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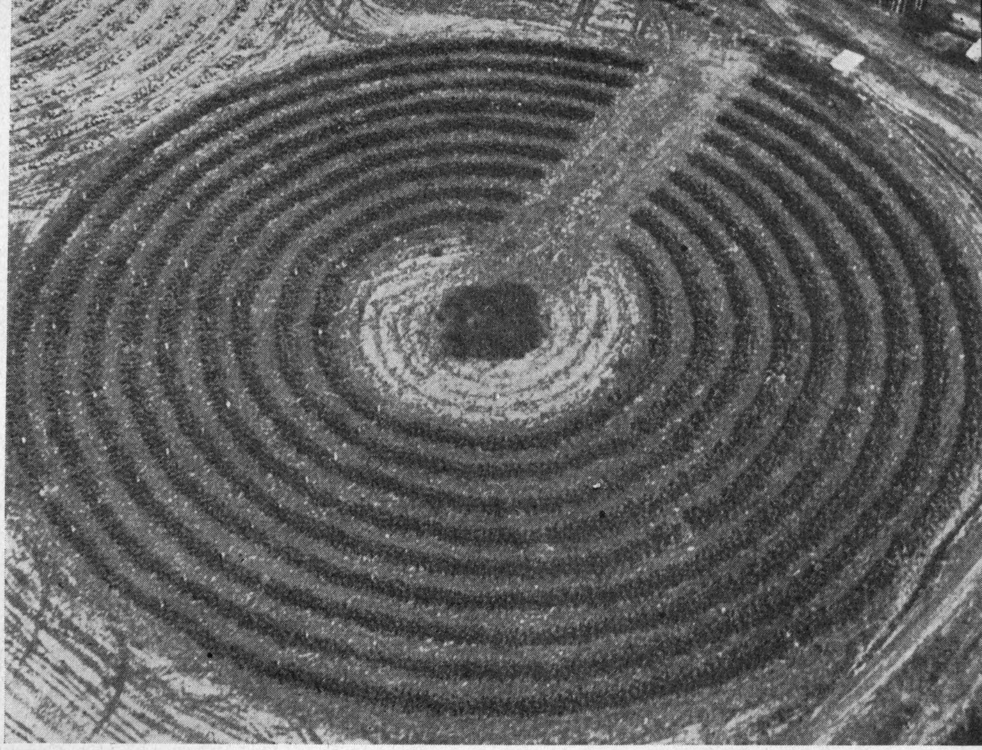

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SPIRALLY ARRANGED PLOTS IN A DESIGN FOR FIELD ASSAY OF FUNGICIDES

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Cover *Illustration*. **View of a spiral of celery. Photograph taken from a helicopter.**

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Spirally Arranged Plots in a Design for Field Assay of Fungicides

James G. Horsfall and Saul Rich[1]

Drudgery makes life hard for the investigator of the protective action of fungicides in the field. This paper, a companion piece to those already published on laboratory assay of fungicides (1-6, 8), will describe a technique which has eliminated for us some of this toil.

The primary source of drudgery in the field assay of fungicides is distance. If many treatments could be tested on a single plant, distance would not be a factor. Many treatments mean many plants, even if only one plant per treatment is necessary. The more plants there are, the farther apart they must be, the more heterogeneous is the soil, the more variable is the inoculation, and the farther the spray and spray machinery must be toted.

The more heterogeneous the plants are, the more plants there must be to compensate for the differences. When more plants are used, the plots must be spaced still farther apart and the chance for differences becomes greater. The more plots the operator must spray, the farther he must be from his supplies, the longer the distances to be travelled and the greater is the drudgery.

In our attempts to reduce drudgery, we tried various expedients before arriving at the technique to be described. Sifting through our trials and errors, some of the principles of the design now become evident.

To overcome the distance effect, the experimental area was limited, so that everything else had to be scaled accordingly. A spraying device was required that was adapted to small amounts of materials, that was autopowered and light in weight, and that was capable of easy and rapid change of materials. The size of the plots and the mean distance between them had to be kept to a minimum. We found that the plots in this design could be as small as 10 feet long and one row wide.

