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FUNCTIONAL PERFORMANCE OF IRRIGATION SYSTEMS FOR ORCHARD CROPS IN FLORIDA[1]

J. Mostella Myers
IFAS, Agricultural Engineering Department, University of Florida, Gainesville, FL 32611

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Abstract. **Considerable variation exists among types of irrigation systems used for orchard crops with respect to functional performance, water use efficiency, initial and operating cost, and maintenance requirements. These factors are discussed for permanent overhead sprinkler, undertree spray, and drip irrigation systems as they relate to supplemental irrigation of orchard crops in Florida. The discussion provides information to support selection of the system which best meets functional requirements that may be established to emphasize control over crop yields, capital cost, operational cost, labor input, water conservation or energy input.**

While all irrigation systems serve to apply water to soil for use by crops, there are significant differences in how each type of system functions to achieve this objective. There are literally hundreds of possible variations in design within each broad classification of irrigation type with each having a special uniqueness. This situation invites wild claims about the functional excellence of a particular system. This is often confusing to persons who are unfamiliar with how the various types of systems are intended to function. It is the purpose of this paper to discuss the functional performance and certain physical characteristics of drip, overhead sprinkler, and undertree spray irrigation systems for orchard crops.

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Materials and Methods

In developing the distinctions between the types of systems, many generalizations must be made for the sake of brevity. The following general situation is common to each of the three irrigation systems: (1) Size of irrigated area—40 acres (16 ha), (2) Soil type—deep sand, (3) Available water holding capacity of soil within root zone—4 inches (102 mm), (4) Source of water—deep well, central location, (5) Power source—electricity, (6) Spacing of trees—20 ft x 20 ft (6.1 m x 6.1 m) 109 trees per acre, and (7) Topography—level.

Fig. 1 is a hypothetical graphic representation of how each type of irrigation system is intended to function in replenishing water in the soil of the root zone. Rainfall does not occur during the 50-day period covered by the graph. Water consumption levels are representative of what might be expected to occur during late spring in Florida. The maximum average daily consumption of 50 gallons (189

