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FUNGICIDE APPLICATION TO EDIBLE BEANS

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SUMMARY:
Spray deposit of two Benomyl fungicide application techniques was determined. Flat fan and hollow cone nozzles were used with varying pressures and water volumes. Plant washing and petri dish samples were used to determine spray volume deposited on beans. Pressure did no affect spray deposition on the crop. Increased water application rate with flat fan nozzles caused less chemical deposit on the beans. Changing water volumes did not affect spray deposit fo hollow cone nozzles. In general, flat fan nozzles deposited statistically higher amounts of chemical on the beans than hollow cone nozzles. Recommendations were made for further

KEYWORDS:
Beans, Fungicides, Sprayers

INTRODUCTION

In the 25,000 acres of edible beans grown in Southern Alberta, Canada, the fungicide Benomyl is used to control Botrytis and Sclerotinia. Due to Southern Alberta's high irrigation rates and environmental conditions, control of Sclerotinia is a serious problem. Benomyl use is reasonably clear in terms of chemical applied, chemical movement in the plant and coverage required. However, little information or research has been documented on effectiveness of application techniques. Benomyl is a systemic fungicide and requires application near the bottom of the plant through a thick crop canopy and onto emerging blossoms. Hunter et al. (1979) concluded coverage of flower stalks next to developing blossoms was essential for fungus control. Due to limited application research, producers are using numerous application techniques with varying degrees of success. Application techniques include drop nozzles, single, double or triple band nozzles, nozzle tips used with deflector bars, row splitters, lifters, full or partial shrouds, skid mounts, conventional sprayers and air assist sprayers. This study addresses the effectiveness of conventional flat fan and hollow cone nozzles under varying pressures and water volumes.

EQUIPMENT AND PROCEDURE

Spray deposition was measured for hollow cone and flat fan nozzles. Pressures of 275 and 620 kPa (40 and 90 psi) with water volumes of 40, 50 and 80 L/ac (8.8, 13.0 and 17.6 gal/ac) were used. Spraying Systems 8001, Lurmark 02F80, 03F80 and 04F80 flat fan nozzles and Spraying Systems TLX 4, 6, 8 and 12 hollow cone nozzles were tested. Nozzles were matched with pressures to achieve desired water volumes. Effects of droplet size were not considered in the experimental results. TABLE 1 illustrates nozzles, water volumes and pressures used.

The experiment was a 2 x 2 x 3 full factorial block design with 3 replications of each trial. The experiment included 12 trials and 3 replications for a total of 36 plots.

TABLE 1. Nozzle Type, Water Volume and Pressure

NOZZLE TYPE		WATER VOLUME		PRESSURE	
		l/ac	(gal/ac)	kPa	(psi)
FLAT FAN	02F80	40	(8.80)	275	(40)
	03F80	60	(13.00)	275	(40)
	04F80	80	(17.60)	275	(40)
	8001	40	(8.80)	621	(90)
	02F80	60	(13.00)	621	(90)
	03F80	80	(17.60)	621	(90)
HOLLOW CONE	TLX-6	40	(8.80)	275	(40)
	TLX-8	60	(13.00)	275	(40)
	TLX-12	80	(17.60)	275	(40)
	TLX-4	40	(8.80)	621	(90)
	TLX-6	60	(13.00)	621	(90)
	TLX-8	80	(17.60)	621	(90)

To measure the amount of spray deposit on the crop a fluorescent tracer dye was used. The tracer dye was applied to the beans using the experimental factors outlined in TABLE 1. A washing technique to find percentage of the total applied dye on the beans was used to rate application techniques. The tracer dye solution was 2.76 g/L of Fluorescein and 0.01% v.v. of a non-ionic surfactant (Agsurf). A petri dish collection method also determined chemical deposit in the crop. Analysis was completed to determine effectiveness of each collection method.

CALIBRATION

Nozzle flow rates were determined under controlled conditions before field testing. Nozzle flow test results were used to determine required tractor ground speeds for field testing. Flow rates at pressures from 200 to 635 kPa (30 to 100 psi) for each set of nozzles were determined. A set of 15 nozzles were used for each flow rate test. Mean nozzle outputs, standard deviations and coefficient of variation were determined for each set of nozzles. Coefficient of variation ranged from 1.0 to 3.7% for the flat fan nozzles. Hollow cone nozzle coefficient of variation ranged from 2.1 to 5.6%. A coefficient of variation over 3% indicates a maximum flow rate variation of 5% of the mean for most agricultural spray nozzles. Varying nozzle coefficient of variation resulted in a maximum nozzle variation of 10% in chemical application rate. Effects of varying application rates were reduced by replication of trials in the experiment.

Nozzle pressure gauges were calibrated before field tests. Calibrations were completed using a Druck DPI 601 digital pressure indicator. Calibration equations were applied to all pressure gauge readings.

