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The Effect of Application Volume and Deposition Aids on Droplet Spectrum and Deposition in Broccoli for Aerial Applications

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Abstract. *A field study was conducted to determine the influence of application volume and tank mix deposition aids on coverage in broccoli for a fixed wing aerial application. The study involved using a turbine powered aircraft to apply five products designed to improve deposition in 28, 47, and 94 l/ha tank mix solutions. Kromekote papers were used to collect the data at low and medium positions in full canopied broccoli plants. Comparisons between treatments using Dropletscan™ software to calculate droplet statistics, deposition (percent area coverage), and number of droplets per cm^2 in the lower and middle portions of the canopy are reported.*

Differences in coverage were found between the product and volume treatments compared with very few being significant. The higher application volumes resulted in higher coverage's for all products tested with the 94 l/ha providing significantly more coverage. The addition of the deposition aids improved the coverage within the 28 and 47 l/ha comparisons with the combination treatment of Interlock and Preference resulting in the highest amount of coverage in the lower canopy. In the 94 l/ha comparisons, the water and prime oil provided more coverage than a combination of Interlock and Preference which were both significantly better than a combination of Interlock and Rivet.

Higher application volumes resulted in an increased number of droplets in the lower canopy. The combinations of Interlock and Rivet and Interlock and AG 06038 improved the droplet counts. Droplet size was slightly affected by the different tank mix products. The trend was for the higher application volume treatments to show increased droplet sizes.

Keywords. Aerial application, deposition, droplet size, spray, deposition aid products

Introduction

One of the most critical aspects of any crop protection product application is determining the proper set-up parameters for the equipment used to make that particular application. Concerns about application volumes (l/ha, GPA), tank-mix components, application height, nozzle type and pressure, droplet size, coverage, canopy deposition, and other critical application parameters are being commonly debated. Controlling disease in dense growing crops may be dependent on achieving adequate canopy penetration depositing the material into the lower parts of the plants where needed. Efficient application practices are needed for on-target deposition and improved efficacy.

Advances in aerial application equipment technology enable the pilots to fine-tune their applications to match the requirements for controlling the targeted pest. One such parameter, management of spray droplet spectrum, is a critical issue in the search of accurate and efficient crop protection application systems. If proper adjustments are made to the aircraft, then nozzle type, orifice size, pressure, shear orientation, and aircraft speed can all be factored into determining a specified droplet spectrum which can then be evaluated. Models are currently available for this purpose.

Aerial application studies have found that applicator adjustment of variables such as spray rate and droplet spectra can improve deposition and distribution in broadleaf row crop canopies (Kirk, et al., 1992). Carlton, et al., 1983, found that application rate had a major influence on spray coverage of leaf surfaces. Uk and Courshee, 1982, found that foliage density has a major influence on the amount of deposit density within the canopy. French, et al., 1992, found that adjuvants did not significantly affect deposition characteristics when added to the tank mix in ground-applied insecticides for aphid control. However, the Spray Drift Task Force has reported that materials added to aerial spray tank mixes will alter the physical properties of the spray mixture affecting the droplet size spectrum (SDTF, 2001). Wolf, et al., 2003 and Wolf (2004) found that the addition of deposition aids to the tank mix for aerial applications tended to increase spray droplet size. Wolf, 2004, reported that application volume and the inclusion of deposition aids did increase the amount of coverage in the lower parts of a soybean canopy.

With new nozzle configurations and higher pressure recommendations (Kirk, 1997), and with the continued development of materials to add to tank mixes, applicators seek to better facilitate making sound decisions regarding the addition of these products into their tank mixes.

Objective

The objective of this study was to evaluate the effect of application volume and deposition aids on droplet spectrum and deposition in a dense broccoli crop for aerial applications.

Materials and Methods

A field study was conducted to determine the effect of deposition aids and application volume on droplet spectrum and canopy penetration during fixed wing aerial applications. All treatments were applied using a fixed wing aircraft, an Air Tractor 402B (Air Tractor Inc., Olney, Texas), equipped with drop booms; CP11TT nozzles (CP Products, Inc., Mesa, Arizona) with an 8 degree deflection; using the 15 orifice (36 nozzles) setting for the 28 l/ha treatments, the 20 orifice (36 nozzles) settings for the 47 l/ha treatments, and the 30 orifice (67 nozzles) settings for the 94 l/ha treatments (3, 5, and10 GPA)); and spray pressures ranging from 400 to 500 kPa averaging 433 kPa (58-73, 63 PSI). The configurations were classified as a medium droplet spectrum according to the USDA-ARS models. The applications were made at a GPS

measured air speed of 206 - 226 km/h averaged at 213 km/h (128 – 141, 132.5 MPH) and an application height of 3 - 3.7 m (10 - 12 feet). The swath width was GPS tracked at 18.3 m (60 feet). Marker flags were positioned at the treatment center line to assist the pilot in verifying swath locations