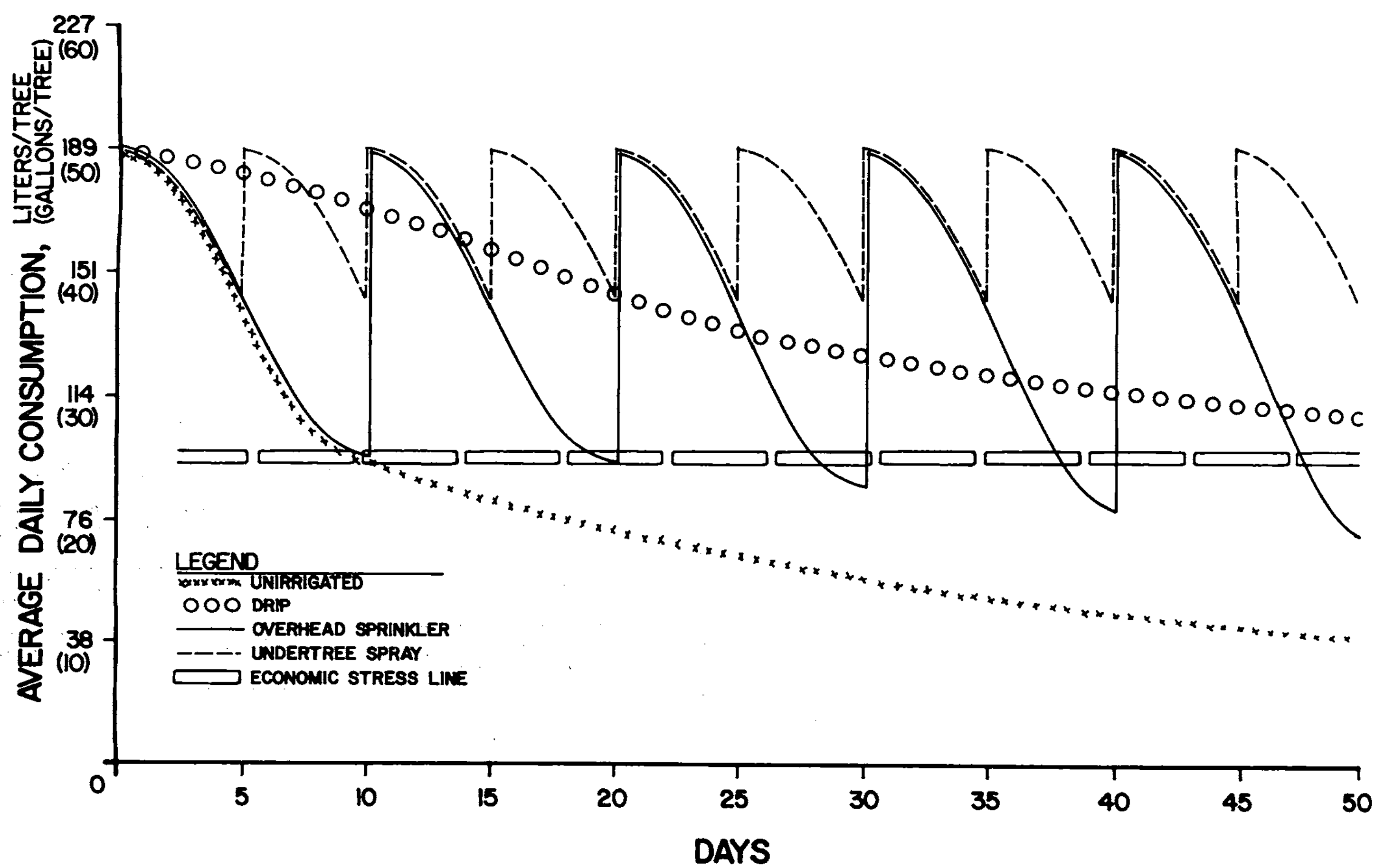

Fig. 1. A hypothetical example of average daily water consumption for mature orchard trees irrigated with three different types of irrigation systems during a period of no rainfall.

liters) per tree is approximately equal to a depth of 0.20 in. (5.1 mm) of water over the 20 ft x 20 ft (6.1 m x 6.1 m) area of land allocated to each tree. Several studies have indicated this quantity to be approximately correct (1, 3, 5). It was assumed that the moisture content of all soil in the orchard was at field capacity on day zero (Fig. 1). An economic stress line is drawn on the figure to show how the different type of systems function with respect to meeting a selected water consumption level. While placing the line at 25 gallons (95 liters)/tree/day is believed to be realistic for design considerations, its location should not be construed as a recommendation (6). Variations in climatic, seasonal, plant, soil and marketing factors contribute to difficulties in fixing exact levels for locating the line.

Results and Discussion

The unirrigated curve represents a moisture extraction of approximately 1000 gallons (3790 liters)/tree for the 50 day period. This quantity is equal to the assumed four inch (102 mm) storage capacity of the soil reservoir allocated to each tree. Theoretically, the tree would die at this point and the water consumption curve would indicate zero on the 51st day. Since very few mature trees succumb to moisture stress in Florida, it is likely that the tree would continue to survive by extending its root system to obtain water from a soil zone below that normally used by the tree. When trees are subjected to severe moisture stresses as visualized by the unirrigated curve at 50 days, negative economic consequences are likely to result. On day one, with water readily available, 50 gallons (189 liters) was consumed from the area allocated to each tree. On succeeding days, as soil moisture becomes less available, a smaller quantity of water is consumed each day until it is down to approximately ten gallons (37.9 liters)/day by the 50th day. This characteristic curve is presented to illustrate the relationship of a realistic level of average daily consumption to the potential as water becomes less available.

The curve depicting drip irrigation is based on water being supplied by a distribution system having 3 emitters per tree ,each with discharge rate of one gallon/hour and operating six hr/day. Thus, the quantity of application is 18 gallons (68.1 liters)/day/tree starting on day two. Emitters are located near the center of the tree where initial water extraction is greatest (2, 4). On the eighth day, estimated daily consumptive use is 43 gallons (162.8 liters)/day, 18 (68.1 liters) from drip irrigation and 25 gallons (94.6 liters) from water stored in the soil reservoir. Prior to the eighth day, the 18 gallon (68.1 liters)/day application is excessive to some extent, however, management control to eliminate this excess is considered impractical at this time. For the remainder of the 50 day period, daily water available per tree is 18 gallons (68.1 liters) from drip irrigation and an amount from the soil storage reservoir that is progressively less each day until on day 50 when the total amount available is 28 gallons (106 liters) from the combined sources. While this quantity is above the economic stress line, it is apparent that by extrapolating the drip curve, an intersection with the economic stress line will eventually occur. It is interesting to note the effect of increasing or decreasing the number of emitters per tree on the shape of the drip curve. Two emitters per tree would give an intersection of the economic stress line at about the 25th day while 4 emitters would extend the intersection to 100 days or more. Of course, with 5 emitters per tree, the lines would not intersect. The point should be made here that more water cannot be made available to the tree by increasing the daily operating time or by increasing the emitter discharge by elevating the operating pressure on the distribution system (7). The additional water would overfill the soil reservoir under the emitter and the excess would be lost to ground water. Rooting growth and activity does intensify in the drip watered soil as a drought progresses, however, the 6 gallons (22.7 liters) per emitter per day used in this example is believed to be near the maximum that can be expected to be held in soil for a humid region and in sandy soils (7).

