A METHOD FOR TESTING LOW-VOLUME ORCHARD SPRAYERS[1]

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Introduction

A low-volume sprayer using a 110-125 mile per hour airstream to carry the pesticide was developed at this laboratory for the control of orchard pests (2). This sprayer greatly reduced spraying time and labour. After the practicability of the sprayer had been demonstrated, a number of commercial versions appeared. Some of these were very good but others were inadequate. This resulted in a demand for sprayer assessments to ensure that the orchardist could get satisfactory equipment. The object was then to develop a sprayer testing procedure for two purposes: determining the effect of sprayer modifications designed to improve spray distribution and assessing commercial sprayers.

To test sprayers in the field, many acres of orchard and large amounts of time, manpower, and materials are required. It was obvious that the demand could not be met with field tests. On the other hand, although much development work had been done in the laboratory, the amount of information that would be obtained this way was limited and far short of that required. The solution appeared to be a method intermediate between those of the field and the laboratory.

Frame for Sampling Spray Deposits

It was decided that the most practical approach was full scale tests, *i.e.*, to measure deposits at distances normally encountered in orchards. Therefore, it was desirable to have a convenient method of obtaining spray deposits at heights up to 25 feet and horizontal distances up to 15 feet. To achieve this, a wooden frame was built upon which could be placed various sampling devices (Figure 1). The frame was 30 feet in height and width. On the back of the frame were 3 plank walks, 6, 14, and 22 feet above the ground. A ramp led from the ground to the three walks.

At heights of 5, 10, 15, 20, and 25 feet, lengths of angle iron were bolted to each end of the frame and extended 18 inches out from the front. A 7-inch length of strap iron was bolted to the end of each angle iron so that it would be at 90° to a line from the midpoint of the sprayer vent (Figure 2). Two galvanized wires, 1/16 inch in diameter, were fastened to the strap iron by heavy springs. The wires were 3 inches apart and sheet aluminum spacers were fastened to them midway between the sampling points to maintain the 3-inch spacing along the 30-foot length. Each sampling position was marked by a short length of string tied to the lower wire (Figure 3). There were 6 sampling positions, 5 feet apart, the end positions being 2.5 feet from the angle-iron brackets.

Sampling Surfaces

Microscope slides, 1 by 3 inches, were used to collect spray deposit samples. To increase the spray holding capacity of the slides, they were put in a silicone preparation[4] for about 3 minutes and then placed on a rack to drain and dry.

The slides were held on the wires on the spray frame by clips made as follows. A piece of 3- by 3.5-inch tinplate was turned over on two edges to form a clip 3 by 3 inches. The sili-

