EVALUATION OF SPRAYERS AND SPRAY COVERAGE ON CONNECTICUT CIGAR WRAPPER TOBACCO

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Experiments were conducted in shade and broadleaf tobacco to determine the best means of obtaining thorough spray coverage. Sprayers evaluated included hand-held guns, backpack sprayers, mistblowers, an air-assisted horizontal boom, nozzles arranged on a vertical boom and drop nozzle sprayers. The results consistently demonstrated that the best spray coverage within the canopy of broadleaf or shade tobacco was achieved by sprays made from within the crop, moving down the row. Spray coverage throughout the broadleaf crop canopy may be three to four times greater with the use of drop nozzles compared to application over the top of the crop with a mistblower or air-assisted boom sprayer. A vertical boom was more effective than backpack wand or backpack mistblower applications. In shade-grown cigar wrapper tobacco, the physical structure of the shade tent prohibits the use of boom sprayers or drop nozzles. Our results indicated that sprays applied over the top of the plants and especially over the top of the tent resulted in poor plant coverage. Sprays applied using a gun over the tent had significantly fewer drops, 12.7 per cm^2 of spray paper, than other methods (150.0, 89.1, 75.5 and 79.5 for vertical boom, backpack, backpack mistblower, and gun sprayer inside the tent, respectively). Sprays applied with the hand-held gun also had a greater percentage of large-diameter drops (greater than 100 microns) than sprays applied using other sprayers (3.6% versus 0.03, 0.3 and 0.1% for vertical boom, backpack, and backpack mist sprayers, respectively). The development of vertical boom sprayers that are brought down spray rows has resulted in spray coverage sufficient for blue mold control under the shade tents.

Additional key words: boom sprayer, broadleaf tobacco, drop nozzles, mist blower, shade tobacco.

INTRODUCTION

The extent and uniformity of spray coverage and deposition may greatly affect the performance of many pesticides applied to plant foliage. Control of blue mold, caused by *Peronospora tabacina* Adam, in tobacco is particularly dependent on fungicide efficacy, timing and coverage. Acrobat MZ is currently the most efficacious fungicide against *P. tabacina* (5). Dimethomorph, an active ingredient of Acrobat (9% a.i.), has translaminar activity, but does not translocate from one leaf to another (2). Mancozeb (60% a.i.), the second active component of Acrobat MZ, is a protectant fungicide with no systemic or translaminar activity. No effective systemic fungicides are currently registered for control of blue mold in Connecticut shade or broadleaf tobacco types. As a result, efficacy is dependent on complete coverage of all plants in the field. Coverage is especially challenging in Connecticut shade tobacco due to the density of the crop (about 27,000 plants per hectare), the fact that each plant is tied to a wire running over each row, and the interference of the cloth-covered shade tent with spray equipment. Shade tents modify the climate to reduce light intensity, increase humidity, reduce wind and reduce evapotranspiration (7). This climate is highly conducive for blue mold disease development. The physical structure of the shade tent, vertical wooden poles placed every 10 m in squares with connecting support wires upon which the tent cloth is placed, the arrangement of tie wires over each plant row, and the fact that each plant is tied to the overhead wire make mechanical spray application difficult.

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The objectives of our research were to compare spray coverage in Connecticut shade and broadleaf cigar wrapper tobacco types using different types of spray equipment.

MATERIALS AND METHODS

Experiments 1 - 3 were conducted at the Connecticut Agricultural Experiment Station Valley Laboratory in Windsor, Connecticut. Experiment 4 was conducted on a commercial broadleaf tobacco farm in Ellington, Connecticut. Shade-grown cigar wrapper tobacco (experiments 1 and 2) was grown in a cloth-covered shade tent in rows 1 m apart with plants 30 cm apart within rows. Broadleaf dark air-cured cigar wrapper tobacco (experiment 3) was grown in a location adjacent to the shade tent in rows 1 meter apart with plants 60 cm apart within rows.