The overhead sprinkler irrigation curve is represented by a permanent type distribution system with 0.12 inch (3 mm)/hour gross application rate. Twenty-four hours of operation will apply a net two inches (50.8 mm) depth of water to the orchard. The management scheme for a 40 acre (16 ha) system with ten day irrigation frequency requires that a four acre setting be irrigated each day. The two inch (50.8 mm) net application depth is equivalent to 50 gallons (189 liters)/tree/day. In theory, this quantity of water meets the maximum consumptive use of the orchard, however, in reality, a tree will average using less than 50 gallons (189 liters)/day for the 10 days between irrigation cycles. As the curve indicates, water use during the first 10 day period is the same as unirrigated with average daily consumption being 37.5 gallons (142 liters)/day. On the tenth day, and continuing at 10 day intervals, 2 inches of net irrigation is applied. Since a larger proportion of water used is from the part of the soil water reservoir under the tree canopy, the subsequent irrigation does not replace all the soil moisture used during the preceeding ten day period. In essence, the 2 inch (50.8 mm) application under irrigates the soil under the tree canopy and over irrigates the remainder of the soil allocated to a tree (4). To generalize, proper distribution based on soil moisture deficit would require perhaps three inches (76.2 mm) under the tree canopy and one inch (25.4 mm) for the remainder of the orchard. It would be erroneous to claim that the dividing line between over and under irrigated soil coincides exactly with the edge of the tree canopy. However, there is ample evidence that a disproportionate quantity of water is used from soil under the canopy during the early days after a thorough wetting of all the soil (4). Before the third and all subsequent overhead sprinkler applications were made, the consumptive use curve dipped below the economic stress line. The magnitude of the dip gets progressively larger which illustrates the culmulative effect of the continuing under irrigation of soil under the tree canopy.

The irrigation system represented by the undertree spray curve on Fig. 1 has one 280° coverage spray head for each tree. Each spray head delivers twelve gallons (45.4 liters) per hour at 15 psi (10.5 kg/cm^2) and wets a soil area about ten feet (3 m) in diameter. The net application quantity is 250 gallons (946 liters)/tree at five day intervals. The curve indicates average daily consumptive use per tree is approximately 44 gallons (167 liters). Water is applied under the canopy near the tree center where the soil moisture deficit is greatest.

Average daily consumptive use for the 50 day period was calculated to be 37.5, 37.5 and 43.8 gallons (142.0, 142.0, and 165.8 liters)/tree/day and the total quantity applied is 882, 2500, and 2500 gallons (3339, 9464, and 9464 liters) for the drip, overhead sprinkler, and undertree spray irrigation types, respectively. Approximately 45 gallons (170 liters) or about 5% of the total 882 gallons (3330 liters) applied by drip irrigation was considered excessive to the needs of the soil. As stated earlier, the excess occured between day 2 and day 7 of the 50 day period. The difference between 50 gallons (189 liters)/tree/day applied by the overhead sprinkler and the undertree spray irrigation systems and 37.5 and 43.8 gallons (142.0 and 165.8 liters) estimated average daily consumptive use, indicates excessive water application of 25.0 and 12.5% for the two systems, respectively. These analyses are based on an assumption of 50 consecutive days without rainfall, an infrequent occurrence in Florida. Under normal rainfall distribution, with sometimes untimely occurrences insofar as irrigation frequency is concerned, the quantity of excessive water application probably would be greater than the above estimates for all three types of systems.

Characteristics relating to costs and physical qualities for the three types of systems are included in Table 1. All values are based on a complete irrigation system for a 40 acre (16 ha) orchard. Standard system designs and current prices are used. The designed capacity of each of the systems is such that continuous operation is required to supply the water requirements as indicated by Fig. 1.

