RESEARCH BULLETIN 1078 JUNE 1975

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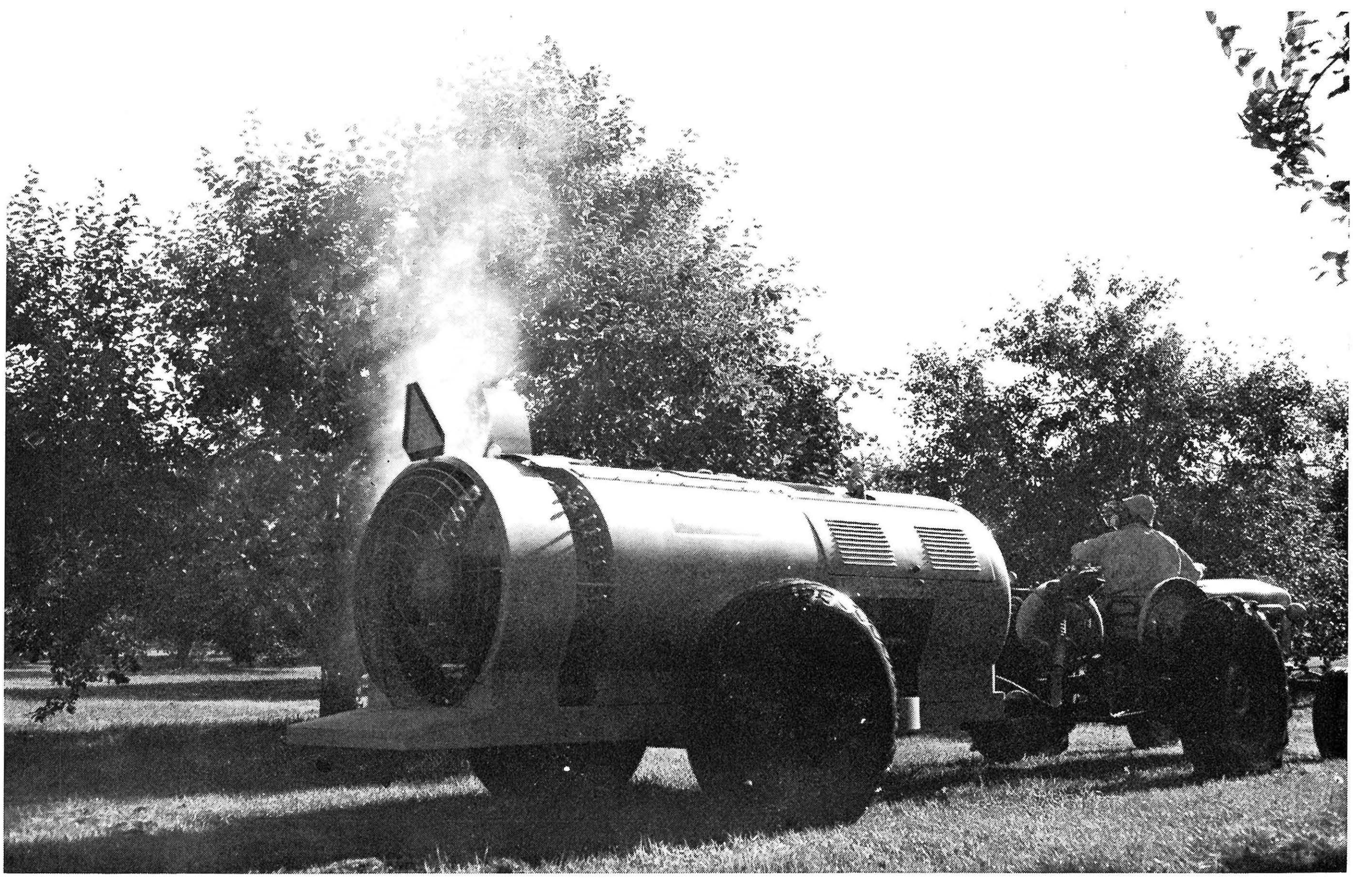

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
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CONTENTS

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Introduction ... 3

Materials and Methods ... 3

- Experimental Design ... 3
- Equipment and Materials ... 3
- Mite and Insect Sampling Methods ... 6
- Apple Scab Sampling Methods ... 6
- Measurements of Air Velocities Produced by Sprayers ... 6
- Droplet Dispersion ... 7

Results and Discussion ... 8

- European Red Mite—Overwintering Eggs ... 8
- European Red Mite ... 8
- Insect Control ... 12
- Apple Scab ... 12
- Phytotoxicity and Pesticide Compatibility ... 14
- Measurements of Air Velocities ... 14
- Droplet Dispersion ... 16

Summary and Conclusions ... 18

Literature Cited ... 19

Appendix ... 20

ACKNOWLEDGMENTS

The authors gratefully acknowledge the in-depth research conducted by H. F. Winter, formerly plant pathologist at OARDC, and O. K. Hedden, formerly USDA-ARS agricultural engineer at Wooster, (both now retired) during the early phases of this project. Appreciation is expressed to Dr. R. D. Brazee, USDA-ARS agricultural engineer, Pioneering Research Laboratory on Fine Particle Physics, Wooster, who contributed to the droplet and spray air velocity phases of the research, and to D. L. Collins, USDA-ARS engineering technician, Wooster, who made the airblast sprayer application, for their support during the conduct of this study. The authors are grateful to those who provided the pesticides and loaned the airblast sprayers for these experiments.

AGDEX 211/606-624-634 6-75-2M

Comparison of Orchard Sprayers for Insect and Disease Control on Apples, 1966-1969[1]

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INTRODUCTION

Fruit trees must be sprayed frequently for effective control of insects, mites, and diseases. This protection represents a large proportion of the total costs of growing fruit (17). Airblast spraying in orchards was introduced about 1948 (21). Since then, airblast spraying has greatly reduced labor requirements which in 1963 were estimated at 6% of spray costs (17). Additional savings have been due primarily to the development of the concentrate airblast sprayer. Concentrate spraying is characterized by the application of 20-100 gallons per acre (g.p.a.) and dilute spraying is 400 g.p.a. or more.

In 1966, after the introduction of the Econ-O-Mist concentrate sprayer, Ohio orchardists were interested in the relative effectiveness of the concentrate method vs. the conventional dilute method of spraying. Since growers were having increasing problems with labor, it seemed opportune to move toward the concentrate system which theoretically could reduce pesticide application costs by as much as 50%. In experiments from other areas of the country, it was noted that the Econ-O-Mist was inefficient in applying pesticides to large apple trees (1). Other studies have demonstrated the problems of impingement of small droplets and even distribution of pesticides throughout large trees (2, 3). Scientists have also studied the additional complications of a changing orchard culture (tree size and density), equipment size, air velocity and volume, droplet sizes, and evaporation factors (6, 7, 8, 19). During the past 10 years, there has also been a significant change from the use of long residual chlorinated hydrocarbons to the less persistent carbamate and organophosphate insecticides. Thus it became apparent that additional information was needed on the biological effectiveness of pesticides applied in various concentrations with three types of orchard sprayers.

In 1966, a series of experiments was initiated to study the effects of different spray volumes on the control of insects, mites, and diseases in apple trees. These experiments were conducted by the Departments of Entomology and Plant Pathology at the Ohio Agricultural Research and Development Center (OARDC), in cooperation with the USDA-ARS Insect Control Equipment and Practices Group and Pioneering Laboratory on Fine Particle Physics who are also located at OARDC, Wooster. Consequently, the expertise of four different groups was combined and directed as a cooperative venture on the 4-year research program.

MATERIALS AND METHODS

Except for one experiment conducted in a commercial orchard at Rittman, Ohio, in 1966, all field testing was done in the Plant Pathology orchard, OARDC, Wooster.

Experimental Design

In 1966, pesticide treatments were applied to unreplicated blocks of 9-15 Rome apple trees in the Wooster orchard. From 1967-69, the experimental design was a replicated block design with features of a Latin square. Each treatment consisted of two 5-12 tree blocks of Rome apple trees and two 8-10 tree blocks of Cortland apple trees. Block placement was designed for approximately equal exposure of each treatment to certain surrounding environmental features (*e.g.*, prevailing southwesterly winds, open fields, sprayed and unsprayed orchards). The trees were planted in 1950 at a spacing of 40 x 40 ft. In 1968, the average tree height was 17.6 ft. and the maximum height of any sprayed tree was 21.7 ft. The average canopy diameter of the sprayed trees was 21.5 ft. and the maximum canopy was 30.0 ft.

The experimental design in the Rittman orchard in 1966 consisted of unreplicated blocks of 14-19 Cortland trees and 16-24 Franklin apple trees. The untreated block consisted of six trees of each of the two varieties. The trees ranged from 10 to 15 years old.

Equipment and Materials

Three sprayers were used during this study. All dilute (1X) sprays were applied with a hand gun and a Myers hydraulic-pressure sprayer, which delivered 35 gal./min. at 400-600 pounds per square inch (p.s.i.) (Fig. 1).

The 4X and 10X sprays were applied with a Myers A-42 airblast sprayer (Fig. 2) with a 42-inch,

[1]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U. S. Dept. of Agriculture and does not imply its approval to the exclusion of other products which may be suitable.

