A STUDY OF

Spray Machines

IN CONNECTICUT ORCHARDS

Philip Garman

THE CONNECTICUT AGRICULTURAL
EXPERIMENT STATION
NEW HAVEN

Bulletin 567, February, 1953

Contents

A STUDY OF SPRAY MACHINES IN CONNECTICUT ORCHARDS[1]

Philip Garman[2]

Spray trends in Connecticut orchards today consistently favor reduction of labor and increase in speed. With the per bushel return for fruit remaining fairly constant, the increasing cost of labor and materials has meant lower profit margins. Thus, anything that reduces labor costs is popular with the fruit grower. One-man spray operation is becoming common, partly because owners of small orchards can do the work themselves and thus become independent of labor except for the harvesting season.

Progress in the art of spraying has been constant since the beginning of the century. Starting with the hand pump and a nozzle or two on a pole, we have passed through the development of the gasoline pump with ever-increasing pressure, the hand gun, the multiple nozzle broom (hand operated or swivel mounted), the fixed boom, driver controlled, and finally the air blast machine with stationary or oscillating outlet, also operated from the driver's seat.

As we have progressed from low to high gallonage pumps, there has been a gradual increase in consumption of water, often taxing farm facilities. In some cases, construction of overhead tanks or small farm lakes or ponds has proved equal to the demand, but sometimes the demand is not easily met. For such conditions, the concentrate machine offers a solution to the problem because of its reduced water requirements. Much time has been spent studying mist blowers in order to determine their adequacy for the jobs to be done. Costs, spray cover, including pattern and deposit, as well as a number of other factors, are involved and have been studied.

COST OF SPRAYING[3]

Spray costs vary with the season and locality. The lowest figures have been obtained from Dr. C. T. Parsons of Vermont. His costs for labor, fuel and depreciation came to approximately $14.00 per acre in 1951 with a seven-spray program in a 70-acre 14- to 16-year-old orchard. Burrell (1951, p. 66) gives some figures for spraying New York orchards. Excluding materials, these costs averaged $39.88 per acre for the Hudson Valley. Cost of application in his own orchard in northeastern New York is much lower—around $20.00 per acre. Connecticut estimates based on a 10-spray program vary from $19.40 to $33.80 per acre (30 trees) with an average of $24.60. Programs using 11, 12 and 15 sprays averaged $27.06, $29.52 and $36.90, respectively. From these figures we can probably assume that the actual cost

1 During this study, cooperation on the part of manufacturers has been excellent; the John Bean Division of the Food Machinery and Chemical Corporation, the Hardie Manufacturing Company, and the Lawrence Aeromist Company have been especially helpful. The aid of growers, particularly S. L. Root of Farmington, N. C. Bean of Bristol, the Bishops of Cheshire, and W. D. Ravenscroft of Avalon Farms, Bantam, is also acknowledged. Valuable technical information was supplied by S. F. Potts of the U. S. Department of Agriculture. A. DeCaprio of The Connecticut Agricultural Experiment Station has been of great help in obtaining data for this publication, and R. A. Spencer, also of the Connecticut Station, has provided the necessary mechanical skill for changes in design and operation of some of the machines studied.

2 Entomologist, The Connecticut Agricultural Experiment Station.

3 This whole subject is discussed in detail by Oppenfeld, Boynton *et al.* in Bulletin 886 of the Cornell Agr. Exp. Station (1952).

of spraying in 1951 was somewhere between $20.00 and $35.00 per acre. Locality influences costs markedly, since the number of sprays applied per year is determined by elevation and the severity of disease and insect infestations. It would seem, therefore, that *any* spray or combination of spray materials that will reduce the *number* of applications would be very profitable, from the standpoint of cost of application alone. Table 1 gives data on cost of a single spray for one acre. Table 2 gives the performance of various spray machines.

TABLE 1. COST OF SPRAYING AN ACRE OF APPLES IN CONNECTICUT, 1951.[1]

Machine	Depreciation	Gas and labor	Totals per acre	Totals per 100 acres
Airblast 1	$1.87[2]	$ .53	$2.40	$240.00
Airblast 2	1.41	.53	1.94	194.00
Airblast 3	.93	1.32	2.25	225.00
Airblast 4	.93	1.16	2.09	209.00
Airblast 5	1.41	.97	2.38	238.00
Airblast 6	1.87	1.01	2.88	288.00
Hydraulic 1	1.41	.95	2.35	235.00
Hydraulic 2	1.33	2.03	3.38	338.00
Average	$1.40	$1.07	$2.46	$245.88

1 Figures are for a single application.
2 Assuming life of each machine to be 10 years.

TABLE 2. STUDY OF SPRAY MACHINES, 1950-1951, SHOWING ACRES SPRAYED PER 8-HOUR DAY, PER MAN AND PER MACHINE, AND ACRES SPRAYED PER FUEL DOLLAR.

Type of equipment	Concentration	Per fuel dollar	Per man	Per machine
Air Blast				
Blower attachment	1X	3.4	13.8	13.8
Fixed outlet, fixed vanes	4X	4.4	33.4	33.4
Fixed outlet, adjustable vanes	4,6X	4.6	24.5	24.5
Fixed outlet, adjustable vanes	4,6X	3.6	16.6	16.6
Flexible outlet	4,6X	5.7	8.5	17.0
Rotating outlet	4,6X	2.6	19.5	19.5
Movable outlet	6X	4.7	10.0	20.0
Oscillating outlet	1X	3.4	15.3	15.3
Fixed outlet	2X	4.4	14.4	28.8
Fixed outlet	1X	4.0	13.2	26.4
Fixed outlet	1X	2.5	18.4	18.4
Fixed outlet	1X	2.5	12.3	24.6
Fixed outlet	1X	3.2	16.1	16.1
	Averages	3.8	16.6	21.1
Hydraulic[1]				
Broom	1X	9.0	10.0	20.0
Broom	1X	11.0	3.6	11.0
Broom	1X	3.6	16.0	16.0
Gun and broom	1X	3.7	3.6	11.0
Gun	1X	3.6	8.7	8.7
Oscillating boom	1X	3.9	17.0	17.0
	Averages	5.8	9.8	13.9

1 All 35 to 50 gallon pumps.

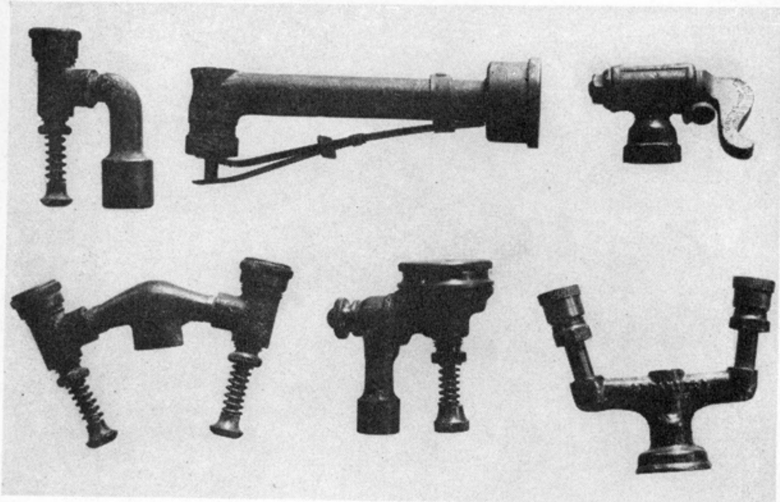


Figure 1—Types of nozzles in use in the early part of this century. Lower row, Vermorel nozzles; upper right, Bordeaux nozzle.

Studies in 1951 (Table 2) indicated that the main difference between hydraulic and blower types of machines lies in the acres covered per man and per machine in an eight-hour day. The more efficiently operated hydraulic sprayers, however, approach or equal the efficiency of the air blast concentrate outfits. This appears to be due chiefly to more convenient and rapid filling operations, or reduction of the size of the spray crew, made possible by more convenient spray controls or utilization of spray booms of various sorts. Gasoline costs so far have been consistently higher for the air blast type of machine (Table 2) than for the conventional hydraulic sprayer.

THE HYDRAULIC OR HIGH PRESSURE SPRAYER

Between 1930 and 1950 nearly all sprayers in Connecticut orchards operated at a pressure of 400-600 p.s.i.[1] and a gallonage of 25-50 gallons per minute. As already mentioned, various types of guns and brooms (multiple nozzle guns) came into use, mostly hand operated. During the war years of the 1940's growers began to look for some labor relief, and the multiple nozzle boom or mast equipped with a number of small guns or nozzles began to be substituted for the man at the rear of the spray outfit. Quick acting shut-offs helped to make these booms practical. Two types were developed, the fixed boom and the oscillating one, attached to the agitator shaft of the sprayer. Steady improvement in boom equipment, together with the shut-off made convenient to the driver, has now brought the hydraulic high pressure sprayer to the status of a one-man operation. Figures 2 and 3 show some of the guns and nozzles in operation between 1925 and 1950. Figure 1 shows still earlier types. Since 1950 we have seen the rise of blower attachments for the less efficient hydraulics, discussed in more detail on p. 18.

[1] Pounds per square inch.

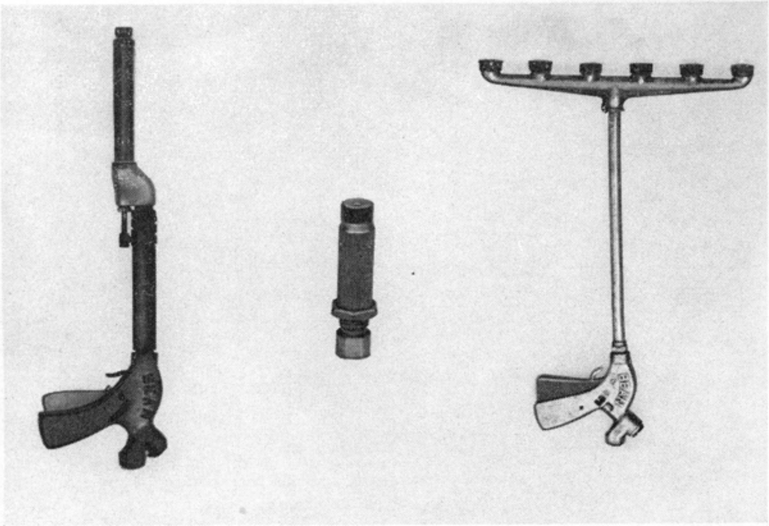


Figure 2—Guns and broom in common use since 1940. Left, gun with automatic shut-off; middle, adjustable gun for boom operation; right, multiple nozzle broom. Many similar kinds were in use between 1940 and 1950.