Experiment 1, July 14, 1998. Plants inside the shade tent were sprayed with one of five different sprayers. Sprayers consisted of 1) a 1.5 m vertical boom with eight paired hollow cone nozzles (six TX-8 nozzles (Spraying Systems, Inc., Wheaton, IL) at 40 cm spacing and two TY-8 nozzles (Spraying Systems, Inc., Wheaton, IL) at 30 cm above the ground), operating at 620 kPa to apply 467 L/ha; 2) a Solo backpack sprayer (Solo, Newport News, VA) with a TGSS-3 nozzle (Spraying Systems, Inc., Wheaton, IL) at 345 kPa to apply 467 L/ha; 3) a Solo type 410 backpack mistblower (Solo, Newport News, VA) to apply 150 L/ha; 4) a handheld Myers B1192 high pressure spray gun (F.E. Myers, Ashland, OH) with a no. 5 disk operating at 2070 kPa to apply 934 L/ha over the top of the tent; and 5) the handheld Myers gun sprayer operating at 2070 kPa to apply 934 L/ha inside the tent. Coverage was determined by means of water and oil sensitive papers (2.5 x 7.5 cm) (Spraying Systems, Inc., Wheaton, IL) placed at three levels within the plant canopy (top = 1.8 m, middle = 1.2 m and bottom = 0.6 m) on the side of the plant near the sprayer and on the opposite side, and on the bottom and top of each leaf. The plant canopy was approximately 2 m in height. There were three replicates at each location. After the water spray had been applied and dried, papers were removed and photocopied to record the black and white pattern of spray droplets on the paper. Each spray paper was scanned using a flat bed scanner at 350 dpi (72.5 µm resolution). Coverage was determined using SigmaScan Pro (version 4.0, SPSS, Chicago, IL) to measure the number of pixels of white versus the total sample and the percent of the surface covered by spray droplets was determined. Data was subjected to Analysis of Variance and means were separated by Fisher's LSD procedure.

Experiment 2, September 1, 1998. Plants inside the shade tent were sprayed with one of four different sprayers. Sprayers consisted of 1) a vertical boom with six TX-8 and two TY-8 hollow cone nozzles at heights described above, operating at 620 kPa to apply 467 L/ha; 2) the vertical boom with six TX-18 (Spraying Systems, Inc., Wheaton, IL) and two TY-18 nozzles (Spraying Systems, Inc., Wheaton, IL), operating at 517 kPa to apply 467 L/ha; 3) an Echo SHR-2100 Type 1 backpack power sprayer (Echo, Inc., Lake Zurich, IL) at 828 kPa to apply 467 L/ha through six D2-DC25 disc-core nozzles (Spraying Systems, Inc., Wheaton, IL) (three paired nozzles were each 60 cm apart on the vertical boom with the bottom pair approximately 60 cm above the soil); or 4) a 60 cm vertical boom sprayer with two TP 8003 standard flat spray nozzles (Spraying Systems, Inc., Wheaton, IL) and two D3-DC23 disc-core hollow cone nozzles (Spraying Systems, Inc., Wheaton, IL) to apply 467 L/ha. Paired nozzles were 55 cm apart on the vertical boom with the bottom pair (TP 8003) approximately 40 cm above the soil. Coverage was determined by means of water and oil sensitive papers placed at three levels within the plant canopy (top = 2.0 m, middle = 1.5 m and bottom = 0.6 m) on the side of the plant near the sprayer and on the opposite side, and on the bottom and top of each leaf. The plant canopy was approximately 2.5 m in height. There were three replicates of each location. Percent spray coverage and data analyses were determined as described above.