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FIG. 1.—Hydraulic-pressure sprayer used to apply all dilute (1X) sprays.

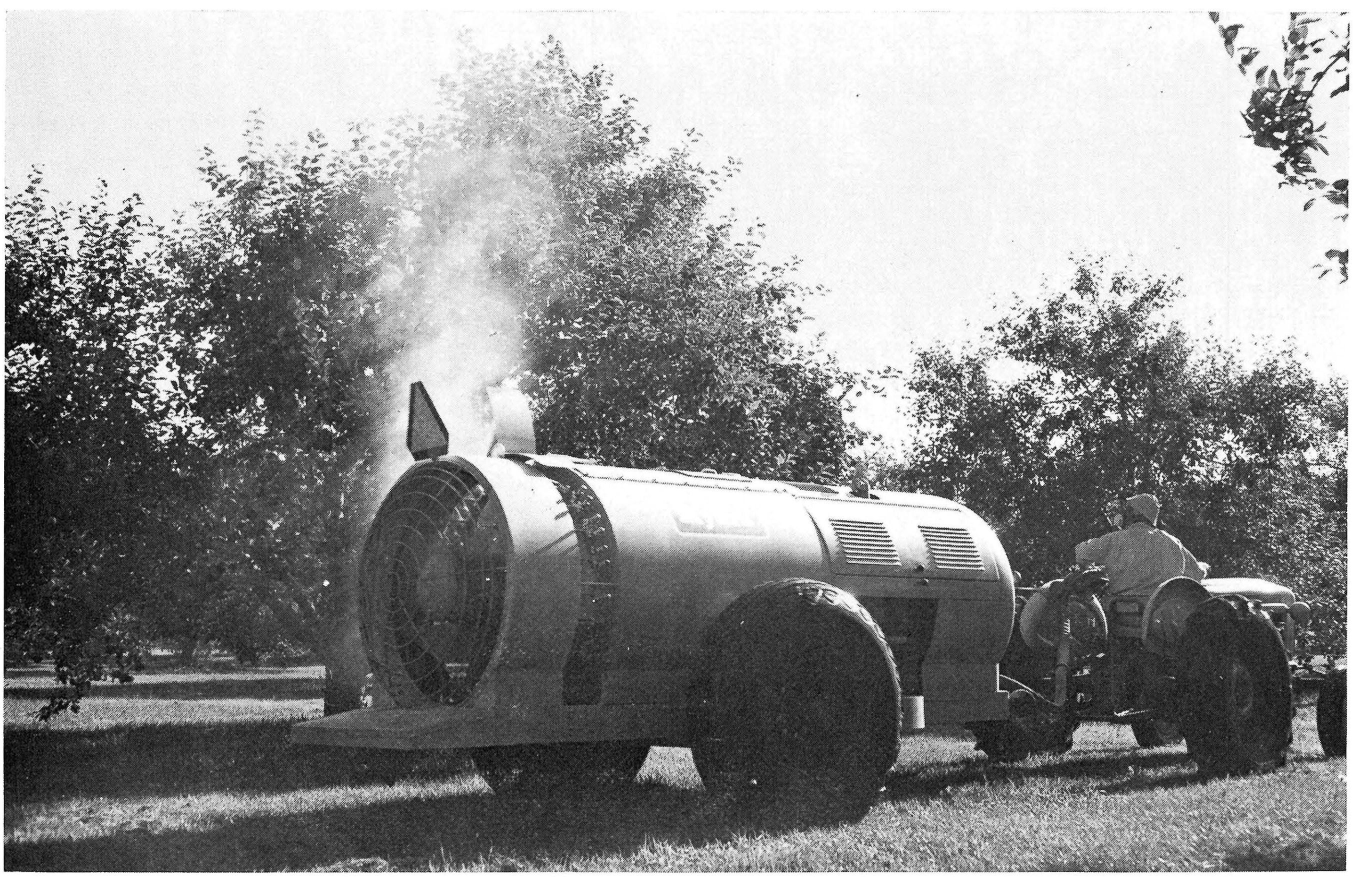

FIG. 2.—LC airblast sprayer used to apply 4X and 10X sprays.

seven-blade, propeller-type axial flow fan rated at 50,000 cubic feet per minute (c.f.m.). Only one side of the air outlet was used, because the trees in the orchard had been planted in 40 ft. rows which were too far apart for the sprayer to reach the inside of two rows at one pass. A 100-gallon tank was attached to the sprayer and was used instead of the large 400-gallon tank to facilitate measurement of the amount of spray material applied.

Two sets of nozzles were placed in the air delivery opening. These nozzles were equipped with individual turnoff valves and check valves so that either set could be used interchangeably. One set was used for the 4X application and the other for the 10X treatment.

Power for this sprayer, hereafter referred to as the lower concentrate (LC) sprayer, was supplied by a separate International Harvester UB-220 engine with 220 cu. in displacement. The spray pump operated at 200 p.s.i. Sprays were applied at a tractor speed of 2½ miles per hour (m.p.h.).

In all 4 years of testing, a Marlow Econ-O-Mist sprayer (Model 36 TD-3) with an air-fan volume of 27,000 c.f.m. was used to apply the 33X, 50X, and 66X sprays. This sprayer, hereafter referred to as the higher concentrate (HC) sprayer, had a turnover attachment (Fig. 3) which permitted air from both sides of the fan to be used in discharge from one side. This power-take-off driven sprayer was operated at a speed of 2 m.p.h.

A small spray tank was substituted for the large spray tank furnished with the sprayer because of the small amounts of spray required to treat the orchard plots. The pump on this sprayer was an adjustable displacement type which delivered its entire output into the spray system. Nine pneumatic, atomizing slotted, ceramic nozzles were located in the airblast outlet. A rotary compressor delivered air internally to the nozzles at 35 p.s.i.

The two airblast sprayers were calibrated to apply the same amount of toxicant per tree which would be applied with a dilute (1X) application. In all

FIG. 3.—HC airblast sprayer used to apply 33X, 50X, and 66X sprays.

concentrate sprays, the full rates were used in all cases, *i.e.*, 66X = 66 times the amount of pesticide per 100 gallons of spray used in the 1X treatment. No adjustments were made for the reduced run-off with the higher concentrate applications.

Data in 1967 and 1968 indicate that about 2 gallons of solution were applied per tree at 4X, 3 quarts at 10X, 1 quart at 33X, 1 pint at 66X, and 10 gallons at 1X.

The schedule of concentrations and equipment used in each year of test is listed in Appendix Table I. The pesticides, rates, and time of application are shown in Appendix Table II (Wooster orchard) and Appendix Table III (Rittman orchard).

Mite and Insect Sampling Methods

All counts in the Wooster orchard were made on two to five Rome apple trees per treatment in 1966, on two Rome and two Cortland trees in 1967, and on four Rome and four Cortland trees in 1968 and 1969. Generally, the sample trees were located near the centers of the treated blocks. An attempt was made to sample from the area of a tree where the potential effects of spray drift from other blocks would be at a minimum. Unless otherwise noted, samples were taken from an area consisting of the lowest branches, up to 6-7 ft. above the ground, and from just inside the periphery of each tree.

Identical insect- and mite-sampling techniques were used in each of the 4 years, except when otherwise noted. Specific sampling procedures were as follows:

1) *Overwintering eggs of the European red mite, Panonychus ulmi* (Koch): At 1-4 days after the oil spray, 12-28 twigs were collected from trees within each treatment. These twigs generally bore 100-200 eggs (a range of 38-814 eggs per treatment). In 1968 and 1969, another set of twigs with a similar number of eggs was collected from the upper branches of the trees (at about 12-14 ft. above the ground). The twigs were brought into the laboratory and cut into 2-3 in. lengths. The twigs were then set on tacks pushed upward through corrugated cardboard and white paper squares. Tanglefoot or Stikem was placed on the paper squares around the twigs. Records were kept of the number of newly hatched larvae trapped on the sticky material during the spring months.

2) *Motile European red mites:* Ten leaves were collected from the periphery of the sample trees, or half-trees, in each block. In the laboratory, a count was made of all motile European red mites found on the under surface of the 40-50 leaves per treatment. In the years 1967-1969, additional sets of leaves were collected from a height of 12-14 ft. on the trees. The motile mite sampling procedure in 1966 at the Rittman orchard generally was the same. Leaves from the lower parts of the trees were collected from two Cortland and two Franklin apple trees. For the sample in the upper parts of the trees (14 ft.), 4-7 Cortland trees were used (40-70 leaves per treatment).

3) *Rosy apple aphid, Dysaphis plantaginia* (Passerini): Control of these aphids was evaluated by counting, from June 10 through June 15 (1966-1969), all the leaf clusters which appeared to have been injured by a single colony of aphids. A second method of evaluation was the recording of the number of harvested fruits with signs of aphid-feeding damage.

4) *Apple aphid, Aphis pomi* Degeer: Records were accumulated on the number of aphids found on 10 vegetative shoots per tree around the periphery of two to four Rome sample trees in each treatment. From 20-40 terminals were examined for each treatment.

5) *General fruit insects:* Additionally, on the sample trees in each block, 100 fruits were inspected for signs of injury by the codling moth, *Laspeyresia pomonella* (L.); plum curculio, *Conotrachelus nenuphar* (Herbst); and redbanded leafroller, *Argyrotaenia velutinana* (Walker). The sample of 400-500 fruits per treatment was usually taken from Sept. 8 through Sept. 19 in each year.