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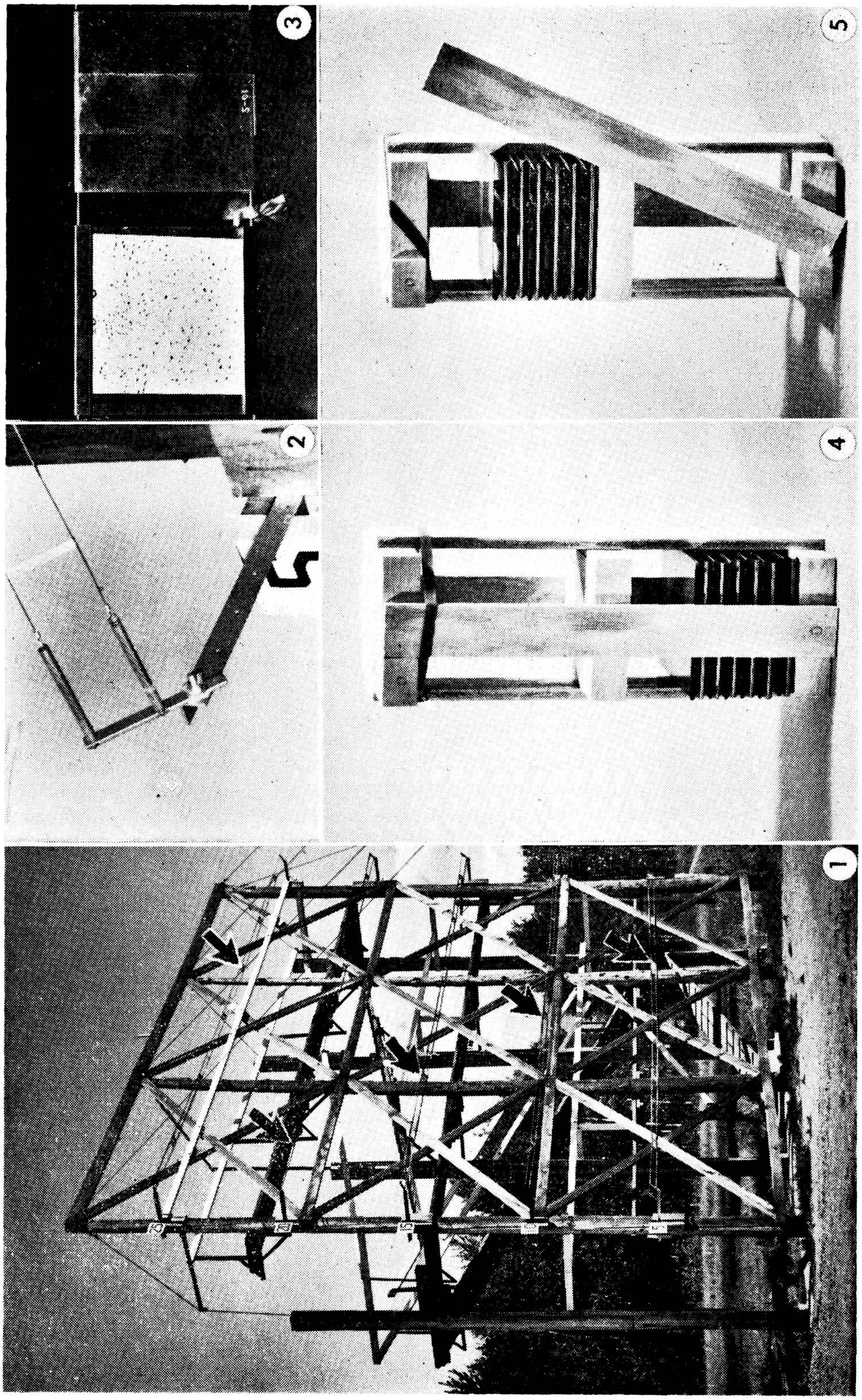
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cone-treated slide was fastened to the clip with rubber cement. Two spots of cement were placed on the clip and on the back of the slide and allowed to stand a few minutes until tacky; and then the slide was placed on the clip so that the spots on the clip and slide were in contact (Figure 3).

Waxed cards were also used to collect samples. These were made from 5- by 3-inch plain index cards that had been immersed for a few minutes in a solution of 15 gm. of paraffin wax in a litre of petroleum ether. When dry, the cards were cut into 2 pieces, 2.5 by 3 inches. These fit between the folded edges of the metal clips (Figure 3). A small amount of rubber cement was placed on the centre of the clip to hold the waxed card securely. When the cement was tacky the card was slipped into the clip and pressed firmly against the cement.

For convenience in handling, the cards and slides were carried in 2-compartment boxes (Figures 4 and 5). The unsprayed cards and slides were placed in the lower compartment, the sprayed in the upper. The turned edges of the clips allowed the sprayed cards and slides to be stacked without smearing the deposits. For each sampling height, one box with 6 cards and 6 slides was required, *i.e.*, 5 boxes, 30 cards and 30 slides for each test.

At each sampling position, the card was placed on the wires before the slide; otherwise the slide would drop off. Those at 5 feet from the ground were put into position from the ground; those at 10 feet from the 6-foot walk; those at 15 and 20 feet from the 14-foot walk; and those at 25 feet from the 22-foot walk. The slide was removed before the card.

Test Solution

A solution of rhodamine B[5] dye in water was used as the spray liquid. For most sprayer tests, 30 gallons of spray was sufficient. The dye solution was prepared by dissolving 90 gm. of rhodamine B in approximately 250 ml. of methanol. This was then added to 30 gallons of water in the sprayer tank and mixed.

