Journal of Electrostatics 90 (2017) 38–44

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Aerial electrostatic spray deposition and canopy penetration in cotton

Daniel E. Martin*, Mohamed A. Latheef

USDA-ARS, Aerial Application Technology Research Unit, 3103 F and B Road, College Station, TX 77845, USA

ARTICLE INFO

Article history:
Received 1 October 2016
Received in revised form
2 June 2017
Accepted 9 August 2017

Keywords:
Fluorescent imaging
Electrostatics
Aerial sprays
Cotton

ABSTRACT

Daylight visible fluorescent dye (10% v/v) mixed with water was aerially applied on mature field cotton with electrostatic and rotary atomizer nozzles. The spray rates for the electrostatic and rotary atomizer nozzles were 9.4 and 28 L/ha, respectively. Images of spray droplets on cotton leaves were digitally analyzed with ImageJ software. Charged spray cloud increased deposition nearly two to three times on adaxial and abaxial surfaces, respectively, of top canopy leaves compared to uncharged spray. Canopy penetration of the spray into the lower layers of the plant foliage was unaffected by spray application method.

Published by Elsevier B.V.

1. Introduction

Gossypium hirsutum L. with an indeterminate vegetative growth pattern and luxuriant foliage on its alternate phyllotaxy of branches poses a great challenge for the application of pest control products relative to canopy penetration and deposition on the bottom surface of cotton leaves. Cotton aphids, *Aphis gossypii* Glover and sweet potato whiteflies, *Bemisia tabaci* (Gennadius) reside on the abaxial surface of cotton foliage and cause 80–90% of lint stickiness from honeydew resulting in contamination and eventual shutdown of lint processing machines [12,37]. Moreover, cotton aphids have evolved from being an occasional pest in the early 1980's to one of the significant pests on seedling and late season cotton in San Joaquin Valley in California [4,11]. In 1997, aphids caused yield losses of as much as 3.4% in California, despite suppression measures which incurred ~ $98.8 per hectare [11,42]. As early as 2014, aphids infested 2 million hectares of cotton amounting to ~46% of the cotton crop planted in the United States [43]. Furthermore, aphids are vectors of more than 50 plant viruses and could reduce yield as much as 100% in a virus epizootic [20,36]. In contrast to aphids, whiteflies cause yield loss in cotton due to a combination of factors including plant diseases from transmitted viruses, direct feeding damage, physiological disorders and lint stickiness concomitant with fungal growth [33]. Furthermore, whitefly honeydew is stickier than aphid honeydew and the cost of controlling whiteflies to prevent yield reduction and stickiness of cotton fibers per hectare is 30-fold greater than that for aphids [1,2,10,13,32].

Adequate spray coverage and penetration of insecticides to the abaxial surface of the cotton leaf are essential for satisfactory control of these organisms and to ensure honeydew-free cotton fibers. However, the difficulty in controlling bottom leaf dwelling insects is exacerbated by the closure of cotton canopy which impedes deposition of pesticides onto the target site. Additionally, the development of improved application hardware is required to increase spray penetration into the cotton canopy. Uk and Courshee [39] reported that the spray distribution in the cotton canopy from an aerial application followed an exponential decay formula dependent upon foliage density with the latter effectively impeding the penetration of the spray droplets into the lower area of the canopy. Hirsch [16] reported that a custom winglet boom, when operated at 1-m above the cotton canopy, increased spray deposition on the upper surface of foliage compared to a conventional boom and nozzles. Canopy penetration also improved with increased deposition on the underside of the leaves in the top canopy. Using ASC rotary nozzles, Latheef et al. [23] found that the increased wake effect of lower air speed at 145 km/h improved deposition in the bottom canopy in cotton compared to that when air speed was higher at 185 km/h.

Several researchers have reported that electrostatically charged sprays increased deposition from two to seven-fold on the abaxial surface of artificial targets compared to uncharged conventionally

---

* Corresponding author.
E-mail addresses: Daniel.Martin@ars.usda.gov (D.E. Martin), Mohamed.Latheef@ars.usda.gov (M.A. Latheef).

http://dx.doi.org/10.1016/j.elstat.2017.08.005
0304-3886/Published by Elsevier B.V.

applied spray applications [24,29,30]. Wolf et al. [45] reported that a combination of 45 kV electrostatic charge and 50 cm nozzle spacing on an electrostatic ground sprayer resulted in a 96% and 345% increase in deposition on smooth pigweed, *Amaranthus hybridus* L. and giant foxtail, *Setaria faberi* Herrmann, respectively, compared to the uncharged controls in a simulated no-till wheat, *Triticum aestivum* L. stubble system. Wolf et al. [45] attributed the increased deposition to the reduction in interference of electrical fields from an adjacent nozzle in a wider spacing configuration. Furthermore, several researchers have demonstrated that full-scale, ground-based prototype electrostatic delivery systems resulted in equivalent levels of pest suppression using 1/2-rates of pesticides compared to conventional spray applications at full rates [14,19,44]. Using about one-fifth of a conventional spray rate at 9.4 L/ha, Kirk et al. [22] demonstrated that an aerial electrostatic spray application increased spray deposit and controlled cotton bollwevil, *Anthonomus grandis grandis* Boheman and the whitefly, *B. argentifolii* comparable to a conventional application at a spray rate of 46.8 L/ha.