Boom pressure losses were determined at each nozzle position over the 7.3 m (286 in) width of the boom. At pressures of 250 and 600 kPa (36 and 87 psi), the coefficient of variation of boom pressures was 0.9 and 0.4%, respectively. The pressure losses in the boom were considered minimal and did not cause significant error in the results. Pressure losses at monitoring gauges were also determined and errors corrected before field tests.

TEST PROCEDURE

Approximately 0.8 ha (2 ac) of irrigated land was used for testing. Test plots were seeded on 30 May 1991, at 75 kg/ha (67 lb/ac) with Great Northern Beans (Phaseolus Vulgaris). Bean row spacing was 56 cm (22 in). Plant counts indicated 77,250 beans per acre. Average height of the crop was 46 cm (18 in). Test plots were located 50 km northeast of Lethbridge, Alberta, Canada. The test area was divided into 15.2 by 7.6 m (50 by 25 ft) trial plots. The split block design used 3 blocks with 12 trials each. Blocks were divided by 10 m (32 ft) boundaries. Sprayer tests were conducted on 30 July 1991, 62 days after seeding.

Environmental conditions were monitored during the tests. Monitored conditions included wind speed, wind direction, relative humidity, air temperature, crop temperature and soil temperature. Boom pressure and true ground speed were also recorded.

A Case IH 7110 two-wheel drive tractor was used. Ground speed was determined using a radar gun mounted on the tractor.

A 7.3 m (286 in) spray boom was mounted on the three-point hitch of the tractor. A tank containing the dye tracer solution was mounted on the tractor and fitted with a hydraulically driven roller pump.

Boom pressure was monitored using a pressure gauge mounted in the tractor cab. Pressure was adjusted using the hydraulic flow control valve in the tractor cab and a gate valve attached to the pump discharge line.

Flat fan and hollow cone nozzles were spaced on 56 cm (22 in) centres on the boom. Nozzles were positioned between the bean rows (FIGURE 1). Boom height for the flat fan nozzles was 56 cm (22 in). Hollow cone nozzles were installed on drop tubes and angled at 45^o to the direction of travel and 45^o to the ground (FIGURE 2). Two hollow cone nozzles were used on each drop tube. One nozzle was angled forward at 45^o and one nozzle angled backward at 45^o. Hollow cone nozzles were 36 cm (14 in) from the ground.

Before spraying tracer solution, three petri dish holders were placed in trial plots. Three dishes were placed at three different levels in a stairway configuration on each holder. Design of the holders ensured movement of spray in the crop canopy was not altered. The bottom dish was on the ground. Middle and top dishes were at 17 cm (6.8 in) and 34 cm (13.5 in) from the ground, respectively. Stairs were positioned in the bean rows for the hollow cone nozzles. For flat nozzles, stairs were placed between bean rows with dishes as close as possible to the beans. The petri dishes were 8.9 cm (3.5 in) in diameter with a 1.3 cm (0.5 in) rim.

Once petri dishes were positioned, required nozzles, tractor speed and boom pressure were set. The tractor then traversed the plot. Ten random plant samples were taken. Each plant sample was cut in two. Measured from the ground level, 20 cm (8 in) of the plant was sampled as the plant bottom. The rest of the plant was considered the top sample. The top half of the bean sample varied in size depending on total plant size. All samples were stored under dark, refrigerated conditions until analysis was completed.