Wind Velocity and Direction

The sprayer testing was done outdoors when the wind velocity was less than 2 miles per hour. Wind direction and velocity were measured during a test because variations affected spray deposits. These measurements were made 12.5 feet above the ground on a small platform 30 feet in front of the spray frame.

Wind direction was determined by means of a simple aluminum wind vane mounted on a wooden dial marked in 10-degree divisions. The dial was set up so that the 0-180 line was parallel to the spray frame. Thus wind direction was recorded in relation to the frame.

Wind velocity was measured by means of an anemometer[6] and a velometer[7]. These were mounted so that they could be pointed in the direction from which the wind was blowing. The anemometer was started at the beginning of the test run and stopped

[5] Rhodamine B-500, Canadian Industries (1954) Limited, 355 Burrard Street, Vancouver 1, B.C., Canada.

[6] Taylor Instrument Companies, Rochester, N.Y.

[7] Illinois Testing Laboratories, Inc., Chicago, Ill.

Fig. 1.—Frame for collecting spray samples. On the back are the ramp and walks with white guard rails. Brackets carrying wires for holding sampling surfaces (arrows) are arranged at 5-foot intervals above the ground.

Fig. 2.—Bracket with spring-loaded galvanized wires on which spray targets are placed. One of the spacers to keep the wires 3 inches apart is shown at top centre.

Fig. 3.—Sprayed waxed card and microscope slide in place. The two darker areas on the slide are cement. The string on the lower wire marks the sampling position.

Figs. 4 and 5.—Two-compartment box containing stacked cards and slides for one sampling height, before and after a test, respectively.

at the end. The air movement was recorded in feet but, as the run was timed, the velocity could be calculated. The operator noted the variation in air movement shown by the velometer. If a wind gust occurred during the spraying period, it was noted and also the position of the sprayer in relation to the frame. As the spraying time in a test run was approximately 30 seconds, gusts occurred in few runs.

Spraying Procedure

The course the tractor was to follow when pulling the sprayer past the frame was marked on the ground with heavy white cord. The course varied depending upon the information wanted. For example, if the effect of a sprayer modification on deposit at one distance was wanted, the course was parallel to the frame. However, if information was wanted on deposits at various distances, as for sprayer assessment, the course was at an angle to the frame. In this case the course was marked so that in the test the mid-point of the sprayer vent passed 15 feet horizontally from the first sampling positions and 5 feet from the last. The tractor and sprayer were driven over the course and the throttle setting for the desired speed was determined. The speed was usually 1 mile per hour but speeds up to 4 miles per hour have been used.

The cards and slides were placed on the frame. When the sprayer was in position, the wind observer ready and air conditions satisfactory, the sprayer was drawn along the marked course. When the sprayer vent passed a point 10 feet before coming into the path of the spray frame, the person in charge gave a signal and started a stopwatch. At the signal, the sprayer operator turned on the spray and the wind observer started the anemometer. Similarly, the spray and instruments were stopped when the sprayer was 10 feet past the frame. The duration of the test, pump pressure, and velocity and direction of air movement and other pertinent items were recorded.

Slide and Card Treatment

As soon as spraying was complete, the targets were removed and stored in the carriers (Figure 4) until dry. Then the slides and cards were removed from their metal clips with a thin-bladed spatula. The cement was removed from the backs of the slides by rubbing with the fingers or a cloth. The slides were stored in microscope slide boxes. A 1- by 2-inch piece of each card was glued on a 12- by 15-inch sheet of black photograph-album paper in the same relative position as on the spray frame (Figure 6) and filed.

To determine the spray deposit, the dye was washed off the slides with water. This was done by placing the slide in a 8-ounce bottle, 2 by 2 by 5¼ inches, and adding 15 ml. of water. The tightly capped bottle was then placed on its side in an oscillating shaker and gently shaken for 5 minutes. The solution was decanted and the absorption measured in a spectrophotometer at 555 millimicrons or in a colorimeter with a green filter transmitting in the 500 to 570 millimicron range. A sample of spray solution taken from the sprayer tank was diluted to 100 times its volume and the absorption measured. The deposit on the slide was calculated as microlitres of spray per square centimeter.

