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Air Carrier Technique for Row Crop Spraying Applications

Dennis G. Watson
Southern Illinois University Carbondale, dwatson@siu.edu

Robert L. Wolff
Southern Illinois University Carbondale

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Dennis G. Watson, Robert L. Wolff
ASSOC. MEMBER ASAE, AFFILIATE ASAE

ABSTRACT

THIS study focuses on the problem of applying spray material to upper-plant, underside-leaf surfaces of corn and soybean plants. Aircraft and ground pressure-atomizer applications of spray solution were quantified. Percent coverage values were generally less than 1% on the sampling locations.

Flat and hollow cone nozzle air carrier units were developed and evaluated for spray application to the upper-plant, bottom leaf surface. The air carrier method tested within a shroud improved spray deposition to the entire plant by 100% for corn and 234% for soybeans. Deposition to the upper-plant, bottom leaf surface was increased by 900% and 400% for corn and soybean plants, respectively. Deposition uniformity was also improved with the air carrier method.

INTRODUCTION

Spray placement research has demonstrated the need for technological improvements for increasing the efficiency of spray material deposition on specific plant targets. Although many chemical applications would benefit from improved spray deposition, this study focuses on the problem of applying spray material to the upper-plant, bottom-leaf surfaces of corn and soybean plants. Two chemicals which are applied in this manner are fungicides and foliar fertilizers. Certain fungicides penetrate leaves through stomata which are principally located on the undersides of leaves. It is therefore necessary to obtain maximum coverage on the bottom of leaves to control disease (Raynor, 1960). Foliar fertilization studies of corn and soybeans revealed inconsistent yield responses, possibly due to ineffective fertilizer application to leaf undersides (Wolff et al., 1978 and Werkheiser, 1979).

Aircraft and over-the-row pressure atomizer arrangements, by design, lack the ability to direct spray primarily to leaf undersides, however spray deposition has not been previously quantified with respect to the extent and distribution of spray material to foliar targets from a given treatment. An alternative arrangement wherein pressure atomizers are located between rows and directed upward toward leaf undersides results in spray pattern distortion due to leaf contact (Wolff et al., 1978). Various row-crop spraying techniques have been developed to improve spray deposition. An air carrier method was used in this study to facilitate application rates of 94 L/ha and allow atomizer placement between plant rows to direct spray to leaf undersides.

Staniland (1960) found that small air blast machines, such as knapsack sprayers, can give excellent coverage when spraying is done from two directions on each row. Zucher and Zamir (1964) developed an experimental four-row air sprayer using a centrifugal fan to provide an air supply. Roehl (1982) evaluated a sprayer concept using an air blast principle to force air past a hydraulic nozzle mounted within an air outlet. A spray shroud used with pressure atomizers to erect growing crops with saturation spray requirements was thought to be feasible (Beasley et al., 1983).

The objectives of this study were to quantify aircraft and ground pressure atomization spraying methods and to investigate an air carrier method of applying spray material to corn and soybean foliage. The air carrier concept investigated in this study consisted of air nozzles located adjacent to each pressure atomizer. Optimum air stream locations relative to the pressure atomizer can allow atomizer positioning between rows with a minimum of spray pattern distortion from leaf contact. A spray shroud used with the air carrier method could also improve spray deposition effectiveness with less spray drift than over-the-row arrangements.

PROCEDURE

Spray deposition was sampled from 31 corn and 16 soybean leaf and stem locations distributed throughout each plant. White onionskin (100% rag content) target papers were attached to 5, 10 or 20 randomly selected plants for each treatment. A 40:1 tracer solution of water and India ink was applied by the different spraying methods (Werkheiser, 1979 and Ziaee, 1982). A solar cell (connected to a voltmeter) was then used to quantify the amount of light transmitted from a light box through the sample papers. Sample papers with greater spray coverage produced lower voltage readings than papers with lesser amounts of coverage. Any damaged sample papers were quantified with a comparison chart of papers with known voltage values. Art screens with known coverage values of 10, 20, 30, 40 and 50% at three line densities were each quantified five times with less than 1.25% variation from the mean. Sample paper voltage values were converted to percent coverage based on the equation resulting from the art screens quantification.

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The authors are: DENNIS G. WATSON, Research Technician, and ROBERT L. WOLFF, Professor, Department of Agricultural Education and Mechanization, Southern Illinois University at Carbondale.

