University of the State of Missouri.

COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

Agricultural Experiment Station

BULLETIN NO. 50.

A Test of Spray Nozzles.

I. The Height of Spray.
II. Shape and Density of Spray.
III. Size of Drops.
IV. Amount of Discharge.
V. Clogging.
VI. Dribbling.
VII. Durability.
VIII. Method of Attachment.

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A Test of Spray Nozzles.

I. Height of Spray; II. Shape and Density of Spray; III. Size of Drops; IV. Amount of Discharge; V. Clogging; VI. Dribbling; VII. Durability; VIII. Method of Attachment.

By N. O. BOOTH, Assistant Horticulturist.

Spraying as a means of combating insect and fungous diseases is a practice which has grown up almost wholly within the last twenty years. With this growth have come numerous manufacturers to supply the demand for spraying machinery. Many improvements have been made since the first implements for performing this work were put on the market, and to a well-informed fruit grower of to-day those early machines seem quite primitive. Certainly the later implements can be used with greater ease and rapidity besides doing better work.

A spraying outfit consists primarily of two things: A pump, and a nozzle, besides there is a hose or pipe connecting the nozzle and pump; an agitator for keeping the liquid evenly mixed, etc. Of these implements the nozzle is by no means of least importance. It should not only be a good nozzle, that is, well designed and of good workmanship, but it should also be adapted to the particular class of work for which it is to be used.

The purpose of this experiment has been to collect by a series of tests such data in regard to the quality of each manufacturer's nozzles as would enable the purchaser to make a more intelligent selection than would otherwise be possible. This experiment was started in the spring of 1898, and includes no nozzles which may have been put on the market since that time. An endeavor was made to secure one of every kind of spray nozzle manufactured in the United States. There was no attempt, however, to secure those devices wherein two or more nozzles are attached side by side for the purpose of combining the spray. With one exception none of these has been tested. In addition to these nozzles of domestic manufacture a Vermorel nozzle was secured from France for comparison with nozzles of the same name and design manufactured in this country. Below is given a list of those tested, together with the name and address of the manufacturer. Opposite each firm's name is a number which is used for designating the nozzles in the diagrams and tables. It has been taken for granted that each company manufacturing spraying machinery made its own nozzles. In some cases this is probably incorrect.

Nozzle Name.	Manufacturer.	Mfgr's Address.	Manufacturers' No.
Vermorel.	Wm. Stahl	Quincy, Ill	1
Excelsior	" "	" "	1
Wellhouse	" "	" "	1
Graduating	" "	" "	1
Vermorel	Field Force Pump Co.	Lockport, N. Y.	2
Niagara	" " " "	" "	2
Numyr	" " " "	" "	2
Vermorel	W. & B. Douglas	Middletown, Conn.	3
Pilter Bourdil	" "	" "	3
Australian	" "	" "	3
Vermorel	Gould M'f'g Co.	Seneca Falls, N. Y.	4
Seneca	" " "	" " "	4
Cyclone	" " "	" " "	4
Masson	" " "	" " "	4
"S. 9" or Cyclone	Bean Chamberlain Co	Hudson, Mich	5
"S. 3"	" " "	" "	5
"S. 4"	" " "	" "	5
Calla	Morrill & Morley	Benton Harbor, Mich	6
McGowen	" "	" " "	6
Vermorel	" "	" " "	6
Double Vermorel	" "	" " "	6
Lilly	Rumsey & Co.	Seneca Falls, N. Y.	7
Deming Vermorel	Deming Co.	Salem, Ohio	8
Bordeaux	" "	" "	8
Lewis Patent	P. C. Lewis M'f'g Co.	Catskill, N. Y.	9
Gemel	H. B. Rusler	Johnstown, Ohio	10
Tervehn.	" "	" "	10
Boss (garden and greenhouse nozzle).	Belknap M'f'g Co.	Bridgeport, Conn	11
New Boston (garden nozzle)	Boston Woven Hose & Rubber Co.	Boston, Mass.	12
Climax or Nixon	A. R. Nixon	Dayton, Ohio	13
Vermorel	V. Vermorel	Villefranche, France	14