Discussion

Frame for Sampling Spray Deposits

Originally it was planned to erect a structure that would have a resistance to a spray stream somewhat similar to that of a mature apple tree. For this purpose the frame was covered with lath snowfencing. However, the resistance was very high; there were practically no deposits on surfaces behind the fencing. Other materials such as netting with various materials fastened to it were considered. Finally, it was decided to use the simple frame instead of a more elaborate structure.

Placement of Sampling Surfaces

The next step was to determine where the spray sampling surfaces should be placed on the frame. By means of an anemometer and small wind vanes the behaviour of airstreams around the frame was examined. In the areas between the structural members of the frame there was considerable air disturbance, but none 12 inches or more in front of the frame. Therefore the sampling surfaces were placed 18 inches in front of the frame. The thin wires used for carrying the surfaces created a negligible amount of disturbance in the airstream and the amount of sag was slight.

When the sampling surfaces were placed vertically, a considerable quantity of spray deposit was blown off by the airstream. Also, because the angle of the sampling surface to the spray stream varied with the position on the frame, it was necessary to calculate the deposits on the basis of a common angle. The deposits on cards could not be corrected and were of little or no value under these conditions, but by tilting the sampling surfaces so that each was at right angles to the spray stream this problem was overcome.

Test Solution and Sampling Surfaces

The information wanted for each sampling point on the frame was the quantity and type of spray deposit. As it was desirable to determine a large number of deposits quickly, a water-soluble dye was used and the amount determined colorimetrically. Rhodamine B was used because its high absorption at a wavelength of 555 millimicrons permits small deposits to be determined. Most materials absorb the dye and are unsuitable for sampling surfaces. However, the recovery of measured amounts of dye from glass was excellent, and microscope slides were used. The slides were treated with a silicone preparation to make the surface hydrophobic. This increased the water-holding capacity. Silicone preparations for treating laboratory glassware are not suitable because they give a very smooth surface from which much of the spray deposit is blown off by the sprayer airstream. Paraffin wax and petroleum oil were also tried but were less convenient and the surface was easily damaged. The silicone preparation finally used produced a satisfactory surface and the slides could be used several times before requiring retreatment.

Cleared photographic film was also tried and is satisfactory for determining small spray deposits. The gelatin layer absorbs the dye as a solution and in this form the amount present can be determined directly by measuring the light absorption in a photoelectric colorimeter. Because the dye solution is not continuous in the gelatin, a colorimeter should be used that measures absorption over an appreciable area of the film. The Klett-Summerson photoelectric colorimeter[8] was found satisfactory. Two sizes of film have been used, 1 by 3 inches and 1¾ by 3 inches. With the smaller size 2 absorption measurements were made, 1 on each end; with the larger, 4 measurements were made, 1 in each quarter. The mean value was used for calculating the spray deposit. The absorption could be measured almost immediately after spraying without processing. However, there is a disadvantage in using film. Because the hydrophilic gelatin surface has a low spray-holding capacity its use is limited to small spray deposits. Dye deposits on other transparent materials, such as glass and

[8] Klett Manufacturing Co., New York, N.Y., U.S.A.

plastics, cannot be measured in this way because the spray solution dries and the dye separates as a solid. For this method the dye must be in solution in a transparent medium.

The amount of material per unit area is not the only factor in assessing spray deposits. The fraction of the sprayed surface covered is of equal, if not greater, importance. Of a number of materials tried for surfaces to assess coverage, plain index cards impregnated with paraffin wax were the most satisfactory. The treatment described gave the cards a smooth, hydrophobic surface upon which droplets of rhodamine B solution left sharp, circular stains. An attempt to measure the spray coverage on the cards by reflectance was not successful. Visual estimation of coverage has been found satisfactory for practical purposes. The majority of sprayers tested by this method delivered spray at approximately 2 gallons per minute and travelled between 1 and 2 miles per hour. Under these conditions there is considerable coalescence of droplets on the waxed cards and they could not be used for determining droplet sizes. However, when the spray deposit was light, drop spectra could be determined from the ratio of stain to droplet diameter. Coalescence of drops on the cards could be detected visually with some experience. Very large spray drops could be detected also as they tended to fall out of the airstream and struck the targets at an acute angle making a distinctive elliptical stain.