Apple Scab Sampling Methods

All counts of apple scab, *Venturia inaequalis* (Cke.) Wint., in 1966 were based on a sample of fruit from six Rome trees per treatment. At harvest, 200 fruits were randomly sampled from the top half and 200 fruits from the bottom half of each sample tree.

In 1967, 1968, and 1969, all fruit scab counts at harvest were based on samples from four trees of each of the two varieties. A total of 200 fruits was randomly sampled from the top half and 200 fruits from the bottom half of each sample tree. Only three trees per variety were sampled in 1968 when a severe frost limited the number of fruit samples. The Cortland variety had top half samples of about 85 per tree, whereas the bottom half samples were near 50 per tree. Those from the Rome variety averaged 150 fruits per tree for both top and bottom samples.

The foliar scab counts made in 1967 through 1969 were based on five randomly chosen terminals from both the top and bottom halves of four trees of each of the two varieties.

Measurements of Air Velocities Produced by Sprayers

Mean air velocities and turbulent intensities were determined at several positions in the air streams produced by both airblast sprayers. Measurements were made with a constant-temperature, hot-wire anemometer. At each position, mean velocity and root mean square (r.m.s.) velocity were recorded for several 10-second intervals. The mean of these values for each position was used to calculate the percentage of turbulent intensity (T.I.), by

$$\% \text{ T. I.} = \frac{\text{r.m.s. velocity}}{\text{mean velocity}} \times 100$$

This relationship indicates how much the velocity fluctuates about the mean.

Figure 4 shows the HC sprayer and a plywood jig for positioning the velocity sensor about the air outlet. After the sensor was positioned, the jig was removed so it would not interfere with the air stream. The sprayers were located inside the building but the air stream was directed out through a large open doorway. Measurements were made on radial lines referenced to the fan axes. The included angle between lines was 8° and angles below the horizontal center line were assigned negative values. The sensor was positioned at positions perpendicular to each radial line and at two radial distances from centerline of fan axes for both airblast sprayers.

Air velocity measurements of the HC sprayer were taken at radial distances of 25 in. and 59 in. These distances correspond to 2 in. and 36 in. from the outer shell of the air outlet, which has an opening width of 6⅛ in. For the 25-in. radius measurements, front, center, and rear sensor positions were respectively 1-17/32, 3-1/16, and 4-19/32 in. behind the front edge of the outlet. Measurements were also made 2 in. outside of the turnover housing and they were designated as Nos. 1, 2, and 3. Position 2 was at the center of the outlet of the turnover and positions 1 and 3 were at the inside and outside edges, respectively. For the 59-in. radius, a velocity traverse across 0° indicated peak velocity at 3 in. behind the front edge of the outlet. This position was used as the center position of the sensor and front and rear positions were 6 in. forward and behind the center position.

Air velocity measurements of the LC sprayer were taken at radial distances of 30 in. and 60 in. These distances corresponded to 6 in. and 36 in. from the outer shell of the air outlet, which had an opening 8⅜ in. wide. At the 30-in. radius, front, center and rear sensor positions were respectively 2-3/32, 4-3/16, and 6-9/32 in. behind the front edge of the air outlet. At the 60-in. radius, a velocity traverse across 0° indicated peak velocity at 5 in. in front of the front edge of the outlet. This peak velocity position was used as the center sensor position and the front and rear positions were 8 in. forward and behind the center position.

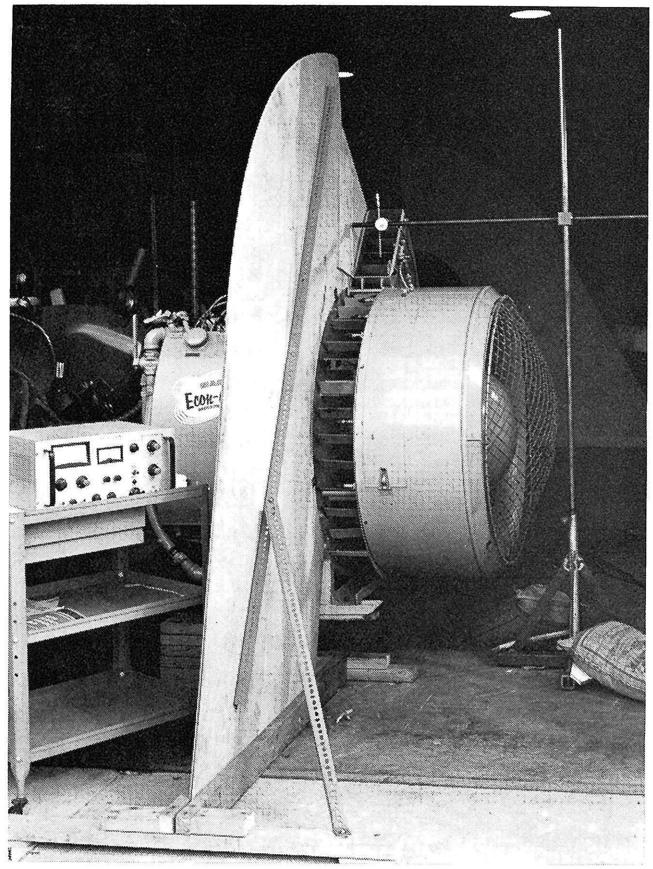

FIG. 4.—HC airblast sprayer with plywood jig used for positioning the velocity sensor.

Air velocities produced by the HC sprayer were also measured on a 48° (above horizontal) radial line at several positions out to 22¾ ft. from the centerline of fan axis. At this distance, a velocity traverse indicated the position of maximum velocity. The other velocity measurements were made on a straight line toward the fan axis and center of outlet.

Droplet Dispersion

Exploratory tests to measure the vertical dispersion of droplets from the LC sprayer were made in February 1970. A tower was erected to simulate the centerline of a tree; targets of 3 x 5 in. developed, glossy photographic paper were mounted on the tower at heights of 10, 20, 22, 24, 26, and 28 ft. The sprayer was driven past the tower at about the same speed and spraying distances as those used in the field tests; *i.e.*, 2½ m.p.h., 15 ft. from the sprayer outlet path to the tower, and with continuous spraying from 15 ft. before to 15 ft. past the tower. The sprayer operation, including nozzle configuration and pressures, was the same as that used for the 10X application rate during the 1969 spraying season. A 2% solution of pontacyl violet dye was mixed with the water to make the droplets visible on the targets. No attempt was made to simulate the leaves, twigs, or branches of the tree; *i.e.,* the targets were not shielded in any way from the sprayer blast. The droplet residue on each card was photographed, then sized and counted on a Flying-Spot Particle Analyzer (4). Thus, by using a spread factor measured by other researchers, the volume of spray which reached each target was estimated.

RESULTS AND DISCUSSION

European Red Mite—Overwintering Eggs

The data on the percentage of overwintering European red mite eggs indicate that the 1X concentration of superior oil consistently gave good reductions in hatch in both the lower and upper parts of the trees (Table 1). These results were not surprising because a spray from a handgun can be directed very effectively into all parts of a tree. The 4X and 10X concentrations also resulted in good reductions in hatch in the lower parts of the trees, but did not seem to do as well in the upper branches in 1968, which was the first year the LC sprayer was used. At this point it should be noted that minor adjustments were made on the sprayers from time to time to make them more effective in spray coverage. Therefore, it is possible that the improved results obtained with a 10X oil spray in 1969 are a more reliable index.

The 33X concentration usually gave a very good reduction in egg hatch in all parts of the trees. In 1968, however, the percentage of hatch in the lower parts of the tree was high. Since this was the only instance of poor control by the 33X sprays, it is possible that the anomalous data in 1968 may have been due to a sampling error, *e.g.,* the chance selection of a few twigs with many eggs from areas with less oil deposit, or the eggs may have been more shielded from an oil spray. Generally, all concentrations of oil, when applied at half-inch green (HIG) stage of apple bud development, effectively reduced the hatch of overwintering European red mite eggs.

Possibly a more reliable index of the efficacy of the various concentrations of oil for mite control could be based on the number of mites found on the leaves. A conclusion based on the selection of some twigs to determine the percentage of hatch would probably be more subject to sampling error (as noted above), whereas counts of motile mites on 40-50 leaves per treatment, taken on two or more count dates, would seem to reflect more correctly the total population on the trees.

TABLE 1.—Efficacy of Superior Oil Against Overwintering Eggs of the European Red Mite, 1966-1969.

Concentration	Percent Hatch of Overwintering Eggs 1966	1967	1968*	1969
	3-7 FT. ABOVE GROUND			
1X	3.9		1.0	5.7
4X		1.5		
10X		0.6		0.7
33X	0.7	14.8		1.1
50X	0.6			
Check	56.1	9.9	16.5	47.4
	12-14 FT. ABOVE GROUND			
1X			2.9	2.3
4X		10.8		
10X		17.8		0
33X		2.6		2.6
Check		18.1	23.7	12.9

*Data collected from adjacent orchard treated in same manner as concentrate test orchard.

TABLE 2.—Control of European Red Mite with Different Concentrations of Superior Oil Measured at 3-7 Ft. Above Ground, 1966.