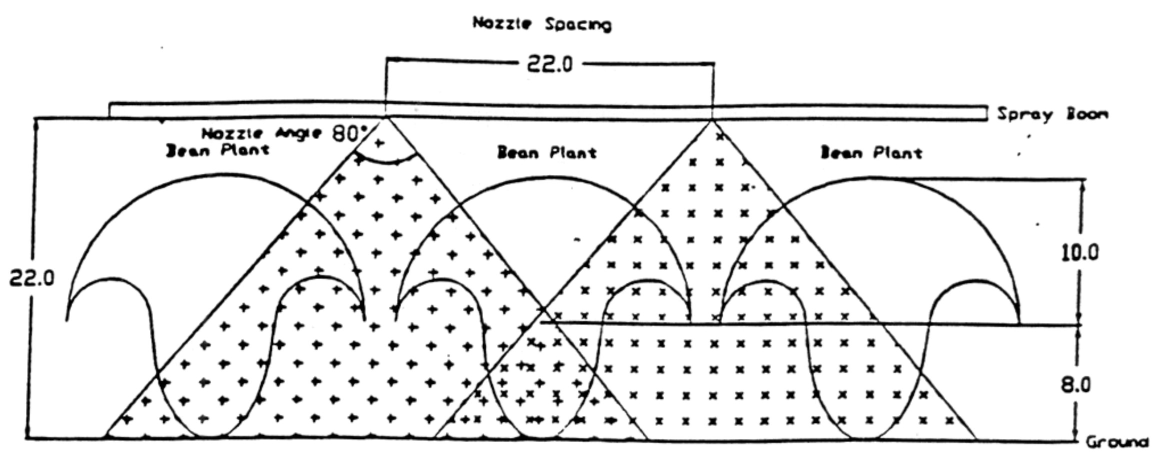

FIGURE 1. **Flat Fan Nozzle Arrangement.**

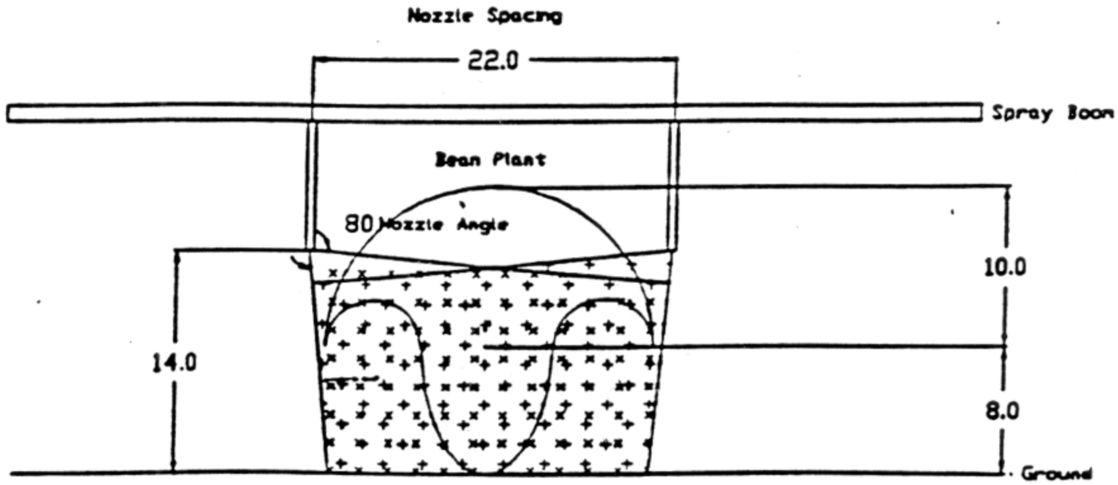

FIGURE 2. **Hollow Cone Nozzle Arrangement.**

ANALYSIS PROCEDURE

Percentage of total applied chemical was determined for the beans and petri dishes.

Plants were analyzed by extracting tracer dye using a solvent washing solution. Washing solution was made up of 95% v.v. hexane and 5% v.v. acetone. Distilled water was applied to the washing solution. Once the distilled water absorbed the dye in the washing solution, the water was separated from the washing solution for sampling. Two 5 mL samples of the distilled water were analyzed. Water analysis was completed using a LKB Biochrom Ultrospec II spectrophotometer. Concentration readings from the spectrophotometer were compared to a calibration curve for the tracer solution. The crop was also sampled to determine background spectrophotometer readings due to the beans. The average background spectrophotometer reading for 5 beans was 18.54 mg/L of tracer solution per plant. Since the beans were cut in two, 9.27 mg/L was used as the background concentration and applied to the plant washing results. Percentage of total applied chemical was used to rate spray deposition. Percentage of applied chemical was determined from the concentrations, nozzle flow rates, nozzle pressures, dye concentrations and travel speeds. A nominal top and bottom plant area of 232 cm^2 (0.25 ft^2) was used to calculate percentage of applied chemical. Since surface area of the beans sampled varied depending on if the top or the bottom of the plant was sampled, some error was introduced to the results. From field observations, the nominal area under estimated the size of the top half of the plants. The nominal area also over estimated the size of the bottom half of the plant. No practical method was available for determining plant surface area.

Petri dishes were analyzed by extracting dye using a solvent washing solution mixed with l0 mL of distilled water. Solvent washing solution was 95% hexane and 5% acetone. Distilled water was then separated from the washing solution and analyzed. Two 5 ml samples of the separated distilled water were then analyzed using a spectrophotometer. The average of the two samples was used in the final results. Concentration readings from the spectrophotometer were compared to a calibration curve for the tracer solution. Percentage of total applied chemical was used to rate spray penetration.

Percentage of total applied chemical on the dishes was determined from the dish area, chemical on the dish and concentration readings. However, since applied chemical values were calculated over the width of the spray pattern, placement of the dish had a significant influence on the results. Applied spray volume assumed a uniform distribution of the nozzle output at ground level. Dishes placed off the ground could have received more than 100% of the applied spray volume.

Fading of the dye was checked by exposing a 10 mL sample to sunlight for the duration of the treatment application and sampling. Maximum fading of the tracer dye was less than 1% of the concentration for any sample. Reduction due to fading was consistent with all samples. No correction factor was applied to the results due to dye fading.

STATISTICS

Separate statistical analysis was carried out for plant washing and petri dish data. An analysis of variance (ANOVA) and a multiple range test was performed using a full factorial model for all tests. Analysis consisted of two nozzles, two pressures and three flow rates (TABLE 2).

TABLE 2. ANOVA Factors and Levels.