Experiment 3, September 1, 1998. Broadleaf tobacco plants were sprayed with one of three different sprayers. Sprayers consisted of 1) a 1.5 m vertical boom with six TX-8 and two TY-8 hollow cone nozzles at heights described above, operating at 620 kPa to apply 467 L/ha; 2) a Solo type 410 backpack mistblower (Solo, Newport News, VA) to apply 150 L/ha; or 3) a Solo backpack model 475 sprayer (Solo, Newport News, VA) at 345 kPa to apply 467 L/ha. The plant canopy was approximately 1 m in height. Coverage was determined as described above. Water sensitive papers were placed at three levels within the plant canopy (top = 1.0 m, middle = 0.5 m and bottom = 0.2 m) on the side of the plant near the sprayer and on the opposite side, and on the bottom and top of each leaf. Percent spray coverage and data analyses were determined as described above.

Experiment 4, September 4, 1998. Broadleaf tobacco plants on a commercial broadleaf tobacco farm in Ellington, Connecticut were sprayed with one of three different sprayers. Sprayers consisted of 1) an Airtrak 785 air-assisted boom sprayer (Willmar Manufacturing, Willmar, MN) with nozzle velocity of 290 kph producing 100µm drops to apply 187 L/ha; 2) an AgTec 400PL mistblower (AgChem Equipment, Niles, MI) calibrated to apply 467 L/ha in two passes in opposite directions; or 3) an H&H 3 pt hitch drop nozzle tobacco sprayer (H&H Farm Machine Co., Indian Trail, NC) with six D2-DC23 nozzles (Spraying Systems, Inc., Wheaton, IL) at 1655 kPa to apply 560 L/ha. The plant canopy was approximately 1 m in height. Percent spray coverage and data analyses were determined as described above.

Table 1. Spray coverage in shade tobacco achieved by different spray techniques as measured by water-sensitive papers, July 14, 1998

	Percent Coverage[b]		
	Near	Far	Mean[c]
Sprayer [a]			
Vertical Boom (621 kPa, 467 L/ha)	52.7	14.3	33.5 a
Solo Backpack (345 kPa, 467 L/ha)	37.7	5.9	21.8 ab
Backpack mist blower (150 L/ha)	17.5	0.5	9.0 bc
Gun (2070 kPa, 934 L/ha over tent top)	0.7	0.5	0.6 c
Gun (2070 kPa, 934 L/ha inside tent)	15.0	7.7	11.4 bc
Level within canopy			
Top of plant (1.8 m)	29.9	10.5	20.2 a
Middle of plant (1.2 m)	23.8	2.2	13.0 a
Bottom (0.6 m)	21.7	7.7	14.7 a
Top or bottom of leaf			
Top surface	40.3	13.4	26.9 a
Bottom surface	9.9	0.2	5.1 b
Factor	Significance (P =)		
Sprayer type	0.0001		
Level within canopy	NS		
Top or bottom of leaf	0.0001		
Near or far side from spray row	0.0001		
Interaction of side by leaf surface	0.03		
Other interactions	NS		

[a] Sprayers consisted of 1) a 1.5 m vertical boom with eight paired hollow cone nozzles (six TX-8 nozzles at 40 cm spacing and two TY-8 nozzles at 30 cm above the ground), operating at 620 kPa to apply 467 L/ha; 2) a Solo backpack sprayer with a TGSS-3 nozzle at 345 kPa to apply 467 L/ha; 3) a backpack mistblower to apply 150 L/ha; 4) a handheld Myers high pressure spray gun with a no. 5 disk operating at 2070 kPa to apply 934 L/ha over the top of the tent; and 5) the handheld gun sprayer operating at 2070 kPa to apply 934 L/ha inside the tent.

[b] Coverage was determined on the side of the plant facing the spray row (Near) or opposite the spray row (Far) by means of water and oil sensitive papers (2.5 x 7.5 cm) placed at three levels within the plant canopy (top = 1.8 m, middle = 1.2 m and bottom = 0.6 m) on the side of the plant near the sprayer and on the opposite side (far), and on the bottom and top of each leaf.

