Measuring Spray Coverage on Sugarbeets

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Introduction

Uniform spray coverage of sugarbeet plants for cercospora control is essential for maximum production. New air-assist sprayers are currently available and questions are being asked about their capabilities. Do they provide better total coverage of the sugarbeet plant as compared to low pressure sprayers, low pressure directed sprays, high pressure directed spray, high pressure broadcast sprayers or spray planes? Better coverage should provide better control of disease which should convert into better yield. But, new spray equipment comes at a higher initial price and operating cost. This higher cost needs to be recovered in more efficient control of the pest.

New analyzing equipment is available that will measure the percentage of leaf area that is covered with spray. New techniques involve adding a fluorescent dye to the spray tank, applying the spray to the crop and measuring the spray coverage on plant leaves. The coverage on plant leaves is measured with a video camera that works under ultra-violet light conditions. The image is digitized whereby the percent of the leaf area that is covered with spray is determined with the use of a computer.

Previous Work

Work has been done on measuring spray coverage in a plant canopy with the use of artificial spray collectors. Those include leaf wash analysis, cotton string collectors installed in the canopy and water sensitive paper attached to leaves. Chemical leaf wash analysis is expensive and time consuming plus it does not indicate the area of the leaf that is covered or protected from organisms. The other two methods may or may not simulate plant leaves and may not provide representative information. The water sensitive paper is the best but when the paper is attached to the leaves, the extra weight will change leaf position and the spray drops may not contact the surface representatively. The analysis of the paper is done with a video camera that photographs the blue spots on the paper, a computer digitizes the image and analyzes the percent area covered with spray.

The cotton collector strings are installed at various levels in the plant, sprayed with a fluorescent dye and analyzed with a fluorometer interfaced with a computer. This method only gives a relative difference in spray penetration and does not indicate how much spray deposits on the plant.

This information is useful to determine how well application equipment is capable of covering leaf material with fungicides. These test methods have their limitations and may or may not be representative of leaf material. It is felt that a new method that measures actual coverage of the leaf surface is a more accurate spray comparison method. This will help to determine the spray coverage efficiency at various levels in the plant canopy. This will help determine effectiveness of low pressure sprayers, high pressure sprayers, spray planes and the newer air assist sprayers as to what percentage of leaf material is covered with spray.

Objective:

The objective of these trials is to determine the spray application efficiency of various types of spray applicators at varying application rates and the affect of moisture condensation on plant leaves or redistribution of spray on plants.

Experimental Method:

Spray coverage trials were completed over two growing seasons on sugarbeets in the Red River Valley. Trials were done with various equipment including 3 spray planes, 2 air-assist sprayers, a high-pressure conventional and the 2 air-assist sprayers with the air curtain off so it will operate similar to a conventional sprayer. These trials were done from early August to the middle of September at Drayton, ND, East Grand Forks, MN, and Kindred, ND during the season when cercospora spraying is done. The applicators included a Hardi-Twin, Ag Chem Rogator, Century pull-type sprayer, an Air Tractor and 2 Thrush spray planes. Two of the planes were turbine powered while the other used a radial engine. The sprayers used for the redistribution of spray was assembled by the Ag. Eng. Dept. and mounted on the 3 pt. hitch of a tractor. During the first year (1996) a spray tracer dye (Rhodamine WT) was mixed with water in the spray tank at the rate of 2 ounces per acre. A spreader/sticker was also added so the spray would act similar to a fungicide application on leaves. Spray was applied with the equipment at various application rates as listed in tables 1, 2 and 3. During the next years trials (1997) (Day Glo blaze-orange) was mixed with water in the spray tank at the rate of 0.75% by volume. A spreader/sticker was also added at the rate of 0.05% by volume. Active pesticide was not used in any trials. Spray was applied with the equipment at various application rates as listed in tables 4 and 5. Both years a camera that works under ultra-violet low light conditions (CCD Camera) was used to measure the dye on leaves. This camera was interfaced with a computer and the picture was digitized and stored in the computer memory. The digitized picture was then analyzed with the computer and software to separate the dye from the background leaf material.

After a spray application, the spray was allowed to dry for several minutes to avoid smearing of the dye on leaves during handling. In 1996, ten leaf samples were taken from top leaves and 10 samples were taken from lower leaves near ground level. In 1997, trial replicated 3 times and 15 leaf samples were taken from top leaves and an equal number from lower leaves near ground level. These leaves were placed under the ultra-violet light in a darkened chamber. The fluorescent dye glows under ultra-violet light and with enhancement, an image is produced. A frame grabber digitizes the image which can then be stored in a computer memory. The fluorescent dye produces an image that is a different color from the background leaf color and with a software package that was developed, the percent of the leaf area covered with spray was determined. The results in all tables are presented as % leaf area covered with spray.