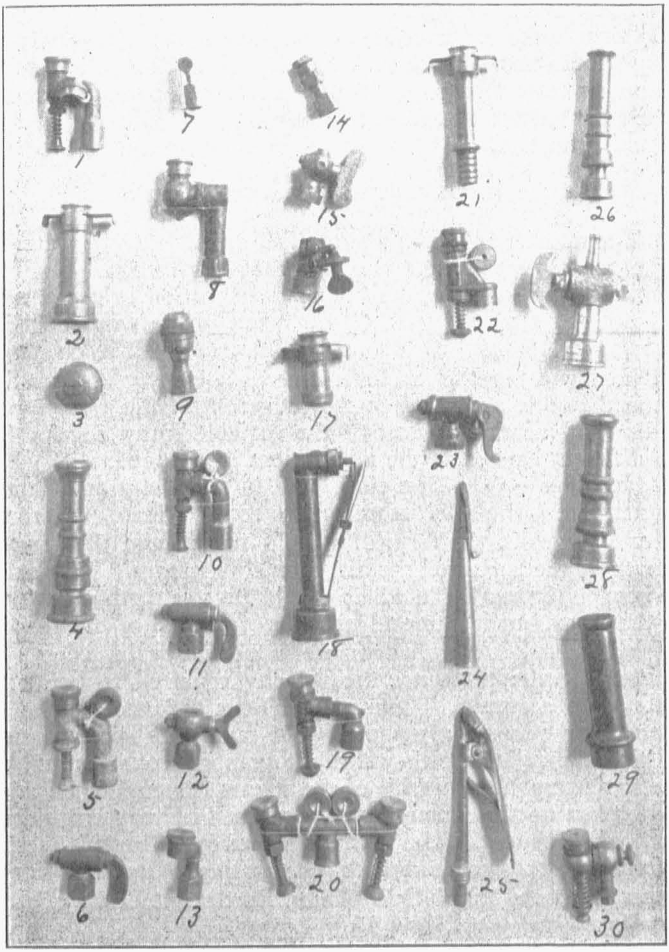

Figure I. Photograph of nozzles tested.

1 Vermorel (Stahl); 2 Excelsior; 3 Wellhouse; 4 Graduating; 5 Vermorel (Field); 6 Niagara; 7 Numyr; 8 Vermorel (Douglas); 9 Australian; 10 Vermorel (Gould); 11 Senaca; 12 Cyclone; 13 Masson; 14 "S. 9"; 15 "S. 3"; 16 "S. 4."; 17 Calla; 18 McGowen; 19 Vermorel (Morrill & Morley); 20 Double Vermorel; 21 Lilly; 22 Deming Vermorel; 23 Bordeaux; 24 Lewis Patent; 25 Gemel; 26 Tervehn; 27 Boss; 28 New Boston; 29 Climax or Nixon; 30 Vermorel (Vermorel).

Every effort has been made to make these tests accurate and impartial. Acknowledgments are made to Professors Marx and Cory of the engineering department of the University for many kindnesses both in the way of counsel and the loan of equipment from their departments. Acknowledgments are also made to the manufacturers who have readily contributed their wares for the test.

MANNER IN WHICH A SPRAY IS FORMED.

The manner in which a spray is formed is a very interesting phase of this subject and one that has received but little attention from investigators. The classification below is modeled after that given by E. G. Lodeman in his work on "The Spraying of Plants," with some modifications. The classes II and III blend together so that some nozzles may be placed in one or the other according to the judgment of the person making the classification. Most of the variable spray nozzles fall into different classes as the adjustment is changed.

Class I.— The first class both in simplicity and date of manufacture is the solid, more or less round stream. Here the water emerges in the form of a solid stream and the spray is formed by the action of the air upon this stream. No nozzles are now on the market in which this is the sole method of forming the spray, but it is one adjustment of several of the variable stream nozzles. A high pressure is necessary in using such nozzles in order to secure the velocity required to break the stream into a spray. These are all long distance nozzles designed for the tops of trees, etc. The fault with sprays formed in this manner is that they are not homogeneous throughout. The air acts upon the outside of the stream first and when this is well broken up the center is still composed of very large drops if not wholly intact. The following nozzles utilize this method of forming a spray: Excelsior, Graduating, Niagara, Numyr, Seneca, Masson, "S3," Calla, Lilly, Bordeaux, Lewis' Patent, Tervehn, Gemel, Boss, and New Boston.

Class II.— The second class embraces those nozzles in which the spray is more or less broken directly by the action of the margin of the outlet. In all sprays the disintegrating action of the air is a factor but in this and the succeeding classes, owing to the fact that the air has equal access to all parts of the stream, its action is more uniform than in the first class. Nozzles belonging to this class are: Wellhouse, Graduating, Niagara, Pilter Bourdil, Seneca, Masson, "S3," "S4," Bordeaux, Gemel, Boss, and New Boston.

