IN COOPERATION WITH COLORADO STATE UNIVERSITY
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The Gates-Type Greenhouse Irrigation System: Design and Problems [1]

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Polyethylene sprinkler irrigation systems used for greenhouse production are often poorly designed. Excessively large main delivery pipes and excessively small lateral sprinkler pipes are common. Sprinkler misting due to poorly designed nozzles and excessive nozzle pressure results in spread of disease and leaf damage—particularly if the bench is watered daily or more often. Large pressure differences between upper and lower ends of small laterals result in large differences in discharge between nozzles and low water distribution efficiency. Not much can be done about nozzle design until manufacturers see fit to change. However, by limiting maximum nozzle pressure to 4 psi, the misting problem can be controlled. If the bench is much wider than 38 inches, more than two lateral sprinkler pipes may be required for complete coverage at these low pressures. Nozzle placement with respect to the plants becomes critical, with the Weirich spacing probably best for carnations in inert media.

The Gates-Type Nozzle

The advent of inert media for greenhouse production requires increased attention to the details of irrigation practice. Among these is proper nozzle spacing and nozzle pressure. As pressure decreases, full spray patterns are difficult to obtain. The closer tolerances needed for irrigation of inert media required that the presently available nozzles be examined for performance and delivery rates so that the entire system could be properly designed. Four types of polyethylene nozzles were examined (Figure 1). Two, designated as "green" and "black," are standard nozzles readily available in Denver. Another nozzle, "white," is of South African manufacture, and a "red" nozzle is a recent import. The four nozzle types, together with the early brass nozzle, are shown in Figure 1. Four nozzles were selected at random from each type, and the water delivery over the pressure range between 1.0 and 15 psi was measured for each nozzle. The variation between nozzles in each type (color) was examined, as well as the differences between types.

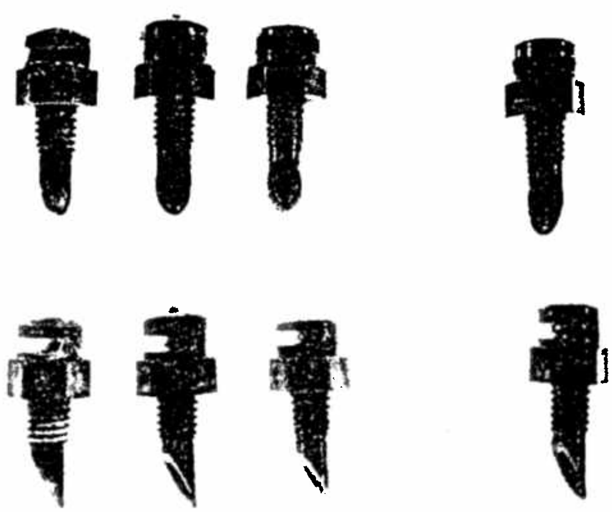

Fig. 1—Various types of gates nozzles. From left to right (top and bottom): Early brass type, standard "black", "red" import, "white", and standard "green" nozzle.

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The probability of significant discharge variation between nozzles within a type ranged from 33 percent for "red" nozzles to 6 percent for "green" nozzles. In most cases these variations are not likely to cause difficulty in system design. The results for the four nozzles of each type were combined to give a mean regression equation by which, for any pressure, the flow rate can be calculated (Figure 2). The correlation coefficients ranged from 0.997 to 0.972, and the standard deviation of flow rate from 0.16 to 0.21. The "green" nozzle had flow rates very similar to the "black" nozzle with slightly less delivery at high pressures; therefore, only the "black" nozzle is discussed here.

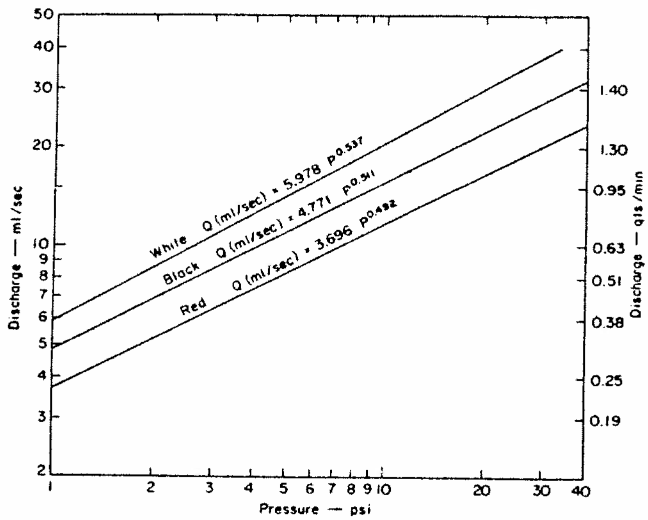

Fig. 2—Logarithmic pressure-discharge relations for nozzles tested.