Plot No.	Concentration	Spray Date	Av. No. Mites/Leaf Sampling Date 7-11	7-20
1	1X	HIG	0.5	2.1
2	33X	HIG	T	0.2
3	50X	HIG	0.4	0.9
4	Check		0.4	3.6

European Red Mite

The efficacy of the oil treatments applied at HIG against European red mite in 1966, as based on leaf counts, is presented in Table 2. Because the check population at least up to July 20 was low, any differences in mite populations cannot be attributed to the different concentrations used for the applications of oil. By August 15, the mite populations in these plots still remained fairly uniform, although on August 22 the mites which received the 66X treatment had increased (Table 3). Although the mites were counted only on the lower branches in 1966, the summer sprays of azinphosmethyl on July 21 and August 3 and dicofol on August 24 generally gave good control of European red mite, regardless of the type of concentration.

The remaining data on summer mite control are presented on an annual basis because, to determine the relative effectiveness of the various concentrations, one needs to consider the pretreatment counts. A direct comparison between the mite counts in the lower and the upper parts of trees treated with a single concentration is difficult to make because mite populations are sometimes naturally lower on the upper branches as compared to the lower branches (see check counts for July 7 in 1967 in Table 5 and for July 15 through August 2 in 1968 in Table 6). In addition, differing pretreatment counts also must be

TABLE 3.—Control of European Red Mite with Different Concentrations of Pesticides Measured at 3 to 7 Ft. Above Ground, 1966.

Concen-tration	Pesticide	Plot No.	Spray Dates	Av. No. Mites/Leaf Sampling Date					
				7-20	8-3	8-15	8-22	8-29	9-7
1X	Carbaryl	1	7-21	0.6	1.0				
1X	Azinphosmethyl 25 WP	1	8-3			0.5	2.1		
33X	Azinphosmethyl 25 WP	2	7-21, 8-3	1.0	T	0.6	5.2		
33X	Azinphosmethyl 25 WP	3	7-21, 8-3	2.1	0.2	0.8	3.7		
66X	Azinphosmethyl 25 WP	4	7-21, 8-3	3.4	1.0	1.8	10.7		
1X	Dicofol 18.5 WP	1	8-24					1.0	2.4
33X	Dicofol 18.5 WP	2	8-24					0.3	0.0
33X	Dicofol 18.5 WP	3	8-24					0.2	T
66X	Dicofol 18.5 WP	4	8-24					1.1	0.2
	Untreated check (no pesticides)	5		1.8	5.5	12.5	12.4	22.2	7.9

considered. Therefore, separate comparisons were made among data from the lower parts of the trees and among data from the upper parts.

Table 4 presents data recorded from the commercial orchard in 1966, where the trees were not pruned as well as those in the Wooster orchard. Although data from lower parts of the trees indicated equal control at 1X and 33X, the upper parts of the large Cortland trees sprayed at 33X showed the typical mite *bronzing* effects, caused by extensive mite feeding. Counts taken August 3 through August 5 showed that more mites were in the upper branches (8.2/leaf) than in the lower ones (0.2/leaf) of trees sprayed at 33X. No bronzing was evident in upper parts of trees sprayed at 1X, which indicates that the 1X treatment provided more effective overall mite control.

After this observation, an attachment was added to the HC sprayer to allow more thorough spraying of the upper parts of the trees. This situation illustrates the point made by Brann (2) that adjustments to the sprayer, made according to the needs of the particular orchard, are necessary if thorough spray coverage is to be achieved.

In 1967 (Table 5), the results show that, for a very low initial population of mites, sprays of dicofol and azinphosmethyl at 66X were successful in maintaining the mite population at a low level in both parts of the trees (plot 3). At higher pretreatment levels, no real differences were observed between the 1X and 33X concentrations for the two parts of the trees. When oxythioquinox was applied at various concentrations at the pink stage of bud development, the data in Table 5 indicate possibly that the 66X concentration was best, at least in the lower parts of the tree. The data also illustrate the influence that all treatments had on the mite population, although the mite populations in all treated plots started to

TABLE 4.—Control of European Red Mite with Different Concentrations of Pesticides Measured at 3 to 7 Ft. Above Ground, 1966 (Rittman Orchard).

Concentration	Pesticide	Plot No.	Spray Dates	Av. No. Mites/Leaf Sampling Date				
				6-17	7-6	7-13	7-20	8-3-5
1X	Dimethoate 2.67 EC	1*	P					
33X	Dimethoate 2.67 EC	2†	P					
1X	Azinphosmethyl 25 WP	1	6-22, 7-7, 7-21, 8-3	0.6	4.4			
33X	Azinphosmethyl 25 WP	2	6-22, 7-7, 7-21, 8-3	0.4	3.9			
1X	Dicofol 18.5 WP	1	7-7, 7-15			0.2	0.2	0.2
33X	Dicofol 18.5 WP	2	7-7, 7-15			0.2	T	0.2‡
	Untreated check	3		0.9	8.3	8.2	18.0	24.6

*Counts for plot 1 are the average number of mites recorded for the 1X block sprayed with captan as the fungicide and another 1X block sprayed with dodine.

†Counts for plot 2 are averages computed in a similar manner for two 33X plots.

‡One count taken in upper parts of trees, 8.2 mites/leaf.

TABLE 5.—Control of European Red Mite with Different Concentrations of Pesticides, 1967.

Concen-tration	Pesticides	Plot No.	Spray Dates	Av. No. Mites/Leaf Sampling Dates* 7-7	7-10	7-17	7-31	8-7	8-25
1X	Oxythioquinox 25 WP	1	P	2.2 **0.2**	3.2				
33X	Oxythioquinox 25 WP	2	P	1.6 **1.9**	6.0				
66X	Oxythioquinox 25 WP	3	P	0.4 **0.2**	0.5				
1X	Dicofol 35 WP	1	7-12, 7-20			0.8			
33X	Dicofol 35 WP	2	7-12, 7-20			2.9			
66X	Dicofol 35 WP	3	7-12, 7-20			0.2			
1X	Azinphosmethyl 50 WP	1	7-26, 8-9				4.9 **0.5**	2.9 **2.7**	8.1 **8.4**
33X	Azinphosmethyl 50 WP	2	7-26, 8-9				3.9 **2.0**	10.0 **3.2**	13.9 **11.2**
66X	Azinphosmethyl 50 WP	3	7-26, 8-9, 8-23				0.1 **0.3**	1.1 **0.3**	2.2 **1.2**
	Untreated check	4		6.5 1.2	2.4	1.7	6.5 5.5	7.4 7.4	1.9 0.9

*Results in light face type are from lower parts of tree (3-7 ft. above ground). Results in **bold** face type are from upper parts of tree (12-14 ft. above ground).

TABLE 6.—Control of European Red Mite with Different Concentrations of Pesticides, 1968.

Concen-tration	Pesticides	Plot No.	Spray Dates	Av. No. Mites/Leaf Sampling Dates* 7-15	7-25	8-2	8-12	8-21	8-27
4X	Superior Oil 70-sec. vis.	1	HIG	T **0.2**	1.0 **1.6**				
10X	Superior Oil 70-sec. vis.	2	HIG	0.5 **0.3**	3.6 **4.7**				
33X	Superior Oil 70-sec. vis.	3	HIG	0.3 **0.9**	18.1 **7.0**				
4X	Azinphosmethyl 50 WP	1	7-29, 8-13			4.8 **2.8**	7.8 **6.8**		
10X	Azinphosmethyl 50 WP	2	7-29, 8-13			4.9 **3.5**	9.4 **15.6**		
33X	Azinphosmethyl 50 WP	3	7-29, 8-13			20.8 **4.9**	40.5 **19.7**		
4X	Tetradifon 50 WP	1	8-13, 8-20					1.9 **3.1**	0.2 **0.2**
10X	Tetradifon 50 WP	2	8-13, 8-20					5.8 **6.6**	0.2 **0.4**
33X	Tetradifon 50 WP	3	8-13, 8-20					24.9 **15.2**	3.4 **3.9**
	Untreated check	4		5.9 **2.8**	12.4 **4.4**	7.0 **5.8**	0.7 **0.6**	0.4 **0.1**	0.1 **0.1**

*Results in light face type are from lower parts of tree (3-7 ft. above ground). Results in **bold** face type are from upper parts of tree (12-14 ft. above ground).

surge in August. The population in the check plot had already peaked by August and remained lower than that in the treated plots.

The data on the check and on the oil treatments in 1968 (Table 6) indicate that possibly the 4X and 10X concentrations applied with the LC sprayer were more effective in mite control than the 33X concentration, at least in the lower parts of the trees. This conclusion on 33X is similar to observations on percentage of hatch (Table 1).

Except for the count on Sept. 8 in 1969 (Table 7), no differences were observed in control of the European red mite with the various concentrations of azinphosmethyl. The last set of counts on Sept. 8 indicates that a 33X concentration was more effective than 1X or 10X sprays in preventing a late season surge of mite populations in both the upper and lower parts of the trees. However, once again, the check populations remained extremely low throughout the year, possibly because of predators or the effects of previous years' treatments (Hall, 1972, unpublished data).