Class III.— The third class includes those nozzles in which the stream having passed the outlet proper is broken into a spray by striking against projecting parts of the nozzle. To this class belong: Numyr, Lewis' Patent, Tervehn, and Nixon. The projecting portion in these nozzles against which the liquid strikes is of various shapes. In Numyr and Lewis' Patent a thin metal strip projects diagonally across the orifice. In Tervehn this projecting piece is of rubber, and in Nixon the stream is thrown against a wire netting.

Class IV.— Nozzles in which a rotary motion is given to the liquid in a chamber adjacent to the outlet and in consequence of this motion the stream emerges in the form of a conical spray. In some cases this rotary motion is given by the direction of the channel leading to the chamber, and in others it is produced after introduction into the chamber by spirals in a spindle inside the chamber. To this class belong all the Vermorels, Australian, Cyclone, and "S9."

Class V.— Nozzles in which the liquid escapes in the form of two converging streams the force of which, acting upon each other, at the point of contact breaks the liquid into a spray. This spray is fan shaped and lies in a plane at right angles to the plane of the two converging streams. To this class belong: Excelsior, Calla, McGowen, and Lilly. In Excelsior, Calla and Lilly there is a sliding metal strip with a series of holes which direct the streams. The adjustments of which there are two in this class are made by sliding this strip so as to present different orifices. In the McGowen nozzle there are two cylinders, one inside the other, the inner one being solid. These lie across the line of water flow and flush with the orifice. The position of these two cylinders is controlled by the pressure of the water and a branched spring running from the base of the nozzle. When the outer cylinder is down no water escapes. If the spring be set so the outer cylinder is forced back and not the inner one the water rushes around the inner cylinder and the spray is formed at the point of junction on the other side. If the nozzle is so adjusted that both cylinders are forced back together, then in addition to the water going around the chamber a certain amount goes straight across toward the outlet, forming a spray of a composite nature.

FURTHER CLASSIFICATION.

Nozzles may be further classified as to whether they have a variable or constant spray, that is, whether the spray may be modified by the operator or is incapable of being so manipulated. The advantages of a nozzle capable of being changed so as to throw a longer or a shorter distance is undoubted in spraying trees where the difference in distance between the lower and the upper branches is so great that it can not be altogether overcome by any changes in the position of the nozzle, in the power of the operator. In spraying small trees, bushes, vines, etc., where the same relative distance from nozzle to foliage can easily be retained this advantage does not exist.

OBJECTS OF THE TESTS.

The object of these tests has been to determine for those nozzles tested all those details in regard to construction of nozzle and properties of the spray produced, which are likely to be of importance to the users of such implements. Eight different points were investigated for each nozzle as follows:

I. Height of spray or distance which the spray could be thrown perpendicularly with various pressures.

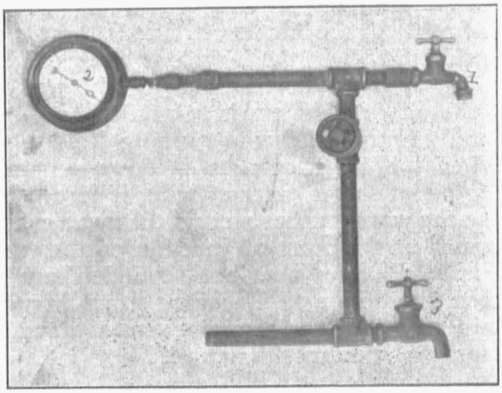

Figure II. Pipe system used in making tests.

II. The width, shape and distribution of the spray at the point where it was considered to be most efficient.

III. Size of the drops.

IV. Amount of liquid discharged by each nozzle in a given time.

V. Liability of the nozzle to clog.

VI. Liability to dribble.

VII. Durability.

VIII. Method of attachment.

In all tests the system of pipes shown in Figure 1 were used. Hose cock No. 1 is the point at which the nozzle was attached. No. 2 is the pressure gauge, a reading of which gave the pressure when the water was escaping through the nozzle. Hose Cock No. 3 was used as an escape faucet to lower the pressure so as to secure the desired reading on the gauge. This system of pipes was afterwards calibrated so as to determine the relation between the pressure as indicated on the gauge and the exact pressure at the base of the nozzle and corrections were made where necessary. The gauge was carefully tested from time to time during the progress of the work and kept correct. Gauges of this class are not very accurate for pressures of less than twenty pounds but since all the nozzles tested demand a greater pressure than this for the best results and every good pump should easily give a greater pressure, this was not considered of special importance.