Both the waxed cards and the microscopic slides had to be cemented to the metal clips. Although the folded edges of the metal clips held the dry cards snugly, sprayed cards bulged and fell out unless cemented to the clips. As the cards and slides are removed from the clips after the spraying, the cement must hold the targets firmly during the test but give a bond that can be readily broken. Rubber cement for paper is suitable if the surfaces are placed together when the cement is tacky but not dry. This cement has a further advantage in that, when dry it can be readily removed from the surfaces by gentle rubbing. The sampling surfaces may be damaged if touched by the fingers and drop stains are obscured. When the waxed card was pressed onto the cement, it was protected with a piece of card. When a slide was cemented to a clip, the cement had to be applied to both surfaces to obtain a satisfactory bond. Also, the slide had to be bonded at 2 points (Figure 3) or the blast of the airstream occasionally spun the slide or blew it off. Before the deposit on the slide was determined the cement had to be removed because it absorbed the dye.

Assessing Deposits

The number of microscope slides used for measuring deposits depended upon the volume of spray. For sprayers applying 50 to 100 gallons per acre, 1 slide was used at each sampling position at heights of 5, 10, 15 and 20 feet and 2 slides at 25 feet. Where smaller quantities of spray were applied more slides were used.

Preliminary experiments were made concerning the course of the spraying run. In each experiment 4 runs were made. In 2 runs the course was 15 feet horizontally from the first sampling positions and 5 feet from the last. In the other 2, the course was 5 feet from the first sampling positions and 15 feet from the last. The means of the 4 runs for 3 experiments were given by Cox (1, pp. 26-33). The data indicated that greater precision would be obtained with 3 runs along the course starting at 15 feet from the sampling positions and ending at 5 feet than with the 4 runs used in the experiments.

Equal amounts of deposit at all sampling positions might be considered ideal. However, this is not the case. The spray frame is 2-dimensional whereas a tree is 3-dimensional. Horticultural practices affect distribution of the deposits in the tree. In British Columbia, apple trees are usually planted 30 feet apart. They are heavily pruned, and open in the centres. Mature trees almost touch their neighbors and are approximately 20 feet high. Under these conditions the sprayer vent passes under the outer edge of the tree. Since the work was directed toward obtaining efficient pest control in British Columbia orchards some of the conclusions may not apply in other areas.

The deposits on the sampling surfaces give information on the distribution of the spray in the airstream. An even distribution of spray in the airstream is not ideal. The airstream expands as it travels out from the sprayer vent so that the shape in vertical section is approximately that of a right-angled fan. The shape of the tree above the trunk is roughly cylindrical and a plane vertical section through the tree is approximately a rectangle. The vertical columns of targets then correspond to vertical lines through the rectangles. These points should be kept in mind when one scrutinizes data obtained on the spray sampling frame.

If the deposits on the sampling surfaces at the 25-foot height were small the top deposits in trees were small. These deposits could be increased by increasing the amount of spray in the upper half of the airstream. However, the amount of spray in the top portion of the airstream should not be high because this portion travels almost vertically and has a comparatively small part of the tree to spray. If the surfaces at the 5-foot level 5 feet from the sprayer were sprayed to the point of run-off then the spray deposit on the parts of the tree nearest the sprayer were high. If the surfaces near this position were also flooded, then a larger portion of the tree was heavily sprayed. In a well-adjusted sprayer the greatest deposit for any level fell approximately on a diagonal line from the nearest position on the 5-foot level to the farthest position on the 25-foot level. The portion of the spray stream sampled on this diagonal was the portion that sprayed from the lower outside of the tree to the top centre. This part of the stream had to carry the greater portion of the spray because it sprayed a greater portion of the tree. Orchard tests showed that the sprayers that gave good spray distribution in trees also gave nearly uniform spray deposits on the frame at distances of 11 to 13 feet.