There was significant variation in discharge between nozzle types. Figure 3 shows the relationship between pressure and discharge, plotted linearly, for each nozzle type. The "white" nozzle was characterized by a full 180° pattern at pressures as low at 1.0 psi, the highest delivery at all pressures, less clogging, and easy adjustment of the horizontal spray angle by bending its cap. The "red" nozzle was unacceptable, since it did not achieve a reasonable spray pattern until pressures exceeded 10 psi, was prone to pattern irregularities, and was readily clogged by debris in the water supply. The "black" nozzles required an intermediate pressure to develop a full 180° pattern, and were not as desirable as the "white" with respect to discharge, clogging, and spray characteristics.

Examination of the nozzles revealed two significant differences between the "white" and all others. First, the bore through the stem of the "white" nozzle was uniform in diameter throughout its length. All others had a narrower outlet than inlet, which increased the chances of clogging. Second, the bore of the "white" nozzle was in front of the back plate, whereas all others had the outlet recessed into the back plate. The deeper this outlet was recessed, the higher the pressure required to obtain a 180° spray pattern. Figure 4 shows the three major types with the caps cut back to show the outlet. The hole in a "black" nozzle was reamed out with a 5/64-inch drill, and a portion of the back plate cut away with a hacksaw in order to bring the outlet ahead of the plate. After smoothing the surfaces against which the water impinges, this modified "black" nozzle performed nearly identically to the "white" type and developed a fully acceptable spray pattern at pressures less than 3 psi.

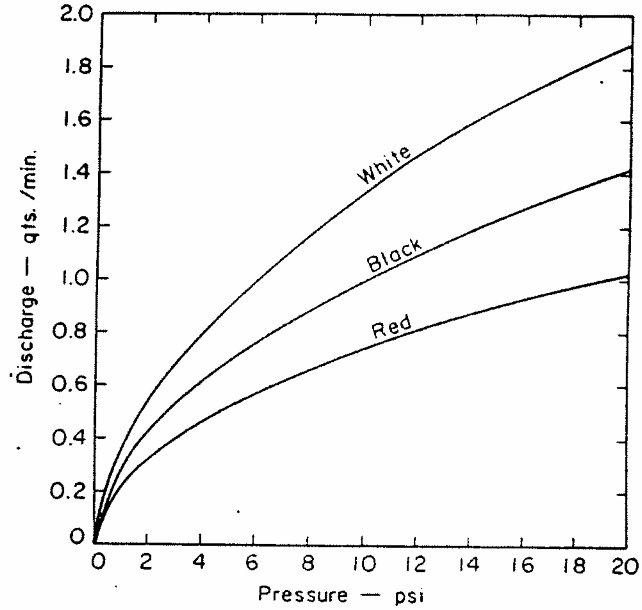

Fig. 3—Linear plot of pressure-discharge relations.

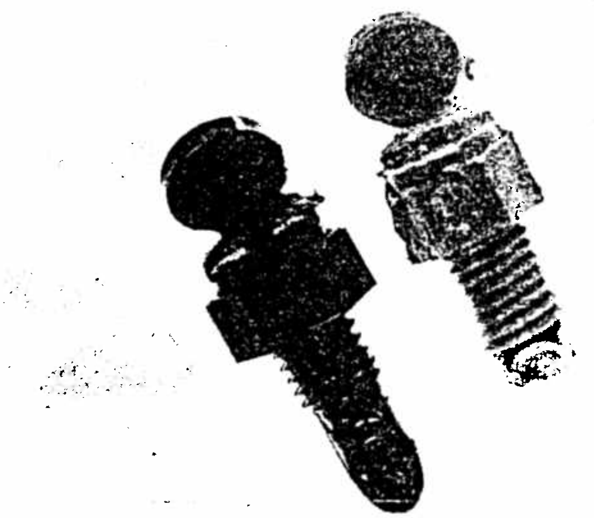

Fig. 4—Partial cut-a-way of "white", "black", and "red" nozzle types. Note that in the "black" and "red", the inlet is larger than the outlet, and that outlet is recessed into the back plate.

The Pipe System

Sprinkler irrigation systems for greenhouse production are unique from two aspects. First, proper operations requires very low nozzle pressures. Second, the allowable operating pressure range is very narrow. With currently available nozzles, complete spray patterns capable of covering the bed area are not developed below about 2 psi. Pressures in excess of 4½ psi result in misting or fogging with attendant undesirable effects.