On the basis of these data, it is concluded that a high concentration of an acaricide should provide adequate mite control, or possibly even equivalent to that provided by a lower concentration of an acaricide. Krestensen (1968, unpublished results) noted that although there was a tendency towards a faster buildup of the European red mite population in plots which received the higher concentration spray applications, all acaricides performed well at all concentrations.

It should be noted, however, that the apple trees in the Wooster experimental orchard were kept well pruned and under 20 ft. in height during the period of this study. The conditions under which the sprays were applied were optimum; *i.e.,* sprays were made during a relatively short period in the day and only when wind velocity was low. Also, the applications were made under strict supervision and by personnel trained to regulate the gallons of spray per tree.

The results obtained in 1966 in the Rittman orchard illustrate the possible need for adjustments for tree density and height. Brann (1, 2), Lewis *et al.* (14), and more recently Fisher (8) have all noted the difficulties in obtaining good coverage and uniform distribution of spray droplets for control of European red mite in the tops of large, mature apple trees. Brann *et al.* (3) noted that some low-volume sprayers frequently deposit up to twice as much material on the lower portion of trees. More recently, Hall *et al.* (11) observed that while greater deposits of azinphosmethyl were found on apple foliage nearest the sprayers, deposits as low as 12% of these were found on foliage in the top centers of large trees. Byass (5) observed that variation among trees within a block, as well as the obvious differences in form, rootstocks, and pruning systems, may result in variations in spray deposits. Byass attempted to construct a geometrical model for the growth of an apple tree in order to define the tree more adequately as a target and to improve spraying efficiency.

Hall and Ferree (10) recently noted that low volume spraying offers economic advantages to the

TABLE 7.—Control of European Red Mite with Different Concentrations of Pesticides, 1969.

Concentration	Pesticides	Plot No.	Spray Dates	Av. No. Mites/Leaf Sampling Date* 7-28	8-6	8-18	8-25	9-8
1X	Superior Oil 70-sec. vis.	1	HIG	0.5 **0.3**	0.4 **1.3**			
10X	Superior Oil 70-sec. vis.	2	HIG	0.3 **T**	1.6 **0.3**			
33X	Superior Oil 70-sec. vis.	3	HIG	0.4 **0.3**	0.2 **1.2**			
1X	Azinphosmethyl 50 WP	1	8-7, 8-21			3.1 **3.6**	2.7 **5.7**	13.8 **12.2**
10X	Azinphosmethyl 50 WP	2	8-7, 8-21			2.3 **3.6**	2.6 **2.0**	19.3 **8.4**
33X	Azinphosmethyl 50 WP	3	8-7, 8-21			1.6 **4.3**	2.2 **8.4**	3.1 **2.8**
	Untreated check	4		0.3 **0.2**	0.1 **T**	0.1 **T**	0.0 **0.0**	T **0.0**

*Results in light face are from lower parts of tree (3-7 ft. above ground). Results in **bold** face type are from upper parts of tree (12-14 ft. above ground).

tree grower with a high density orchard. In addition, the use of dwarfing rootstocks (200-400 trees per acre) should aid this factor of coverage since the sprayer is significantly closer to a much higher percentage of the target area.

Insect Control

The results listed in Table 8 indicate that regardless of the concentration of carbaryl used, the apple aphid was controlled very well in 1966. This conclusion reflects only the efficacy of the concentrate sprays in the lower parts of the trees, because no samples were taken from the upper branches.

The adult plum curculio is not as active as either codling moth or redbanded leafroller adults and will usually spend more time feeding and laying eggs. Therefore, if there is little insecticidal deposit on a branch on which the curculio is located, the percenage of fruit damage might increase for a particular treatment. However, as noted in Table 9, the control of plum curculio in all years under all treatments was excellent, and commercially acceptable even with high concentrate applications.

Although the codling moth population was high in the Wooster orchard in 1966, all concentrations of insecticides gave excellent control. Control of low populations of redbanded leafroller was also excellent (Table 9). Data from subsequent years follow similar trends. This is to be expected since these moths are quite mobile and are likely to come into contact with insecticidal deposits, even if such deposits are poorly distributed throughout the tree. Populations of redbanded leafroller were too low to record in both 1968 and 1969. Superior oil was applied at HIG each year and, except in 1967 when parathion was applied at early tight cluster, there was little reduction in rosy aphid damage with any of the concentrate sprays.

TABLE 8.—Control of Apple Aphid with Different Concentrations of Carbaryl, 1966.

	No. Aphids/Distal End of Terminal	
Concentration	6-20	7-11
1X	10.2	2.0
33X	19.0	0.1
66X	17.8	2.5
Check	151.0	37.7

Apple Scab

The control of apple scab by the different types of application for 1966-1969 is shown in Table 10. Although there was a consistently higher amount of fruit scab in the upper portions of trees in all treat-

TABLE 9.—Control of Plum Curculio, Codling Moth, Redbanded Leafroller, and Rosy Apple Aphid with Different Concentrations of Insecticides, 1966-1969.

	Percent Injured Fruit				Av. Curled Leaf Clusters per Tree
Concentration	Plum Curculio	Codling Moth	Redbanded Leafroller	Rosy Apple Aphid	Rosy Apple Aphid
			1966		
1X	0.2	0	0.5	3.2	105.0
33X	0.2	0	0.1	1.8	22.2
66X	0.0	0	0.2	0.6*	31.4*
Check	16.2	55.8	3.5	9.2	141.8
			1967†		
1X	0	0	0	0.8	0.5
33X	0	0	0	1.8	8.5
66X	0	0.5	0	0.5	5.5
Check	6.8	24.8	0.8	3.8	18.0
			1968		
4X	0	0		2.2	2.2
10X	1.0	0		1.0	3.2
33X	1.8	0		1.0	2.5
Check	22.2	16.8		3.2	3.2
			1969		
1X	0	0		1.8	21.8
10X	0.5	0.2		1.2	18.5
33X	0.8	0		2.2	14.2
Check	8.2	26.5		2.5	14.0

*No record taken on 66X plot, data shown for 50X plot (oil only).
†In 1967, parathion was applied at early tight cluster.

ments in 1966, the means for the whole tree for all treatments were similar. With severe fruit scab pressure in 1966, the control provided by all treatments was good when compared to the unsprayed check.

In 1967, scab counts on Cortland fruit and foliage were obviously higher in the 66X plot as compared to either the 33X or 1X plots. This difference, however, did not appear in the Rome, a more scab-tolerant apple variety, as evidenced by the smaller amount of scab in the checks.

A more severe disease situation presented itself in 1968. Although the unsprayed fruit and foliage of both Corland and Rome had nearly 100% infection, the 4X treatment was fairly successful. On the other hand, in the upper level of the trees, fruit scab in the 33X treatment was slightly higher in the Rome variety while fruit scab in the 10X treatment was higher in the Cortland variety. Commercially acceptable control of fruit scab in the Cortland variety was not provided by any treatment. Similar results were illustrated in Table 6, where mite populations in the 33X plot were higher at both levels of the trees.

In 1969, the more susceptible Cortland variety had significantly higher amounts of fruit scab at both levels from the 33X treatment than from the 1X and 10X treatments. The data on the Rome variety follow a similar trend.

As shown by the 1969 data, the spray concentrations tested were more effective in controlling insects (Table 9) than in controlling apple scab (Table 10). The difference may have resulted from inadequate spray coverage when spraying conditions were less than optimum. Inadequate spray coverage can complicate the problem of attempting to control sedentary organisms such as apple scab. The problem could be further complicated if the primary scab season were prolonged, and particularly if it were followed by conditions conducive to secondary infection.

Over a 6-year period, Krestensen and Graham (12, 13) obtained commercial control of apple scab, insects, and mites with concentrate sprays applied at reduced rates, as did Hall and Ferree (10) in a recent 2-year study. Carmen *et al.* (6) showed that although some materials can be applied at lower rates in low volume sprayers, a great variability will occur in the amount of deposits on the leaves and fruit. More recent data by Hall *et al.* (11) also show a substantial variation in pesticide deposits throughout apple trees. Brann *et al.* (3) concluded that the Econ-O-Mist was not efficient in applying an even distribution of the pesticide to large mature apple trees. Wilde *et al.* (18) concluded that low-volume applications often affected the beneficial insect species much less than the

TABLE 10.—Control of Apple Scab on Cortlands and Romes with Concentrate Sprays, 1966-1969.

Concentration	Cortland				Rome			
	Percent Foliar Scab		Percent Fruit Scab		Percent Foliar Scab		Percent Fruit Scab	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
				1966				
1X							3.8	1.4
33X							2.6	0.9
66X							3.4	0.8
Check								94.7*
				1967				
1X	2.3	3.0	0.2	0.3	4.2	8.2	0.5	0
33X	3.6	3.9	3.6	0.5	7.8	10.0	0.8	0.3
66X	13.4	11.7	7.6	2.9	7.6	6.7	0.2	0.2
Check	76.6	94.5	82.3	88.4	42.6	73.0	19.4	32.4
				1968				
4X	7.7	5.2	14.3	4.1	8.1	4.8	1.7	0.6
10X	18.5	6.3	19.0	1.3	5.8	4.5	2.3	0.5
33X	5.5	3.4	12.1	7.2	13.5	10.3	4.1	3.2
Check	92.4	97.8	100	100	87.9	94.5	92.8	97.8
				1969				
1X	37.2	16.2	6.3	3.1	47.6	30.3	1.2	0.9
10X	35.6	21.3	7.9	6.6	32.3	25.7	1.5	1.0
33X	52.9	40.2	32.9	30.2	40.5	33.2	6.8	4.4
Check	92.9	96.9	100	100	88.5	91.3	96.7	99.1

*Mean includes percent scab top and bottom halves of check trees.

high-volume applications, while still providing economic control of insect pests.