I. HEIGHT OF SPRAY.

The importance of knowing the distance a spray may be thrown with a given nozzle is apparent, for this is the chief factor in determining the class of work to which a nozzle is adapted.

The pipe system shown was set up at the base of the power house chimney, and connected with the city waterworks. Hose cock No. 1 was turned upward and a short piece of hose with male hose coupling at upper end was attached. On the chimney was fastened a standard graduated to half feet, and running to the top. A ladder against the chimney completed the arrangement. Three men were required for the work; one at the nozzle to regulate the pressure and direct the stream, another on the ladder to determine the height of the spray and one below to record the observations. A superficial glance showed that the very highest point to which the spray was thrown is not of great importance. A few drops will rise a

No. of Manufacturer	NAME.	5 lbs. Pressure			10 lbs. Pressure			15 lbs. Pressure			20 lbs. Pressure			30 lbs. Pressure			45 lbs. Pressure			50 lbs. Pressure		
		Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance	Height	Character of Stream	Spraying Distance
1	Vermorel (large hole cap).....	4	Poor	3	5	Poor	3.5	5.5	Fair	3.5	5.5	Better	3.5	5.5	Max.	3.5	6	....	3.5	6	....	3.5
1	Vermorel (small hole cap).....	5	Poor	3	6	Poor	4	6.5	Fair	4	7	Max.	4	7	Max.	4	7	......	4	7	....	4
1	Excelsior (1 large hole).........	12	Solid	....	17	Solid	....	18	Coarse	16	21	Coarse	18	25	Better	20	26	Better	22	....	....	....
1	Excelsior (2 large holes).......	7	Coarse	4	10	Better	5	12	Good	6	14	Good	6	16	Good	7	16	Good	8	....	....	...
1	Excelsior (2 smaller holes).....	6	Fair	3.5	9	Good	4	10	Good	5	11	Good	5	12	Good	6	12	Good	6	12	Good	6
1	Wellhouse.................	6	Coarse	4	9	Coarse	6	12	Coarse	8	15	Coarse	10	17	Fair	11	20	Good	14	20	Good	14
1	Graduating (wide open)........	4	Poor	..	8	Poor	..	10	Better	8	12	Coarse	10	16	Coarse	12	20	Max.	14	....	....	....
1	Graduating (small stream).. ..	5	Poor	....	10	Poor	8	13	Fair	10	16	Good	12	24	Good	16	24	Good	16	24	Better	16
1	Graduating (wide stream).....	4	Fair	2.5	6	Good	3	6.5	Good	3	6.5	Good	3	7	Good	4	8	Good	4	8	Good	5
2	Vermorel (large hole cap)......	4	Poor	...	7	Poor	6	7	Better	6	8	Fair	6.2	9	Good	7	12	Max.	9	...	....	....
2	Vermorel (small hole cap).....	4	Poor	....	6	Poor	...	8	Better	5	9	Fair	7	9	Good	7	9	Max.	7	....	....	....
2	Niagara (round hole free).....	10	Poor	....	14	Poor	12	20	Poor	17	22.5	Poor	18	26	Fair	20	28	Good	20	30	Good	20
2	Niagara (round hole against side....	6	Fair	5	8	Good	7	9	Good	7	10	Good	7	14	Max.	7	..	....	...	...	....	...
2	Numyr (open)	8	Poor	7	13	Poor	11	18	Poor	15	22	Fair	18	26	Good	18	28	Good	20	....	....	....
2	Numyr (closed)	6.5	Poor	5.5	11	Fair	8	12	Good	7.5	12.5	Good	8	13	Better	8	14	Max.	8	....	....	....
3	Vermorel..........	3	Poor	.. .	3.5	Better	2	3.7	Better	3.2	4	Fair	3.5	4.5	Good	3.5	5	Max.	3.5	....	......	....
3	Pilter Bourdil....	....	....	...	...	.... ..	...	......	....	...	. ....	....	....	.. .	....	. ..	....	. .. ..	....	..	....	...
3	Australian.......	3	Fair	2	5	Fair	3	5	Fair	3	5	Good	3	5	Max.	3	5	... .	3	5	....	3
4	Vermorel (large hole cap)	4	Poor	2.5	5	Poor	3	5.5	Good	3	5.5	Good	3	5.5	Good	3	6	Max.	3	6	....	3
4	Vermorel (small hole cap).....	4.5	Poor	2.5	5.5	Poor	3	6	Fair	3	6.5	Max.	3.5	6.5	....	3.5	6.5	... ...	3.5	6.5	....	3.5
4	Seneca (round hole free).......	10	Poor	....	14	Poor	13	20	Poor	17	22	Poor	18	24	Fair	18	26	....	18	....	....	....
4	Seneca (round hole against side).........	6	Fair	4	7	Better	4.5	8.5	Good	4.5	9	Good	5	10	Good	5	12	Max.	6	12	....	6
4	Masson (open)............ ...	6	Coarse	5	10	Better	8	14	Better	13	17	Fair	13	20	Better	15	23	Good	17	....	....	..
4	Masson (hole against side).....	6	Fair	4	9	Good	6	12	Good	8	14	Good	9	16	Max.	10	19	....	10	....	....	....
4	Cyclone	4	Coarse	2	5	Good	3	5	Good	3	6	Max.	3	6	....	3	6	....	3	...	... .	....
5	Cyclone or "S 9"..............	3.7	Poor	....	4	Better	...	4	Better	3	4	Good	3	4	Good	3.2	4	Max.	3.2	....	....	....