[c] Means within columns followed by the same letter are not significantly different (P = 0.05) according to Fishers protected LSD procedure.

RESULTS

Experiment 1. Spray coverage within the shade tobacco canopy was significantly different for the sprayers tested (Table 1). Spray coverage was best with the vertical boom and pump-up backpack sprays. Coverage was poor with the high-pressure spray gun application over the top of the shade tent or over the top of the plant canopy within the tent. Sprays applied using a gun over the tent had fewer drops per cm^2 spray paper (12.7 versus 150.0, 89.1, 75.5 and 79.5 for vertical boom, backpack, backpack mistblower, and gun sprayer inside the tent, respectively) (P = 0.002). Sprays applied with the hand-held gun also had a greater percentage of large-diameter drops (greater than 100 microns) than sprays applied using other sprayers (3.6% versus 0.03, 0.3 and 0.1% for vertical boom, backpack, and backpack mist sprayers, respectively) (P = 0.001). When sprays were applied down rows within the tent, coverage was higher on the spray row side of the plant and on the top of the leaf. There were no significant differences in coverage on spray papers at different levels in the canopy. There was an interaction of side of the plant (spray row or far side of plant) with coverage on the top or bottom of the leaf (P = 0.03) such that the bottom of the leaf received nearly 25% of the coverage of the top on the side of the plant facing the sprayer, whereas on the far side of the plant, the bottom of the leaf received only 1.5% of the spray deposited on the top.

Experiment 2. In a second experiment within the shade tent, there were no differences between sprayers that traveled down the spray row with nozzles on a vertical boom or with manual coverage of the entire plant using an Echo backpack power sprayer (Table 2). All sprayers were calibrated to deliver the same volume of spray per hectare but differed in number and type of nozzle. Percent spray coverage was numerically higher for sprayers with greater numbers of nozzles, but the only significant difference was that the sprayer with fewer nozzles had difficulty in achieving adequate coverage on the far side of the plant. There was an interaction of side of the plant (spray row or far side of plant) with coverage on the top or bottom of the leaf (P = 0.04) similar to that observed in Experiment 1. The interaction of sprayer with coverage on the near or far side of the plant (P = 0.02) resulted from poor coverage on the far side of the plant with the 4-nozzle vertical boom sprayer (2%) compared to the other sprayers tested (17% to 96%).

Table 2. Spray coverage in shade tobacco achieved by different spray techniques as measured by water-sensitive papers, September 1, 1998

	Percent Coverage[b]		
	Near	Far	Mean[c]
Sprayer [a]			
Vertical Boom (621 kPa, 467 L/ha, T8 nozzles)	40.5	14.3	27.4 a
Vertical Boom (621 kPa, 467 L/ha, T18 nozzles)	36.0	14.2	25.1 a
Echo backpack (828 kPa, 467 L/ha)	29.7	11.3	20.5 a
Vertical Boom (621 kPa, 467 L/ha, 8003, 23-core nozzles)	26.9	2.7	14.8 a
Level within canopy			
Top of plant (2.0 m)	14.8	0.7	7.8 b
Middle of plant (1.5 m)	43.7	8.7	26.2 a
Bottom (0.6 m)	41.3	22.5	31.9 a
Top or bottom of leaf			
Top surface	51.3	18.8	35.1 a
Bottom surface	15.2	2.4	8.8 b
Factor	Significance (P =)		
Sprayer type	NS		
Level within canopy	0.004		
Top or bottom of leaf	0.0001		
Near or far side from spray row	0.0001		
Interaction of spray row side by top or bottom of leaf	0.04		
Interaction of sprayer by near or far side of the plant	0.02		

[a] Sprayers consisted of 1) a vertical boom with six TX-8 and two TY-8 hollow cone nozzles at heights described above, operating at 620 kPa to apply 467 L/ha; 2) the vertical boom with six TX-18 and two TY-18 nozzles, operating at 517 kPa to apply 467 L/ha; 3) an Echo backpack sprayer at 828 kPa to apply 467 L/ha; or 4) a 60 cm vertical boom sprayer with two 8003 and two D3 with 23 core hollow cone nozzles to apply 467 L/ha. Paired nozzles were 55 cm apart on the vertical boom with the bottom pair approximately 40 cm above the soil.