FACTOR	LEVEL
NOZZLES (2)	80^{o} FLAT FAN HOLLOW CONE
PRESSURES (2)	275 kPa (40 psi) 620 kPa (90 psi)
WATER VOLUMES (3)	40 L/ac (8.8 gal/ac) 60 L/ac (13.0 gal/ac) 80 L/ac (17.6 gal/ac)

RESULTS AND DISCUSSION

PLANT COUNTS

At ten random sites through the test plots, a line was laid down the row and the number of plants per length of string was counted. Results indicated an average of 77,250 bean plants per acre.

ENVIRONMENTAL CONDITIONS

Environmental conditions were monitored throughout the test. Air temperature, soil temperature, crop temperature, in-crop relative humidity, wind speed and wind direction were measured.

Air temperature was measured at a height of 1 m (39 in) from the ground. Air temperature varied from 10.3^{o} to 22.8^{o} C. Crop canopy temperature varied from 15.4^{o} to 24.0^{o} C.

Wind speed was measured at a height of 1 m (39 in) above ground. Maximum wind speed measured over 5 minutes was 8.1 km/h (5.0 mph). Minimum wind speed was 0.9 km/h (0.6 mph). Travel speed of the tractor varied from 6.5 to 9.2 km/h (4.1 to 5.7 mph). Theoretical maximum wind speed when spraying was 17.3 km/h (10.6 mph). Relative humidity was measured at 15 cm (6 in) above the ground in the crop canopy. Relative humidity ranged from a minimum of 18.35% to a maximum of 86.8%.

PLANT WASHING RESULTS

Relative percentages of chemical measured on the bean plants varied from 5.2% to 31.8% of total applied chemical. TABLE 3 and FIGURES 3 and 5 illustrate plant washing results. Average trial coefficient of variation (CV) for plant washing was 73.4%. The high CV was due to the nominal plant surface area used in determining percent of total applied chemical. However, ten plant samples on each trial replicate reduced the plant area affect on statistical significance. ANOVA tables for the plant washing (TABLE 4) showed significant among trial variance at both the 1% and 5% levels of significance.

TABLE 3. Plant Washing Results

NOZZLE TYPE		WATER VOLUME		NOZZLE PRESSURE		AVERAGE % OF APPLIED CHEMICAL (%)	
		L/ac	(gal/ac)	kPa	(psi)	Top	Bottom
FLAT FAN	02F80	40	(8.80)	275	(40)	31.8	30.8
	03F80	60	(13.00)	275	(40)	11.9	13.3
	04F80	80	(17.60)	275	(40)	8.2	5.2
	01F80	40	(8.80)	621	(90)	7.2	16.9
	02F80	60	(13.00)	621	(90)	9.4	15.9
	03F80	80	(17.60)	621	(90)	8.4	9.3
HOLLOW CONE	TLX-6	40	(8.80)	275	(40)	10.4	9.9
	TLX-8	60	(13.00)	275	(40)	15.2	12.7
	TLX-12	80	(17.60)	275	(40)	5.4	6.4
	TLX-4	40	(8.80)	621	(90)	7.0	14.8
	TLX-6	60	(13.00)	621	(90)	13.0	10.8
	TLX-8	80	(17.60)	621	(90)	22.5	9.9

TABLE 4. Analysis of Variance for Plant Washing.

SOURCE	DF	SS	MS	F	P VALUE
TREATMENT	23	3383.1	147.1	4.44	<0.005
BLOCKS, BL	2	137.3	68.6	2.07	+0.100
NOZZLE, NZ	1	117.2	117.2	3.53	0.0712
PRESSURE, PR	1	33.6	33.6	1.01	+0.100
FLOW RATE, FR	2	538.5	269.2	8.12	<0.005
POSITION, PS	1	3.7	3.7	0.11	+0.100
NZ * PR	1	338.2	338.2	10.20	<0.005
NZ * FR	2	695.1	347.5	10.48	<0.005
NZ * PS	1	69.7	69.7	2.10	+0.100
PR * FR	2	715.9	357.5	10.79	<0.005
PR * PS	1	26.2	26.2	0.79	+0.100
FR * PS	2	165.3	82.6	2.49	0.096
ERROR	46	1525.5	33.2		
TOTAL	71	5045.8	71.1		

PETRI DISH RESULTS

Percentages of applied chemical measured on the dishes varied from 12.9% to 163.5%. Applied spray volume assumed a uniform distribution of the nozzle output at ground level. Dishes placed off the ground could have received more than 100% of the applied spray volume. TABLE 5 and FIGURES 4 and 6 illustrate petri dish results. The 12.9% to 163.5% range of chemical deposit was due to differences in dish placement. Dish placement differences caused an average trial coefficient of variation of 31.0%. Placement of petri dishes was critical to spray sampling. Changes in spray deposit due to sample heights also caused errors in dish results. Depending on sample height, dish placement influenced the amount of spray deposited in dishes. Decreasing distance between nozzle and sampling devices increased influence of dish placement. Error caused by reduced deposit because of plant material covering the dishes also occurred. Increased sampling numbers would have decreased placement effects.