Environmental conditions during and immediately following application are extremely important factors in determining both coverage and subsequent residual activity. For example, Cunningham *et al.* (7) found that up to 40% of the original volume of some concentrate sprays may be subject to evaporation under certain environmental conditions. In the 4 years of research reported here, insects and mites were generally much easier to contain at low levels of injury as compared to apple scab infections on a highly susceptible variety such as Cortland under severe inoculum pressure (100% infection on checks). Thus, both proper timing and accurate placement of spray into trees are necessary for efficient pest control.

Phytotoxicity and Pesticide Compatibility

No serious phytotoxicity was observed on the leaves or fruit of Cortland, Rome, and Franklin apple trees. In the Rittman orchard, some slight spotting on 10-15% of Cortland leaves was noted July 20 in the plot sprayed with dodine and insecticides (Appendix Table III) at 33X. However, the authors agree with the conclusion of Lewis *et al* (14) that, in general, concentrate sprays are less phytotoxic than dilute sprays if an even distribution of small droplets is obtained. However, as the volume of solution is decreased (or the concentration of chemical is increased) the chance of error in either calibration or application techniques increases markedly. Accurate calibration of these new low-volume sprayers is a very important procedure for orchardists (10). In terms of the newer, integrated pest management programs, it becomes even more imperative that the applications of specific compounds at specific rates be accomplished in a precise manner.

The only physical incompatibility of pesticides noted was a *swelling* of the wettable powder slurry when large quantities of pesticides were combined in the tank.

Measurements of Air Velocities

Tables 11 and 12 show the mean velocity and the percentage of turbulent intensities of air streams as measured in the core of the jets from the HC and LC sprayers, respectively. When measured close to the air outlets, the mean velocities were almost always considerably higher at one-quarter the outlet distance behind the front edge than at the center or rear positions. For example, at 56° above horizontal and at 6 in. from the LC sprayer outlet, the air velocity at the front position was 1.7 and 5.1 times greater than the velocities at the center and rear positions, respectively (Table 12). Therefore, to make most efficient use of the air discharge, the nozzles should be located farther forward on both sprayers.

There was little difference between means of all turbulent intensities for the two sprayers. These means were 22% and 18% for the LC and HC sprayers, respectively. Also, the mean of turbulent intensity taken close to the air outlets of both sprayers was about the same as the mean of measurements taken 36 in. from the air outlets of both sprayers. The strength of turbulent motion, as measured by turbulent intensity, is known to affect the drift and spreading of suspended material in air. Thus, high turbulent intensities within the air jet will cause more rapid dispersion of droplets away from the core of the jet.

TABLE 11.—Mean Air Velocity and Turbulent Intensity Values for the HC Airblast Sprayer.

Position (degrees)	Velocity (f.p.s.)			Percent Turbulent Intensity		
	F	C	R*	F	C	R*
			25-INCH RADIUS			
—40	40	45	27	22	21	22
—32	68	55	43	13		18
—24	77	50	35	12	19	21
—16	64	52	37	16	16	18
—8	55	45	35	17	19	21
0	76	77	41	13	19	20
8	94	54	45	13	20	19
16	82	57	45	14	18	21
24	62	55	34	16	18	23
32	94	44	32	12	20	23
40	123	86	32	7		25
48	120	64	25	7	21	29
56	115	70	30	10	20	9
64	125	84	30	10	18	28
72	120	54	29	16	22	24
80	160	130	72	16	9	19
No. 1	110	125	140	15	13	8
No. 2	82	76	66	14	12	12
No. 3	180	146	144	5	4	7
			59-INCH RADIUS			
—16	15		23			
—8	16	23	14			
0	15	32	18			
8	11	34	17	27	14	21
16	11	29	18	28	17	21
24	13	32	19	26	15	21
32	20	37	19	25	16	24
40	36	48	17	18	15	28
48	45	38	12	13	16	29
56	42	37	14	14	17	27
64	39	68	54	17	9	15
72	58	103	64	14	6	13
80	86	100	21	11	9	22

*F, C, and R correspond to front, center, and rear probe positions as follows. On 25-in. radius, F, C, and R = 1-17/32, 3-1/16, and 4-19/32 in., respectively, behind the front edge of air outlet. On 59-in. radius, F = 3 in. in front of front edge of outlet and C and R = 3 and 9 in., respectively, behind the front edge of outlet.

The mean velocity decreases very rapidly and the turbulent intensity increases as the distance from the core of the jet increases. The degree of change of both of these measurements is highly dependent on mean velocity and turbulent intensity of the surrounding atmosphere. This interaction between the jet and the atmosphere is not well understood and must be studied further because it greatly influences spray dispersion. More knowledge in this area is essential to improvement of sprayer design and to more accurate selection of local atmospheric conditions for best coverage with minimum drift.

Figures 5 and 6 depict on radial lines the mean air velocities at the front positions for measurements nearest the air outlets for the LC and HC sprayers, respectively. Both figures show considerable variation in mean velocity around the air outlet peripheries. The LC sprayer produced a higher air velocity at 0°

TABLE 12.—Mean Air Velocity and Turbulent Intensity Values for the LC Airblast Sprayer.

Position (degrees)	Velocity (f.p.s.) F	C	R*	Percent Turbulent Intensity F	C	R*
			30-INCH RADIUS			
—24	58	40	35	12	15	17
—16	74	72	42	7	5	16
—8	68			7		
0	90	35	11	21	29	26
8	70	22	6	12	27	25
16	60	14	5	14	32	33
24	20	24	7	12	24	36
32	21	15	8	22	31	35
40	64	32	12	14	28	39
48	65	46	15	15	26	38
56	76	44	15	12	24	35
64	60	28	14	13	28	30
72	74	40	28	10	21	25
80	72	52	25	12	17	33
			60-INCH RADIUS			
—16	7	17	30	28	27	21
—8	15	62	78	30	14	10
0	31	68	21	21	13	24
8	33	60	12	20	14	11
16	35	34	7	19	22	31
24	45	38	10	17	22	30
32	41	25	8	17	26	31
40	45	36	10	16	22	33
48	37	50	22	18	17	31
56	32	56	21	21	15	30
64	26	63	30	22	11	25
72	13	50	50	32	18	19
80	6	12	17	33	33	25

*F, C, and R correspond to front, center, and rear probe positions as follows. On 30-in. radius, F, C, and R = 2-3/32, 4-3/16, and 6-9/32 in., respectively, behind the front edge of air outlet. On 60-in. radius, F and C = 13 and 5 in., respectively, in front of the front edge of outlet and R = 3 in. behind the front edge of outlet.

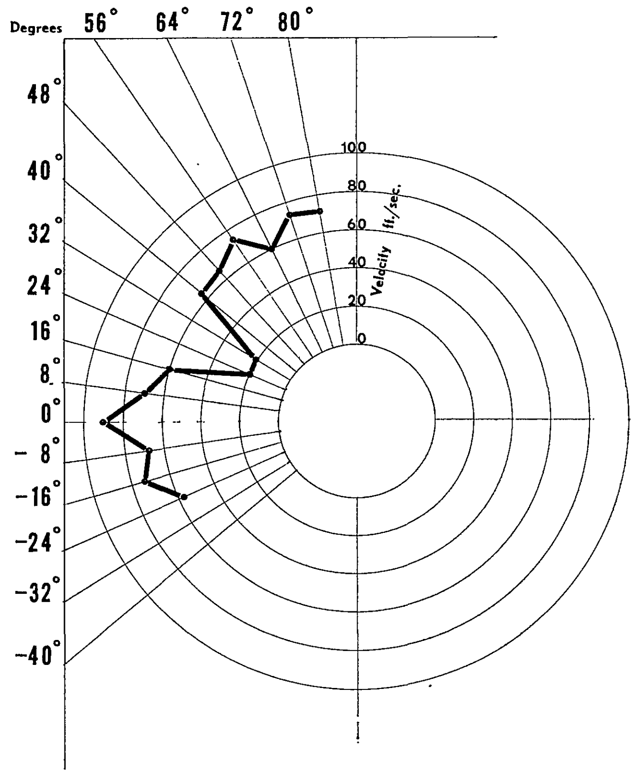

FIG. 5.—Mean air velocity profile on 30-in. radius from center of blower axis and 2-3/32 in. behind front edge of the LC airblast sprayer air outlet.