The study was conducted on March 7 and 9, 2006 in a broccoli field in Yuma, AZ. The study area was flat and the broccoli was in the post-harvest stage, planted on ridges in double rows, and was 45 – 61 cm (18 to 24 inches) tall and very dense. Five different products and tank mix combinations (Table 1) including water only were evaluated in three application volumes. Treatments 1-12 were completely randomized over days 1 and 2 while treatments 13-15 were done in a randomized block on day 2. Spray mixes containing 189 liters (50 gal) of tap water, Prime Oil (crop oil concentrate – COC) at 219 ml/ha (3 ounces per acre), a pink marking dye, and deposition aids were applied at 28, 47 and 94 l/ha (3, 5, and 10 GPA)). Temperature, relative humidity, wind direction, and wind velocity was recorded using a Davis weather station averaged during the time of application for each treatment. Wind speed ranged from 3.2 -16 km/hr (2-10 MPH). Relative humidity was measured at 40% on day 1 and 66% on day two. Temperature ranged from 22 – 8.8°C (73 - 48°F) during the duration of the study. A weather front passed on day 1 with treatments 1-7 complete. The remaining treatments were completed on day 2.

Spray deposits were collected for measurement and analysis using 5 x 9 cm (2 x 3.5 inch) kromekote papers (KKP). Five collector rods holding 3 kromekote papers each were placed in the canopy of each treatment. Each collector rod had single kromekote papers placed at the top, 61 cm (24 inches); middle, 30 cm (12 inches); and bottom, 5 cm (2 inches) of the canopy.

After all treatments and replications were completed and dried, the collection papers were placed in prelabeled-sealable bags for preservation. Because of the high humidity a desiccant pack was placed in each bag to prevent the papers from absorbing additional water. Data envelopes were used to organize and store the papers until analysis was complete. DropletScan™ (WRK of Arkansas, Lonoke, AR; and WRK of Oklahoma, Stillwater, OK; Devore Systems, Inc., Manhattan, KS) was used to analyze the papers. DropletScan™ has been tested as a reliable source for predicting droplet stain characteristics when compared to other card reading methods (Hoffman 2004).

Statistical analyses of the data were conducted with SAS 9.13 (SAS, 2003). The model used was a General Linear Model (GLM) procedure to analyze the kromekote paper data by treatment as summarized with DropletScan® looking at comparisons of product, volume, mix, and volume-mix interaction. The LS Means for each product were tested and used to report the differences (alpha = 0.05) found for each treatment.

Results and Discussion

Comparisons of amount of deposition in the different canopy locations were taken. These measurements were used to compare differences in application volume and deposition aid products. The water was considered the standard for comparison. For the purposes of this report only the means for the middle and bottom collectors are presented.

The average amount of coverage in the middle of the canopy for all treatments was 2.5% with a range of 0.60 to 6.6%. The average for the 28 l/ha (3 GPA) application volumes was 1.13%, 47 l/ha (5 GPA) was 2.52%, and 94 l/ha (10 GPA) was 5.37%. When comparing the 28 l/ha (3 GPA) and 47 l/ha (5 GPA) application volumes in the middle of the canopy the best coverage was provided by the 47 l/ha (5 GPA) treatment containing water and COC at 3.03%. This was not significantly different from the next two highest coverage amounts of 2.87% for AG 06038 and 2.83% for Interlock, both applied at 47 l/ha (5 GPA). Several of the treatments had

significantly less coverage. The highest amount of coverage in the middle of the canopy was provided by the 94 l/ha (10 GPA) treatment consisting of a combination of Interlock and Preference at 6.6%. The top three coverage amounts measured were at 94 l/ha (10 GPA). The 94 l/ha (10 GPA) volumes were not significantly different from each other but were significantly better than all the 28 l/ha (3 GPA) and 47 l/ha (5 GPA) treatments (see table 2).