By the laws of geometry, the mean distance between plots in any given area is the least within a circle. Therefore, if the field plots are arranged within a circle, the differences between plots and the amount of travel will be reduced to the minimum amount consistent with the number of treatments to be used. Not only are soil differences reduced, but the distance that the fungus must spread after its establishment is also reduced to the minimum. This last point is particularly important in view of the fact that disease decreases logarithmically with distance from the primary source of inoculum as Zentmyer, *et al.* (11) have shown.

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SUITABILITY OF SPIRALLY ARRANGED PLOTS

The arrangement of plots along an Archimedean spiral within the circle (cover) has proved to be a practical method of planting and cultivating.

The spiral arrangement has other interesting possibilities to reduce distance as listed below:

1. The spray machine can be spotted at the center of the spiral. At that point it is the closest to the average plot that it can ever be.

2. The spray machine can be stationary. This saves the operator's muscles.

3. A rotating boom may be used to support the spray hose. This also saves energy and delivers spray equally to all plots within the circular area.

4. The travel between the last replicate of one treatment and the first replicate of the next treatment is negligible because the first and last replicates, being on a circle, are contiguous.

5. Irrigation is accomplished by the use of a rotating overhead sprinkler placed at the center. With plants in a spiral, there are no dry corners.

6. The overhead irrigation helps spread the test organism and keeps the plants wet following inoculation.

7. The spiral arrangement helps to minimize the effect of spray drift because there are a minimum number of plots crossing the direction of the prevailing wind.

8. Planting and cultivation is simplified in a manner to be described.

9. The spiral arrangement of small plots yields data having a high order of precision.

PLANTING THE SPIRALS

Each spiral is 80 feet in diameter. Each has at its center riser pipes for water supply and for drainage. The drainage riser serves as the locus for the establishment of the spiral each year. The planter or marker is tied to a cable that winds around a fixed drum which is anchored to the drainage riser at the center. Planting begins in a clockwise direction at the periphery of the spiral and as the planter goes around the center, the cable winds on the drum and pulls the planter inward at a uniform rate. The drum used at the Mt. Carmel Experimental Farm is 11.1 inches in diameter. This establishes a three-foot interval between laterally adjacent plots. Nine complete revolutions are made around the pivot leaving a central working area 26 feet in diameter. This planting procedure produces a continuous spiral row which can be broken into single row plots. It has been possible to lay out and plant five spirals of beans with a hand-pushed planter in a single afternoon.

A 10-foot roadway is left from the outer edge to the center of the spiral for moving in the trailer-mounted sprayer. After subtracting the space for the roadway, each spiral contains 1,320 feet of plants or exactly one-fourth mile. This turns out to be a convenient number. By making each plot 10 feet long, there are 132 plots. By using four replicates, there are 33 plots each. Taking out one for a non-treated check, 32 are left. Thirty-two is still a very useful number because it is divisible by 32, 16, 8, 4, 2 and 1. From that, one can use numerous combinations: 32 treatments, one dose each; 16 treatments, two doses each; 8 treatments, four doses each, or any combination thereof.

The plots are randomized in each quadrant, making four replicated wedge-shaped blocks. The arrangement is such that the first plots in each row are in a straight line at the beginning of the first and third quadrants, but form a "sawtooth" design at the beginning of the second and fourth quadrants.

CULTIVATING THE SPIRALS

The spirals may be cultivated by a wheel hoe or a close-coupled garden tractor. Mulching between the rows reduces soil compaction and weed growth, thus keeping cultivation to a minimum.

WATER SUPPLY

When the spirals were first tried, water from the nearest hydrant was delivered to the spiral with garden hose. The spirals now have permanently installed underground water pipes of ½-inch galvanized or black iron, placed at least 2½ to 3 feet beneath the ground surface so as to avoid the plowshare during plowing. These pipes are laid so that they will drain away from the spirals and, at convenient locations, there are plugs for drainage of the pipes during the winter months.

SEWAGE SYSTEM

A simple sewage system which has been used successfully is a dry well or sump into which the excess spray material is drained directly from the spray tank. The used dry well may be cleaned out at the end of the season and refilled with clean soil in order to avoid poisoning the land. Permanent drains of 1¼-inch pipe have now been installed below the plow sole. These drain pipes run from the center of each spiral downgrade to the sump, then into a tile line and from there into a permanent dry well which is located under one of the farm roads. This location for the permanent well prevents the poisoning of the ground under cultivation.