TABLE 5. Petri Dish Results.

NOZZLE TYPE		WATER VOLUME		NOZZLE PRESSURE		AVERAGE % OF APPLIED CHEMICAL (%)		
		L/ac	(gal/ac)	kPa	(psi)	Top	Middle	Bottom
FLAT FAN	02F80	40	(8.8)	275	(40)	117.6	112.7	110.8
	03F80	60	(13.0)	275	(40)	109.1	75.8	69.6
	04F80	80	(17.6)	275	(40)	101.5	84.8	72.0
	01F80	40	(8.8)	621	(90)	98.8	76.3	61.6
	02F80	60	(13.0)	621	(90)	163.5	144.2	94.7
	03F80	80	(17.6)	621	(90)	86.1	80.8	68.5
HOLLOW CONE	TLX-6	40	(8.8)	275	(40)	14.6	108.5	71.1
	TLX-8	60	(13.0)	275	(40)	12.9	96.2	74.8
	TLX-12	80	(17.6)	275	(40)	26.5	113.1	68.0
	TLX-4	40	(8.8)	621	(90)	31.4	83.3	66.7
	TLX-6	60	(13.0)	621	(90)	72.3	111.8	60.1
	TLX-8	80	(17.6)	621	(90)	17.2	103.1	64.1

TABLE 6 outlines analysis of variances for petri dish results. ANOVA results illustrate an amoung trial variance at the 1% and 5% levels of significance for petri dish results.

TABLE 6. Analysis of Variance for Petri Dish Results.

SOURCE	DF	SS	MS	F	P VALUE
TREATMENT	35	119899.7	3425.7	7.42	<0.005
BLOCKS, BL	2	468.2	234.1	0.51	+0.100
NOZZLE, NZ	1	25128.3	25128.3	55.14	<0.005
PRESSURE, PR	1	65.6	65.6	0.14	+0.100
FLOW RATE, FR	2	6102.3	3051.2	6.70	<0.005
POSITION, PS	1	19413.4	9706.7	21.30	<0.005
NZ * PR	1	35.3	35.3	0.08	+0.100
NZ * FR	2	2710.2	1355.1	2.97	0.061
NZ * PS	2	39252.8	19626.4	43.07	<0.005
PR * FR	2	13075.2	6537.6	14.35	<0.005
PR * PS	1	2490.6	1245.3	2.73	0.077
FR * PS	2	2976.4	744.1	1.63	+0.100
ERROR	70	31899.8	455.7		
TOTAL	107	152267.7	1423.1		

NOZZLE TYPE

Flat fan and hollow cone nozzles were used. Plant washing ANOVA results (TABLE 4) showed flat fan nozzles had significantly higher percentages of applied chemical than hollow cone nozzles at a P value of 0.071. Petri dish ANOVA results (TABLE 6) showed significantly higher chemical deposit with flat fan nozzles than hollow cone nozzles. However, for hollow cone tests, the top petri dish was located only 2.5 cm (1 in) below the nozzle tip. Since petri dishes only 2.5 cm (1 in) below a nozzle tip did not take representative samples, an average application of only 29.2% of the applied chemical resulted. The amount of spray deposited in the top dish during hollow cone tests ranged from 12.9 to 72.3%. Flat fan nozzles had an average deposit of 112.8% in the top dish. Percentage of spray deposited in the top dish ranged from 86.1 to 163.5%. FIGURES 3 and 5 illustrate typical spray deposit on the plants for flat fan and hollow cone nozzles.

