 (See Figure 1): 82 each hydraulic electrostatic spray charging nozzles operating at 70 psi, 0.06 g/m with a system calibration to apply 0.5 gal/acre.
  4. Nozzles for T_4 (See Figure 2) 32 each CP hydraulic nozzles operated at 28 psi with system calibrated to apply 5.0 gal/acre.

B. Treatment (T_i), $_{i = 1, 2, 3, 4.}$
  T_1: Electrostatic charging of insecticide at full label active ingredient (a.i.)
  rate applied at 0.5 gal/acre.
  T_2 Identical to T_1, except without charging.
  T_3 Electrostatic charging of insecticide at one-half label rate applied at 0.5 gal/acre.
  T_4 Conventional applied insecticide at full a.i. label rate at 5 gal/acre using CP nozzles.

C. Spray application number (Appl. #), dates, and insecticides.
  Appl. 2. (7/28-29/95), Insecticide was Thiodan/Ovasyn.
  Appl. 3. (8/5-6/95), " " Danitol/Orthene
  Appl. 4. (8/16-17/95), " " "
  Appl. 5. (8/25/95), " " "
  Appl. 6. (8/31-9/1/95), " " "
  Appl. 7. (9/7-8/95), " " Capture/Orthene.

D. Aerial spray parameters for Danitol/Orthene only
  1. Atomization (See technique by Bouse (1994))
    T_1 and T_2, $D_{v0.5}$ = 174 µm
    T_3 , $D_{v0.5}$ = 178 µm
    T_4 , $D_{v0.5}$ = 282 µm

  2. Spray charging parameters for Danitol/Orthene only.
    a. Bipolar (±), dc induction charging nozzle operating at 0.06 g/m,70 psi.
    b Average spray charge/mass (Q/M) ratio.
      T_1, Q/M = ± 1.15 mC/kg
      T_3, Q/M = ± 0.80 mC/kg.

Table 2. Spray charging nozzle data depicting performance characteristics obtained with Arizona well water (T_0) and with Danitol/Orthene insecticide treatment formulations (T_1) and (T_3).*

Test formulation (T) with spray current (I) and charge/mass ratio (Q/M, mC/kg).

Charging Voltage	T_0		T_1		T_3	
(±kV dc)	I (µA)	Q/M	I (µA)	Q/M	I (µA)	Q/M
1	0.75	0.20	1.00	0.27	0.50	0.13
2	1.75	0.47	1.75	0.47	1.00	0.27
3	2.75	0.73	2.60	0.69	1.60	0.43
4	3.25	0.87	3.50	0.93	2.25	0.60
5	4.25	1.13	4.30	1.15	3.00	0.80
6	5.25	1.40	5.20	1.39	4.00	1.07
7	5.75	1.53	6.20	1.65	4.80	1.28
8	6.25	1.67	7.00	1.87	5.40	1.44
9	6.50	1.73	7.50	2.00	6.50	1.73
10	4.75	1.27	7.50	2.00	7.10	1.89
11	-	-	6.00	1.60	7.60	2.03
12	-	-	-	-	7.60	2.03
13	-	-	-	-	6.00	1.60

* Test blower air velocity 120 mph, nozzle spray pressure 70 psi, with flowrate of 225 mL/m.

Table 3. Mean* aerial spray cotton leaf dosages obtained showing variation among treatments, application number, and results of statistical analysis.

	Application order and dosage means (ng/cm^2)					
Treatment	Appl. 2	Appl. 3	Appl. 4	Appl. 5	Appl. 6	Appl. 7
T1	56.0a	25.7a	25.5a	24.3ab	41.1a	34.4a
T2	23.9c	13.2b	20.7b	18.1c	27.7b	25.6b
T3	43.9b	21.5a	22.5ab	20.5bc	31.3b	28.2b
T4	36.7b	24.1a	22.1ab	27.2a	30.7b	36.7a

* Means in each separate column followed by the same letter are not significantly different, α = 0.05.

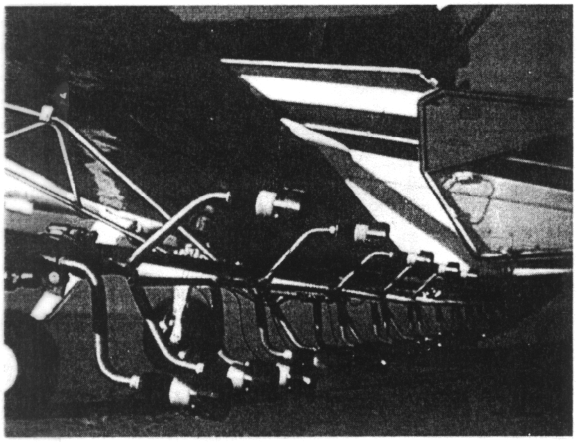

Figure 1. Photograph of electrostatic spray charging boom system setup on Ag Husky Aircraft.

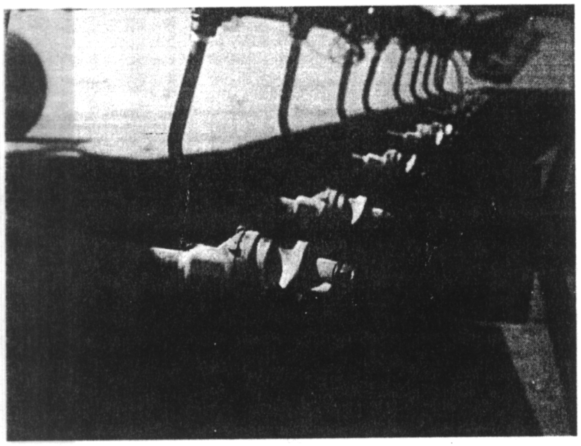

Figure 2. Photograph of the conventional CP nozzle/boom system used in the study.

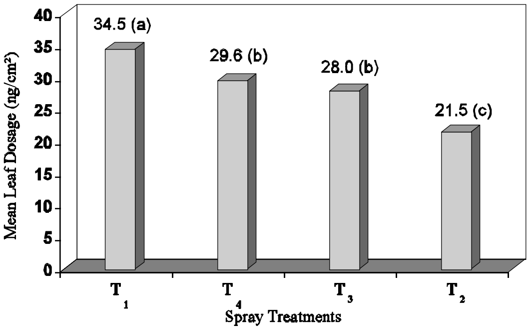

Figure 3. Bar graph showing mean spray deposits from season-long spray treatment applications. (Treatment dosage means with the same letter are not statistically different, α = 0.05)

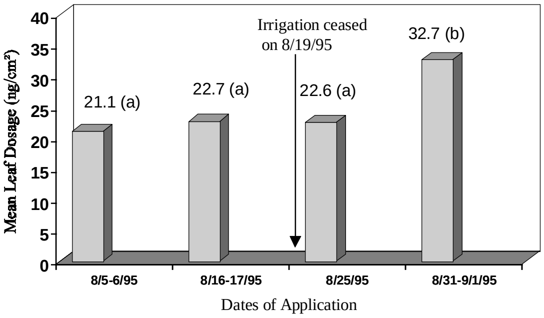

Figure 4. Bar graph showing effects of aerial spray pesticide deposition on cotton before and after inducing drought-stress. (Mean dosages with the same letter are not significantly different, α = 0.05)