IRRIGATION

A valve and plug arrangement in the sump (Figure 1) allows the same pipe to be used either for drainage or for irrigation. The drain pipe is connected to the water system through the valve. The drainage plug is placed on the spiral side of the valve. For drainage, the valve is closed and the plug taken out so that the waste chemicals can drain from the spiral into the sump and then into the tile. To irrigate, the plug is placed in position and the valve opened so that the water runs up through the pipe to the center of the spiral. For irrigation, the sprayer is removed and a revolving type overhead irrigator is placed on the drain riser. Water is applied at night when there is less wind and, hence, less variability in the overhead irrigation. The irrigation is controlled by means of a time-clock on a motorized valve.

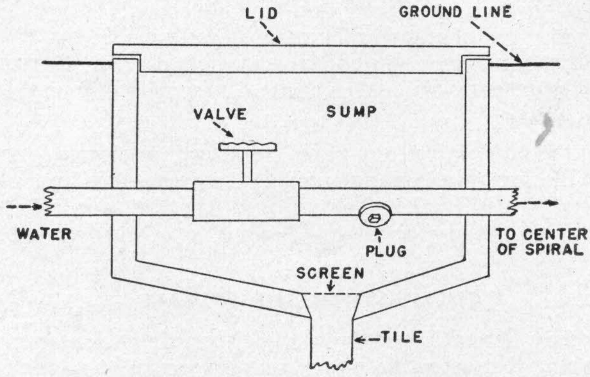

Figure 1. Diagram of valve and plug arrangement at the sump. Valve is open and plug is in when the line is used for irrigation. Valve is closed and plug is out when the line is used for drainage.

SPRAYING EQUIPMENT AND TECHNIQUE

The sprayer is a restyled John Bean, cub model, equipped with a pump with a capacity of six gallons per minute, and mounted on a rubber tired trailer so that it may be moved from spiral to spiral.

It is provided with two 15-gallon tanks, making it possible to mix in one tank while spraying from the other. Each tank has an external glass gauge calibrated in gallons. This allows a direct reading of the volume of

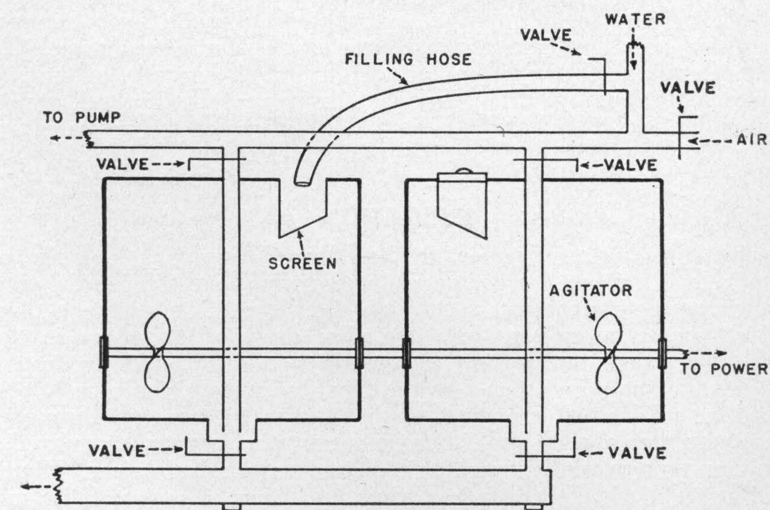

Figure 2. Diagram of spray tank piping. Note location of valves.

liquid within the tanks, which is useful in making dilutions. The sprayer must be level if these gauges are to be accurate. Therefore, the sprayer is equipped with two leveling bubbles at a right angle for horizontal leveling, both laterally and longitudinally.

The drainage runs down from each tank through valves into a single pipe attached by means of a 1¼-inch rubber hose to the drainage riser in the center of the spiral. Likewise, the suction lines from each tank connect through valves to the pump (Figure 2). The suction lines also connect through valves to the incoming water line for flushing. Another valve admits air to the pump for clearing out spray material and flush water. Finally, a short length of ½-inch garden hose to the water line permits the operator to wash the spray materials through a screen into the tank. All valves are the so-called lever-action, quick-acting type.