5	"S 3" (open)......	6	Poor	....	10	Poor	....	16	Poor	....	20	Poor	...	26	Fair	....	*	....	....	....	....	....
5	"S 3'' (lever ½ turned)........	2.5	Coarse	2	5	Coarse	4	8	Better	6	9	Fair	6	11	Good	7	12	Max.	7	13	....	7
5	"S 4"........................	4.5	Poor	2	7	Fair	4	8	Fair	4.5	10	Good	5.5	12	Better	6.5	14	Max.	8	....	....	....
6	Calla (1 large hole)............	7.5	Poor	3	14	Better	11	18	Fair	14	20	Good	14	24	Better	16	24	Good	18	....	....	....
6	Calla (2 larger holes).	6.5	Fair	6	7	Better	4	9	Good	4	10	Max.	4	10	....	4	11	....	4	11	....	4
6	Calla (2 smaller holes)....	5	Poor	4	7	Poor	3.5	8	Fair	3.5	10	Good	3.5	10	Max,	3.5	10	....	3.5	10	....	3.5
6	McGowen (open)..............	9	Poor	8	16	Poor	12	16	Fair	13	20	Fair	15	24	Good	18	....	....	....	....	....	....
6	McGowen (little spring loose, large spring medium tight)..	....	....	....	....	....	....	12	Fair	6	14	Good	8	21	Better	10	23	Better	12	...	....	...
6	McGowen (little spring very loose, large spring real tight)	....	....	....	....		....	......	....	....	.. ...	....	.. .	12	Poor	...	18	Good	9	23	Better	12
6	McGowen (both springs medium tight)...........	3	Weak Good	2	5	Stronger	3	7	Good	4	10	Good	5	12	Good	7	12	Max,	8	12	Good	8
6	McGowen (both springs tight).	5	Good	3.5	8	Good	4	9	Good	4.5	11	Good	5	12	Good	7	13	Max.	8	....	... .	....
6	Vermorel..........	5	Poor	3	5.5	Fair	3.7	6.3	Good	4	6.5	Good	4.2	7	Max.	5	7	... ...	5	7	....	5
6	Double Vermorel (small hole cap)....	5	Poor	2.5	6.5	Fair	3	7	Good	3	7	Max.	3	7	....	3	7	....	3	7	......	3
6	Double Vermorel (large hole cap....	3	Poor	2	5	Poor	2.5	6	Good	3	6	Good	3	6.5	Max	3	6.5	....	3	6.5	....	3
7	Lilly (1 large hole).	12	Solid	....	16	Coarse	...	21	Coarse	18	21	Coarse	18	23	Better	20	28	Better	22	....	....	....
7	Lilly (2 larger holes)...........	8	Fair	5	10	Better	6	12	Good	8	14	Good	9	16	Good	10	16	Good	10	16	Max.	11
7	Lilly (2 smaller holes)..........	7	Good	5	8	Good	5	9	Good	5.5	10	Good	6	13	Max.	8	13	....	8	13	....	8
8	Vermorel (large hole cap)......	1.5	Fair	1	3	Good	2	4	Good	2.5	4	Good	2.5	5	Max,	3	6	....	3	6	....	3
8	Vermorel (small hole cap).	4	Poor	....	4	Poor	...	4	Better	3.5	4	Good	3.5	4.2	Max.	3.7	4.2	....	3.7	....	....	....
8	Bordeaux (round hole).........	6.5	Poor	....	11	....	....	18.5	Poor	16	22	Poor	17	26	Good	20	28	Max.	20	28	Good	20
8	Bordeaux (small hole against side of nozzle	6	Fair	4.5	7	Good	5.5	8	Good	6	10	Max.	6.5	11	....	6.5	12	....	6.5	....	....	....
9	Lewis Patent (open)............	6	Poor	....	7	Poor	....	12	Better	10	20	Fair	16	22	Good	18	22	Good	18	....	....	....
9	Lewis Patent (closed)..........	4	Good	3	6	Good	4.5	8	Good	5	8	Good	5	8	Good	5	10	Max.	6	...	....	....
10	Tervehn (open)...............	7	Poor	....	12	Poor	....	18	Better	14	20	Better	17	24	Good	18	24	Good	18	....	....	....
10	Tervehn (closed)..............	6	Poor	4	10	Better	6	12	Good	8	12	Good	8	13	Good	8	13	Max.	8	....	... .	....
10	Gemel (wide open)............	5	Poor	...	9	Better	7	13	Better	9	16	Better	12	20	Max.	13	20	....	14	. ..	....	....
10	Gemel (small stream)..........	5	Poor	....	9	Coarse	6	15	Coarse	10	17	Better	10	17	Good	10	18	Max.	11	..	....	....
10	Gemel (wide stream)...........	4	Good	2.5	4	Good	2.5	6	Good	3	6	Good	3	7	Good	4	8	Max.	4	....	....	....
11	Boss (round hole).............	6	Poor	...	9	Poor	8	14	Poor	11	20	Poor	16	....	.. ....	....	....	....	...	....	....	....
11	Boss (flat stream).............	3	Coarse	....	4	....	....	6	Coarse	5	. ....	....	....	....	....	....	....	....	....	....	....	....
12	New Boston (wide open)......	2.5	Poor	...	4.5	Poor	...	6	Coarse	4	6	Coarse	4	13	Better	9	14	Good	9	...	....	...
12	New Boston (small stream)....	5	Poor	....	6	Poor	4	10	Good	8	12	Good	10	14	Good	10	16	Good	12	17	Max.	12
12	New Boston (wide stream)....	4	Good	3	6	Good	4	6	Good	4	7	Good	4	8	Max.	5	8	....	5	8	....	5
13	Nixon.........	6	Poor	3	8	Better	6	9	Better	4	9	Max.	4	9	....	4	....	....	....	....	....	...
14	Vermorel....	4	Poor	2	5	Fair	3	6	Good	4	6	Max.	4	6	....	4	6	....	4	..	....	....