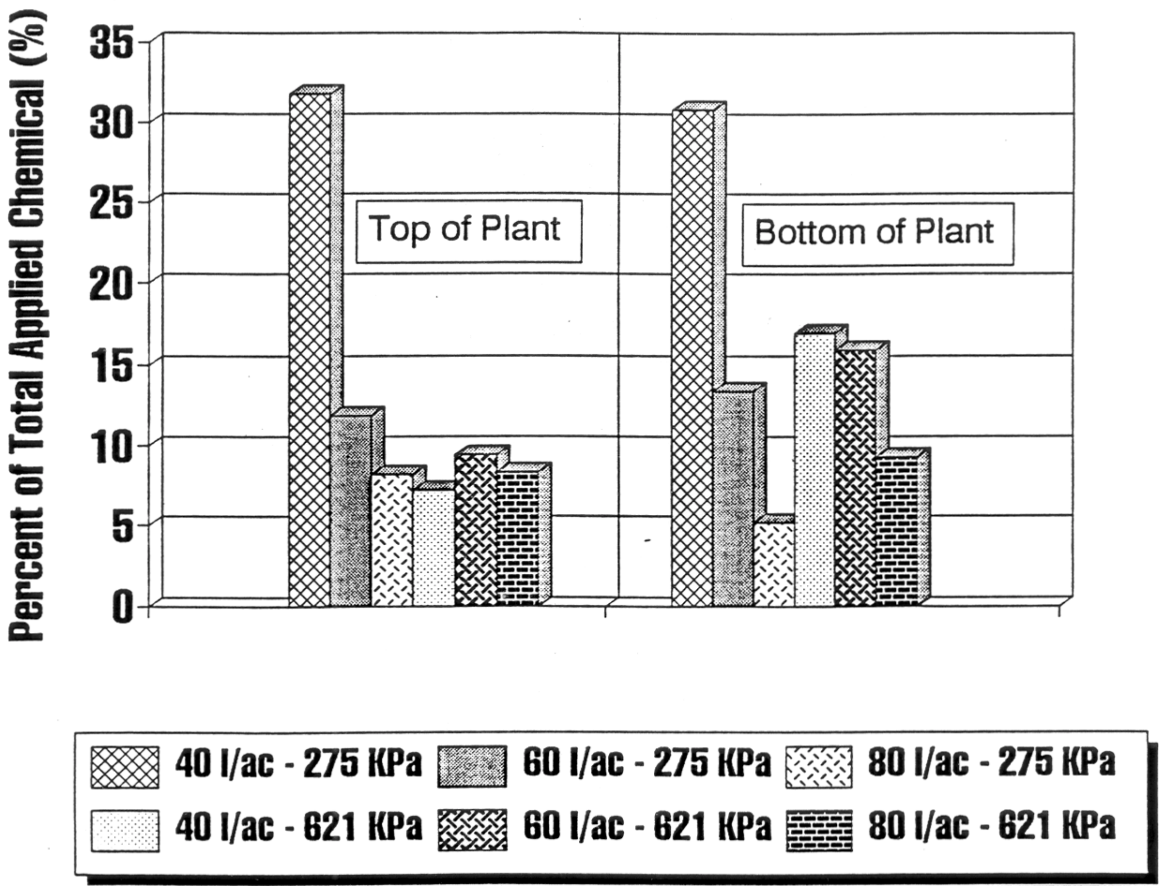

FIGURE 3. Plant Washing Results for Flat Fan Nozzles.

