

WATER MOVEMENT IN MULCHED BEDS IN A ROCKY SOIL OF MIAMI-DADE COUNTY

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Abstract. Efficient irrigation and fertilizer management for vegetables grown with plasticulture requires an understanding of water movement in mulched beds. Soluble blue dye and controlled irrigation events were used in a dye test conducted on 14 October 2003 on a Krome very gravelly loam soil in Homestead, Fla. The objectives of this study were to visualize the wetting patterns of several drip tapes and provide guidelines for scheduling irrigation. The dye test consisted of preparing mulched beds with different drip tapes, injecting dye, irrigating with a predetermined volume of water (V), digging longitudinal and transverse sections of the beds, and taking measurements of depth (D) and width (W) of the wetted zone, and emitter-to-emitter coverage (L). Drip tape brands were Aqua-Traxx [12-inch emitter spacing (ES); 22 gal/100ft/h], Eurodrip (12-inch ES; 35 gal/100ft/h), Netafim (12-inch ES; 24 gal/100ft/h), Queen Gil (4-inch ES, 33 gal/100ft/h), and T-Tape (8-inch ES, 21 gal/100ft/h). After digging, dye patterns appeared as blue rings under each emitter. Increasing V from 21 to 142 gal/100 ft did not significantly increase D, W, and L. All measurements ranged between 4 and 9 inches. For each drip tape, increasing V significantly increased W, but only within the narrow 4 to 9

inch range. After 2 to 3 hours of irrigation, the dye reached the calcium carbonate bedrock and moved into it thereafter. Hence, the flow rate and emitter spacing had no practical effect on the wetted zone of this rocky soil, possibly because of shallow soil depth (7 to 10 inches) and high soil heterogeneity.

The vegetable acreage in Miami-Dade County is approximately 40,000 acres (Degner et al., 2001). Vegetables are grown on both calcareous marl and rocky soils, which are characterized by very low nutrient and water holding capacities, an alkaline pH in the 7.4-8.4 range, and levels of calcium carbonate (CaCO₃) ranging from 1% to 100% (Li, 2001). Soil profiles of rocky soils appear as a 4 to 10 inch thick layer of crushed limestone particles over the porous limestone bedrock. In these shallow soils with high water table (2-to-4-ft-deep), frequent applications of water and fertilizer are needed to ensure rapid growth and economical yields of vegetable crops.

Scheduling irrigation for vegetables grown on sandy or rocky soils typically consists of knowing when and how much water to apply in a way that satisfies crop water needs, maintains soil water tension between field capacity and 15 kPa at the 12-inch depth, and prevents nutrient leaching (Simonne et al., 2003a). Irrigation scheduling requires a target water amount adjusted to weather condition and crop growth, a measure of soil moisture, a method to account for rainfall contribution to soil moisture, and a rule for splitting irrigation (Olczyk et al., 2002; Simonne et al., 2003a). Splitting irrigation is needed when the scheduled volume of irrigation exceeds the amount of water that can be stored in the root zone (Clark and Smajstrla, 1993). In practice, splitting irrigation has to be a compromise between two constraints. On one side, the more frequent the short irrigation, the less likely soluble nutrients are to be leached below the root zone. On the other side, frequent and short irrigations may waste water and reduce irrigation uniformity due to a large portion of the irrigation cycle used for system charge and flush. In addition, each irrigation cycle has to deliver enough water to ensure complete wetting between two adjacent emitters to maintain crop uniformity, especially when the plants are small. For typical Florida sandy soils, the amount of water that can be stored in the root zone ranges between 48 and 72 gal/100 ft of bed (Simonne et al., 2003a). However, this estimate cannot be used for the coarse-textured soils of the Miami-Dade County and current irrigation recommendations do not specify how to split irrigation (Li et al., 2002).

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How much water can be stored in the root zone can be demonstrated by visualizing water movement in the soil using soluble dye (German-Heins and Flury, 2000; Simonne et al., 2003b). Blue dye and controlled irrigation conditions were used to visualize the wetting pattern of different drip tapes on a coarse-textured soil of southern Miami-Dade County where vegetable crops are grown. The main objectives of this project were to (1) describe the shape of the wetting zone for several water volumes applied by drip irrigation, (2) determine vertical, lateral, and longitudinal movements of irrigation for these water volumes, (3) quantify the relative volume of the wetted raised bed, and (4) provide guidelines for splitting irrigation.