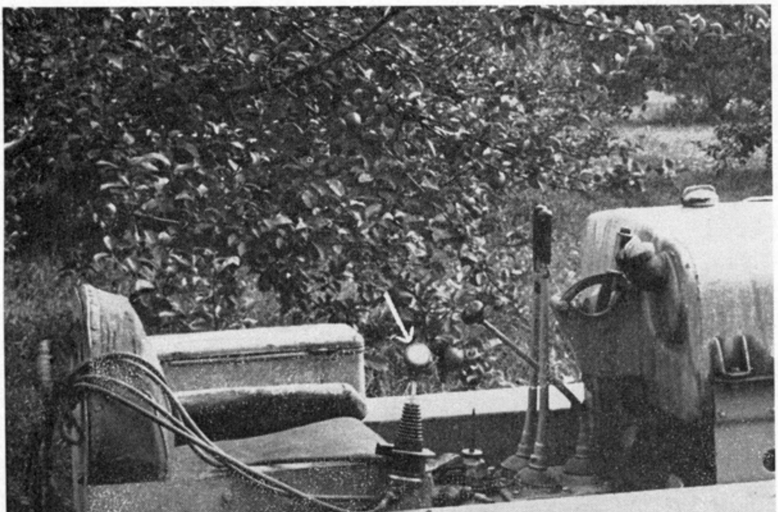


Figure 3—Modern control mechanism (arrow), convenient to the driver and requiring little effort to turn off or on.

However modified or equipped, the high pressure water-driven sprayer has some basic disadvantages when compared with the mist blower or air-driven sprayer. One of these is the greater consumption of water, which may be a scarce item on some farms. High volume pumps empty a spray tank in a few minutes so that one must operate a supply outfit or spend considerable time driving back and forth to the water supply. Large size tractor tires may enable the outfit to reach the water supply more quickly. This factor, together with improvements in machine design, may make it possible for a hydraulic rig to operate almost as efficiently as a mist blower, if there is a good water supply.

The main advantage of hydraulic sprayers lies in their ability to put spray where it is needed even in windy weather.

Recently, outfits equipped with light, centrifugal, high volume, high pressure pumps with special guns (Figure 16) have been developed. The performance of these machines appears to be good although, to date, only one has operated in Connecticut. They are reported to be capable of putting out 100 gallons or more per minute and permit operation through the orchard at speeds up to four miles per hour. The real problem here, as with other hydraulics, lies in water supply which, unless solved in one way or another, will reduce efficiency.

THE MIST BLOWER OR AIR BLAST MACHINE

Probably the first air blast machine to come into use in eastern orchards was the so-called Liqui-duster, introduced about 1925. Twenty years later came the speed sprayer, operating with a high speed fan and supplied with a low pressure centrifugal pump, designed to spray one or both sides of the rows, and with controls so situated that they were convenient to the tractor driver. It is easily understood why speed sprayers became popular. Several factors incorporated in the machines tend to reduce spray costs: (1) one-man operation, (2) high air volume, which drives the spray away from the operator, except when gusty conditions prevail, and (3) speed of operation, so that sizeable amounts of orchard can be covered quickly, particularly with a supply rig and two-side spraying.

When air was substituted for water as the vehicle for moving the spray, it became apparent that more concentrated materials might be used, thereby eliminating some of the expense of obtaining water and possibly saving spray materials as well. This principle had been advocated even before the speed sprayer's invention. Some of the earliest concentrate machines were converted dusters with a small pump and water tank. The "Liqui-duster" has been mentioned. Refer in this connection to French (1934, 1942), Young (1945), Potts and Friend (1945), Borden (1948), Brown (1948), Pratt, Massey and Parker (1949) and Brann (1951). Typical air blast machines are shown in Figures 14, 15 and 17.

Knowing the type of cover needed and the difficulty of placing spray throughout the tree when air was used as the transporting agency, it was at first feared that pest control with mist blowers could not be achieved. There were two reasons for this: (1) in some cases, the spray deposit was not continuous, leaving gaps for entry of disease spores, and (2) in other cases, too light a deposit was obtained and not enough was placed on the undersides of the leaves to control such pests as mites and leafhoppers. While these objections may have been justified at the time mist blowers first began to be used, they are no longer so in the light of experiment and practical experience. Failures to control have indeed been noted (Mitchell, 1950, and Burrell, 1951, p. 72), but the percentage appears to be no greater than with other types of machines.

Another objection, perhaps more serious, deals with the filtering out of sprays by dense trees so that the outer leaves receive adequate deposits, but deposits inside are inadequate. Under such conditions high volume, medium velocity air delivery is considered more satisfactory. Dense trees have little place in Connecticut orchards, however, since they tend to hold moisture within the canopy and controls are frequently unsatisfactory even with the best hydraulic equipment. Success depends in part, therefore, on good orchard practice and not solely on the use of any particular type of machine.

It should be mentioned that some air blast machines do not have enough air volume and velocity to give pest control in tall trees no matter how the trees are pruned. A few are extremely variable in air delivery from one portion of the air exit to another. Such machines should probably be used only on smaller trees, for example, peaches, or apples pruned down to suitable height. The graph shown in Figure 4 gives a general picture of our observations of machines operating in Connecticut.

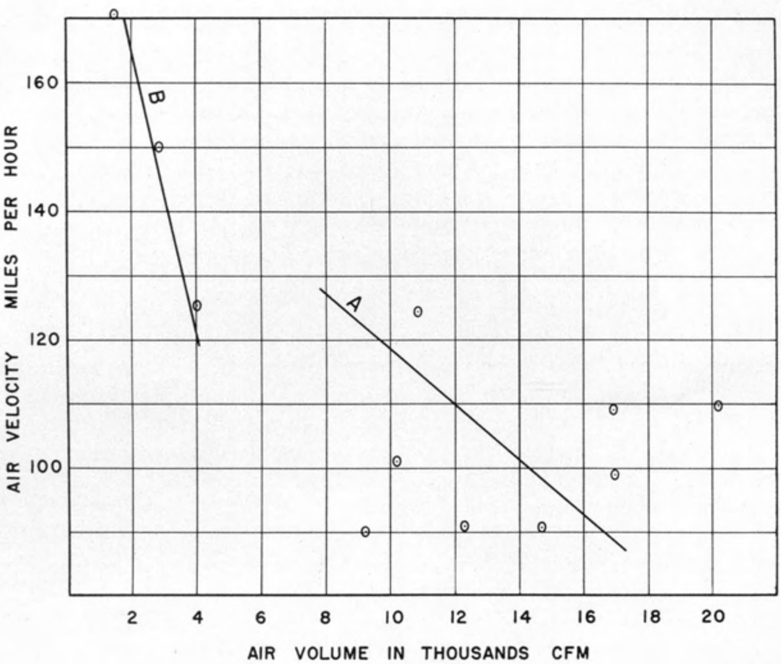


Figure 4—Air volume and velocity of different commercial mist blowers. The lines have been drawn to represent the average. Machines performing to the right of the average are satisfactory; those to the left of the average may be unsatisfactory. A. Fixed outlets. B. Circular outlets (except revolving type).

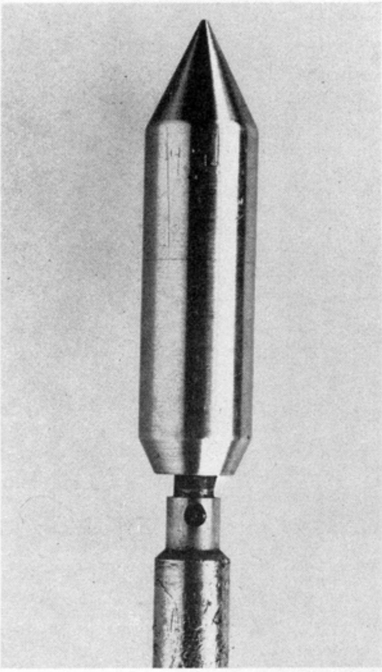


Figure 5—The Brann nozzle used in one make of mist blowers. Closes when pressure is off. Photograph shows orifice open.

Nozzles

In our early study of mist blowers it soon became apparent that available nozzles were not suitable for concentrated orchard pesticides. The main difficulty was clogging, partly because the water pressure was frequently too low to drive the spray through fine openings. As a result, provisions have been made to overcome clogging (1) by using nozzles better suited for mist blowers, (2) by invention of a suck-back mechanism which returns all the spray mixture to the spray tank whenever the lines are shut off, and (3) by increasing pump pressure.

At least three types of nozzles may be mentioned as being relatively clog-proof: The Brann nozzle (Figures 5 and 6), the Hurst "Aqua-jet" nozzle (Figure 7), and the larger size Whirljets (Figure 8). Other nozzles in common use, such as the T-jet (Figure 9) and the Monarch (Figure 8), are constructed to provide a minimum of clogging, there being no parts immediately behind the nozzle orifice to obstruct the flow of liquid. Almost any nozzle will give trouble, however, if the openings are smaller than 3/64 inch. Of the spray materials, sulfur pastes have caused us the most difficulty.

With the fixed air slot, experience indicates that it is best to provide the greatest amount of spray in the upper portion of the tree. Borden (1950) stresses the "butterfly" pattern of delivery. Where the slot is an arc, there

Figure 6—The Brann nozzle in operation.

should be more spray delivered at "ten and two o'clock", either by using nozzles with larger openings or by using more nozzles (Figure 13). For moveable hand-operated tubes, nozzles placed in the center of the discharge outlet have been generally satisfactory.

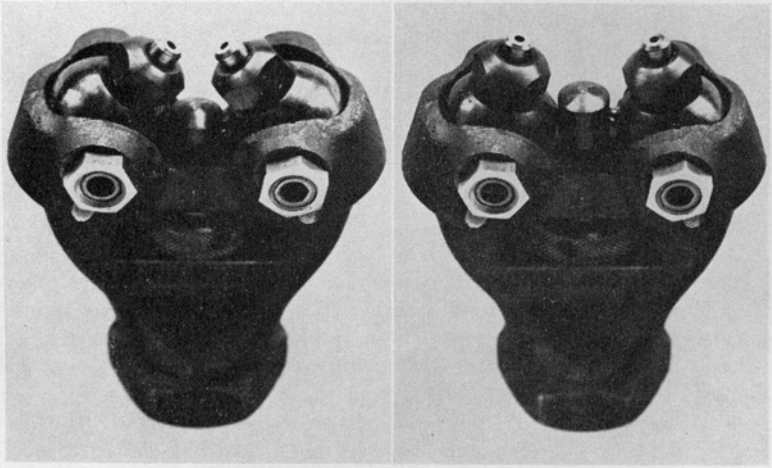


Figure 7—The Hurst "Aqua-jet" nozzle giving a break-up by collision of two jets of spray. Left and right, two different positions of spray outlet. Requires high pressure, 500 to 600 pounds.