The objective of this study was to determine if electrostatically charging an aerial spray cloud could increase deposition and canopy penetration of spray droplets in late season field cotton. A corollary to this objective was to assess whether or not DayGlo Rocket Red dye could serve as a fluorescent marker for quantifying spray deposits in field cotton.

2. Materials and methods

2.1. Treatment description

This study was conducted in a mature cotton field in Burleson County, near College Station, TX (30° 40′ N, 96° 18′ W) in late August when at least 10% the bolls were opened. Three different aerial spray treatments using an Air Tractor 301A flying at 3-m height and 210 km/h, were established on late-season field cotton; electrostatic nozzles (Spectrum Electrostatic Sprayers, Houston, TX) with charge off, electrostatic nozzles with charge on, each at a spray rate of 9.4 L/ha and a rotary atomizer nozzle (Model Hi-Tek, Davidon, Inc., Unadilla, GA) at a spray rate of 28.1 L/ha. We chose to compare the electrostatic nozzle spray application with that of the rotary atomizer nozzle in lieu of conventional hydraulic flat fan nozzles. Rotary atomizer nozzles produce a narrower controlled spectrum of spray droplet sizes with smaller droplet size and higher droplet density comparable to electrostatically charged nozzles [15,18,23,38]. Electrostatic nozzles induce a charge on spray droplets by an applied electric field between the grounded nozzle and the electrode encircling the spray cone. Larger electric fields increase the induced charge on the droplets. More charge can be placed on the droplets by increasing the applied electric field. However, too large an electric field can cause the system to short-out. The pilot optimizes the charge on the spray by setting the applied current equal on both left and right booms while staying below the “short-out” voltage. Table 1 showed that the meteorological conditions between treatments were stable with no cross wind during the time of the test. Seventy one aerial electrostatic nozzles were mounted on the boom with the left and right boom charged at - 7.0 and + 8.0 kV, respectively. Total system current was 250 μA. The left boom was negatively charged while the right boom was positively charged. There were seven and six rotary atomizer nozzles on the right and left booms, respectively. The pressure was set at 483 kPa. Each spray consisted of three 20-m swaths, each 200-m in length. There were 3 replications of each treatment and the treatments were assembled in a randomized complete block design. A daylight visible fluorescent dye mixed with water at 10% v/v (DayGlo Tintex Rocket Red, TX-13, DayGlo Color Corp., Cleveland, OH) was used as a tracer for the applied spray. The spray was allowed to dry on the cotton leaves for ca. 10 min. before collection. Main stem leaves from each of the top and bottom canopy regions were clipped from individual plants in the center swath of each experimental plant. There were 10 sampling locations in each experimental unit that were diagonally oriented and separated by two rows longitudinally and 3-m axially. The sample leaves were placed individually in properly labelled plastic zippered bags and placed in coolers for transport to the laboratory. The petioles of the cotton leaves were clipped with a knife.

2.2. Fluorescent imaging

A digital camera (Model Alpha 7R, Sony Corp., Tokyo, Japan) secured to a tripod with the lens focused on the target area, was used to image the cotton leaves. The abaxial and adaxial leaf surfaces were digitally imaged by placing each leaf on a matte black platform in the laboratory and the palmate lobes of the leaves were flattened by holding the leaves under a glass plate while imaging. The images for the top and bottom leaves were saved in a lossless. TIFF format. Two 1.2-m black light bulbs (Model F40BLB, General Electric, Fairfield, CT) placed 36 cm overhead provided illumination of the leaf surface. After imaging, the photographs of both the top and bottom leaf surfaces were then processed using ImageJ, a public domain, Java-based image processing software. The image processing procedure was similar to that described earlier by Martin [28]. However, some modifications were made to the thresholding parameters to enhance the spray droplets on cotton leaves. Adequate brightness of the image was assured by adjusting the brightness slide bar between a minimum of 46 and a maximum of 255. The default thresholding method with red threshold color and HSB color space was thereafter used to obtain filtered images selecting the Rocket Red color of the fluorescent dye used in the study. The software identified and outlined the individual spray droplets and the image was saved for the top and bottom surfaces. Figs. 1 and 2 show thresholded images of the uncharged and charged treatments in the adaxial and abaxial surfaces of top canopy leaves, respectively, with fluorescent spray droplets illuminated under black light. These droplets were then selected for analysis (Figs. 3 and 4). The spray droplets were filtered by setting the particle size from 0 to infinity, and the circularity to 0.20 to 1.00 to ensure that only spray droplets were analyzed. Drawings of the analyzed droplets were produced by the software and are shown in Figs. 5 and 6. Table 2 summarizes the results of the ImageJ analysis of the spray particles and describes the total number of droplets, total area occupied by the droplets, the average size of the droplets, the percent area of the image the droplets occupied and the mean

Table 1
Meteorological conditions at the time of spray applications.

Treatment	Application Time	Wind Speed (km/h)	Temperature (°C)	RH (%)
Uncharged	11:50	2.99	34.8	55.6
Charged	11:55	4.04	34.8	55.6
Rotary Atomizer	12:10	3.20	34.8	55.6