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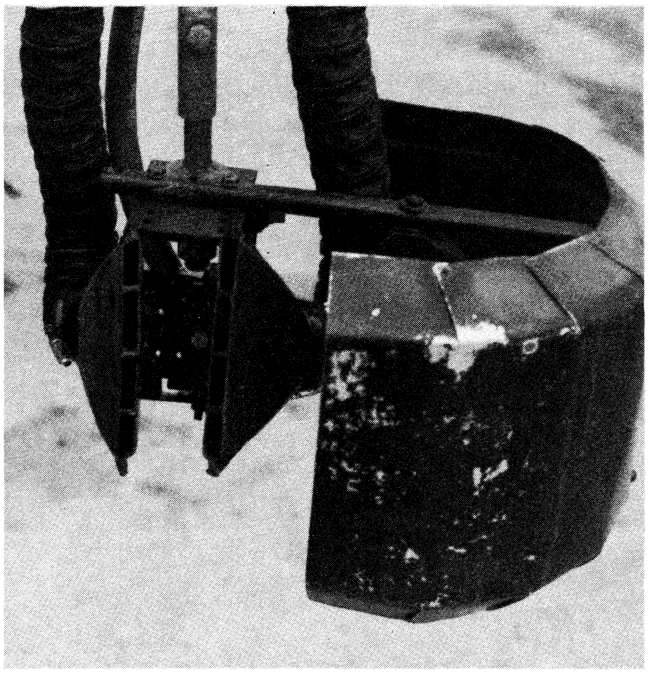

Fig. 1—Flat air nozzle unit mounted on sprayer.

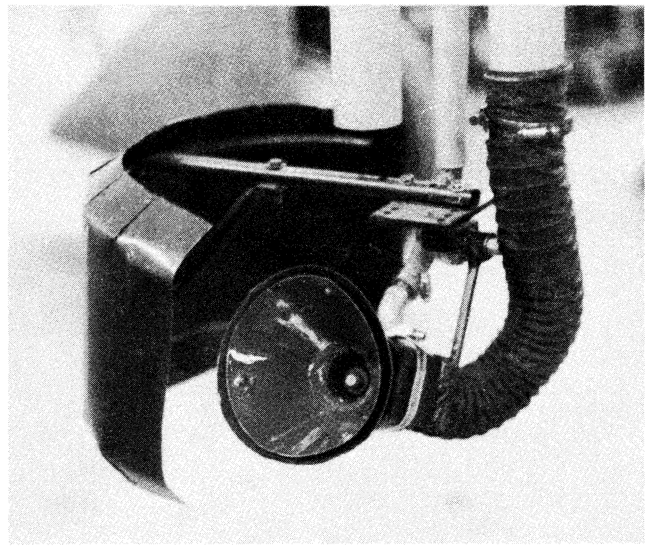

Fig. 2—Hollow cone air nozzle unit mounted on sprayer.

Aircraft and ground hydraulic atomization spraying treatments of 47, 94 and 140 L/ha were tested. The ground applications, with hollow cone atomizers, also consisted of each combination of two and three nozzles per row and 276, 345 and 414 kPa spraying pressure. Ground speed was 4.8 to 8 km/h for the high clearance ground sprayer and 145 km/h for the aircraft. Three aircrafts and eighteen ground spray treatments were applied to corn and soybean crops. Spray applications were targeted to the upper half of the plants and applied when wind velocity was less than 8 km/h.

Modified hydraulic nozzle units were constructed to evaluate the air carrier concepts. The units were designed for single-row foliar applications. Air nozzles were positioned to form an air curtain to direct and confine the spray particles. Air streams on either side of a flat atomizer (Fig. 1) intersected the spray pattern at 30 deg, approximately 15 cm from the pressure nozzle. The conical air stream for the hollow cone atomizer (Fig. 2) completely surrounded the spray pattern (Watson, 1984). Atomizer flow rate was 0.28 L/min with a volume median droplet diameter of 159 and 146 microns* for the flat and hollow cone atomizers, respectively.

The target area of the air carrier method was the upper-plant top and bottom leaf surfaces. The air nozzle units were positioned between the rows and angled up at 30 deg from horizontal.

Air from a centrifugal fan was routed to the air nozzles through flexible tubing (Fig. 3). Three fan speeds (900, 1200 and 1500 r/min) were used to vary air flow and velocity. Air flow at 1500 r/min was 2.0 m^3/min at 968 m/min for each hollow cone nozzle and 1.3 m^3/min at 2031 m/min for each flat nozzle.

Testing of the air stream concept was first conducted during 1982 with flat nozzle units mounted within a spray shroud. Twelve treatments were tested on both corn and soybeans using two and three nozzle per row arrangements with different air nozzle sizes and angles relative to the pressure atomizers. Four hollow cone pressure-atomizer treatments, without the air carrier, were applied for comparison with the air carrier method.