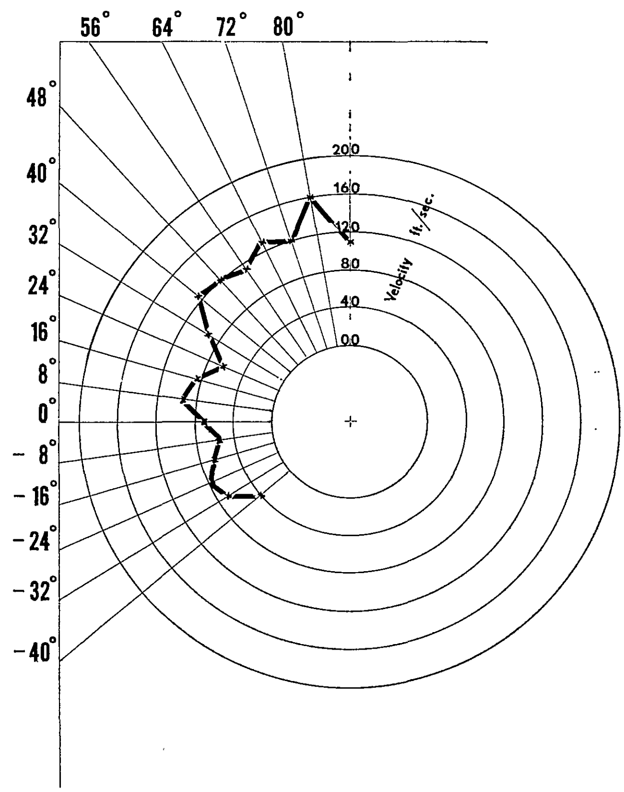

FIG. 6.—Mean air velocity profile on 25-in. radius from center of blower axis and 1-17/32 in. behind front edge of the HC airblast sprayer air outlet.

than at any other angular position. Since spray droplets must travel farther to reach the upper parts of the tree, the highest air velocity would be more useful at a higher angular position. The HC sprayer delivered higher air velocities at the upper angular positions than at lower angular positions because it was equipped with a housing to convey air from the right side to the upper left outlet. Probably some of the variation in mean velocity was caused by structural members. These structural members could be modified to provide more optimum flow patterns, but the additional cost may not be justified.

Figure 7 shows a rapid decrease in mean air velocity produced by the HC sprayer as the distance from the outlet increased. At 21 ft. outside the outlet, the velocity decreased to about 16% of that at 2 in. from the outlet. Cunningham *et al.* (7) also showed similar results. All velocity measurements during this experiment were made with the sprayers stationary.

Both Fisher (8) and Randall (15) showed a large decrease in mean air velocity as the forward speed of the sprayer increased. For example, Randall used a sprayer which delivered 271 c.f.m. with 133 f.p.s. velocity at the outlet. At a horizontal distance of 16 ft. from the center of the sprayer and 11.75 ft. above the ground, he measured air velocities of 16.5 and 8.25 f.p.s. at ground speeds of 2 and 4 m.p.h., respectively. Sufficient air velocity is extremely important because it is needed to convey and effect impingement of the droplets.

Although air velocity is frequently mentioned in this paper, the volume of transported air is just as important and possibly more important. Gauthier (9) experimented with three air jets which had equal momentum but different air velocities and flow rates. He reported that the air jet with the highest air flow rate and lowest velocity delivered the greatest spray volume at 36 ft. from the outlet.

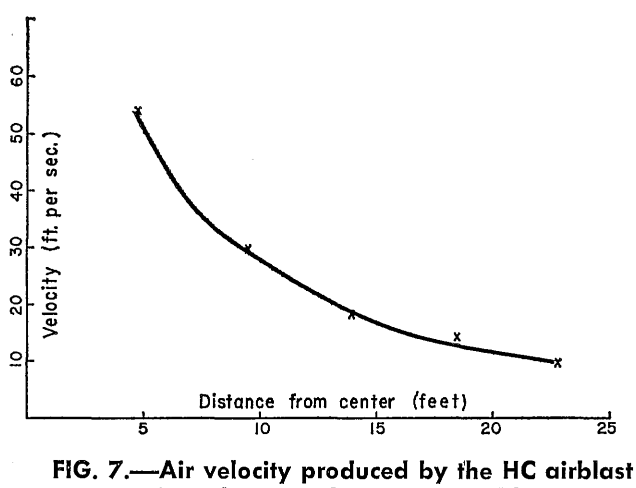

FIG. 7.—Air velocity produced by the HC airblast sprayer at various distances from center of blower axis and on a 48° radial line.

Droplet Dispersion

These tests were made on 3 days on which wind conditions were quite different (Fig. 8); therefore, the results for each were considered separately. Because the relative humidity was above 85% each day, droplet evaporation was considered to be minimal. For the nozzles measured, the mean volumetric diameter of the droplets was about 350 microns (μ). Therefore, to compare the amount of material which reached each target, the numbers of droplets deposited were transformed to the volumetric equivalent of 350 μ droplets. The number and size of droplets were measured in two sample areas on each target, each of which was one-half in. square.

These tests were made to find the *order of magnitude* values. Figure 8 shows that significantly fewer droplets reached the higher targets when the wind was stronger (see points marked B). At the 22 ft. level, the amount of spray material reaching the targets averaged about the same for all 3 days. However, at 24 ft., only 20% as much spray material reached the targets on day B. At 26 ft. and 28 ft. on day B, tar-

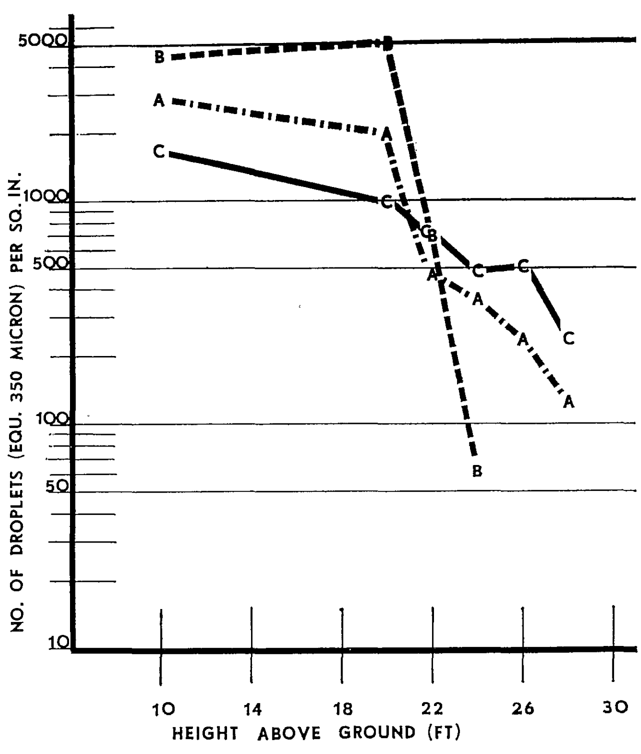

FIG. 8.—The amount of spray material reaching various heights is shown for three different days. A is the average of two tests made Feb. 2, B is the average of three tests made Feb. 6, and C is the average of five tests made Feb. 7, 1970. Wind conditions were: A, very light wind; B, 2-7 m.p.h. wind; C, very calm (light fog).

gets received less than 5% as much material as they did on the two calmer days. The larger droplets were concentrated on the lower targets. Hence the number of equivalent 350 μ droplets was much larger on the lower targets, even though some of the higher targets had nearly the same number of droplets by count. These findings agree with the results of Gauthier (9), who found that low velocity airstreams carry small droplets farther than they do large droplets. Brann (2) and Cunningham *et al.* (7) have stated that low-velocity small droplets do not impinge on leaves as readily as larger droplets. Thus, because the droplet velocities were lower near the higher targets, probably a smaller proportion of the droplets reaching this area was deposited on the targets. A large variation occurred in the number of droplets reaching the higher targets (20-28 ft.) on passes made only a few minutes apart on a very calm day. Even under calm conditions, large scale air motion influenced the droplet dispersion pattern of the sprayer.

Fisher (8) has illustrated how the wind velocity can alter the spray distribution pattern. This effect is probably caused by the stronger wind at the higher levels carrying away the droplets which normally reach those heights.

These results indicate that during calm atmospheric conditions, the sprayer usually transported sufficient droplets to give good coverage up to 28 ft. high. As the wind velocity increases, the level of coverage is likely to become lower. To illustrate the reason for this result, consider Figure 7 (ignoring the effect of a moving sprayer). Figure 7 shows that the sprayer jet velocity is less than 15 f.p.s. beyond about 17 ft. from the sprayer outlet. Hence, a wind velocity of 15 f.p.s. (10 m.p.h.) will dominate droplet transport beyond 17 ft. The airblast from the sprayer has the primary influence on droplet transport only in the region of the sprayer outlet, where the mean jet velocity is greater than the mean wind velocity. It is known that near the ground wind velocity increases rapidly as vertical distance increases. Thus, atmospheric motion may dominate transport of the droplets at relatively short vertical distances from the sprayer outlet, even when the atmosphere seems calm.

Although mean jet and atmospheric motion largely determine the movement of the main body of droplets, the turbulent motion in the sprayer jet, turbulent atmospheric motion, and their interaction are important factors in dispersing the droplets about the mean droplet path.

SUMMARY AND CONCLUSIONS

- The hatch of overwintering eggs of European red mite was effectively reduced with 1X, 4X, 10X, and 33X concentrations of oil. The percentage of hatch was always very low from the hand gun (1X) applications, but it was variable after applications with the airblast sprayers.