[b] Coverage was determined by means of water and oil sensitive papers placed at three levels within the plant canopy (top = 2.0 m, middle = 1.5 m and bottom = 0.6 m) on the side of the plant facing the spray row (Near) or opposite the spray row (Far), and on the bottom and top of each leaf.

[c] Means within columns followed by the same letter are not significantly different (P = 0.05) according to Fishers protected LSD procedure.

Experiment 3. The vertical boom sprayer resulted in the best spray coverage in the shorter broadleaf tobacco canopy, particularly on the far side of the plant (Table 3). There were no differences in coverage at different heights within the broadleaf canopy. However, there were large differences between the top or bottom surfaces of each leaf, as well as penetration through to the other side of the plant. There was an interaction of side of the plant (spray row or far side of plant) with coverage on the top or bottom of the leaf (P = 0.0001). Coverage on the top of the leaf was much higher in the spray row (64.3% versus 10.8% for the bottom of the leaf) compared to the far side of the plant (8.0 and 4.5% for the top and bottom, respectively) due to the drooping nature of the long-leaved broadleaf tobacco.

Experiment 4. The drop nozzle sprayer, with 59% coverage, achieved greater spray coverage than either the mistblower, (15.3%) or the air-assisted boom sprayer (11.8%) (Table 4). There were no differences in coverage throughout the plant canopy, but coverage was significantly better on the top of the leaf than on the bottom surface for all of the sprayers tested.

DISCUSSION

These experiments consistently demonstrated that the best spray coverage within a broadleaf or shade tobacco crop canopy was achieved by sprays made from nozzles placed within the crop, with the sprayer moving between rows. Broadleaf tobacco is a field-grown, full-sun, stalk-cut cigar wrapper type. Spray coverage for this tobacco type may best be achieved by high-pressure hydraulic boom sprayers with drop nozzles (5). Previous research has shown that air-assisted sprayers increase penetration and coverage into the canopy of row crops such as currants (3). Other researchers have demonstrated that sprays placed vertically within a crop canopy result in the best coverage (1). Our results indicate that spray coverage throughout the crop canopy may be up to three to four times greater with the use of drop nozzles compared to application over the top of the crop with a mistblower or air-assisted boom sprayer. It should make little difference in broadleaf whether the nozzles are suspended from an overhead boom in a drop-nozzle arrangement or nozzles are arranged on a vertical boom pulled down the rows.

In shade-grown cigar wrapper tobacco, the physical structure of shade tent construction with poles on 10-m squares, the arrangement of support wires between poles and tie wires over each plant row, and the fact that each plant is tied to the overhead wire prohibit the use of boom sprayers or drop nozzles. Our results indicate that sprays applied over the top of the plants and especially over the top of the tents result in very poor plant coverage. The shade cloth, used to increase humidity and reduce solar radiation by about 33% (7), intercepts a large portion of the spray applied over the top of the tents. Drops form on the fabric and rain down onto plants, resulting in inefficient coverage by widespread large drops. Insecticide applications made to shade tobacco by airplane were partially intercepted by the shade tent (4) and there was a gradient of coverage with the highest application at the top of the plant and on the top of the leaves (6).

The development of vertical boom sprayers that are brought down spray rows (every other row at 1-m row spacing) has resulted in acceptable spray coverage under the shade tents. We have observed that blue mold control has greatly improved on farms utilizing improved spray technology. The types of nozzles used on the vertical boom were not as important as the number of nozzles. Greater numbers of nozzles (eight as opposed to four in these experiments) should allow for overlapping spray patterns and better coverage on tall plants, as well as the ability to direct sprays through to the far side of plant leaves opposite the spray row.