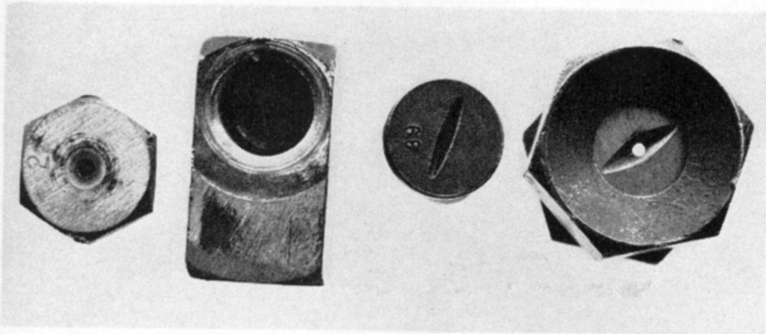


Figure 8—Whirljet and Monarch nozzles, discs removed. Left, Whirljet. Right, Monarch.

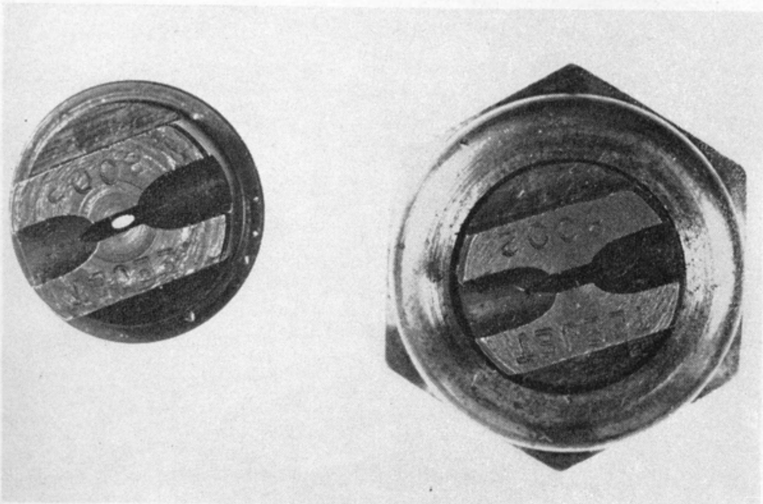


Figure 9—T-jet nozzle. Left, disc removed.

Pumps

Several types of small-volume pumps have been used in mist blowers. Among these are the plunger type, centrifugal (Figure 11), and low pressure gear pump.[1] Of these, the plunger types have been longest in use and are probably the sturdiest. More recently the diaphragm pump (Figure 12) has made its appearance; it seems to be relatively sturdy and provides higher pressures than the gear pumps. Brann (1951) states that it is abrasion resistant, which the gear pumps are not. Gear pumps are not much used today in orchard mist blowers. Pump capacities used vary considerably depending on the machine and the nozzle; they may range from 40 to 500 p.s.i., and 1 to 60 g.p.m.

1 "Rolloflex" pumps are being mentioned as of 1952 but have not yet come into general use.

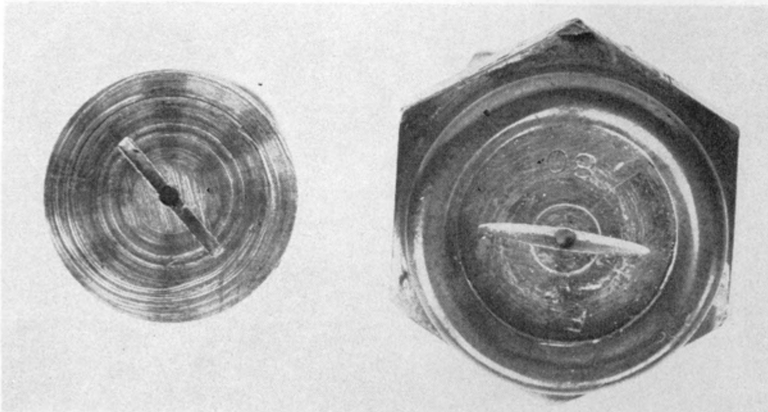


Figure 10—Bete nozzle. Left, underside of the disc.

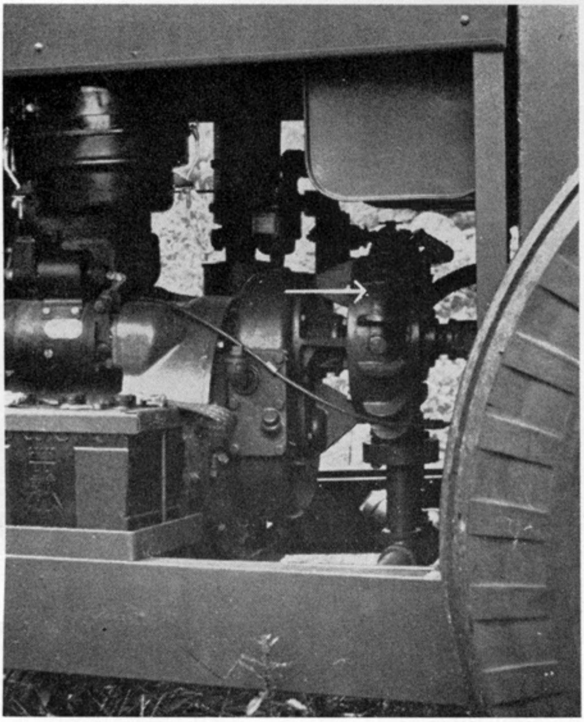


Figure 11—The centrifugal pump (arrow), geared direct to the engine.

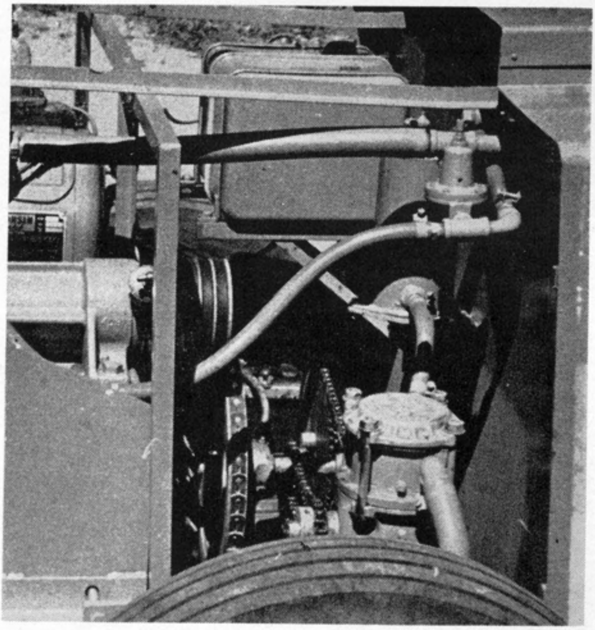


Figure 12—The diaphragm pump (lower right), provided with synthetic rubber diaphragm and operated from below and with two valves in the upper portion. This pump has stood up well in operation.

Air Volume and Velocity

What does it take to drive spray into tall or dense trees with air? On the answer to this question largely rests the success or failure of concentrate machines or air blast types in general. Obviously a large volume of air will move spray farther than a low volume. Likewise, high speed air will move spray farther than low speed. The balance between the two is the important feature—one not completely solved at the moment. Brann (1951) states that "to date there has been no way of calculating or predetermining the volume and velocity of air necessary to handle any given problem. It is only through experimentation . . . that the proper combination of volume and velocity can be determined." For circular outfits, Potts *et al.* (1950) consider that a 4-inch opening requires 1,300 c.f.m. and 170 m.p.h., while a 20-inch orifice would require 21,000 c.f.m. and 120 m.p.h. These figures would not apply to the fixed air slot. Incidentally it should be noted that air speed drops rapidly with distance from the nozzle.

TABLE 3. LOSS IN AIR SPEED AT DIFFERENT DISTANCES FROM THE NOZZLE

Machine	Air speed in m.p.h. at nozzle	Volume in c.f.m.	Speed in m.p.h. at different distances (feet) from the nozzle				
			5	10	15	20	25
Fixed slot	110	9500	....	17	15	14	10
Circular tube	160	1200	40	24	15	8	5

To arrive at some estimate regarding specifications for air volume and velocity necessary to obtain control in Connecticut, we have taken readings from successful and unsuccessful outfits. The findings are given in Table 4 and Figure 4. During this investigation it was noted that blowers with directional vanes or louvres seemed to out-perform those without means of directing the air from the air delivery slot. This, of course, does not apply to moveable circular outlets. Whether the curve as indicated on the chart will have to be altered in view of further improvements in design remains to be seen, but it does give some basis for judgments on the value of machines available today.

TABLE 4. MIST BLOWER PERFORMANCE

Machine	Air volume (one-side)	Air velocity (average)	Slot with vanes	Control conditions	Pest control
A	20,200	106	no	severe	satisfactory
B[1]	16,000	108	yes	severe	satisfactory
	12,000	90	yes	light	satisfactory
C	13,000	125	no	severe	satisfactory
D	11,400	104	no	severe	unsatisfactory
E	12,000	93	no	severe	fair
F	17,700	98	yes	severe	satisfactory
G	3,000	140	circular outlet	severe	satisfactory

1 Two machines of same make tested.

Deposit

The question is often asked—what kind of spray deposit is desirable? From general experience in this region the cover must be sufficient so that distances between the spots of spray will not be much more than 1 millimeter (1/25 inch) or certainly not greater than 1/16 inch. Some authors say "continuous", but spots 1 millimeter apart readily coalesce when rain or dew occurs. All foliage must, of course, be hit by the spray. In dry seasons, however, there is often a tendency to pile on too much pesticide. Since the mist applications usually do not remove any of the previous spray, excessive residues may result.

Borden (1952) gives the following figures for mist blowers operating on 1 to 10X concentration based on the gallonage required to do the work of high pressure outfits.