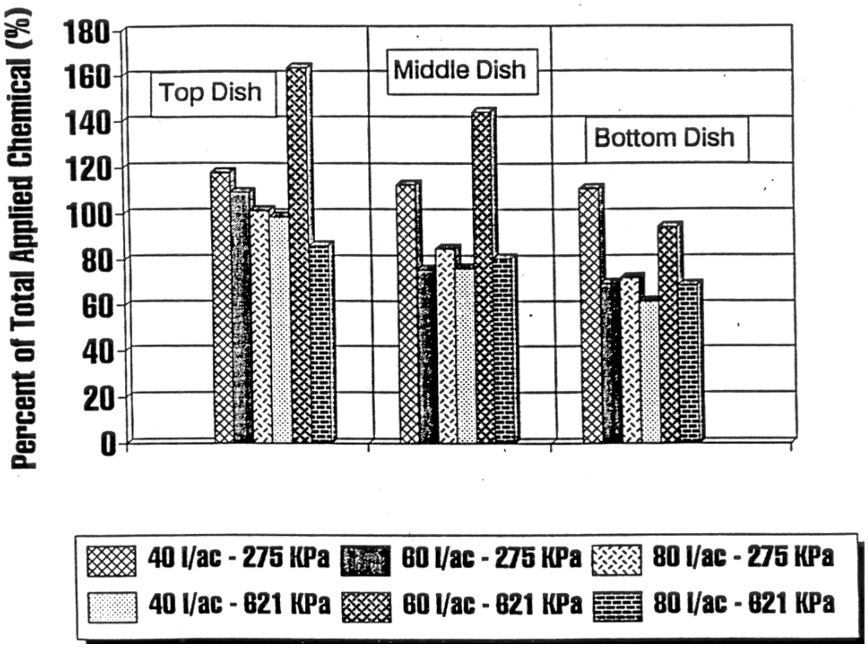

FIGURE 4. **Petri Dish Results for Flat Fan Nozzles.**

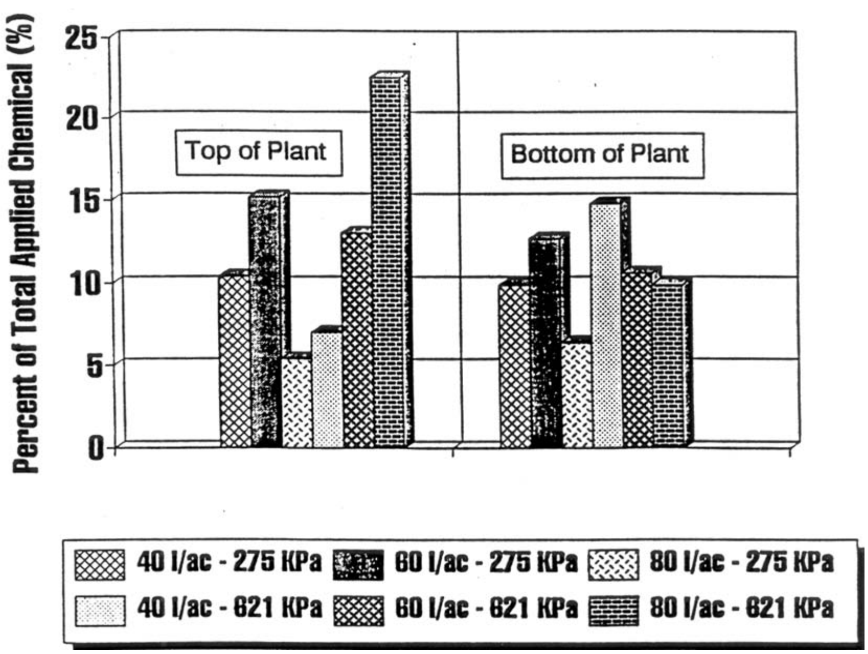

FIGURE 5. **Plant Washing Results for Hollow Cone Nozzles.**

NOZZLE TYPE

Flat fan and hollow cone nozzles were used. Plant washing ANOVA results (TABLE 4) showed flat fan nozzles had significantly higher percentages of applied chemical than hollow cone nozzles at a P value of 0.071. Petri dish ANOVA results (TABLE 6) showed significantly higher chemical deposit with flat fan nozzles than hollow cone nozzles. However, for hollow cone tests, the top petri dish was located only 2.5 cm (1 in) below the nozzle tip. Since petri dishes only 2.5 cm (1 in) below a nozzle tip did not take representative samples, an average application of only 29.2% of the applied chemical resulted. The amount of spray deposited in the top dish during hollow cone tests ranged from 12.9 to 72.3%. Flat fan nozzles had an average deposit of 112.8% in the top dish. Percentages of spray deposited in the top dish ranged from 86.1 to 163.5%. FIGURES 3 and 5 illustrate typical spray deposit on the plants for flat fan and hollow cone nozzles.

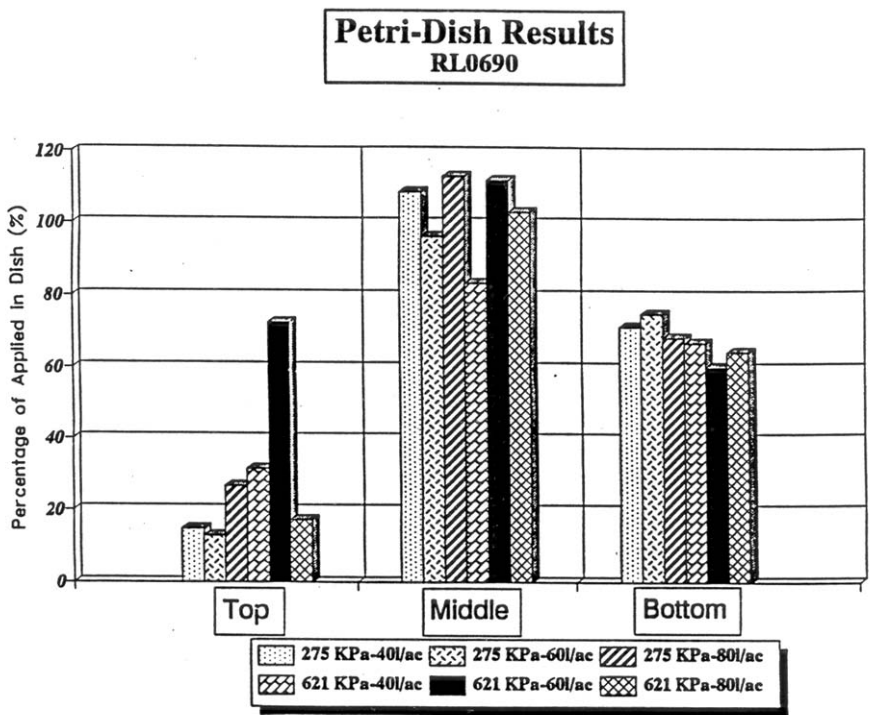

FIGURE 6. Petri Dish Results for Hollow Cone Nozzles.

PRESSURE

Two nozzle pressures, 275 and 621 kPa (40 and 90 psi), were used. Nozzle pressure provided no statistically significant difference among means of plant washing results (TABLE 4). Flow rates, rather than nozzle sizes, were used as the factor levels in the experiment. Therefore, the effect of pressure on the statistical analysis was reduced due to droplet size difference.