The average amount of coverage in the bottom of the canopy for all treatments was 0.85% with a range of 0.33 to 2.2%. The average for the 28 l/ha (3 GPA) application volumes was 0.52%, 47 l/ha (5 GPA) was 0.76%, and 94 l/ha (10 GPA) was 1.67%. When comparing the 28 l/ha (3 GPA) and 47 l/ha (5 GPA) application volumes in the bottom of the canopy the best coverage was provided by the 47 l/ha (5 GPA) tank mix combination of Interlock and Preference at 0.96%. None of the treatments in the bottom of the canopy were significantly better except for the 28 l/ha (3 GPA) treatment of AG 06011 and both the 28 l/ha (3 GPA) and 47 l/ha (5 GPA) treatments of AG 06038 which were significantly less that all the other comparisons. The 94 l/ha (10 GPA) treatments of water and COC alone and the combination of Interlock and Preference were significantly better than all the other treatments (see table 3).

The number of droplets per centimeter squared (D/C^2) on the collector surface are also reported as a comparison. In the middle of the canopy the number of droplets counted ranged from 47.3 to 123 D/C^2 with an average of 38. The best treatment was the 28 l/ha (3 GPA) combination of Interlock and Rivet (123 D/C^2). The same combination at 47 l/ha (5 GPA) was very similar at 119.3 D/C^2. The top six treatments were not significantly different. In the bottom of the canopy the range was 10.3 to 32.7 D/C^2 with an average of 19. The top treatment in the bottom canopy was the 94 l/ha (10 GPA) treatment combining Interlock and Preference. As in the canopy middle, the top six treatments were not significantly different.

The final comparison reported is volume median diameter (VMD, VD 0.5) and is used to reference the droplet size that was being deposited in the middle and lower parts of the canopy. The average of the means measured in the middle canopy was 304 microns and was 284 for the bottom canopy. Significant differences were measured indicating that the treatment variables did impact the size of the droplets collected.

Conclusions

This study was conducted to determine the influence of deposition aid products and application volume on droplet spectrum and deposition in a broccoli canopy during fixed wing aerial applications. An Air Tractor 402B was used to apply the treatments. Differences were found based on position in the canopy and as would be expected more coverage was found in the middle of the canopy when compared to the bottom. Coverage was also increased as the amount of carrier volume increased.

In general, adding deposition aid products to the tank mixes only slightly improved the amount of coverage in the middle and bottom canopy locations with a very few of the comparisons significant. This trend was not true in the 94 l/ha (10 GPA) application volume comparisons where the water only treatment provided better coverage. The findings of this study support using higher application volumes to achieve increased coverage in the canopy. At 47 l/ha (5 GPA)), the combination of Interlock and Preference resulted in the highest amount of coverage in the canopy. Higher application volumes resulted in an increased number of droplets in the lower canopy. The combinations of Interlock and Rivet and Interlock and AG 06038 improved the droplet counts.

The higher application volumes and the inclusion of deposition aids influenced the volume median diameter in both the lower and middle canopy regions.

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Tables

Table 1. Treatment, application volume, mix rate, nozzle and orifice, pressure, and air speed.

Treatment[1]	Volume(gpa/l/ha)	Mix Rate[2]	Nozzle Orifice	PSI	Air Speed
1	5/47	COC 3 fl oz/A	CP11TT-20	60	128
2	3/28	COC 3 fl oz/A	CP11TT-15	60	128
3	5/47	COC 3 fl oz/A Interlock 2 fl oz/A	CP11TT-20	61	128
4	3/28	COC 3 fl oz/A Interlock 2 fl oz/A	CP11TT-15	60	126
5	5/47	COC 3 fl oz/A Interlock 2 fl oz/A Preference 0.25% v/v	CP11TT-20	60	127
6	3/28	COC 3 fl oz/A Interlock 2 fl oz/A Preference 0.25% v/v	CP11TT-15	63	131
7	5/47	COC 3 fl oz/A AG 06011 5 fl oz/A	CP11TT-20	65	128
8	3/28	COC 3 fl oz/A AG 06011 5 fl oz/A	CP11TT-15	58	128
9	5/47	COC 3 fl oz/A Interlock 2 fl oz/a Rivet 0.5% v/v	CP11TT-20	58	134
10	3/28	COC 3 fl oz/A Interlock 4 fl oz/a Rivet 0.5% v/v	CP11TT-15	67	134
11	5/47	COC 3 fl oz/A AG 06038 5 fl oz/A	CP11TT-20	73	140
12	3/28	COC 3 fl oz/A AG 06038 5 fl oz/A	CP11TT-15	64	135
13	10/94	COC 3 fl oz/A	CP11TT-30	62	140
14	10/94	COC 3 fl oz/A Interlock 4 fl oz/A Preference 0.25% v/v	CP11TT-30	65	140
15	10/94	COC 3 fl oz/A Interlock 4 fl oz/A Rivet 0.5% v/v	CP11TT-30	66	141

[1] Treatments 1 and 2 were mixed using tap water and crop oil concentrate only.