Concentration	*Gallons required (fraction of that used by conventional outfits)*
1X	4/5
2X	2/5
3X	3/10
4X	1/5
6X	1/8
8X	1/10
10X	1/12

In view of the non-removal of previous sprays, it is well to reduce the concentration gradually as the season advances in order to avoid excessive residues and at the same time save as much spray as possible. On the other hand, the grower changing from dilute to concentrate sprays will do well, at least in the beginning, to apply as nearly as possible the same amount of actual spray material (not diluted spray) as he is accustomed to apply with hydraulic or high pressure rigs, later reducing the amounts as he acquires experience.

The amounts applied per acre with a machine providing continuous spray delivery varies with the ground speed and the gallons per minute pumped through the nozzles. Table 5 provides information on the dosage in gallons per tree with two ground speeds and six rates in gallons per minute. Such figures are obtainable from manufacturers of spray equipment or from Bailey and Smith (1951).

TABLE 5. SPRAY DOSAGE IN GALLONS PER TREE WITH CONTINUOUS SPRAYING (From Bailey and Smith, 1951)

Ground speed	Gallons per min.	Distance between trees (feet)					
		50	45	40	30	20	10
1 mile per hour	50	28.0	25.2	22.4	16.8	11.2	5.6
	40	22.5	20.2	18.0	13.5	9.0	4.5
	30	19.0	17.1	15.2	11.7	7.6	3.8
	20	11.0	9.9	8.8	6.6	4.4	2.2
	10	5.6	5.0	4.4	3.4	2.2	1.12
	5	2.8	2.5	2.2	1.7	1.1	.56
2 miles per hour	50	14.0	12.6	11.2	8.4	5.6	2.8
	40	11.0	9.9	8.8	6.6	4.4	2.2
	30	9.5	8.5	7.6	5.7	3.8	1.9
	20	5.5	4.9	4.4	3.3	2.2	1.1
	10	2.8	2.5	2.24	1.68	1.12	.56
	5	1.4	1.3	1.12	.84	.56	.28

NOTE: At 100 gallons per minute one could drive 4 m.p.h. and still put on 28 gallons per tree if the trees were 50 feet apart, 16 gallons per tree if 30 feet apart—enough to protect a well pruned orchard.

Drop Sizes

The size of drop reaching the tree depends on the type of nozzle, size of orifice or opening, pump pressure, kind of spray mixture, and distance from the nozzle to the tree. Our tests show that drops above 100 microns in diameter settle first, and smaller sizes carry for a considerable distance (Table 6). The very small sizes, below 10 microns, may not settle on the leaves at all unless the air is very quiet. They may possibly impinge directly on the leaf or twig surface and not settle in the strict sense of the word. Then, too, very small drops may evaporate rapidly in dry air so that dry spray material hits the tree. This evaporation can be avoided by spraying at night. It is possible to prevent evaporation by addition of certain materials to the spray mixture, but the materials developed for this purpose are not compatible with common ingredients used in orchards.

Experiments in 1952 showed that drops below 15 microns in diameter were deposited on glass slides at air speeds as low as 15 m.p.h. The machine under test produced an air speed and volume that carried these small droplets 15 feet from the nozzle at a speed of 15 m.p.h. Since the large droplets settle first, the deposits became more and more uniform as the distance of collection from the nozzle was increased.

It would seem from this that should one desire to use small size drops, at least 15 m.p.h. air speed should be maintained at the target which, in the orchard, would be leaves and fruit. By reference to Table 3, it is evident that such speeds are not available beyond 15 feet in the case of the circular tube machine and 20 feet in the case of the blower with a fixed outlet. Calculation of the distance from the nozzles to the top of a 20-foot tree, assuming that the sprayer is operating at 15 feet from the trunk and 4 feet from the ground means that the fixed slot machine would have barely enough air speed to deposit small drops in the top, a distance of 22 feet. If, however, the tree is 30 feet high, the distance from machine to top would be 30 feet, which is too far from the machine for small drops to be deposited. In such a case it becomes desirable, in order to take advantage of small drop deposition, to increase either air velocity or air volume. This is essentially what has been done in some of the better outfits. It may explain, in part, the failure of certain air-blast equipment to give adequate protection in the tops of tall trees. All the above assumes quiet air conditions during operation.

There is some question as to whether a nozzle should produce a variety of drop sizes or whether a uniform size is best. With the higher concentrations (6 to 10X), more uniform sizes would probably be best, but this has not yet been definitely established. We have seen good control with both uniform and variable drop sizes (up to 6X).

Table 6 shows, as already noted, how the larger drops settle out first and the mass volume deposited at all distances beyond 20 feet from the nozzle is greatest at 50 to 100 microns. In this experiment none of the drops over 100 microns were deposited at 40 feet. Greater air speeds or volume or perhaps elevation of the nozzle would probably have driven the larger drops farther.

TABLE 6. MIST BLOWER: DROP SIZE AND VOLUME DETERMINATIONS

Size of drops	Distance from nozzle (feet)			
	20	40	60	80
	Percentages deposited of the different sizes			
15-30 microns	57.4	64.8	75.2	76.1
30-50 microns	20.6	24.3	20.3	20.1
50-100 microns	20.1	10.8	4.4	3.7
100 microns or above	1.8	0.0	0.0	0.0
	Estimated volume (cubic microns)			
15-30 microns	2,394	4,717	5,442	5,515
30-50 microns	7,056	8,064	6,720	6,720
50-100 microns	44,880	22,464	9,874	8,302
100 microns or above	10,500	0	0	0

NOTES: Mist blower discharge using 16 No. 3 potato nozzles, whirl plate design; pump pressure, 200 p.s.i.; air speed at the nozzle 100-110 m.p.h.; air volume, 6,500 c.f.m. (13,000 c.f.m. both sides).
Temperature, 52-54° F.; humidity, 68-70 per cent; tail wind, 7 m.p.h. Spray mix, 8/100 lead arsenate.

Air Discharge Outlets

Mist blowers offered for sale in Connecticut have been equipped with several kinds of air discharge outlets. Only two are currently operating in Connecticut orchards, the fixed slot and the hand-controlled tube. Each has its advantages and disadvantages. Advantages for the hand-operated discharge

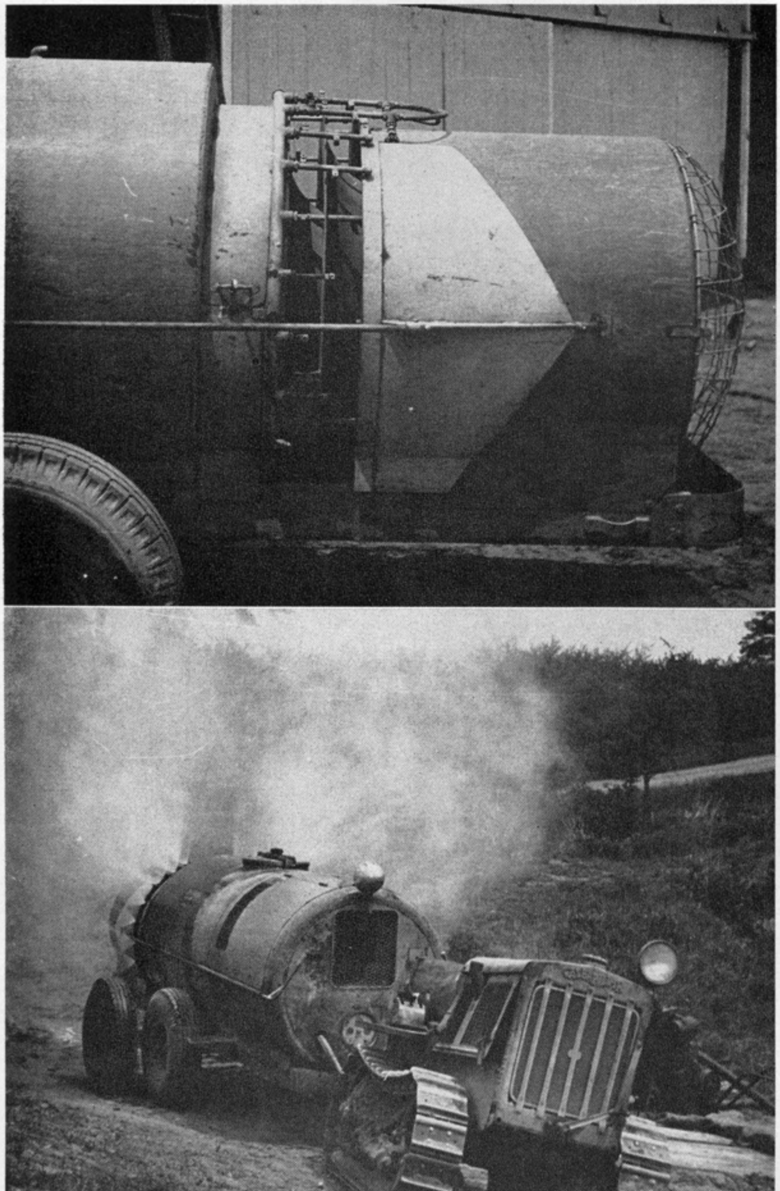


Figure 13—The Bean Speed Sprayer equipped with Whirljet nozzles for normal concentrations. The sprayer is shown in operation, using normal concentration, in lower picture. Note greater delivery in upper portions. The machine is easily converted to the use of concentrates.

lie in its ability to allow for wind currents and the low gasoline consumption in machines of this type offered to date. The fixed outlet means one-man operation and, generally, more uniform coverage than is commonly obtained with a hand-operated discharge. More territory may be covered per day, but this is partly dependent upon capacity of the spray tank and the ability to spray both sides of the row at once. Figures 13, 14 and 15 show some of the machines examined.

Attachment Blowers

The hang-on blower has been developed largely as a means of converting older, less efficient hydraulic sprayers to more efficient operation. It can be readily attached to the conventional hydraulic sprayer and is controlled from the driver's seat. While it reduces the necessary man-power, there are some drawbacks to the hang-on blower. The first attachments were too light, with no shock absorbers, so that they shook themselves to pieces in a few hours or days. The second disadvantage lies in the rather low air volume and air speed so that tall (25-30 feet) trees are not easily covered. Figure 21 shows the height reached by one of the machines tested. The top bar of the screen is 27 feet from the ground. For small apple trees or peaches, the attachment blower is nevertheless a distinct improvement over older methods.

Another feature to be considered is the extra engine required and the additional gasoline and servicing. In spite of these disadvantages, a few of these machines operated successfully in Connecticut during 1952. Figures 18, 19, 20 and 21 show some common types in operation.