WATER VOLUME

Water volumes of 40, 60 and 80 L/ac (8.8, 13.0 and 17.6 gal/ac) were used. Dye concentration was the same for all water volumes. For plant washing results (TABLE 4), 40 L/ac (8.8 gal/ac) water volume showed significantly higher percentages of applied chemical on the beans than the 60 or 80 L/ac (8.8 or 13.0 gal/ac) volumes. The 60 L/ac (13.0 gaL/ac) flow rate indicated statistically higher application than 80 L/ac (17.6 gal/ac) rate. In contrast, petri dish results (TABLE 6) showed 80 L/ac (17.6 gal/ac) water volume had significantly higher deposit rates than 60 L/ac (13.0 gal/ac) or 40 L/ac (8.8 gal/ac) flow rates. The 60 L/ac (13.0 gal/ac) flow rate indicated statistically higher deposit rates than the 40 L/ac (8.8 gal/ac) rate.

Differences in plant washing and petri dish results were attributed to the ability of petri dishes to trap spray. Field observations showed the larger the water volume, the more chemical ran off the beans. Since petri dishes trapped all spray regardless of droplet size, high water volumes resulted in higher chemical deposits. In addition, petri dishes trapped chemical running off the beans.

Increased chemical runoff was caused by increased droplet size. For 80 L/ac (17.6 gal/ac) water volumes, larger nozzle sizes such as the 03 or 04 nozzles were used. The smaller 40 L/ac (8.8 gal/ac) flow rates were obtained with smaller 01 or 02 nozzles. The larger the nozzle, the larger the volume median diameter of the droplets (Spraying Systems 1991). Volume median diameter is the value where 50% of the total volume of liquid sprayed is made up of the droplets with diameters larger and smaller than the median value. While the higher water volumes penetrated deeper into the crop, less chemical was deposited on the beans.

CROP CANOPY PENETRATION

Hollow cone nozzle results were affected by nozzle angle. Since hollow cone nozzles were angled at 45^o to the petri dishes, the area of the dishes available to the spray was reduced. Petri dish results should be used only to compare specific nozzle types.

Flat fan and hollow cone nozzles showed an average of 112.8% and 29.2% of chemical applied was deposited on the top dish, respectively (FIGURES 4 and 6). The top dish was 34.3 cm (13.5 in) from the ground. The middle dish received an average of 98.5% and 102.7% of the applied chemical for flat fan and hollow cone nozzles, respectively. The middle dish was located 8 cm (3.2 in) from the ground. The ground level dish received an average percentage of total applied chemical of 79.6% for flat fan nozzles and 67.5% for hollow cone nozzles.

In general, as water volume increased, chemical deposit into the petri dish increased. FIGURES 4 and 6 illustrate petri dish results and how water volume affected chemical deposit.

SPRAY DEPOSIT ON PLANTS

Flat fan nozzles deposited an overall average of 15.3% of total chemical on the top and bottom of the beans. Amount of chemical deposited on the bottom of the beans ranged from 5.2 to 30.8%, with an average of 15.2% deposited on the bottom of the beans. Hollow cone nozzles deposited an overall average of 10.7% of total applied chemical on the top and bottom of the beans. Hollow cone nozzles deposited an average of 10.7% on the bottom of the beans, with a minimum of 6.4% to a maximum of 14.8% deposited. For percentage of applied chemical calculations, the same surface areas were used for bottom and top plant samples. Since bottom plant samples were approximately half the area of top samples, percentages of applied chemical on the bottom of the beans were under estimated. The results should only be considered relative comparisons since actual surface areas were not measured.

Increasing water volume with the flat fan nozzles caused percentage of total applied chemical on the beans to decrease. No relationship between water volume and spray deposition was apparent for hollow cone nozzles. FIGURE 3 and 5 illustrate the results of the plant washing.

Results indicated no relationship between pressure and spray deposit on beans.

CONCLUSIONS AND RECOMMENDATIONS

Pressures of 275 and 621 kPa (40 to 90 psi) were used. Pressure did not affect crop penetration or spray deposition. No relationship between pressure and spray deposition or crop penetration was apparent. However, the affect of droplet size was not considered in the results.

Water volumes of 40, 60 and 80 L/ac (8.8 13.0 and 17.6 gal/ac) were used. For flat fan nozzles, chemical deposit into petri dishes increased with increases in water volume. However, increased water volumes caused decreases in spray deposit measured on the beans. No relationship between spray deposit and water volumes were apparent for the hollow cone nozzles.

The average trial coefficient of variation for plant washing results was 73.4%. The high coefficient of variation was attributed to using a nominal area measurement for all beans. Since nominal areas were used, only relative percentages of dye applications were found. Nominal areas were used because of the complexity of measuring plant surface areas. Simpler and less tedious plant surface area measurement techniques are required.

Water volume, pressure and nozzle type were used as experimental factors. Droplet size, velocity and nozzle height affect spray penetration and deposition. Future work should include the affects of droplet size, droplet velocity and nozzle height on spray deposit and penetration.

Petri dishes and plant washing were used to determine spray deposition on beans. Since petri dishes trapped water which ran off the bean leaves, petri dishes were not acceptable for determining spray deposition on bean plants.

Producers are using several spray techniques for the application of Benomyl. Future work should involve more of the techniques used for fungicide application.

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