Flat and hollow cone air carrier units were tested in an open boom arrangement at 94 L/ha and 4.8 km/h ground speed for spray deposition on soybeans. Treatments without the air stream and with the air stream at three fan speeds were used to evaluate the air nozzle units.

Over 24,000 spray deposition samples were collected and quantified. Data subsets including the entire plant, upper-half of the plant, upper-plant top leaf surface and upper-plant bottom leaf surface were used for treatment comparison.

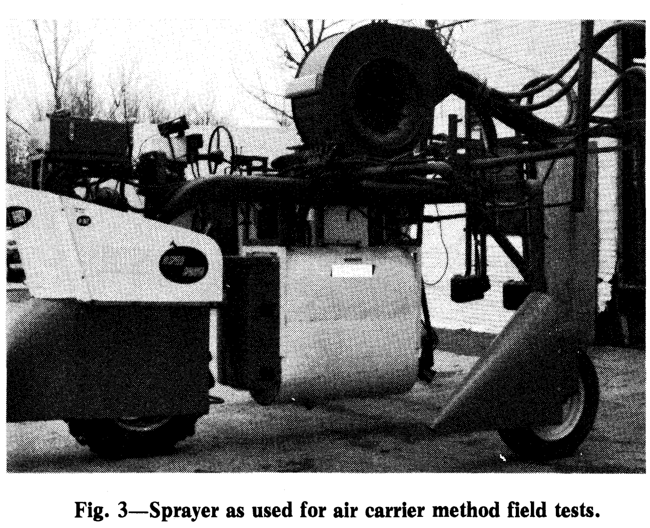

Fig. 3—Sprayer as used for air carrier method field tests.

*These data are based on Delavan laboratory measurements conducted with a specific atomizing device, using specific instruments and experimental procedures under certain environmental conditions on the date tested. Therefore it should not be inferred that the results are equivalent to those for actual operating conditions in specific agricultural, commercial or military applications. Accordingly, Delavan makes no warranty, express or implied, regarding the end use of the tested atomizing device, and similar device, or of the data supplied and shall not be responsible to any person for any incidental or consequential damages.

TABLE 1. SPRAY DEPOSITION OF AIRCRAFT AND PRESSURE ATOMIZING GROUND APPLICATIONS ON CORN AND SOYBEAN PLANTS

Treatment	Crop	Entire plant	Percent coverage values: Upper-plant leaf surface Top	Bottom
Aircraft 140 L/ha	Corn	0.18	0.83	0.00
Aircraft 140 L/ha	Soybeans	0.14	0.88	0.06
Ground 94 L/ha	Corn	0.52	1.05	0.27
Ground 140 L/ha	Corn	0.86	1.60	0.64
Ground 94 L/ha	Soybeans	0.33	1.98	0.09
Ground 140 L/ha	Soybeans	0.88	4.24	0.14

TABLE 2. SPRAY DEPOSITION OF HOLLOW CONE PRESSURE ATOMIZER AND AIR CARRIER TREATMENTS, WITHIN A SPRAY SHROUD, AT 94 L/ha ON CORN AND SOYBEAN PLANTS

Treatment	Crop	Entire plant	Percent coverage values: Upper-plant leaf surface Top	Bottom
Pressure atomizer	Corn	0.26	0.63	0.09
Air carrier	Corn	0.53	0.79	0.94
Pressure atomizer	Soybeans	0.41	1.58	0.44
Air carrier 1	Soybeans	1.37	3.11	0.82
Air carrier 2	Soybeans	1.04	0.05	2.26

RESULTS AND DISCUSSION

The quantification of aircraft and hydraulic ground spray application methods revealed that less than 1% of the sampled area was covered by the spray material. Due to the number of treatments, only those resulting in the highest coverage values are reported here.

The highest coverage value with aircraft applications was obtained from the 140 L/ha treatment with 0.83% and 0.88% coverage on the upper-plant top leaf surfaces of the corn and soybean plants, respectively. Aircraft application was essentially ineffective in depositing spray on the undersides of leaves, with coverage values of less than 0.1% (Table 1). Based on these results, aircraft application could not be recommended for spray deposition to the underside of leaves.

Ground hydraulic atomization equipment resulted in greater plant coverage than aircraft. A 140 L/ha treatment on corn resulted in coverage values of 1.6% and 0.64% for the upper-plant top and bottom leaf surfaces, respectively. The best 94 L/ha treatment covered 1.05% of the upper-plant top leaf surface and 0.27% of the upper-plant bottom leaf surface. A 140 L/ha ground application to soybeans resulted in 4.24% coverage of the upper-plant top leaf surface, whereas a 94 L/ha rate yielded 1.98% coverage. Coverage of the bottom leaf surface was less than 0.15% for both application rates (Table 1).