In Figure 6 are shown waxed-cards sprayed by a sprayer as received from the manufacturer and after modifications had been made to give a better deposit distribution. The spray output in the 2 tests was the same, 2.24 imperial gallons per minute. The larger stains on the more heavily sprayed cards are formed by coalescence of drops on the cards. In the right-hand group, there has been little or no coalescence of drops on the left-hand 25-foot level card. On the next 2 cards to the right some coalescence has taken place. The larger stains surrounded by comparatively clear areas, on these 2 cards, are distinctive of coalesced drops. There has been coalescence of drops on all cards in this set with the exception of the 1 on the upper left. The spray did not contain any coarse drops. These would be detected as large oval stains present in greater concentration on the lower cards than on the upper.

Figure 7 shows the deposits obtained on the spray sampling frame and on the foliage of mature apple trees. The sprayer used applies 70 imperial gallons per acre and has given good control of insect pests in British Columbia. It is evident that there are

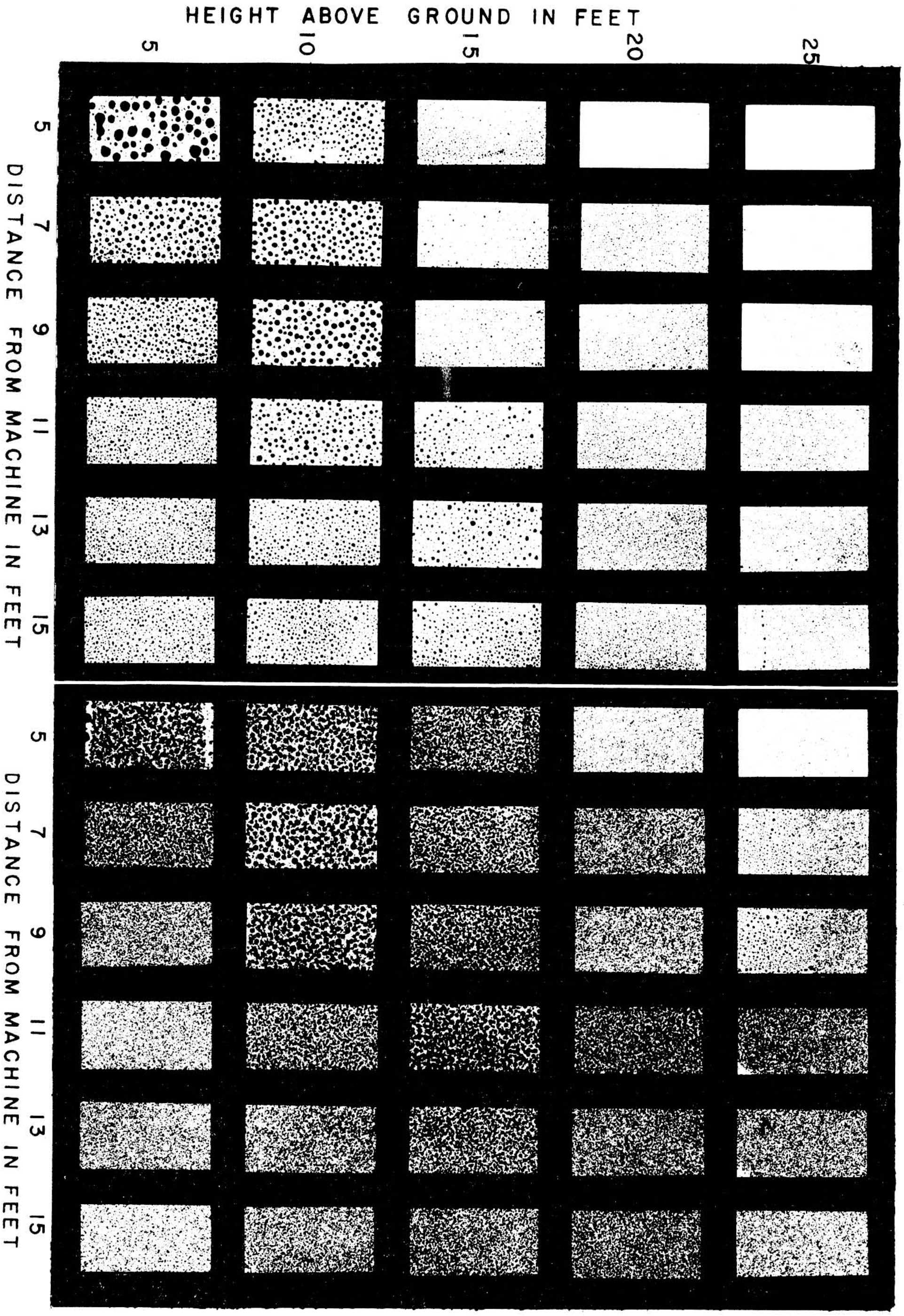

Fig. 6.—Mounted sprayed wax-card targets mounted for reference. Upper a poor spray distribution; lower, good.