*Spraying distance too great to test.

foot or two higher after the bulk of the stream has fallen back. A new point was therefore established and recorded which is here called the *spraying distance.* This represents the distance from the mouth of the nozzle to that point where the bulk of the spray being retained it is best broken up. This point is only approximate and there is a good spray on both sides of it, getting thinner above as gradually the drops fall back and becoming more dense as we descend towards the nozzle. In the column styled character of stream, in the table of results, an attempt has been made to indicate the pressure at which each nozzle gave its best spray, higher pressures not improving it or the improvement being so slight as to be unnoticeable. As will be seen in the table there is a certain distance that each nozzle will throw a spray and no increase in the pressure will increase that distance, once the maximum is reached. With the large orifice, solid-stream nozzles the pressure required to give the best results was frequently greater than the city waterworks main would furnish. In all this work calm days were selected for the tests so as to avoid the variation from wind.

II. WIDTH, SHAPE AND DENSITY OF SPRAY.

It seems impossible to say what shape of stream is most desirable in a spray. It would appear as if the prime essential is to secure a spray such that when passed at a uniform rate of speed over any surface it will cover every part touched with a film of liquid of equal thickness. The shape of the stream otherwise seems of little importance so long as it is not so irregular as to make it difficult to bring the stream to bear equally on all parts of the foliage.