Spray trials were done during calm conditions with air temperatures in the 70's and low 80's.

Results

Tables 1, 2, and 3 lists the results of 1996 tests and tables 4, 5 and 6 are results of 1997 tests. Several types of applicators were used depending on availability. The % coverage in the trials from Drayton, (table 1.) show lower coverage percentages than all the other tests. There is no explanation for this as these trials were completed like the others by using the same amount of dye per acre and randomly selecting samples. This should be used as preliminary information as it was the first test done on sugarbeets. A possible explanation may be due to the density of the canopy and a limited number of leaf samples may have been selected that were shielded by other leaves. This is part of the reason more samples were collected in 1997.

In Table 1, the % coverage values from the bottom leaf position are not large enough to provide reliable information. Some error enters into the measurement which may be 1 to 2 % due to the transition from the drop to the background leaf.

Tables 2 and 3 show much higher values of % leaf area covered. The error mentioned previously will occur but will not have as much affect on the results. Table 2 shows some coverage variability for the spray plane with lower values on bottom leaves with higher application rates. Replicated trials with more samples per trial should reduce this affect. The aircraft values are comparable to the ground applicator which was applying 20 gallons per acre. In tables 2 and 3, the average value is probably the best comparative value as total plant coverage is needed to protect plants from disease. In these tables, the coverages for the aircraft are slightly lower but it should be remembered that the spray planes are using a significantly lower amount of water. The spray planes are applying 10 gpa or less while the ground sprayers are all applying 20 gpa.

Tables 4, 5 and 6 show the results of the spray trials completed during the 1997 growing season. The trials at Drayton were completed with a Hardi Twin sprayer and a turbine powered Thrush aircraft. The Kindred trials were completed with an Ag Chem Rogator and a radial engine powered Thrush.

The results of the spray trials completed in 1997 do not show as much variability as was found in 1996. The variability was less in 1997 due to 3 replications per trial and more leaf samples collected for each replication for a total of 45 samples per trial. Still, in each trial a considerable amount of variability occurred. For example, in some trials, some leaves contained almost 100% coverage while another leaf may contain almost no spray. This was due to shielding of some leaves by other leaves.

Table 4 shows variability between trials for the air-assist and conventional with a large amount explained by the reduction in application rate but the overall average for the air-assist sprayer (46.9%) show a small but not significant increase over the spray planes (23.5%) but the plane was applying 5 and 7.5 GPA as compared to higher rates (10 to 20 GPA) for the ground sprayer. The spray plane used a spray nozzle with an adjustable deflector plate that produces a coarse or a fine spray drop. The 90° deflection directs the spray at a 90° angle to the plane movement, creating greater wind across the spray nozzles and a finer drop. The averages of the 2 trials with the 90° deflection show an improvement in coverage over the 30° deflection.

In Table 4, the application rates for the spray plane is 5 and 7.5 GPA. If one compares the spray plane at the 7.5 GPA rate with 90° deflection at 34.5 percent coverage, the ground sprayers applying 10 GPA show a coverage of only slightly more at 37.3 and 39.3%. This is not a significant difference.

Table 5 shows the results of the Kindred spray trials. Again, variability exists between the air-assist and conventional tests with a considerable amount caused by the reduction in application rate. The average coverage for the air-assist sprayer (53.9%) is less than the conventional sprayer (65.5%) and the average for the spray plane (23.5%) is less than either of the ground applicators. The ground sprayers are applying a higher application rate at 10 and 20 GPA as compared to the spray plane at 5 and 7 GPA.

Statistical analyses were completed on these trials. A least significant difference (LSD) (95% confidence interval) was determined for all top leaves, bottom leaves and for the average plant coverage. The LSD for the upper leaves is 12.8, for lower leaves 18.4 and 23.5 for the average total plant coverage.

In most of the trials whether it is a ground sprayer or aircraft, as the application rate drops from 20 GPA to 15 to 10 GPA or less, the coverage decreases as well. This is to be expected depending on spray drop size produced, the amount of plant surface area that is being covered and the amount of spray mix available to cover the crop.