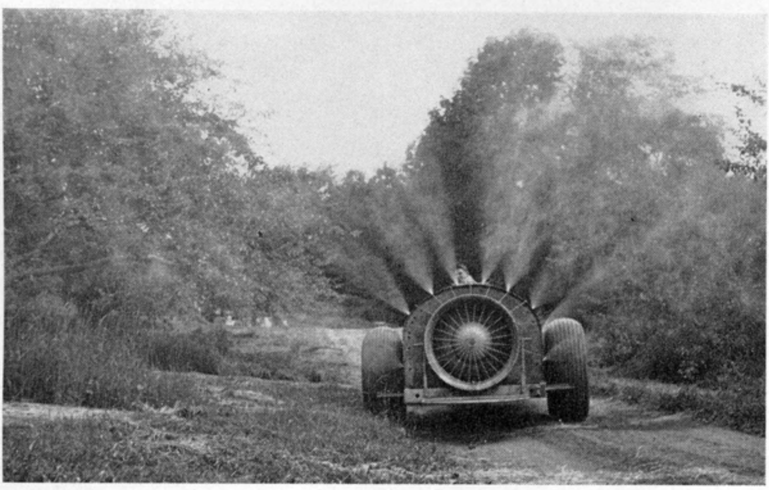


Figure 14—The Hardie King, designed for concentrates and operating from both sides. Note large size tires for ease in operation on soft ground.

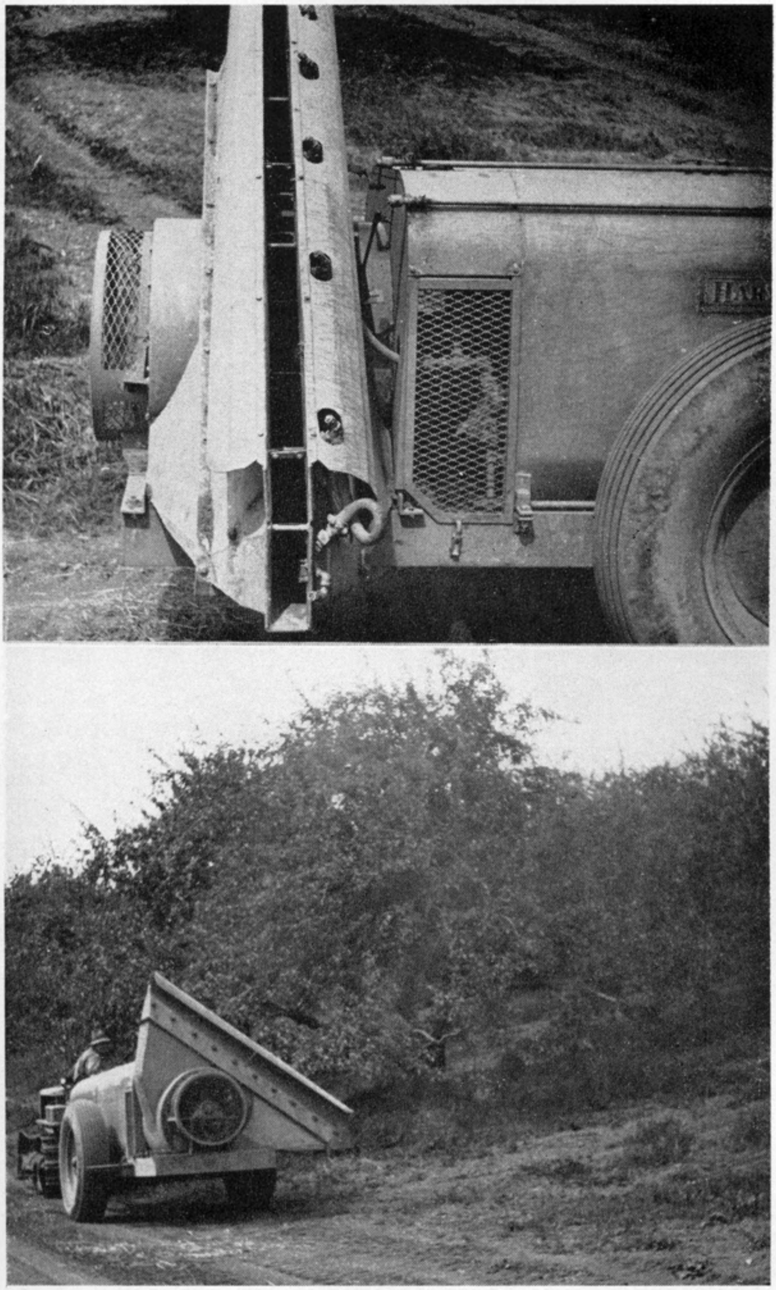
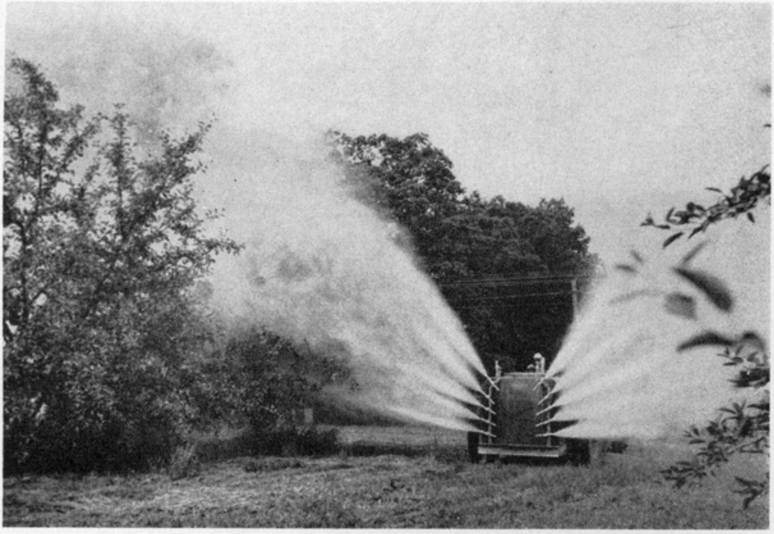


Figure 15—The Hardie "Orchard Mist" provided with T-jets and movable vanes in slot for directing the spray. This machine is designed for concentrates.



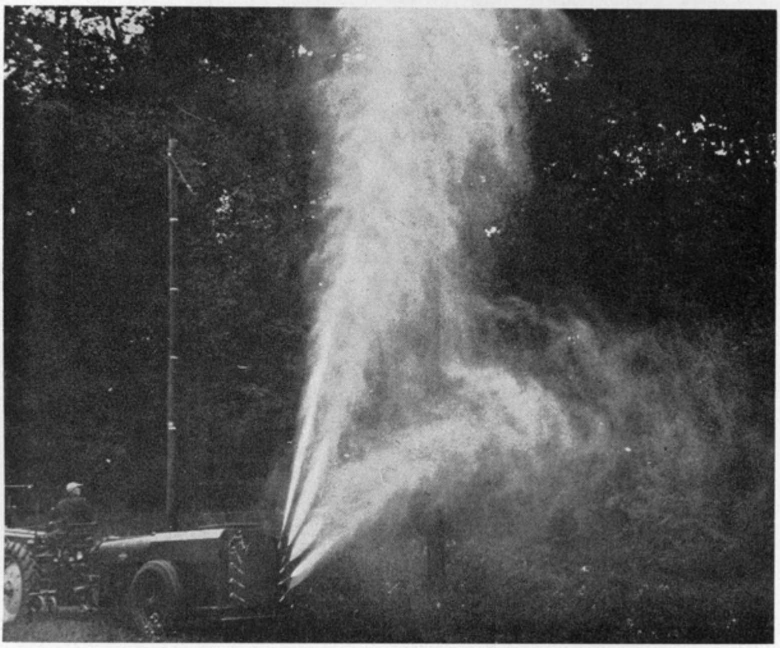


Figure 16—The Hale centrifugal sprayer. This machine is not designed for concentrates. It can be operated at relatively high ground speeds through the orchard. In the lower photograph, the sprayer is shown being tested against a screen for measuring height of spray. The spray reaches well over 30 feet.

Small Blowers

The wheelbarrow type developed by Potts and Spencer (1947) is designed for use on small trees in the home orchard. It is not suitable for more than a few trees, the time necessary to spray each tree and the low capacity spray tank making it impractical for larger plantings. Between this and the

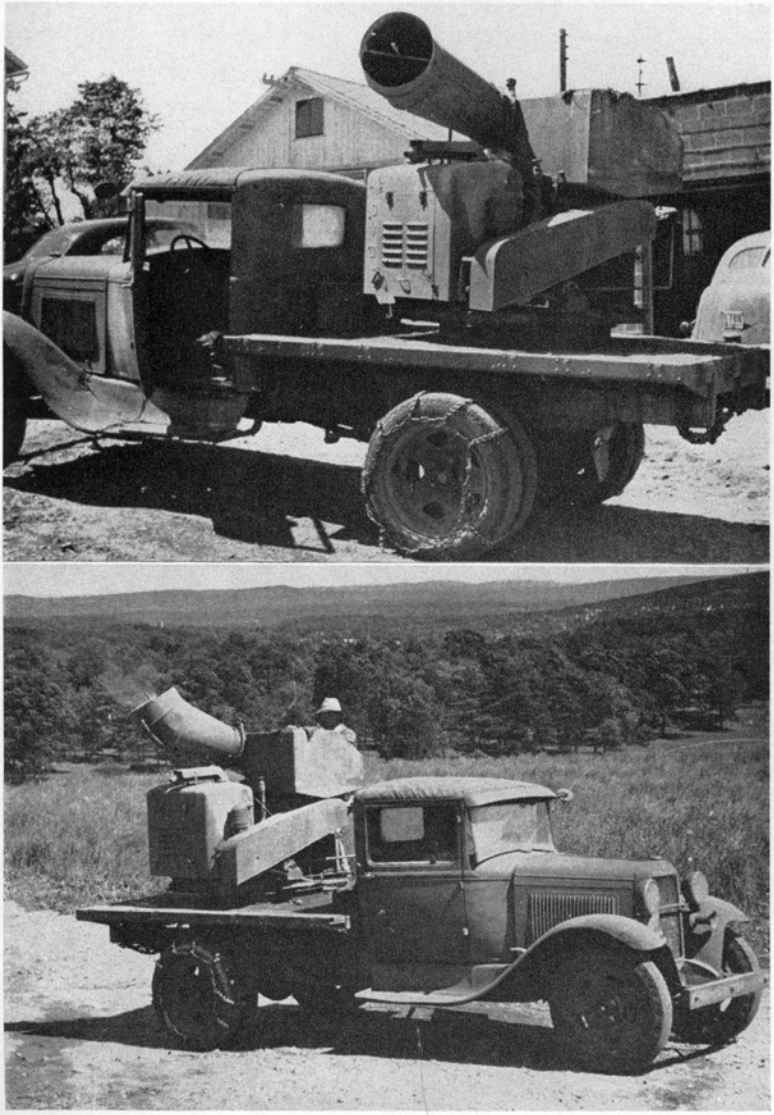


Figure 17—A converted shade tree mist blower used successfully in a Connecticut orchard.

hang-on orchard blower is still another size having a 30-gallon tank suitable for transportation in a pick-up truck. This type, too, is inadequate for large areas of large trees although it is suitable for larger numbers than can be handled with the wheelbarrow mist blower. It is designed for low-growing crops, such as grapes, blueberries, raspberries, or peaches.