These facts accepted, the questions is how to determine if a spray be so regular that all parts touched by the moving stream will receive an equal quantity of liquid, or if the distribution is unequal the relative amount falling on each portion. Now if a spray be passed straight across any object at a uniform speed it is evident that any particular point on that object describes a line directly across the spray and receives liquid from each point in that line in succession, starting in at one edge of the stream and passing out at the other. When the passage of this stream is continuous, these points would be mere points forming a line, but the same principle will be true if they are an inch square or six inches square—subject however to any irregularities which might exist in the area taken, hence if a row of six inch squares be taken extending across the spray in the direction in which the spray has been moving, and the nozzle being held perfectly still be allowed to discharge liquid for one second on these squares, the whole amount of water which would fall on this row would represent the amount which would fall on each square in the row in one whole passage of the stream at the rate of six inches per second. But this square is any square in the row and this row of squares is any row lying in the direction in which the stream is passed. Consequently if a series of these rows be placed side by side extending clear across the spray and the nozzle being held perfectly still be allowed to discharge on them for any given time, then a comparison of the whole amount falling in each row with the amount falling in each other row would show the proportional amount which would fall in each square in a row of squares at right angles to the line of passage. But a series of these second rows would represent all the surface passed over, which is the object desired.

In actual spraying the stream is frequently not passed clear across the surface sprayed for when the outside edge of the foliage is reached it stops. Owing, however, to the fact that the foliage is thinner there than towards the center I have not considered this factor, since it would vary with every case.

As is indicated above the apparatus used in making this test consisted of a quantity of square, galvanized iron cans or boxes, measuring six inches each way. These cans were made by the local tinner with the edges at the top turned down inside to prevent their being easily bent out of shape. They were sufficiently true that they could be placed side by side without leaving any appreciable spaces between. Trial showed that even on the calmest days there was some breeze outside which diverted the spray, possibly to a harmful extent, so the central room of the greenhouse was used for this work. This place with the doors closed gave a quiet atmosphere and was high enough for the purpose.

A flat platform was first constructed in the center of the room to set the cans upon. Next staging was erected and a platform laid fourteen feet above the first with an opening four of five feet across in the center. Down through this opening and fastened to the roof at the top, a strip was placed, with an arrangement to clamp a nozzle at the lower end. This strip was so arranged that it could be moved up or down and fastened at any height. The system of pipes shown in Figure I was set up just above the upper platform and connected with the city waterworks. A hose from hose cock to nozzle completed the arrangement. Each nozzle was placed so the distance from the mouth of the nozzle to the top of the cans below was the best spraying distance of the nozzle as determined in test I. The water in each case was allowed to run until those cans receiving the most were nearly full. The depth of the water in each can was then carefully measured and recorded. This test manifestly gives the boundary of the spray within six inches and further for the reasons already given, by a comparison of the added quantities in each row it can be seen how near the nozzle comes to spreading its liquid evenly over the sprayed surface. For lack of space the results are given only added one way, that is, with the spray having one side to the front. Where the cross section of the stream does not approximate a circle the rows are taken the shortest way across and where the cross section is round they were taken just as they came.

These results have been co-ordinated in the form of diagrams which are given in Figures III, IV, V and VI. These diagrams also show the shape of the cross section of each stream with figures attached showing the size.

As will be seen by a glance at the figures, most all of the nozzles seem to be deficient in this particular. This suggests to the man directing the spray that in place of passing the stream directly across the foliage he give it a rotary motion, and let the edges lap over to even up irregularities and give better distribution.

III. SIZE OF THE DROPS.

For determining this point logwood was used and a half barrel of brownish black ink was made neither thick nor viscous. This fluid was pumped through each nozzle with a pressure sufficiently high to throw the best spray the nozzle was capable of throwing. This spray was directed against blank sheets of paper placed at the proper distance for the best spray. It was intended to have the spray in each case bear upon the paper for the same length of time, but it was found that with most of the nozzles to keep the drops from being so numerous as to merge together the time had to be made so short that accurate timing was impossible. Therefore the spray was merely passed rapidly across the paper. These papers were photographed and