- Acaricide concentrations of 1X, 4X, 10X, and 33X all provided satisfactory control of motile mites. Except for some hot spots on poorly pruned trees, the HC airblast sprayer performed as effectively as the LC airblast sprayer in providing control of European red mite.

- Insecticide concentrations of 1X by hand gun, 4X and 10X by an airblast sprayer, and 33X by the high concentrate airblast sprayer all provided satisfactory control of plum curculio, codling moth, and redbanded leafroller.

- Neither the hand gun nor the airblast sprayers provided as good apple scab control in the tops as in the bottoms of the trees. Even distribution of a pesticide within the tree canopy is essential for efficient pest control. Obtaining adequate coverage in the upper sections of large trees without overspraying lower sections may be difficult, especially when high concentrate (low volume) sprays are applied under adverse weather conditions (*e.g.,* high winds).

- None of the concentrations produced any serious phytotoxicity on the leaves or fruit. However, as the volume of spray application is reduced, the chances for significant application or measurement error increase markedly. Consequently, frequent monitoring of sprayer calibration during the spray season is essential with concentrate airblast sprayers.

- Only the 66X concentration from the HC sprayer caused any major application difficulties during spraying. The nozzles plugged more frequently and some of the wettable powder slurries swelled in the tank. There is an indication that high concentrations of present formulations may not be entirely satisfactory; *i.e.,* combinations of pesticides may be easier to mix in slurries if the percentage of toxicant in the pesticide formulation is higher than that used in these tests. Additional information should be gathered on the compatibilities of pesticide mixtures for use with low volume orchard sprayers.

- After the turnover housing was added in 1967, the HC airblast sprayer provided similar pest control to that with the other airblast sprayer. Other adjustments, such as nozzle arrangement, size, and sprayer speed, should be made to coincide with the structure of the spraying target, *i.e.,* the size and density of the trees.

- Measurements of air velocities produced by both airblast sprayers indicated considerable variation around the air outlets. Much of this was probably caused by structural members within the air outlets. At almost all angular positions, both airblast sprayers delivered the highest air velocity at one-quarter the outlet distance behind the front edge of the outlet. To make most efficient use of this high air velocity, it would seem the spray nozzles should be placed farther forward on both types of airblast sprayers.

- Atmospheric motion has a major influence on the transport and dispersion of droplets from an airblast sprayer. The velocity of air delivered by the airblast sprayers decreased very rapidly after leaving the outlets. At 21 ft. from the air outlet, the HC airblast sprayer produced an air velocity only 16% of the velocity it had 2 in. from the outlet. Also, even low velocity wind greatly influenced deposition of droplets. For example, only 5% as much spray material was deposited above 25 ft. during a 5 m.p.h. wind as was deposited during calm conditions. More research on the interaction between the air jet and the atmosphere is needed. This is essential to improve sprayer design and selection of optimum times for spraying.

- The airblast sprayer used to apply the 4X and 10X concentrations deposited a greater proportion of small droplets on the higher spray targets than it did on the lower targets. This uneven distribution could be caused by both evaporation of droplets during transport and droplet fallout due to the low air jet velocity. Further studies on pesticide drift, residue distribution, and its effect on pests are needed to measure the impact of this problem in the orchard environment.

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APPENDIX

APPENDIX TABLE I.—Schedule of Concentrations and Equipment, 1966-1969.

Year	Concentration	Application Equipment
1966	1X*	Myers Hydraulic Handgun
	33X*	Econ-O-Mist
	50X†	Econ-O-Mist
	66X	Econ-O-Mist
1967	1X	Myers Hydraulic Handgun
	33X	Econ-O-Mist
	66X	Econ-O-Mist
1968	4X	Myers A-42
	10X	Myers A-42
	33X	Econ-O-Mist
1969	1X	Myers Hydraulic Handgun
	10X	Myers A-42
	33X	Econ-O-Mist

*1X and 33X concentrations used in both Rittman and Wooster orchards.

†50X concentration used only for oil application in 1966.

APPENDIX TABLE II.—Pesticides, Rates, and Times of Application at the Wooster Orchard.

		Time* of Application and Amount (Lb.) of Formulation per 100 Gallons Dilute†																		
Pesticide‡	HIG	Late HIG	Early TC	Late TC	PP	P	Full P	B	B	Late B	PF	1C	2C	3C	4C	Spec.	5C	6C	7C	Spec.
1966	4-22		4-25	4-29	5-4	5-3		5-20			5-27	6-7	6-22	7-7	7-21		8-3	8-24		
Dodine 65 WP**			3/8	3/8	3/8	3/8		3/8			3/8	3/8	1/4	1/4	1/4		1/4			
Captan 50 WP**			2	2	2	2		2			2	2	1	1	1		1			
Superior oil (70-sec. vis.)	2 g.																			
Lead arsenate WP											3	3								
Carbaryl 50 WP††													1½	1½	1½					
Azinphosmethyl 25 WP††																	1			
Dicofol 18.5 WP																		2		
1967	4-10		4-14			4-20	4-26	5-3	5-10	5-17	‡‡	5-31	6-13	6-27	7-12	7-20	7-26	8-9	8-23	
Dodine 65 WP	1/2		3/8			3/8	3/8	3/8	3/8	3/8										
Captan 50 WP***											2	1	1	1	1		1	1	1	
Parathion 15 WP			1																	
Oxythioquinox 25 WP						1/2														
Lead arsenate WP***											3									
Carbaryl 50 WP***												1½	1½							
DDT 50 WP														2	2					
Dicofol 35 WP															1	1				
Azinphosmethyl 50 WP																	1/2	1/2	1/2	
1968	4-10	4-12	4-16		4-19		4-25		5-2	5-10	5-15	5-24	6-5	6-12	7-1		7-15	7-29	8-13	8-20
Dodine 60 WP		3/8	1/2		3/8		3/8		3/8	3/8		1/2								
Captan 50 WP											2		1	1	1		1	1	1	1
Sulfur 95 WP																	2	2	2	
Superior oil (70-sec. vis.)	2 g.																			
Lead arsenate WP											3	3								
DDT 50 WP													2	2						
Carbaryl 50 WP															1½		1½			
Azinphosmethyl 50 WP																		1/2	1/2	
Tetradifon 50 WP																			1/2	1/2
1969	4-14	4-16	4-21	4-28		5-5			5-12		5-20	5-29	6-12	6-26	7-10		7-24	8-7	8-21	
Dodine 65 WP		3/8	3/8	3/8		3/8														
Captan 50 WP											2	2	1	1	1		1	1	1	
Sulfur 95 WP													4		2		2	2	2	
Superior oil (70-sec. vis.)	2 g.																			
Lead arsenate WP											3	3								
Carbaryl 50 WP													1½	1½						
DDT 50 WP															2		2			
Azinphosmethyl 50 WP																		1/2	1/2	

*HIG = half-inch green, TC = tight cluster, PP = pre-pink, P = pink, B = bloom, PF = petal fall, 1C = 1st cover, 2C = 2nd cover, etc., Spec. = special spray.
†All materials applied on the same date were tank-mixed.
‡Formulations presented as percent WP; oil is 70-second viscosity.
**Dodine applied at 33X to plot 1 only; captan applied to plots 2, 3, 4 in 1966.
††In plot 4 (1X) at 4C, carbaryl applied at 1½ lb. instead of azinphosmethyl in 1966.
‡‡PF spray to 1X plot applied on 5-22; 33X and 66X sprays applied on 5-23 in 1967.
***By mistake, carbaryl at 1½ lb. and captan at 1 lb. applied at 1C to 1X plot instead of lead arsenate and captan at 2 lb. in 1967.

APPENDIX TABLE III.—Pesticides, Rates, and Times of Application at the Rittman Orchard, 1966.

	Time* of Application and Amount (Lb.) of Formulation per 100 Gallons†												
Pesticide‡	Late HIG	TC	Late TC	PP	P	B	PF	1C	2C	3C	Spec.	4C	5C
	4-22	4-25	4-28	5-3	5-11	5-17	5-27	6-7	6-22	7-7	7-15	7-21	8-3
1X and 33X blocks (2 each)													
Dodine 65 W			**										
Benzene hexachloride WP			**										
Dimethoate 2.67 EC					3/4 pt.								
Lead arsenate WP							3	3					
Azinphosmethyl 25 WP									1	1		1	1
Dicofol 18.5 WP										2	2		
1X and 33X blocks (1 each)													
Captan 50 WP	2	2		2	2	2	2	2	1	1		1	1
1X and 33X blocks (1 each)													
Dodine 65 WP	3/8	3/8		3/8	3/8	3/8	3/8	3/8	1/4	1/4		1/4	1/4

*HIG = half-inch green, TC = tight cluster, PP = pre-pink, P = pink, B = bloom, PF = petal fall, 1C = 1st cover, 2C = 2nd cover, etc., Spec. = special spray.
†All materials applied on the same date were tank-mixed.
‡Formulations presented as percent WP or lb. AI per gallon EC.
**Grower applied pesticides.

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Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Green Springs Crops Research Unit, Green Springs, Sandusky County: 26 acres

Jackson Branch, Jackson, Jackson County: 344 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Agricultural Research Service, U. S. Dept. of Agriculture)

North Central Branch, Vickery, Erie County: 335 acres

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Western Branch, South Charleston, Clark County: 428 acres