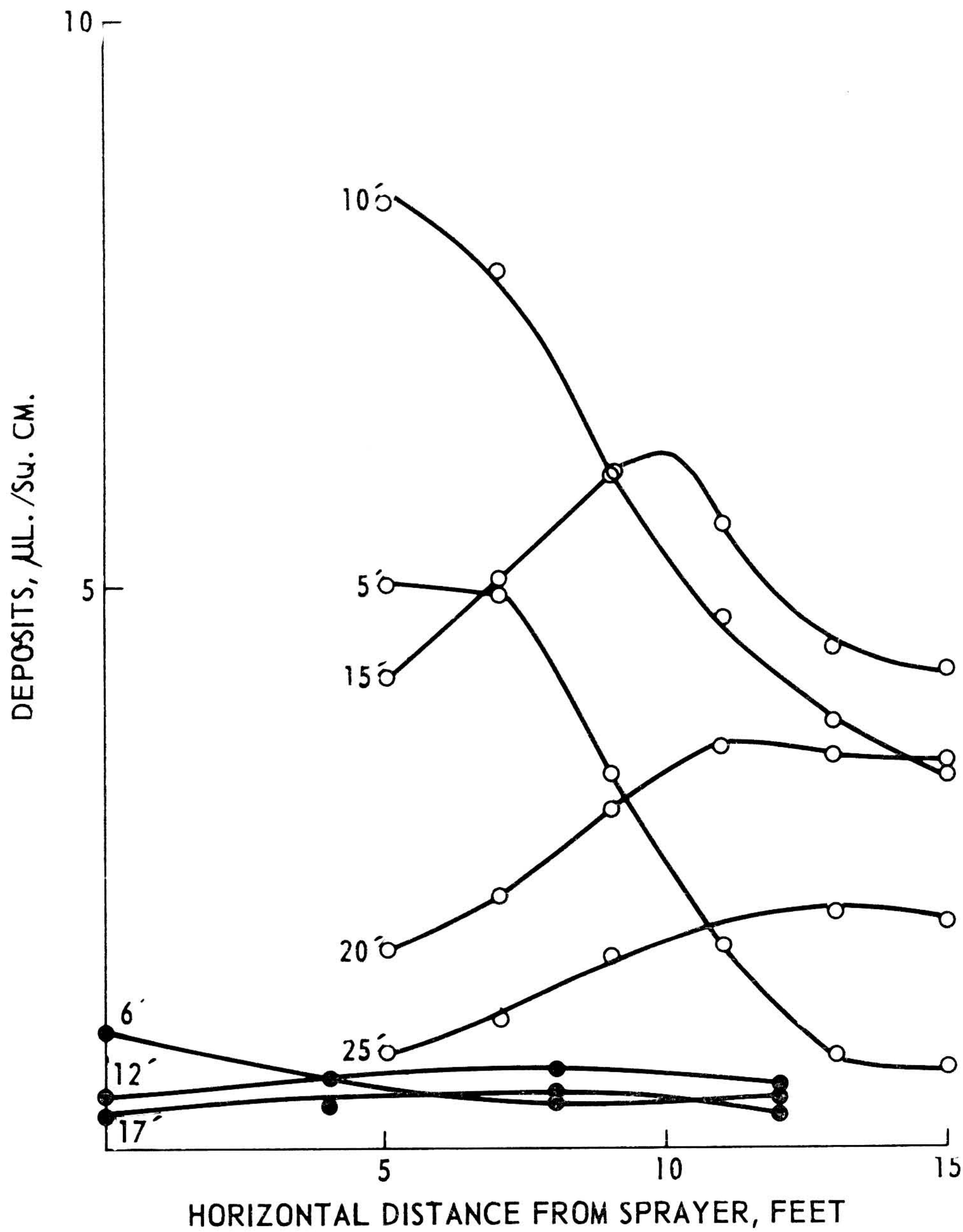

Fig. 7.—Spray deposits, 5 upper curves on spray sampling frame at 5-, 10-, 15-, 20-, and 25-foot heights; 3 lower curves on mature apple trees at 6-, 12-, and 17-foot heights.

large differences between the frame and tree deposits. Nevertheless, when the correlation between frame and tree deposits is known, the efficacy of a sprayer in the orchard can be predicted from the frame data with considerable accuracy.

Abstract

A method is described for full-scale testing of orchard sprayers with outputs up to 100 gallons per acre. Performance is assessed from deposits obtained on waxed cards and treated microscope slides.

Acknowledgment

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A Note on Catching Insects at a Small Pool

In 1960 I was very successful in collecting insects when I sat over a small pool on several occasions during the very hot summer. I had caught several good species at the same place in previous years. It was much the same as sitting over a water hole in Africa, but with an insect net instead of a rifle, and in the heat of the afternoon instead of just before sundown. I found that insects of certain families seem to need a drink in the hottest part of the afternoon on the really hot days. The hotter it is the more anxious for a drink and the less alert they are.

I had lunch about noon and rested until 1:30, then started out for the pool, which is a little less than two miles from home, a good half of the walk up a side-hill that faces south. It was generally between 90° and 95° F. on the north wall of my house when I left home so it must have been well over 100° F. going up the hill. I told some friends about it and one remarked I should have my head examined, for I was over 76 at the time.