Materials and Methods

A dye test was conducted at the Tropical Research and Education Center (TREC), in Homestead, Fla. on 14 Oct. 2003 on a 6-to-10-inch-deep Krome very gravelly loam soil. Before the day of the test, 150-ft-long raised beds were formed, and drip tape and polyethylene mulch were laid. Treatments were four drip-tape types and four irrigation durations (1, 2, 3, and 4 h). Selected drip tapes [emitter spacing (ES), nominal flow rate at manufacturer-specified operating pressure] were Aqua-Traxx (TORO Agricultural Irrigation, Bloomington, Minn.; 12 inches, 22 gal/100 ft/h), Eurodrip (Eurodrip USA, San Diego, Calif.; 12 inches, 35 gal/100ft/h), Queen Gil (Queen Gil Intl. Co., Jerusalem, Israel; 4 inches; 33 gal/100 ft/h), and T-Tape (T-Systems Intl., Inc., San Diego, Calif.; 8 inches; 20 gal/100 ft/h). Each bed received a different drip tape. The irrigation system consisted of a well, a pump, a back-flow prevention device, a fertilizer injector (model DI16-11, Dosatron, Clearwater, Fla.), a 150-mesh screen filter, a 10 psi pressure regulator, and drip tape. The dye test consisted of injecting the dye, irrigating with a selected volume of water, digging longitudinal and transverse sections of the raised beds, and taking measurements. After pressurizing the irrigation system, a soluble blue dye (TerraMark SPI High Concentrate, ProSource One, Memphis, Tenn.) was injected at a 1:49 (v:v) dye:water dilution rate for the first 30 min and at a 1:100 (v:v) dilution rate thereafter.

Digging was done immediately after completion of the test. For each treatment, a 4-ft-long longitudinal and two transverse sections were dug, which allowed us to take measurements on approximately four to 12 and two emitters, respectively. The shapes of the wetted zones were described qualitatively and quantitatively. Wetted zones were described as round (circular), elongated (true elliptic), rectangular (modified elliptic shapes due to the joining of the wetting pattern of two adjacent emitters), or irregular (when none of the above descriptions applied) (Simonne et al., 2003b). For the quantitative description of the wetted zone, depth (D), width (W), and length (L) were measured under each emitter as the longest vertical distance from the drip tape to the bottom of the blue ring, the horizontal length perpendicular to the bed axis at the widest point of the wetted zone, and the horizontal length parallel to the bed axis at the widest point of the wetted zone, respectively. Actual measurements were transformed into relative wetting measurements based on the greatest possible wetting lengths imposed by bed width for W (32 inches), soil depth for D (7 to 10 inches in this field), and emitter spacing for L. Depth, W, and L responses to water application rates were analyzed using ANOVA, Duncans Mul-

multiple Range Test, and linear and quadratic orthogonal contrasts (SAS, 2001).

Results and Discussion

Because initially concentrated dye was injected followed by diluted dye, the dye patterns in the soil appeared as a 1-inch-thick blue ring surrounding a lightly colored section of soil. The dye was easily distinguishable in the soil, but the contrast between the soil color and the blue ring was improved by allowing a 1-to-2-h drying period after digging. Diluted dye, instead of clear water, was injected after the initial concentrated dye injection to prevent losing the water front. In a preliminary trial in a nearby field, it was observed that clear water injected after the dye would flow through different soil channels and at times flowed deeper than (got ahead of) the blue dye. Hence, by injecting dye throughout the test, the position of the dye was a true representation of the position of the water front.

The wetted zones were irregular in shape for all apparent flow rates and lengths of irrigation. Gravelly textured soils are difficult to pack during bed formation, and water may flow irregularly following soil particles. Irregular wetted zone shapes