Day Versus Night Spraying

The advantages of night over daytime operation of mist blowers are obvious, at least to growers who have used the method, and in 1952 there was a trend in Connecticut towards night spraying. Whether improvement in performance of mist blowers will reverse this trend remains to be seen. Advantages of night over daytime operation are: (1) Ability to see where the spray is going; it is difficult to observe concentrates in daylight. (2) Air currents are frequently down at night instead of up as they are during the day, so that small drops settle readily. (3) Evaporation rates are less, giving small drops a chance to settle without further concentration. (4) Temperatures are cool and wind currents are usually less, adding to the comfort and safety of the operator, except when very poisonous materials, which may hang in the orchard, are used.

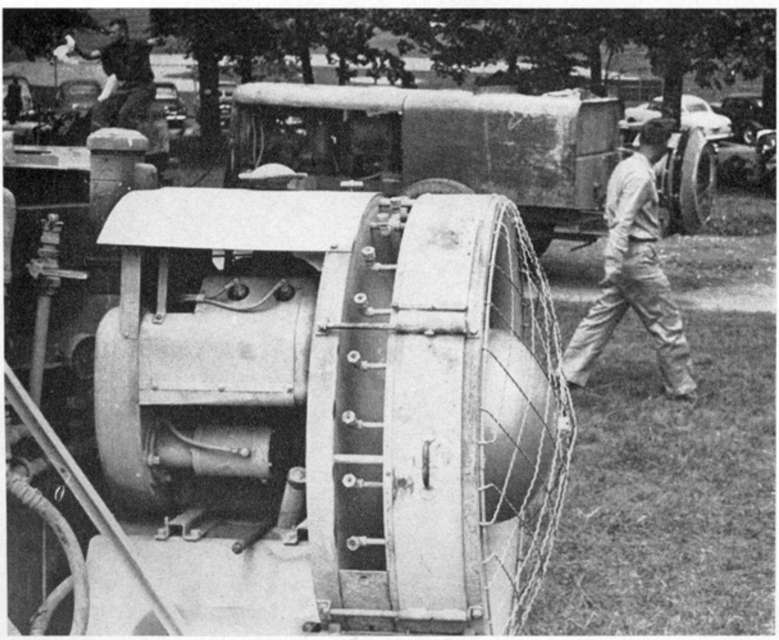


Figure 18—The Bean Orchardaire hang-on blower equipped with a sliding plate (with handle) to shut off one side and direct the spray in the tops.

Figure 19—The Hurst hang-on equipped with nozzles shown in Figure 7. This outfit is equipped with fixed directional vanes (not shown).

One drawback to night spraying is the difficulty of getting labor willing to work at that time. Caustic sprays, which damage the trees if kept in a moist condition too long, should probably not be applied at night.

On the whole, however, the advantages of night over daytime operation of mist blowers (or, in fact, hydraulic sprayers) are considerable, and whenever possible, it would appear advisable to apply sprays at night.

DETAILS OF OPERATION AS OBSERVED IN CONNECTICUT

Between 1950 and 1952 records of operation were made in a number of Connecticut orchards, including both hydraulic and mist blower machines. Not all observations were possible at the same time of year, hence they are not strictly comparable in such items as gallons per tree. Data furnished by Mr. Ravenscroft of Avalon Farms is of interest in showing the advantage in speed of cover when double, rather than single, concentrations are used. These records are for the same time of year and indicate a gain of about three acres per eight-hour day with the more concentrated mixture. Changes from hydraulic sprayers to mist blowers have in some instances resulted in a saving of several days in the time needed to cover, for example, a 60-acre orchard. This has meant the difference between success or failure in pest control in a number of cases.

Hardie Air King—Orkill Farm, Simsbury

Orchard	Orkill Farm, Simsbury.
Date	July 10, 1951.
Spray	Maggot; concentration, 4X.
Machine	Hardie Air King, 5 Monarch nozzles each side. 400 gallon tank.
Total gasoline per 8-hour day	33.6 gallons.
Labor	1 man, a little help at filling.
Time to turn around[1]	1 hr., 19 min., with one side operating; 51 minutes with both sides operating.
Time to spray one tank	1 hr., 8 min., with one side operating, or 5.8 gallons per minute.
Time to fill	5 minutes.
Trees sprayed with one load	144 or 2.7 gallons per tree.
Tanks per hour	Less than 1.
Tanks per 8-hour day	6.1
Rate of travel	2.2 miles per hour.
Gallons spray per acre	84
Acres per 8-hour day	33.4
Acres per man	33.4
Acres per fuel dollar	4.4

1 Time to complete one load and start another.

NOTES: Large wheel tractor and airplane tires on sprayer. Very rapid cover and travel from filling station to orchard. Good pest control.

Hardie Orchard Mist—S. L. Root, Farmington

Orchard	S. L. Root, Farmington.
Date	May 22, 1951.
Spray	First cover; concentration, 4X.
Machine	Hardie Orchard Mist type with six No. 3 T-jet nozzles. 300 gallon tank.
Total gasoline per 8-hour day	6.1 gallons in tractor; 18.3 in sprayer. Total 24.4.
Labor	1 man.
Time to turn around	Average, 1 hr., 18 min.
Time to spray 1 tank	Average, 48 minutes or 6.8 gallons per minute.
Time to fill	Average, 6¼ minutes.
Trees sprayed with one load	Large trees, 126. Small, 139. 2.4 gallons per large tree.
Tanks per hour	About 2/3.
Tanks per 8-hour day	6.1. 1830 gallons.
Rate of travel	Average, 2 miles per hour.
Gallons spray per acre	Large trees, 74.
Acres per 8-hour day	24.5
Acres per man	24.5
Acres per fuel dollar	4.6

NOTES: This machine should operate efficiently below 6X with this combination of equipment and spray nozzles. Acreage covered is probably high for daily performance.

Friend 'Speed Sprayer'—Auer Farm, Bloomfield

Orchard	Auer Farm, Bloomfield.
Date	July 11, 1951.
Spray	Maggot-mite; normal concentration.
Machine	Friend "Speed" Sprayer, 31 nozzles. One side operation. 500 gallon tank. Air velocity mostly above 125 m.p.h. 13,140 c.f.m. one side.
Total gasoline per 8-hour day	17 gallons in sprayer; 11.4 in diesel. Total 28.4.
Labor	1 man.
Time to turn around	Average 35 minutes.
Time to spray 1 tank	25 min. or 20 gallons per minute.
Time to fill	Approximately 3 minutes.
Trees sprayed with one load	Average 37; medium to large.
Tanks per hour	1.7
Tanks per 8-hour day	13.6
Rate of travel	2.6 miles per hour, probably somewhat less.
Gallons spray per acre	420 (14 gallons per tree).
Acres per 8-hour day	16.1
Acres per man	16.1
Acres per fuel dollar	3.2

NOTES: Good job of spraying, tops and bottom. Excellent control. This machine could operate at a much higher concentration.

Bean Speed Sprayer—Rogers Orchards, Southington

Orchard	Rogers Orchards, Southington.
Date	July 15, 1950.
Spray	First maggot; normal concentration.
Machine	Bean Speed Sprayer operated from both sides, 42 speed sprayer nozzles, 500 gallon tank.
Total gasoline per 8-hour day	Total, sprayer, truck, supply pump, 45 gallons.
Labor	2 men (1 supply).
Time to turn around	27 minutes.
Time to spray 1 tank	8 min., 55 secs.
Time to fill	16 minutes (includes wait for supply).
Trees sprayed with one load	42 large trees. 11.9 gallons per tree.
Tanks per hour	2.2
Tanks per 8-hour day	17.6
Rate of travel	2½ to 3 miles per hour.
Gallons spray per acre	357 (30 large trees per acre).
Acres per 8-hour day	24.6
Acres per man	12.3
Acres per fuel dollar	2.5

NOTES: Both side operation does not cover tall trees adequately. Speed of cover could be increased by cutting the number of nozzles in half and using 2X instead of normal concentration.

Bean Hydraulic—Bishop Farm, Cheshire

Orchard	Bishop Farm, Cheshire.
Date	May 15, June 7, 1951.
Spray	Calyx, 3rd cover; concentration, 1X.
Machine	Bean Hydraulic 35 g.p.m. pump, with Hardie blower attachment, six Monarch nozzles, each side. 400 gallon tank.
Total gasoline per 8-hour day	33.5 gallons.
Labor	1 man.
Time to turn around	45 minutes.
Time to spray 1 tank	Average, 38½ minutes or 10.4 gallons per minute.
Time to fill	Average, 8-2/3 minutes.
Trees sprayed with one load	Average 74 or 5.4 gallons per tree.
Tanks per hour	1.3
Tanks per 8-hour day	10.4
Rate of travel	2 miles per hour.
Gallons spray per acre	162-180
Acres per 8-hour day	13.8
Acres per man	13.8
Acres per fuel dollar	3.4

NOTES: This machine with these nozzles should not be operated at more than 2X concentration. Cover not good in tops.

Mist-O-Mite—N. C. Bean, Bristol

Orchard	N. C. Bean, Bristol.
Date	June 16, 1951.
Spray	Third cover; concentration, 4X.
Machine	Mist-O-Mite, one Brann nozzle. 200 gallon tank. 60 lbs. pressure.
Total gasoline per 8-hour day	4.1 gallons in tractor; 9.5 in sprayer. Total 13.6.
Labor	2 men.
Time to turn around	1 hr., 29 min.
Time to spray 1 tank	55 minutes or 3.6 gallons per minute.
Time to fill	9 minutes, 13 seconds.
Trees sprayed with one load	97 large trees. Approximately 2 gallons per tree.
Tanks per hour	.67
Tanks per 8-hour day	5.4
Rate of travel	Between 1½ and 2 miles per hour (rate slower on hills).
Gallons spray per acre	62 or slightly more than 2 gallons per tree (30 trees per acre).
Acres per 8-hour day	17
Acres per man	8.5
Acres per fuel dollar	5.7

NOTES: Compared with an average gallonage per tree of 15 for hydraulic sprayers, this machine could operate economically at 4X, possibly as much as 7X, but no higher.