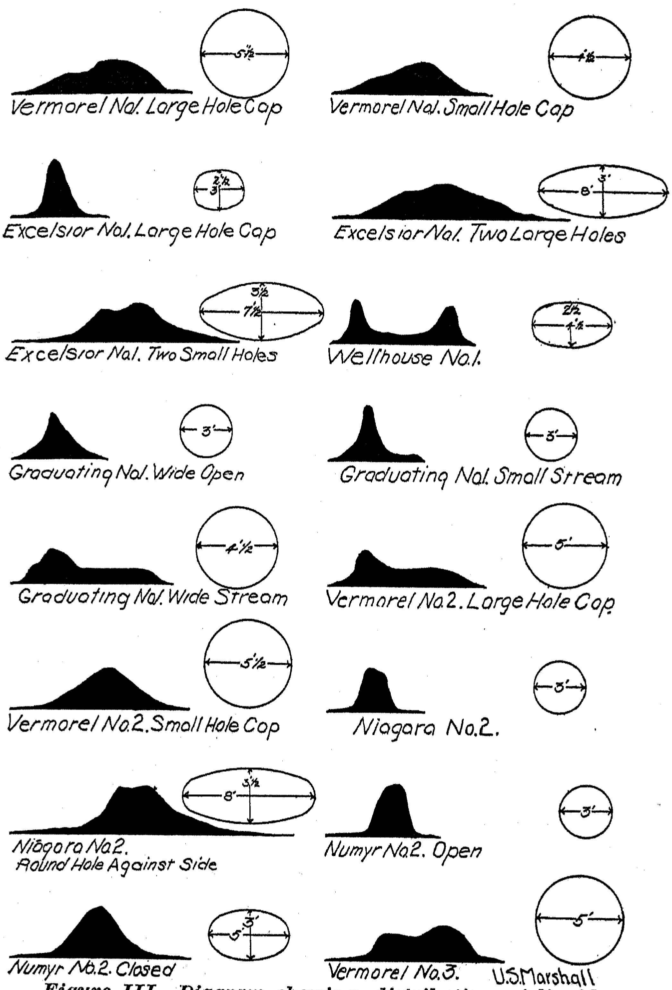

Figure III. Diagram showing distribution of liquid over sprayed surface and cross section of spray.

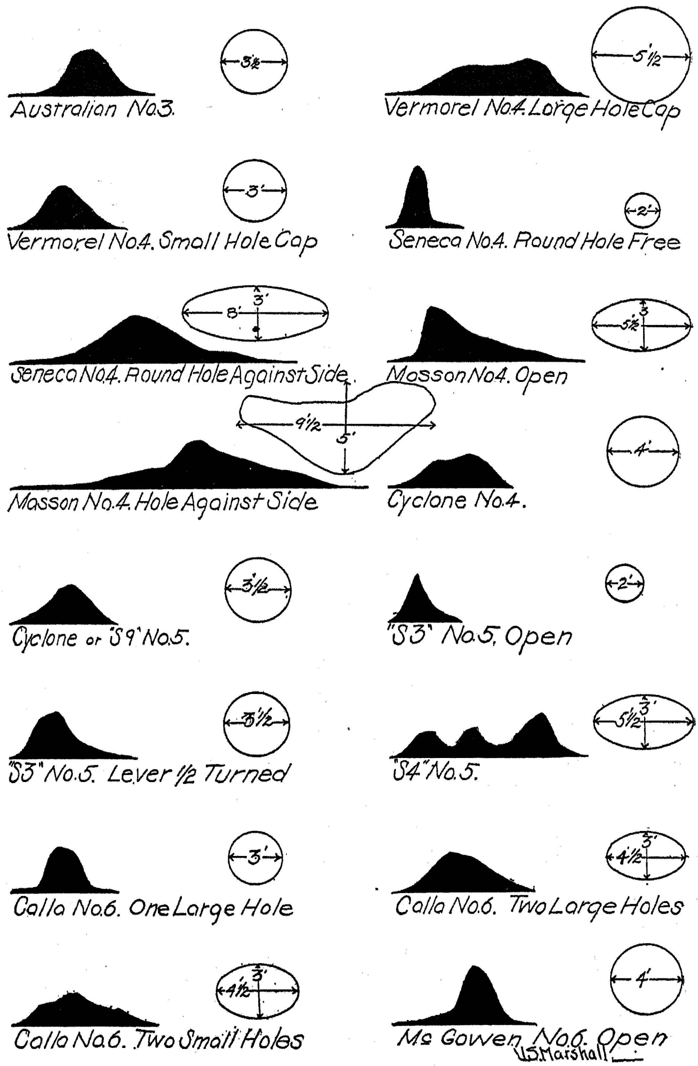

Figure IV. Diagram showing distribution of liquid over sprayed surface and cross section of spray.