Because of the low pressure drop desired, relatively large lateral sprinkler pipes are required. The nomograph of Figure 5 was prepared, using the characteristics of the "white" nozzle, to show the relation between length of run, nominal pipe size, nozzle spacing, and maximum pressure attained at the first nozzle (upper end). In all cases, the minimum pressure (last nozzle) was selected to be 2 psi.

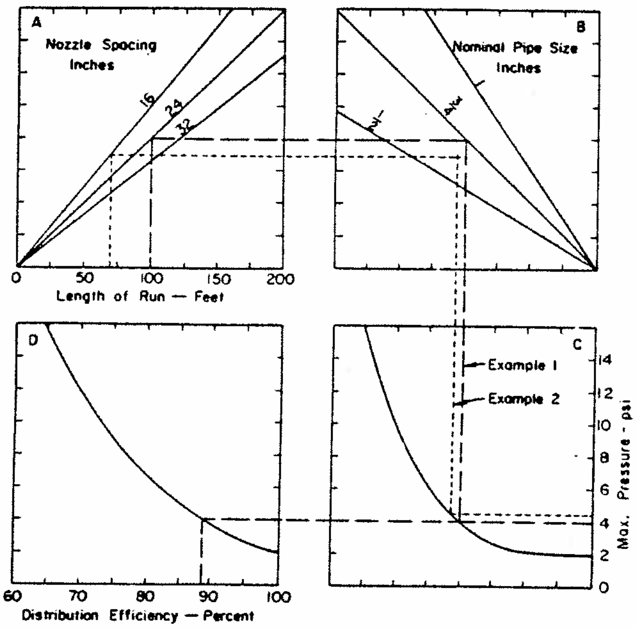

Fig. 5—Nomograph showing relation between length of run, nozzle spacing, pipe diameter, maximum nozzle pressure, and distribution efficiency for "white" nozzle.

Decreasing the nozzle spacing has the same effect as decreasing the pipe diameter. Doubling the number of nozzles increases the pressure drop in the lateral about four times. Thus, a larger lateral pipe is needed if nozzles are space closer together.

Figure 5 also illustrates the maximum attainable irrigation efficiency as affected by maximum nozzle pressure. Because of higher pressures at the upper end of the lateral, nozzles on that end will have a higher flow rate than nozzles on the lower end. Thus, if the system operates long enough to adequately irrigate the lower end of the bed, excess water is applied at the upper end of the bed. The amount of excess increases (i.e., efficiency decreases) as the maximum nozzle pressure increases. As an example, Figure 5 shows that a 150 foot bed, with nozzles space 24 inches apart on a ¾-inch lateral, will have a maximum pressure of 10 psi and 72 percent efficiency. The same system using 1-inch laterals will develop a maximum nozzle pressure of 4 psi and operate at 89 percent distribution efficiency.

The two examples following will illustrate the use of Figure 5: **Example 1.** Suppose a grower wishes to install a sprinkler system, with nozzles 24 inches apart, on 100-foot beds. What will be the maximum pressure and the distribution efficiency if ¾-inch lateral pipe is used?

SOLUTION: Enter graph A of Figure 5 at 100 feet (the length of the bed). Follow vertically upward to intersect the line representing 24-inch nozzle spacing. From this point of intersection, project horizontally to the line representing ¾-inch pipe size on graph B. Project downward to intersect the maximum pressure curve in graph C. From this point, project horizontally to the right to read the maximum pressure 4 psi. From the same point of intersection, project horizontally to the left to intersect the efficiency curve in graph D; then project downward to read the distribution efficiency, 89 percent.

Thus, the system as proposed will operate between 2 and 4 psi at all nozzles, with an efficiency of 89 percent.

Example 2. Suppose a grower wishes to install a system, with 16" nozzle spacing, on beds 70 feet long. The maximum desirable pressure is 4.5 psi. What diameter lateral must be used?

SOLUTION: Begin as in example 1, projecting upward from the 70-foot length of run to the 16-inch spacing, then across into graph B. From graph C, begin at 4.5 psi and project to the left to intersect the pressure curve. Project upward from this point of intersection into graph B. The intersection of the two projections into graph B gives the required pipe size. In this example, the intersection falls above the line representing ½-inch pipe. Therefore, the proper lateral size is ¾-inch.