Spray coverage was consistently better on the top of the leaves than on the bottom. Coverage to the undersides of leaves may not be as important in relation to blue mold management and the use of dimethomorph fungicide (Acrobat MZ), as it has translaminar and local systemic activity (2). The differential coverage that occurs on the top and bottom of leaves may have more impact on the efficiency of the mancozeb mixing partner and its utility in reducing the development of fungicide resistance.

Table 3. Spray coverage in broadleaf tobacco achieved by different spray techniques as measured by water-sensitive papers, September 1, 1998

	Percent Coverage[b]		
	Near	Far	Mean[c]
Sprayer[a]			
Vertical Boom (621 kPa, 467 L/ha)	48.5	14.3	31.4 a
Backpack mistblower (150 L/ha)	26.2	1.1	13.7 b
Solo backpack (345 kPa, 467 L/ha.)	38.0	3.4	20.7 ab
Level within canopy			
Top of plant (1.0 m)	45.6	7.8	26.7 a
Middle of plant (0.5 m)	40.9	5.9	23.4 a
Bottom (0.2 m)	26.1	5.2	15.7 a
Top or bottom of leaf			
Top surface	64.3	8.0	36.2 a
Bottom surface	10.7	4.5	7.6 b
Factor	Significance (P =)		
Sprayer type	0.03		
Level within canopy	NS		
Top or bottom of leaf	0.0001		
Near or far side from spray row	0.0001		
Interaction of side by leaf surface	0.0001		
Other interactions	NS		

[a] Sprayers consisted of 1) a 1.5 m vertical boom with six TX-8 and two TY-8 hollow cone nozzles at heights described above, operating at 620 kPa to apply 467 L/ha; 2) a backpack mistblower to apply 150 L/ha; or 3) a Solo backpack sprayer at 345 kPa to apply 467 L/ha. The plant canopy was approximately 1 m in height.

[b] Coverage was determined by placing water sensitive papers at three levels within the plant canopy (top = 1.0 m, middle = 0.5 m and bottom = 0.2 m) on the side of the plant near the sprayer (Near), on the opposite side (Far), and on the bottom and top of each leaf.

[c] Means within columns followed by the same letter are not significantly different (P = 0.05) according to Fishers protected LSD procedure.

Table 4. Spray coverage in commercial broadleaf tobacco achieved by different spray techniques as measured by water-sensitive papers, September 1, 1998

	Percent Coverage[b]
Sprayer[a]	
AirTrak 785 air-assisted boom sprayer	11.8 b[c]
AgTec 400PL mistblower	15.3 b
Drop nozzle sprayer	59.0 a
Level within canopy	
Top of plant (1.0 m)	25.3 a
Middle of plant (0.5 m)	30.5 a
Bottom (0.2 m)	24.9 a
Top or bottom of leaf	
Top surface	34.4 a
Bottom surface	19.4 b
Factor	Significance (P =)
Sprayer type	0.0001
Level within canopy	NS
Top or bottom of leaf	0.01
Interactions	NS

[a] Sprayers consisted of 1) an Airtec 785 air-assisted boom sprayer with nozzle velocity of 290 kph producing 100µm drops to apply 187 L/ha; 2) an AgTec 400PL mistblower calibrated to apply 467 L/ha in two passes in opposite directions; or 3) a drop nozzle sprayer with six D2 nozzles at 1655 kPa to apply 560 L/ha.

[b] Coverage was determined by placing water sensitive papers at three levels within the plant canopy (top = 1.0 m, middle = 0.5 m and bottom = 0.2 m) on the side of the plant near the sprayer, on the opposite side, and on the bottom and top of each leaf.

[c] Values within columns followed by the same letter are not significantly different (P = 0.05) according to Fishers protected LSD procedure.

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