I wanted to catch species of the Stratiomyid genus **Euparyphus,** but I found that several species of Therevidae came for a drink just as readily as the Stratiomyids, although Therevidae are reported to be dry area flies. I also caught some Tabanids. The flies took little notice of me. Apparently all they worried about was to get to the water for a drink. The bottom of the creek was covered with rocks of different sizes and when I put my net over a fly it would just walk or fly through one of the openings caused by the net being held up by rocks. I was very discouraged at catching so few in proportion to the number I had the net over and should have bagged had the surface been more nearly level.

On the way home I remembered making a very small net years ago to catch flies around the house. That evening I made one with a rim 5 inches in diameter. The frame was of baling wire; the handle was the two strands of wire twisted tightly together. The handle was only 10 inches long so you can tell how "tame" the flies were. The small net did not get so wet as the large one. The Stratiomyids in particular liked to go directly to the edge of the pool, or to climb down the perpendicular face of a small rock standing a little out in the water. It was funny to see them walk down this perpendicular rock; they waddled, or perhaps backpeddled, down it. I missed quite a few with the small net, but it was much better than a large one. I could just clap it over some of the rocks and the trapped fly had to climb into the net. I caught several horse flies but had to use the large net for these as they were very alert. I caught two **Tabanus rhombicus** O.S. males and one **Tabanus agrotus** O.S. male, besides **Euparyphus crotchi** O.S., **E. crucigerus** Coq., **E. major** Hine, and **E. latelimbatus** Cn. and several **Scoliopelta luteipes** Will., all more or less flying together. There were ten or a dozen species of Therevidae, four of which were not in the C.N.C. I did not catch a great number but most were very good finds. I shall be watching that place next year.

—H. R. Foxlee, Robson, B.C.