Since nozzle discharge increases with nozzle pressure, higher total flow rates to the bed are required for the smaller diameter laterals. Figure 6 shows the total flow rate to a bed with two laterals. Continuing with example 1, Figure 6 shows that the total flow to the bed (24-inch nozzle spacing) will be about 15.5 gallons per minute.

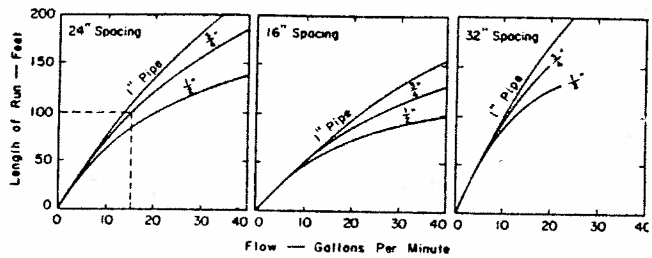

Fig. 6—Total flow to bed as a function of length of run, nozzle spacing, and pipe diameter.

High nozzle pressures and resultant high flow rates require relatively high pressures at the main delivery line. Low main pressure will result in low flow rates and lower nozzles on the bed will not have adequate pressure to develop acceptable spray patterns. Figure 7 shows the relation between total flow to the bed and required main line pressure. In all cases, the valve and header line are the next pipe size larger than the laterals. The size of valve and header is a very important design consideration. For example 1, if a 1-inch header and valve are used, the required line operating pressure will be 9 psi. However, if a ¾-inch valve and header are used, the required line pressure will increase to about 16 psi. Although excessive pressure drop at this point does not affect nozzle performance, it does reduce the number of beds that can be irrigated simultaneously from a given water supply system.

Conclusions

It is ironic that we have been using inadequately designed irrigation systems for nearly twenty years. Present nozzle types are no better than the old brass nozzles. It was not until changes were made in cultural procedures, where requirements are more stringent, that we began to see the damage resulting from these poorly designed systems.

The studies presented here should provide a means

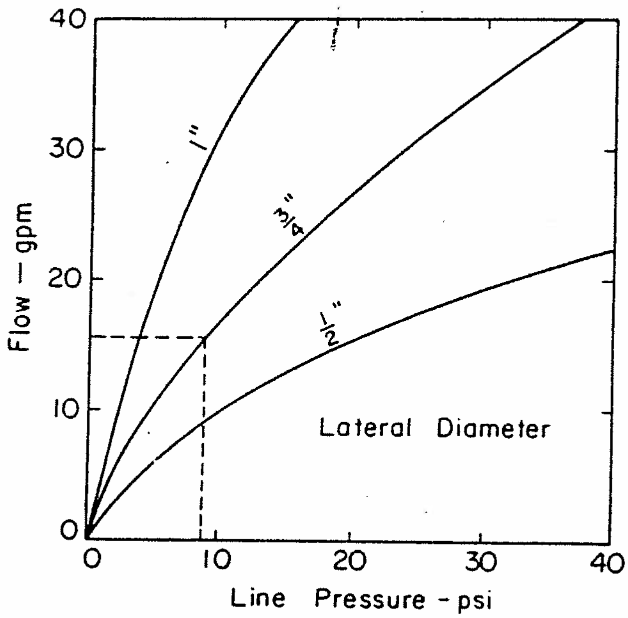

Fig. 7—Required line pressure as a function of total flow rate and lateral diameter.

for approaching the design of greenhouse sprinklers on a logical scientific basis. It should be emphasized, however, that Figures 5 and 6 present their data specifically for the "white" nozzle. Use of these figures with "black" (or "green") nozzle may result in a slight overdesign of the lateral pipe system. Table 1 illustrates the maximum length of run for each pipe size to maintain nozzle pressures within the range 2 to 4.5 psi.

Table 1. Maximum length of run for common lateral sizes.

Lateral Pipe Size	Length of Run: Black Nozzles	Length of Run: White Nozzles
	FEET	FEET
½	75	65
¾	125	110
1	190	160

The pressures and flow rates will be affected to a certain extent by the condition of the pipe, care in constructing the system, and brand of valves used. Therefore, the values obtained from the accompanying graphs should be used only as a guide.

Also note that the lengths given on the graphs refer to length of run, or the distance from the delivery system to the last nozzle on a line. Therefore, these figures may be applied to longer bed lengths if water is delivered to the center of the bed. For example, a 100-foot bed, with main line across the center of the bed, can be treated as two 50-foot beds. In such a case, however, the valve and header should be two sizes larger than the lateral line (i.e., one-inch valve on one-half inch lateral) if both ends of the bed are irrigated through one valve.

Your editor,

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