Air carrier treatments on corn resulted in 100% greater spray coverage overall compared to pressure atomizer treatments tested within the same spray shroud. Air carrier application on corn at 94 L/ha increased spray coverage from 0.26% to 0.53% overall, and from 0.09% to 0.94% on the bottom surface of the leaves, compared to the pressure atomizer treatment. Application uniformity was improved by the air carrier method with a 25% reduction in the coefficient of variation.

The air carrier treatments on soybeans also demonstrated improvement over pressure atomizer spraying methods. One air carrier treatment resulted in 3.11% and 0.82% coverage of the upper-plant top and bottom leaf surfaces, respectively. The coverage value for the entire plant was 1.37%. This air carrier treatment improved overall spray coverage by 234% and improved the deposition uniformity compared to the pressure atomizer treatment. Another air carrier treatment on soybeans resulted in higher spray coverage on the bottom surface of the leaves, with coverage values of 0.05% and 2.26% for the upper-plant top and bottom leaf surfaces, respectively (Table 2).

The air streams which intersected the spray pattern and accelerated the droplets resulted in greater spray deposition to the plant target area, than with pressure atomizers alone. It should be noted that effects of the air stream upon the spray droplet size were not quantified in this study.

Flat and hollow cone air nozzle units were also tested without the shroud. The hollow cone unit resulted in a significantly higher coverage of the upper-plant leaves compared to the flat unit. Tests of the hollow cone unit revealed that the addition of the air stream did not significantly increase spray coverage (Table 3). Air from the hollow cone unit did not intersect the spray pattern, but only formed a curtain around the spray pattern. This design may not increase spray deposition within the target area unless wind conditions were such that the air stream would reduce droplet drift. Locating the hollow cone atomizer within the air nozzle cone minimized leaf contact problems reported by Wolff and others (1978).

The flat nozzle unit operated with the highest fan speed (1500 r/min with 2.0 m^3/min airflow per nozzle) resulted in a 70% reduction in the coefficient of variation while increasing coverage over 200% on the upper-plant bottom leaf surface of the soybean plant when compared to the treatment without the air stream (Table 3). With the air stream, less spray material was deposited to the lower-plant area than without the air stream. This could be due to the effect of the air stream intersecting the fluid pattern, causing increased particle velocity and maximizing coverage on the target area.

The flat nozzle unit also resulted in a significantly higher coverage on the stem samples compared to the hollow cone unit. Coverage on these samples is indicative of spray droplet penetration through the outer plant foliage. The greatest benefit of the air carrier method may be the acceleration of spray droplets, such as occurs with the flat nozzle unit design.

SUMMARY AND RECOMMENDATIONS

Aircraft and ground pressure-atomizer applications of

TABLE 3. SPRAY DEPOSITION OF FLAT AND HOLLOW CONE AIR CARRIER UNITS, AT 1500 r/min FAN SPEED, WITHOUT THE SPRAY SHROUD AT 94 L/ha ON SOYBEAN PLANTS

Treatment	Entire plant	Percent coverage values: Upper-plant leaf surface Top	Bottom
Hollow cone without air stream	0.65	1.34	2.87
Hollow cone with air stream	0.66	2.41	1.76
Flat without air stream	0.63	0.00	0.59
Flat with air stream	0.92	1.37	1.73

spray solution to corn and soybean plants were quantified. Percent coverage values were generally less than 1% on the sampling locations. It was determined that aircraft application methods were ineffective in delivering spray material to the bottom surface of leaves compared to pressure atomizing and air carrier types.

Flat and hollow cone air carrier units were developed and evaluated for spray application to the upper-plant, bottom leaf surfaces. The air carrier method, tested within a shroud, improved spray deposition to the entire plant by 100% and 234% for corn and soybeans, respectively. Deposition to the upper-plant bottom leaf surfaces increased by 900% for corn and 400% for soybeans. Uniformity of application was also improved with the air carrier method. The advantage of the air carrier method seems to be the acceleration of spray particles which improves the control of spray placement.

As a result of this study, deposition characteristics of pressure atomizer and air carrier methods have been quantified. The amount of chemical required and the specific target area for applications need to be determined, so appropriate application methods could be utilized to deposit the chemical in the most effective manner.

Pest control and crop yield studies with various arrangements of the flat air nozzle unit are needed to evaluate chemical applications with this air carrier concept. Possible benefits of this air carrier design for reducing spray particle drift should be evaluated as well as the effects of the air stream upon droplet size. Based on the results of the flat air stream intersecting the spray pattern, a hollow cone unit with the air stream intersecting the spray pattern could be beneficial.

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