Hardie Hydraulic—Barnes Orchard, Wallingford

Orchard	Barnes Nursery and Orchard, Wallingford.
Date	June 7, 1951.
Spray	Fourth cover; normal concentration.
Machine	Hardie Hydraulic, 8 nozzle broom on rear, shade tree gun (No. 202) on top. 400 gallon tank.
Total gasoline per 8-hour day	14 gallons.
Labor	3 men.
Time to turn around	Average 28 minutes.
Time to spray 1 tank	Average 13 minutes or 30 gallons per minute.
Time to fill	Average 7 minutes.
Trees sprayed with one load	20
Tanks per hour	2.1
Tanks per 8-hour day	16.8, probably somewhat less.
Rate of travel	About 1.5 miles per hour.
Gallons spray per acre	600
Acres per 8-hour day	11.3
Acres per man	3.7
Acres per fuel dollar	3.7

Data in the following tables show the degree of control achieved with several machines. Records for two years were taken for the Mist-O-Mite and one each for Hardie and Bean sprayers. The figures are intended to show what can be done with mist blowers in Connecticut and should not be construed as a recommendation for any particular type of machine.

Tables 7 and 8 give results of Mist-O-Mite control of pests on Baldwin and McIntosh apples. Scab was severe in 1952, but both tests indicate good control of insects. The interesting part of Table 7 deals with spray russet on Baldwin, which was distinctly higher in the lower portion of the trees. It indicates perhaps a too heavy deposit there, possibly from overspraying. The actual percentage russetted seems high, but is no higher than that on Baldwins (40%) in some of our experimental plots at Mt. Carmel during 1951 and 1952. The machine under consideration, on the other hand, produces a variable drop size with some very large drops which *may* have had some influence. The same condition was noted in the Rogers Orchard (Table 9) where a shear type concentrate nozzle producing a variable drop size was used. This nozzle has since been discarded, but, where it was used, the percentage of russetted apples was not much higher than percentages noted in Table 7. The only other concentrate machines on which russet records were kept were the Hardie Queen and Orchard Mist, operating at the Root Orchard in Farmington. In these tests the total russet (not shown in Table 11) on Baldwins varied from 17 to 35 per cent, averaging 24 and 29 per cent, respectively, for the two machines. Drop sizes produced by the Hardie outfits equipped with T-jet nozzles are more uniform than either the Brann nozzle or the shear nozzles of the Speed Sprayer. This would indicate, as suggested on page 16, the desirability of uniform size for high concentrations because of the lower russet rate, when drop size is smaller and more uniform. Since these experiments were conducted, a new fungicide (406) shows promise of giving us a much smoother Baldwin than has been produced heretofore. Its performance in concentrate sprays will be watched with interest.

Table 9 shows results in the Rogers Orchard with a Speed Sprayer equipped with shear nozzles.

Table 10 is the result of analyses from trees sprayed with the conventional Speed Sprayer, operating with banks of nozzles distributed in the air slot, and the same machine, operating from one side only, with concentrate nozzles and concentrations of 2 to 8X. It will be seen that very little spray reached the tops when both sides were open. Recent modifications by Burrell and others have attempted to correct this deficiency and it should be remarked that normal concentration, one side spraying in 1952 reached well over the top of the test screen shown in Figures 16 and 21.

TABLE 7. PEST CONTROL WITH LAWRENCE MIST-O-MITE ON BALDWIN[1] APPLES IN 1950
N. C. BEAN ORCHARD, BRISTOL

(Figures Are Percentages)

Tree	Good[2]	Curculio	Red-banded leaf roller	Codling moth	Aphis	Others	Scab	Russet[5]	
								Light	Heavy
1	88.0[3]	1.0	.5	.5	9.0	1.0	.5	20.5	7.0
2	87.6	1.8	....	.6	8.8	2.9	.6	18.8	12.4
3	92.8	.5	1.0	....	4.1	1.5	.5	15.9	12.8
4	93.7	1.3	....	....	3.2	1.9	.6	33.5	13.9
5	89.7	....	.7	....	7.6	2.7	.7	14.3	7.0
Average	90.3[4]	.8	.5	.2	6.7	2.0	.6	19.5	10.0

1 No record on McIntosh, but scab control appeared to be excellent.
2 Includes apples listed as russetted; means free of insect and disease blemishes.
3 Duplication of injuries may give a higher figure here than is obtained by subtracting total injuries from 100%.
4 Averages are taken from the total number of fruit, rather than by averaging the percentages in the column.
5 Russet worse in bottoms, outside.

			Total russet
Example:	Top	(1)	16
		(2)	5.5
	Bottom	(1)	43.1
		(2)	43.9

Spray Schedule—1950[1]
N. C. Bean Orchard

Spray	*Material*	*Concentration*
Delayed dormant	oil[2]	6X[3]
Bloom	sulfur-fermate	8X
(on McIntosh and Cortland)	sulfur	8X
Calyx	lead arsenate-sulfur	6X
1st. cover	lead arsenate-sulfur	5X
2nd. cover	lead arsenate-sulfur	4X
3rd. cover	sulfur-parathion	3X
	lead arsenate	2X

1 Dates of spray application not available.
2 One spray between delayed dormant and bloom—concentration unknown.
3 The designations 1X, 6X, etc., refer to concentration of the ingredients in the tank. 1X is the dilution usually used in spraying with hydraulic machines. 6X is six times as much material in 100 gallons, etc.

Table 11 gives results of spray tests at the Root Orchard, partly described already. Scab was much better controlled here with concentrates than with dilute sprays, and the difficulty of scab control in tall trees with hydraulic, high pressure equipment should be noted. Poor scab control with the "Queen" can be attributed to low air volume and speed which were insufficient to reach trees about 30 feet high in some instances. Control with that machine was considered satisfactory in smaller trees.

TABLE 8. PEST CONTROL WITH MIST-O-MITE ON McINTOSH APPLES IN 1952 FUNK ORCHARD, SOUTH GLASTONBURY[1]

(Figures Are Percentages)

Tree	Good	Curculio	Sawfly	Bud moth	Red-banded leaf roller	Red bug	Others	Scab	Sun scald	Russetting Light	Russetting Heavy
1	78.5	....	.9	....	....	3.7	1.9	....	7.5	5.6	1.9
2	91.5	....	1.2	....	....	....	.6	....	6.7	.6	....
3	85.4	....	....	....	.5	.5	2.2	....	7.7	3.8	....
4	64.4	....	....	....	....	....	2.5	....	21.2	9.3	2.5
5	87.3	....	....	....	....	....	....	....	11.1	1.6	....
6	78.9	3.0	....	.7	1.5	2.3	2.2	2.3	4.5	4.5	.9
7	77.0	....	....	....	....	....	.7	....	14.1	7.4	.7
8	79.6	....	1.0	....	1.0	3.1	1.0	....	11.2	1.0	....
9	89.5	....	.7	....	.7	....	4.5	....	3.7	.7	....
10	80.3	....	.5	.5	....	....	1.6	....	12.0	3.8	.5
Average	81.9	.3	.4	.1	.4	.8	1.7	.4	9.7	4.3	
	Pest control minus scald and russet 95.9%										

[1] See footnotes 2, 3 and 4, Table 7.

Spray Schedule—1952
Funk Orchard

Date	*Material*	*Concentration*[1]
April 16	Oil (99%)	4X
April 21	Fermate	4X
April 26	Fermate	6X
April 29	Fermate—phygon	4X
May 2 (one side of tree only)	Fermate	6X
May 6	Fermate	6X
May 11	Sulfur—fermate	4X
May 14 (Calyx)	Phygon—fermate—lead arsenate TEPP	6X
May 20	Sulfur	6X
May 23	TEPP	4X
May 28	Sulfur—fermate—TEPP Lead arsenate—Marlate	4X
June 3 (one side only)	Sulfur—fermate—(no TEPP) Lead arsenate—Marlate	4X
June 13	Lead arsenate—fermate—Marlate	4X
June 27	Sulfur—fermate—Marlate— TEPP	4X
July 11 (one side only)	Sulfur—fermate—Marlate— TEPP	4X
July 24	Lead arsenate—Marlate—TEPP Sulfur	4X 1X

NOTE: Sulfur-fermate combinations consisted of 4 pounds sulfur, ½ pound fermate as a base concentration.

[1] See footnote to spray schedule on page 28.

TABLE 9. INSECT AND DISEASE CONTROL WITH BEAN "SPEED SPRAYER" MODIFIED FOR CONCENTRATE APPLICATION ON BALDWINS IN 1949
ROGERS ORCHARDS, SOUTHINGTON

(Figures Are Percentages)

Concentration	Good[1]	Curculio	Codling moth	Other insects	Scab	Scald	Russet Light	Russet Heavy
1X	81.3[2]	6.1	1.2	11.7	.0	.1	32.0	10.6
2X	89.6	1.1	1.7	7.0	.1	.4	28.7	10.3
4X	87.2	1.7	2.9	8.4	.2	.4	22.6	7.0
8X	92.4	1.1	.7	5.1	.0	.2	26.8	12.2

1 Includes apples listed as russetted; means free of insect and disease blemishes. Figures are averages of five trees each. Examined October 6.
2 See footnote 3, Table 7.

Spray Schedule—1949
Rogers Orchards

The spray program was that ordinarily used by the grower with the concentration stepped up to two, four, and eight times normal. There were nine applications during the season, not including dormant sprays. Puratized was used on May 4 (2X, 4X) and parathion (2X). The materials consisted mostly of sulfur-fermate applied early and fermate-lead arsenate applied in the later sprays.