[2]All products and mixing directions provided by Agriliance. Tap water, crop oil concentrate, and red dye (32 oz/100 gal of water) were common to all treatments.

Table 2. LS Means for percent area coverage for middle canopy positions.

Treatment[1]	VD 0.1[2]	VMD	VD 0.9	% Area coverage	Droplets/cm^2
1	204.7^{bc}	310.7^{cd}	522.7^{ab}	3.03^{bcd}	65.0^{c}
2	165.3^{defg}	274.3^{ef}	413.7^{b}	1.67^{de}	61.3^{c}
3	165.3^{defg}	301.3^{de}	428.0^{ab}	2.83^{bcde}	83.7^{abc}
4	146.7^{fg}	260.0^{f}	382.3^{b}	1.53^{de}	83.7^{abc}
5	188.3^{bcde}	303.3^{de}	433.3^{ab}	2.30^{cde}	66.7^{c}
6	213.3^{ab}	341.7^{abc}	449.7^{ab}	2.33^{cde}	56.7^{c}
7	240.0^{a}	367.3^{a}	485.0^{ab}	2.47^{cde}	69.7^{bc}
8	156.0^{efg}	302.7^{de}	407.0^{b}	0.60^{e}	47.3^{c}
9	188.0^{bcde}	311.0^{cd}	437.0^{ab}	1.93^{de}	119.3^{ab}
10	144.3^{g}	274.3^{ef}	389.3^{b}	1.00^{de}	123.0^{a}
11	196.7^{bcd}	317.0^{cd}	437.3^{ab}	2.87^{bcde}	91.3^{abc}
12	195.7^{bcd}	310.0^{cd}	565.7^{a}	1.33^{de}	58.3^{c}
13	178.7^{cdef}	321.3^{bcd}	466.0^{ab}	5.10^{ab}	78.7^{abc}
14	208.0^{abc}	353.0^{ab}	501.7^{ab}	6.60^{a}	61.7^{c}
15	178.0^{cdef}	325.0^{bcd}	459.0^{ab}	4.50^{abc}	71.3^{bc}
LSD	32.63	34.46	150.5	2.4	50.6

[1]See table 1 for description of products used in each treatment.

[2]Means with the same letter are not significantly different at alpha = 0.05.

Table 3. LS Means for percent area coverage for bottom canopy positions.

Treatment[1]	VD 0.1[2]	VMD	VD 0.9	% Area coverage	Droplets/cm[2]
1	184.6^{abcd}	278.6^{bc}	376.6^{abcd}	0.70^{b}	13.7^{de}
2	162.6^{bcde}	268.6^{bc}	404.0^{abc}	0.66^{b}	15.3^{de}
3	165.0^{bcde}	277.3^{bc}	369.6^{bcd}	0.93^{b}	16.7^{cde}
4	146.3^{cde}	266.0^{bc}	364.0^{bcd}	0.66^{b}	16.7^{cde}
5	208.0^{ab}	287.3^{ab}	384.6^{abcd}	0.96^{b}	13.3^{de}
6	213.6^{ab}	305.3^{abc}	383.6^{abcd}	0.70^{b}	10.3^{e}
7	224.0^{a}	318.0^{ab}	411.6^{ab}	0.73^{b}	12.0^{e}
8	138.6^{de}	333.0^{a}	435.3^{a}	0.20^{c}	11.7^{e}
9	169.6^{bcde}	262.3^{c}	414.3^{ab}	0.80^{b}	29.3^{abc}
10	166.6^{bcde}	282.0^{ab}	389.3^{abcd}	0.60^{b}	25.3^{abcd}
11	174.0^{abcde}	269.6^{b}	368.3^{bcd}	0.46^{c}	21.7^{abcde}
12	125.6^{e}	262.0^{c}	343.3^{d}	0.33^{c}	18.7^{bcd}
13	198.0^{abc}	292.0^{abc}	381.5^{bcd}	2.20^{a}	31.0^{ab}
14	202.0^{ab}	306.0^{abc}	419.0^{ab}	1.85^{a}	32.7^{a}
15	174.0^{abcde}	255.0^{c}	346.0^{cd}	0.95^{b}	23.0^{abcd}
LSD	52.6	53.1	60.3	0.87	12.9

[1]See table 1 for description of products used in each treatment.

[2]Means with the same letter are not significantly different at alpha = 0.05.