The spray must be delivered to all parts of the spiral, including the periphery, 40 feet from the center. This is accomplished by supporting the spray hose in an overhead cantilever aluminum pipe which is free to rotate (Figure 3).

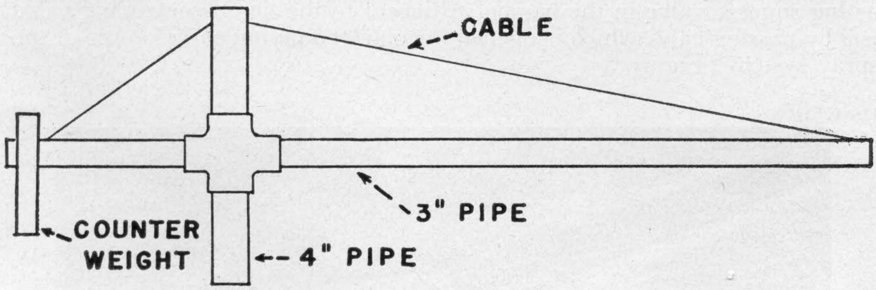

Figure 3. Diagram of boom used to hold spray hose above the plots.

The long arm of the boom is 20 feet. This is about the longest practicable dimension. The spray hose passes through the inside of the aluminum pipe. Where the hose enters the bottom of the upright support, it is provided with a swivel connection so that the boom can rotate freely. The hose extends about 22 feet beyond the end of the boom so that the operator can reach the outermost plant 40 feet from the center. A second swivel connection located at the point where the hose leaves the outer end of the boom prevents the hose within the boom from twisting as the boom rotates.

The boom is mounted as an integral part of the sprayer so that it can be transported with the sprayer. It is mounted six feet above the ground to allow head clearance for the operators.

Any hand-held spraying device may be used with the spiral equipment. At Mt. Carmel, various types of sprayers are used. One of these is a three-nozzle sprayer with one nozzle directed vertically downward, and the other two nozzles directed horizontally inward (Figure 4). This device is used when the material being applied is already in a wettable form and readily available. The three-nozzle sprayer is controlled by a quick-

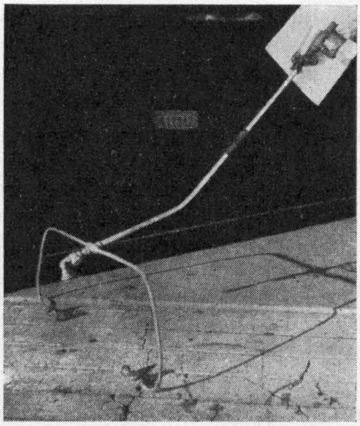

Figure 4. Three-nozzle spraying device. Top nozzle sprays downward. Side nozzles spray inward.

acting squeeze valve in the handle. Adjacent to the liquid-controlling valve is a by-passing valve which is opened for quick emptying and cleaning of the spray system (Figure 5).

Figure 5. Close-up of valves on handle of three-nozzle sprayer. Squeeze valve at top is for controlling flow of spray to nozzles. Valve pointing downward is opened to release pressure during cleaning of the pump and line system.

Drift, the bugaboo of so many field experiments, has been found to be negligible in our trials. Spring-loaded check valves (Figure 6) are placed immediately behind each of the three nozzles. When the spraying is being