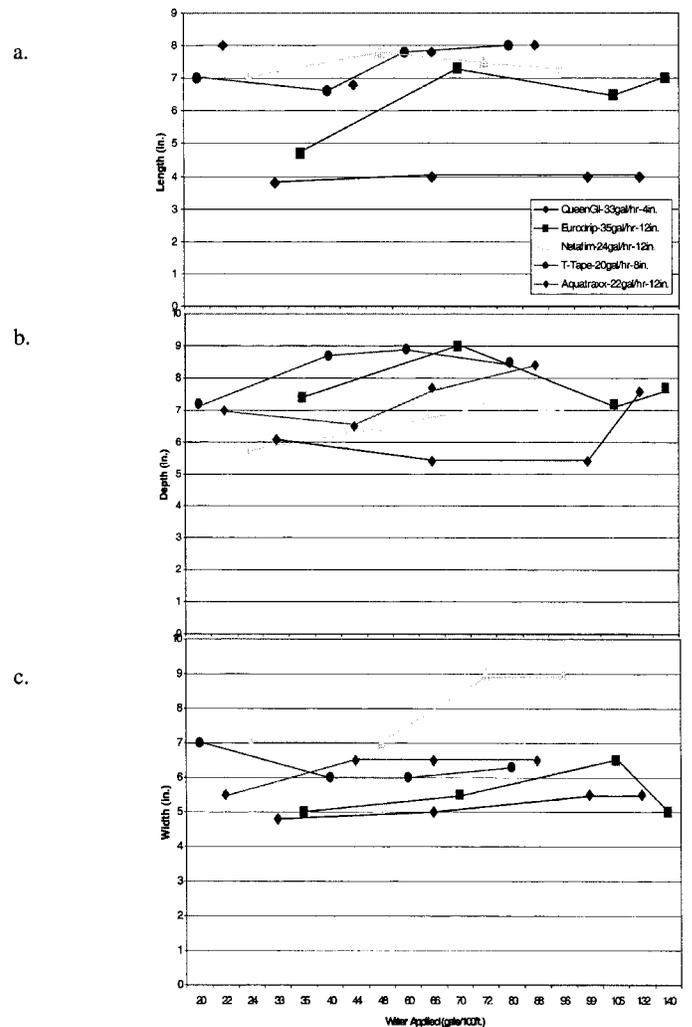


Fig. 1. Response of depth (a), width (b) and emitter-to-emitter (c) coverage to irrigation volume (V) for selected drip tapes on a Krome very gravelly loam of Miami-Dade County, Fla.

such as the ones observed in the Krome very gravelly loamy soil are in contrast with those observed in sandy soils, which tended to be round to elongated in the absence of an impermeable layer (Simonne et al., 2003b).

Increasing V from 21 to 142 gal/100 ft did not have a practical effect on D, W, and L (Fig. 1) as all measurements ranged between 3.8 and 8.0 inches. For each drip tape, increasing V significantly increased W, but only within the narrow 4-to-9-inch range. After 2 to 3 h of irrigation, the dye reached the calcium carbonate bedrock and moved into it thereafter. Once water reaches the bed rock, it become barely available to plants since roots do not colonize the bedrock extensively. Wetted zone widths ranging only between 4.5 and 8 inches illustrates the poor lateral movement of water in coarse-textured soils in the absence of an impermeable layer. Poor lateral movement seldom affects crop water uptake since seeds or transplants are usually placed within 6 to 8 inches of the drip tape. The most important implication of a limited lateral water movement is for fumigant application. Total bed wetting is necessary for the uniform application of fumigants that stay in the water phase such as potassium N-methyldithiocarbamate (K-Pam) and sodium N-methyldithiocarbamate (VaPam). These results support the need for narrow beds and two drip tapes per bed when complete bed wetting is needed.

Complete emitter-to-emitter coverage (L) was observed after 1 h of irrigation for the tapes with 4-inch or 8-inch emitter spacings (Fig. 1a). The highest L for the tapes with 12-inch emitter spacing was 8 inches, suggesting incomplete coverage.

The drip tape flow rates selected in this study ranged from 20 to 35 gal/100 ft/h, which covers the medium-to-high flow range. Emitter spacings used by the vegetable industry also corresponded to those used in this trial (4 to 12 inches).

Based on our results, flow rate had no practical effect on the wetted zone of this rocky soil, possibly because of shallow soil depth (7 to 10 inches) and high soil heterogeneity. Optimal emitter spacing seemed to be 8 inches. The soil depth used in this study (7 to 10 inches) is representative of soil depth in the area. In some fields, the root zone may be even smaller. These results support the practice of using short irrigation events for the application of fertilizer to vegetable crops grown on calcareous soils.

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