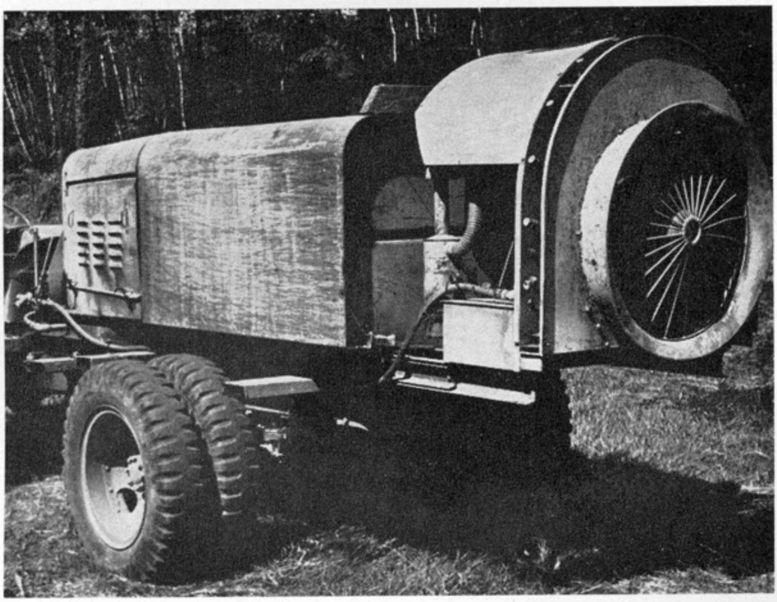


Figure 20—The Hardie hang-on blower, without directional vanes.

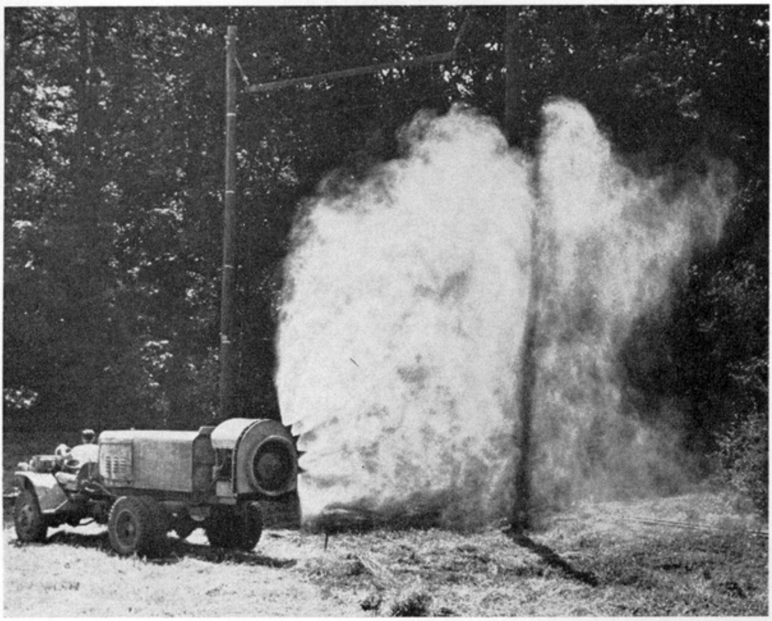


Figure 21—Spray delivery from the Hardie hang-on blower, showing the height reached by the spray—about 24 feet. Trees should not be over 20 feet high for this machine.

TABLE 10. DEPOSIT IN DIFFERENT PARTS OF THE TREE[1]

Concentration	Tree	Location of sample	Mg. lead per sq. in.
1X	1	Top	0.0
Standard equipment	1	Bottom	.08
discharge both sides	2	Top	.0
	2	Bottom	.13
2X	3	Top	.04
(one side delivery)	3	Bottom	.13
	4	Top	.09
	4	Bottom	.10
4X	5	Top	.01
(one side delivery)	5	Bottom	.11
	6	Top	.04
	6	Bottom	.10
8X	7	Top	.05
(one side delivery)	7	Bottom	.06
	8	Top	.05
	8	Bottom	.13

1 Sampled May 12, 1949.

TABLE 11. COMPARISON OF HARDIE "QUEEN" AND "CORNELL" MIST BLOWERS WITH HYDRAULIC SPRAYER OF CONVENTIONAL TYPE. 1950. ROOT ORCHARD, FARMINGTON

(Figures Are Percentages)

Machine	Good	Curculio	Red-banded leaf roller	Codling moth	Others	Scab
		McIntosh				
"Queen"—large trees Average of three	78.5[1]	.9	.6	1.7	7.3	12.5
"Queen"—small trees Average of six	93.7	.5	.1	1.3	3.0	1.6
"Cornell"[2]—large trees Average of four	85.3	1.2	.8	1.1	5.4	7.3
"Cornell"—small trees Average of two	83.5	.6	.6	.4	5.2	10.9
Hydraulic—large trees Average of three	63.9	.5	.6	1.5	7.8	28.0
Hydraulic—small trees Average of two	86.6	....	.8	2.4	7.1	4.7
		Baldwin				
"Queen"—large trees Average of five	91.4	.2	....	.6	3.3	1.6
"Cornell"—large trees Average of five	91.5	.3	.3	.1	4.0	2.2
Hydraulic—large trees Average of five	87.0	.4	.9	.3	8.3	3.1

1 See footnote 2, Table 7.
2 "Orchard mist".

NOTES: Distinct advantage for "Cornell" machine for large McIntosh.
Field examination showed no more scab in tops than in other parts of the tree with this machine.
Both operate at about the same cost for gasoline and labor.
"Queen" did a better job on small trees than the "Cornell".

Spray Program—1950
Root Orchard

Date	*Material*	*Concentration*
May 2 (prepink)	Sulfur	6X
May 12 (pink)	Fermate	5X
May 19-20 (bloom)	Fermate	5X
May 25-26 (late bloom)	Puratized	4X
May 31	Fermate—lead arsenate	5X
June 12	Fermate—lead arsenate	4X
June 20 (Special on McIntosh only)	Sulfur	4X
July 14-15	Fermate	4X
	Parathion	2X
August 9-12	Sulfur	2X
	Parathion	2X

NOTE: Concentration (standard) lead arsenate, 3; sulfur, 6; fermate, 1½.

SUMMARY

1. Spray practice in Connecticut tends more and more towards one-man operation.
2. Costs favor air-blast machines partly because of speed of cover per man. Fuel saving is not a consideration since, in general, it costs more to run a mist blower than a hydraulic sprayer.
3. Savings in water haulage, supply or pumping costs favor the mist blower operating on concentrates or semi-concentrates.
4. Drop sizes of 50-100 microns seem to be indicated (for 2 to 6X concentration), since very small sizes do not settle readily and the very large sizes drop out quickly and are not suitable for concentrate mixtures.
5. Movable (hand-operated) outlets have some advantages for mist blowers, but also some disadvantages. Fixed outlets are faster, especially if operated from both sides of the machine, but do not reach the tops of trees more than 20-25 feet high unless adequate velocity and volume are provided. In general, the "hang-on" blower is not provided with enough power, but there are some exceptions. Improvements in manufacture have been continuous and rapid.
6. Performance of mist blowers during at least two years, one average, the other severe as regards pest control, is about equal to the average hydraulic sprayer, that is, with adequate velocity and volume. The ability to cover the orchard faster has naturally brought some improvement in control where mist blowers have replaced older hand-operated hydraulics.

LITERATURE CITED

1. Bailey, S. F., and Smith, L. M. Handbook of Agricultural Pest Control. 1951. Industry Publications, Inc. New York.
2. Borden, A. D. Low volume spraying of deciduous fruit trees successful with air carrier speed sprayers. Calif. Agr. (Calif. Agr. Expt. Sta.) **2**(6):5,16. July, 1948.
3. ————. Air carrier equipment economical and effective in applying concentrated spray mixtures. Ibid. **4**(2):8-10. Feb., 1950.
4. ————. Spray chemical concentrations recommended for bulk, semi-concentrate, concentrate methods of spray application on deciduous fruit trees. Ibid. **6**(1):11-13. Jan., 1952.
5. Brann, J. L., Jr. The use of mist concentrates on fruit trees. N. Y. State Hort. Soc. Proc. **95**:96-104. 1950.
6. ————. Mist concentrates on fruit trees. N. Y. State Hort. Soc. Proc. **96**:100-107. 1951.
7. ———— and W. W. Gunkel. Improved pest control aim of research men. Farm Research (N. Y. State Agr. Expt. Sta.) **17**(3):6-7. July, 1951.
8. Brown, L. R. Program report on the Cornell low volume flexible outlet spray duster. N. Y. State Hort. Soc. Proc. **93**:93-100. 1948.
9. Burrell, A. B. Partial concentrates for air-blast sprayers. Amer. Fruit Grower. **69**(2): 28, 46. 1949.
10. ————. Efficiency in spraying with special consideration of concentrates. Proc. Conn. Pom. Soc. 1951. pp. 61-76.
11. French, O. C. Machinery for applying atomized oil sprays. Agr. Eng. **15**(9):324-326, 329. 1934.
12. ————. Spraying equipment for pest control. Calif. Agr. Expt. Sta. Bul. 666. 1942.
13. Garman, P. Two years of experience with mist blowers for control of apple pests. Jour. Econ. Ent. **41**:213-216. 1948.

14. Mitchell, A. E. Application of concentrate sprays with a conventional speed sprayer. Agr. Eng. **30**:533-534. 1949.

15. Oppenfeld, H. von, D. Boynton, J. L. Brann, A. B. Burrell and E. S. Shepardson. Cost and effectiveness of different insect and disease control practices in New York apple orchards. Cornell Agr. Expt. Sta. Bul. 886. 1952.

16. Potts, S. F. Concentrate spray mixtures and their application by ground and aerial equipment as compared with standard spraying and dusting methods. U. S. Bur. Ent. and Pl. Quar. E-508. 1940.

17. ———— and R. B. Friend. Mist blowers for applying concentrated spray. *In* Conn. Agr. Expt. Sta. Bul. 501. pp. 47-60. 1945.

18. ————. Particle size of insecticides and its relation to application, distribution and deposit. Jour. Econ. Ent. **39**(6):716-720. 1946.

19. ————, P. Garman, R. B. Friend, and R. A. Spencer. Construction and operation of ground equipment for applying concentrated sprays. Conn. Agr. Expt. Sta. Cir. 178. 1950.

20. ———— and R. A. Spencer. A small portable mist blower for applying concentrated spray. U. S. Bur. Ent. and Pl. Quar. ET-234. 1947.

21. Pratt, R. M. The Cornell spray-duster. N. Y. State Hort. Soc. Proc. **91**:148-152. 1946.

22. ————. Status of the Cornell spray-duster. N. Y. State Hort. Soc. Proc. **93**:87-93, 226-227. 1948.

23. ————, L. M. Massey and K. G. Parker. Fruit disease control with a new type of spray-duster and mist sprayer. (Abs.) Phytopathology **39**:19. 1949.

24. Young, H. C. New air blast sprayer. Amer. Fruit Grower. **65**:22. 1945.