Another parameter that was addressed on a limited scale is redistribution of spray by moisture (dew) condensing on the plant overnight. This is presented in Table 6. All trials in Table 6 were completed with a ground sprayer owned by the Ag and Biosystems Engineering Department. The first trial (76) was sprayed late one afternoon, samples were taken and analyzed for coverage. Then, the next morning after the moisture from dew had dried, more samples were taken from the same area and analyzed. This is trial 77. On the top of the plant, the average area covered with spray shows an increase while the lower leaf coverage decreased a small amount. The principle of rewetting and moving on the plant surface depends on the condensation occurring on the plants and on the rewetting capability of the dye and surfactant. Actual fungicides may react differently than the dye used in the trials.

Two trials in Table 6 (trials 92 and 93) present the largest change in redistribution. These two trials were completed early in the morning when the sugarbeet plants were wet from dew. Trial 92 was done at 5 GPA and trial 93 was done at 10 GPA. The average coverage for trial 92 was significantly better than what was found in trial 76 which was sprayed on dry leaves at 5 GPA. Also, trial 93 shows similar results except the application rate was 10 GPA. This tends to indicate that the moisture on plants acts as makeup water for the spray application.

The redistribution of spray may indicate why aerial application of fungicides are usually successful so long as they produce a uniform spray pattern and overlap their swaths properly. Spray planes usually do most of their spraying early in the morning when plants are wet or late in the evening when moisture is starting to condense on plants which will add water to the application which allows the spray to spread more. The same concept also occurs with ground sprayers helping them provide better coverage.

The question then arises, how much of the leaf needs to be covered for adequate pest control Plant pathologists suggest with protective fungicides, as more of the leaf is covered, the better the control of the pest. Then, the questions arises "how much of the leaf needs to be covered by initial application and how much is covered by redistribution of spray with dew?"

Conclusion

The information in the tables show considerable variation. This to be expected as lower leaves are more difficult to cover with spray. The spray planes tend to show lower coverage percentages than ground sprayers. In one trial, the air-assist sprayer produced better coverage than the conventional sprayer but in the other trial, the conventional sprayer outperformed the air-assist. If all trials with air-assist and all conventional trials are averaged, there is no significant difference in coverage.

The most significant occurrence in 1997 tests showed up in redistribution of spray from wet leaves. From limited tests, coverage increased by a factor of 2 to 3 times when leaves wet with dew were sprayed early in the morning. The same principle will probably occur late in the evening when moisture in the air is condensing and starting to build on plant leaves.

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Table 1. Percent of sugarbeet leaves covered with spray using a Hardi Twin and conventional sprayer with varying application rates. Trials done at Drayton, ND on August 9, 1996.

Sprayer Type	Spray Pressure (psi)	Application Rate (GPA)	% of leaf area covered with spray Top	Bottom	Average
Air Assist On	52	10	22.5	9.0	15.7
Air Assist On	150	10	22.6	4.0	13.3
Air Assist On	50	20	29.1	5.2	17.1
Air Assist On	110	20	27.9	1.2	14.5
Air Assist On	100	28	17.0	6.1	11.5
		Average	23.8	5.1	14.4
Air Assist Off	52	10	12.7	11.8	12.2
Air Assist Off	150	10	30.9	7.9	19.4
Air Assist Off	50	20	27.8	2.6	15.2
Air Assist Off	110	20	40.1	2.4	21.2
Air Assist Off	100	28	34.9	6.5	20.7
		Average	29.3	6.2	17.7
Coverage On Back Side of Leaves					
Air Assist On	50	20	21.3	1.5	11.4
Air Assist On	110	20	12.8	1.1	6.9
Air Assist On	100	28	15.8	2.3	9.0
		Average	16.6	1.6	9.1
Air Assist Off	50	20	14.7	5.6	10.1
Air Assist Off	110	20	23.2	1.6	12.4
		Average	19.0	3.6	11.3

Table 2. Percent of sugarbeet leaves covered with spray using a ground applicator and spray plane at varying application rates. Trials done at East Grand Forks, MN, on August 27, 1996.

Sprayer Type	Application Rate (GPA)	% of leaf area covered with spray		Average
		Top	Bottom	
Air Tractor- Spray Plane	5	66.6	45.5	56.0
Air Tractor-Spray Plane	7.5	46.7	28.9	37.8
Air Tractor- Spray Plane	10	69.6	25.8	47.7
	Average	61.0	33.4	47.2
Century Sprayer, 100 psi	20	63.3	35.3	49.3
Century Sprayer, 150 psi	20	80.6	49.3	67.9
	Average	71.9	42.3	57.1

Table 3. Percent of sugarbeet leaves covered with spray using an air-assist, conventional, and spray plane at varying application rates. Trials done at Kindred, ND on September 16, 1996.