Table 1. Physical characteristics, estimated cost and other attributes of drip, undertree spray and overhead sprinkler irrigation systems for orchard crops.[z]

Item	Type of System		
	Drip	Undertree Spray	Overhead Sprinkler
Water distribution system—Cost/acre (ha)	$350 ($865)	$500 ($1235)	$1200 ($2965)
Water supply—Cost/acre (ha)[y]	$101 ($250)	$182 ($450)	$215 ($531)
Well size—Diameter inches (cm)	4 (10.2)	6 (15.2)	6 (15.2)
Power requirement—Electric motor, hp (kw)	3.0 (2.3)	7.5 (5.6)	20.0 (14.9)
Pump capacity—gpm (liters/sec)	58 (3.7)	179 (11.3)	215 (13.6)
Operating pressure—psi (kgs/cm2)	12 (8.4)	15 (10.5)	55 (38.7)
Average irrigation efficiency—percent	95	85	70
Power costs—Per day at $0.04/kwh	$1.94	$6.45	$16.92
Water filtration required	Yes	Yes	No
Water chlorination—Cost/day, 5 ppm	$0.84	$2.16	—
Labor—opn and maint, man-hrs/acre (ha)/year	6.0 (14.8)	2.0 (4.9)	1.6 (4.0)

[z]All calculations are based on 40 acre (16.2 ha) production unit.
[y]Assuming 300 ft (91 m) deep well, with 100 ft (30 m) casing and pumping water level 75 ft (23 m) below ground surface.

The drip system costs less initially and to operate than the other 2 systems. The undertree spray is next lowest in costs. Water requirement for the drip system is about one third of the requirement for the other two systems. Both the drip and the undertree spray systems are likely to experience a clogging problem to some degree depending on water quality. For this reason, costs were allowed for equipment and chemicals to combat the problem for these type systems. The chemical properties of waters of Florida do not cause equipment problems for overhead sprinkler irrigation. However, trees could probably tolerate water with higher salt content if it were applied with drip or undertree spray systems since water applied by these systems does not generally come in contact with foliage (2).

Lateral distribution pipelines for most drip and some undertree spray systems are installed on the ground surface. This pipeline exposure can lead to maintenance problems associated with other cultural practices and harvesting operations. Also, exposed pipelines deteriorate faster than buried pipelines. Useful life of exposed pipelines varies relative to exposure to the sun, quality of plastic, and operational practices, however, 5 to 10 years of service can be expected. The pipelines of permanent overhead systems are buried beneath the surface and are expected to last 20 years.

Summary

A hypothetical analysis was made of function, costs, and physical requirements for 3 types of irrigation systems widely used by orchard growers in Florida. The systems offer a range of choices with regard to initial costs, water use efficiency and operating costs. With respect to function, major differences are found in the quantity of water applied, the frequency of application and the place of application. Approximately 3 times more water is applied per unit area with the overhead sprinkler and the undertree spray systems than with the drip system. A drip system with 3 emitters per tree probably would not be adequate to supply enough water to prevent an economically significant soil moisture stress near the end of a long-term drought. Daily, 10 and 5 day frequencies of application are used for the drip, overhead sprinkler and undertree spray systems, respectively. Water is applied to about 10,100 and 20% of the soil for the 3 systems, respectively.

Literature Cited

1. Anonymous. 1971. Irrigation water requirements. *USDA Soil Conservation Service, Engineering Division. Tech. Release No. 21.*
2. Calvert, D. V. and H. J. Reitz. 1966. Salinity of water for sprinkler irrigation of citrus. *Proc. Fla. State Hort. Soc.* 79:73-78.
3. Gerber, J. F. and F. Hashemi. 1968. Water use patterns of citrus in sandy soil underlaid by clay. *Proc. Fla. State Hort. Soc.* 81:69-74.
4. Hagan, R. M., H. R. Haise and T. W. Edminster. 1967. Irrigation of agricultural lands. *American Society of Agronomy,* Madison, Wisconsin. p. 438-574.
5. Halderman, A. D. 1973. Grapefruit and orange water use. *Univ. of Ariz. Ext. Cir. Q205.*
6. Israelsen, O. W. and V. E. Hansen. 1962. Irrigation principles and practices. John Wiley and Sons, Inc. (New York, N.Y.) pp. 231-256.
7. Myers, J. M. and D. S. Harrison. 1973. Drip irrigation of tree crops; Distribution systems and design criteria. *Proc. Fla. State Hort. Soc.* 86:67-71.
8. Myers, J. M., D. S. Harrison and W. J. Phillips, Jr. 1976. Soil moisture distribution in sprinkler irrigated orange grove. *Proc. Fla. State Hort. Soc.* 89:23-26.