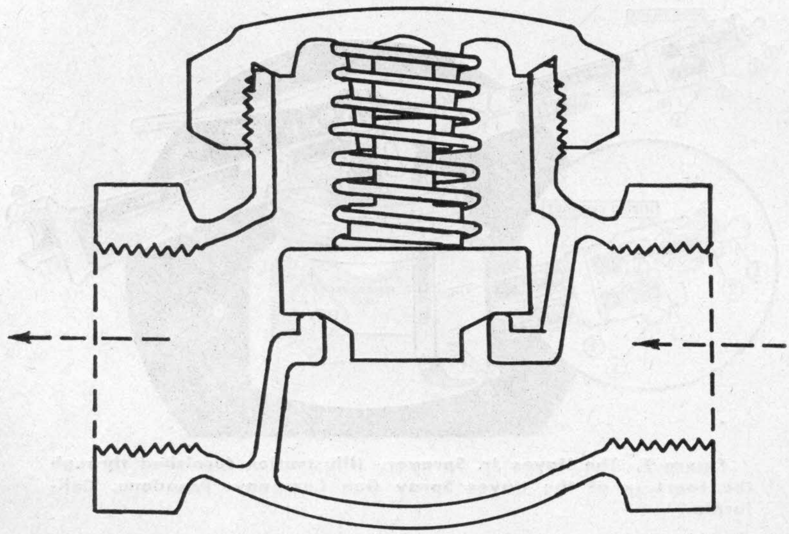

Figure 6. Drawing of a spring-loaded check valve. (Diagrammatic sketch from an illustration furnished through the courtesy of Jenkins Brothers, Manufacturers of Valves, Bridgeport, Connecticut.)

done, the pressure of the spray liquid compresses the springs, forcing open the valves and allowing the liquid to pass through the nozzles. When the spray material is shut off, the pressure of the springs forces the check valves closed and thus prevents any drizzle from the nozzles as the operators move from plot to plot.

The lessening of the drudgery has allowed for much more accurate spraying throughout the whole spray period so that the treatment effects cut off sharply at the plot terminals. Season after season, good treatments next to ineffective treatments stand out clearly, with no apparent drift effect in any direction. The lack of drift error may be explained by: (1) accuracy in spraying; (2) the use of the spring-loaded check valves to prevent drizzle, and (3) the fact that the smaller sized droplets, which tend to drift the most, do not stick to foliage, but actually bounce (10).

The Hayes Jr. sprayer, another spraying device used in the spirals, helps solve two of the serious problems in field testing of new organic compounds: (1) poor wettability and (2) insufficient quantity of sample. Usually an attempt is made to answer the first problem by formulating the compounds with wetting and suspending agents. In such cases the researcher cannot distinguish the inherent performance of the material from the performance of the formulation. The usual solution for the second problem is to wheedle additional material from the chemists.

The Hayes Jr. sprayer (Figure 7) is a liquid proportioner designed primarily for home gardeners, and intended for use with garden hose. This sprayer has a small reservoir from which the spray concentrate is injected into the water stream near the nozzle by means of a Venturi jet. The non-wettable materials can be dissolved in acetone, isopropyl alcohol,

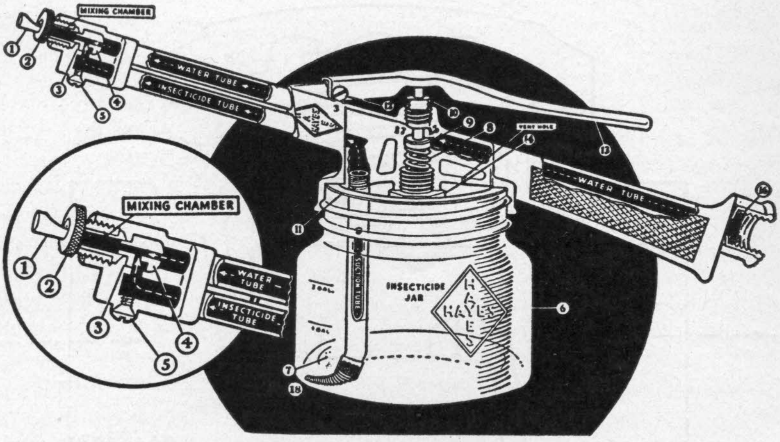

Figure 7. The Hayes Jr. Sprayer. (Illustration furnished through the courtesy of the Hayes Spray Gun Company, Pasadena, California.)

or some other suitable organic solvent, and are conveniently suspended in water by the sprayer at the Venturi jet immediately prior to deposition on the plant. Spraying check plots with solvents alone has demonstrated no adverse effects from these materials. The Hayes sprayer should be carefully cleaned and calibrated before each use and cannot be used with gummy materials which would clog the small Venturi hole.

The use of the Hayes sprayer, or any other liquid proportioner, makes possible the application of materials without complex spray rigs. As pres-

Figure 8. Spraying the spiral plots.