Sprayer Type	Operating pressure (psi)	Application Rate (GPA)	% of leaf area covered with spray		Average
			Top	Bottom	
Ag Chem Air Assist	45	20	86.2	65.4	75.8
Ag Chem Air Assist	90	20	86.0	78.7	82.4
		Average	86.1	72.0	79.1
Ag Chem Conventional	45	20	75.3	45.2	60.2
Ag Chem Conventional	90	20	83.9	32.4	58.1
		Average	79.6	38.8	59.2
Thrush Spray Plane	32	5	59.3	28.2	43.7
Thrush Spray Plane	60	7	65.5	38.9	52.2
		Average	62.4	33.5	47.9

Table 4. Percent of sugarbeet leaves covered with spray using an air-assist sprayer, conventional sprayer and a turbine powered aircraft. Tests done near Drayton, ND on August 28, 1997.

Trial #	Sprayer Type and Operating Specs	% of leaf covered with spray		
		Top	Lower	Average
84	Hardi Twin Air-Assist 20 GPA, 100 psi, 8 mph	63.8	41.0	52.4
86	Hardi Twin Air-Assist 20 GPA, 100 psi, 8 mph, ½ air rate	70.0	31.4	50.7
88	Hardi Twin Air-Assist 15 GPA, 80 psi, 8 mph	49.3	41.3	45.3
90	Hardi Twin Air-Assist 10 GPA, 35 psi, 8 mph	36.0	42.5	39.3
	Average	54.8	39.1	46.9
87	Hardi Conventional 20 GPA, 100 psi, 8 mph	59.6	37.1	48.4
89	Hardi Conventional 15 GPA, 80 psi, 8 mph	43.2	24.8	34.0
91	Hardi Conventional 10 GPA, 35 psi,8 mph	39.5	35.3	37.4
	Average	47.4	32.4	39.9
80	Thrush 5 GPA, 18 psi, 130 mph, 30° deflection	14.7	28.3	21.5
81	Thrush 7.5 GPA, 30 psi, 130 mph, 30° deflection	19.8	19.5	19.6
82	Thrush 5 GPA, 18 psi, 130 mph, 90° deflection	16.7	34.5	25.6
83	Thrush 7.5 GPA, 30 psi, 130 mph, 90° deflection	39.1	29.9	34.5
	Average	22.6	28.1	25.3
	LSD (0.05)	12.8	18.4	23.5

Table 5. Percent of sugarbeet leaves covered with spray using an air-assist, a conventional sprayer and a radial engine powered aircraft. Tests done at Kindred, ND on September 18, 1997.

Trial #	Sprayer Type and Operating Specs	% of leaf area covered with spray		
		Top	Lower	Average
95	Ag Chem Air-Assist 10 GPA, 70 psi, 7.8 mph	49.4	51.1	50.3
98	Ag Chem Air-Assist 20 GPA, 65 psi, 9.5 mph	73.2	41.8	57.5
	Average	61.3	46.5	53.9
96	Ag Chem Conventional 10 GPA, 70 psi, 10 mph	72.5	51.3	61.9
97	Ag Chem Conventional 20 GPA, 70 psi, 10 mph	77.4	61.0	69.2
	Average	74.9	56.2	65.5
99	Thrush 5 GPA, 12 psi, 120mph, 8020 FF	32.2	23.5	27.9
100	Thrush 7 GPA, 30 psi, 120mph, 8020 FF	28.9	38.0	33.5
	Average	30.6	30.8	30.7
	LSD (.05)	12.8	18.4	23.5

Table 6. Percent of sugarbeet leaves covered with spray using a conventional sprayer and measuring the affect of redistribution of spray from dew. Tests done in early Sepember, 1997 at the NDSU test plots.

Trial #	Sprayer Type and Operating Specs	% of leaf area covered with spray		
		Top	Lower	Average
76	Ag Eng Sprayer 5 GPA, 55 psi, 7 mph, 8001 nozzle Sprayed in afternoon and sampled	16.8	20.8	18.8
77	Ag Eng Sprayer 5 GPA, 55 psi, 7 mph, 8001 nozzle Previous (76) trial-sampled the next morning	28.0	17.5	22.8
92	Ag Eng Sprayer 5 GPA, 55 psi, 7 mph, 8001 nozzle Sprayed at 7 AM on wet leaves	54.7	68.5	61.4
93	Ag Eng Sprayer 10 GPA, 55 psi, 3.5 mph, 8001 nozzle Sprayed at 7 AM on wet leaves	48.8	54.9	51.9
	LSD (0.05)	12.8	18.4	23.5