ASSESSMENT OF CROP WATER USE FOR DRY BEANS WITH DRIP IRRIGATION

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INTRODUCTION

In many areas, irrigation has provided the means to optimize plant water use and increase crop production. Irrigation scheduling is a necessary means to overcome excessive irrigation and eliminate many associated problems. Therefore, a knowledge of crop water use will help establish a better understanding of irrigation requirements.

Drip irrigation was used in this study to determine dry beans water requirements. Precise water application directly to the root zone by the drip system will minimize water loss due to runoff and deep percolation. Accurate irrigation is necessary to produce the water rates required to generate desired production. The flexibility of a drip system in research and agriculture production was investigated by Bauder, et al, (1975) to obtain the high degree of water control needed.

The objectives of this study were to determine the proper water requirement as related to yield using five different rates of irrigation, to develop a crop coefficient that is related to regional conditions, and to demonstrate the use of a drip irrigation system.

MATERIALS AND METHODS

The study was conducted during the summer of 1992 at the Colorado State University Southwestern Research Center at Yellow Jacket, Colorado. The experiment consisted of five plots with dimensions of 20x10 feet. Five rates of irrigation applications were used. The treatments were 0%, 33%, 67% 100%, and 133% of actual ET. Drip irrigation was used to provide the above-mentioned irrigation rates.

The drip irrigation system used in this experiment consisted of a 2 inch I.D. main line of black polyethylene connected to the source line of irrigation. A filter system was installed in the main line to prevent sediment from blocking the emitters. Four lateral 0.5 inch I.D., 120 feet long tubes were connected perpendicular to the main line.

The drip-irrigation system delivered four different rates of water at 15 PSI. Delivery rates were 33%, 67%, 100%, and 133% of actual ET by using 0.5, 1.0, 1.5, and 2.0 gph emitters to provide 0.13, 0.26, 0.38, and 0.51 in/h . The soil infiltration rate was 0.4 to 0.5 in/h.

Dry beans were planted in 30 inch rows of 70,000 plants per acre. The five irrigation treatments were assigned randomly to five plots of dry beans, 20x10 feet, by using Randomized Complete Block Design (RCBD). The plots were separated by a buffer zone of 10 feet. To reduce any possibility of runoff, the plots were diked to contain the water application within each plot. In each plot, a 5 foot access tube was installed. A neutron probe was used to measure moisture content at five different increments twice a week. Irrigation was applied based on actual ET calculations by using climatological data available from the local weather station.

Samples for dry matter production were taken at different growth stages. Grain yield and final biomass were estimated at harvest. The following water balance relationship was used in estimating ET from soil moisture and irrigation data:

$$I+P=R+SW+DP+ET$$

where:

I = irrigation water, depth
P = precipitation, depth
R = surface runoff, depth
SW = change in soil water content, depth
DP = deep percolation from root zone, depth
ET = evapotranspiration, depth

Deep percolation (DP) and surface runoff (R) were assumed to be zero.

RESULTS AND DISCUSSION

Daily average water use (evapotranspiration) under five different irrigation treatments was measured by using a water balance approach and the Penman equation. Figure 1 summarizes daily average irrigation and ET. The results show that water use increased with irrigation for all treatments. However, 1.0 ET and 1.33 ET show a significant increase in water use. This can be attributed to high growth as compared to other treatments (Tables 1 and 2). Field observations showed a striking difference in canopy development, which was more profound with 1.0 ET and 1.33 ET as compared to 0 ET, 0.33 ET, and 0.67 ET treatments.

Water use by dry beans as estimated by using the Penman equation and water balance approach shows an increase as the rate of irrigation is increased (Figs. 1a and 1b). Seasonal average water use estimated by the Penman equation was 0.05, 0.10, 0.15, and 0.20 in/day for the irrigation treatments 0.33 ET, 0.67 ET, 1.0 ET, and 1.33 ET, respectively. The water balance approach estimate of water use was 0.05, 0.11, 0.13, and 0.20 in/day for the same irrigation treatments. The estimated water use by both methods shows no significant differences at the alpha=0.05.

Crop coefficients estimated by using the water balance approach and actual ET data, are summarized in Fig. 2. The crop coefficients were the ratio of ET to potential ET of the Penman equation. However, the peak value of crop coefficients were 0.32, 0.65, 0.96, and 1.27 by using the actual ET versus 0.55, 0.73, 1.0, and 1.36 as estimated by the water balance approach for 0.33 ET, 0.67 ET, 1.0 ET, and 1.33 ET, respectively.

The results reveal that crop coefficients estimated from the water balance approach data were greater than those estimated from actual ET data. The increase in crop coefficients values under the high irrigation treatments may be attributed to advection conditions from the uncultivated area around the experiment site. The lowest values of crop coefficients were associated with low rates of irrigation. This can be attributed to the limited soil moisture supply under low irrigation rates, which limit soil evaporation, (Ritchie, 1971) and transpiration (Ritchie & Burnett, 1971).

Figure 3(a, b, and c) shows the dry matter, soil moisture content, and irrigation of various treatments, respectively. Data of soil moisture content in Fig. 3b represent the average of the top 3 feet.

The effect of different irrigation rates on dry matter production shows a considerable increase for the 1.0 ET treatment as compared to other treatments. The biomass production at harvest shows a significant difference between treatments, except treatments 1.0 ET and 1.33 ET, where no significant differences were detected (Fig. 3a). Grain yield was also significantly different (Tables 1 and 2). Differences among treatments in yield were strongly related to soil moisture depletion from the soil profile (Fig. 3b).

There was more variation in grain yield at all irrigation rates. The increased variation can be attributed to more sensitivity of grain to soil moisture influence during the season than is dry matter (Hanks, 1974). Total water use efficiency (TWUE) and irrigation water use efficiency (IWUE) for both dry matter and grain yield show a lower water use efficiency as the rate of irrigation increased.

CONCLUSION

The use of controlled drip irrigation at different rates offers a reliable method of evaluating irrigation rates and yield response. By applying different rates, it was possible to evaluate the existing irrigation scheduling. The use of a drip irrigation system reduces the deep percolation and run off. Drip system provides flexibility to be adopted in agriculture production and water management.

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Table 1. Water use efficiency and dry matter yield of dry beans.

Treatment	Irrigation (inch)	Moisture change (in/ft)	Total ET (inch)	Dry Matter (lb/a)	IWUE	ETWUE
0ET	0.00	(1.89)	2.96	1,696 a	0	573
0.33ET	4.57	(1.33)	6.97	2,929 b	641	420
0.67ET	9.25	(0.95)	11.27	4,299 c	465	318
1.0ET	13.46	(0.79)	15.32	5,646 d	419	369
1.33ET	18.87	(0.70)	20.64	5,683 d	301	275

Means with the same letter are not significantly different at 0.05.

Table 2. Water use efficiency and grain yield of dry beans.

Treatment	Irrigation (inch)	Moisture change (in/ft)	Total ET (inch)	Grain Yield (lb/a)	IWUE	ETWUE
0ET	0.00	(1.89)	2.96	931 a	0	315
0.33ET	4.57	(1.33)	6.97	1,640 b	359	235
0.67ET	9.25	(0.95)	11.27	2,462 c	266	218
1.0ET	13.46	(0.79)	15.32	2,986 cd	222	195
1.33ET	18.87	(0.70)	20.64	3,493 d	187	169

Means with the same letter are not significantly different at 0.05.

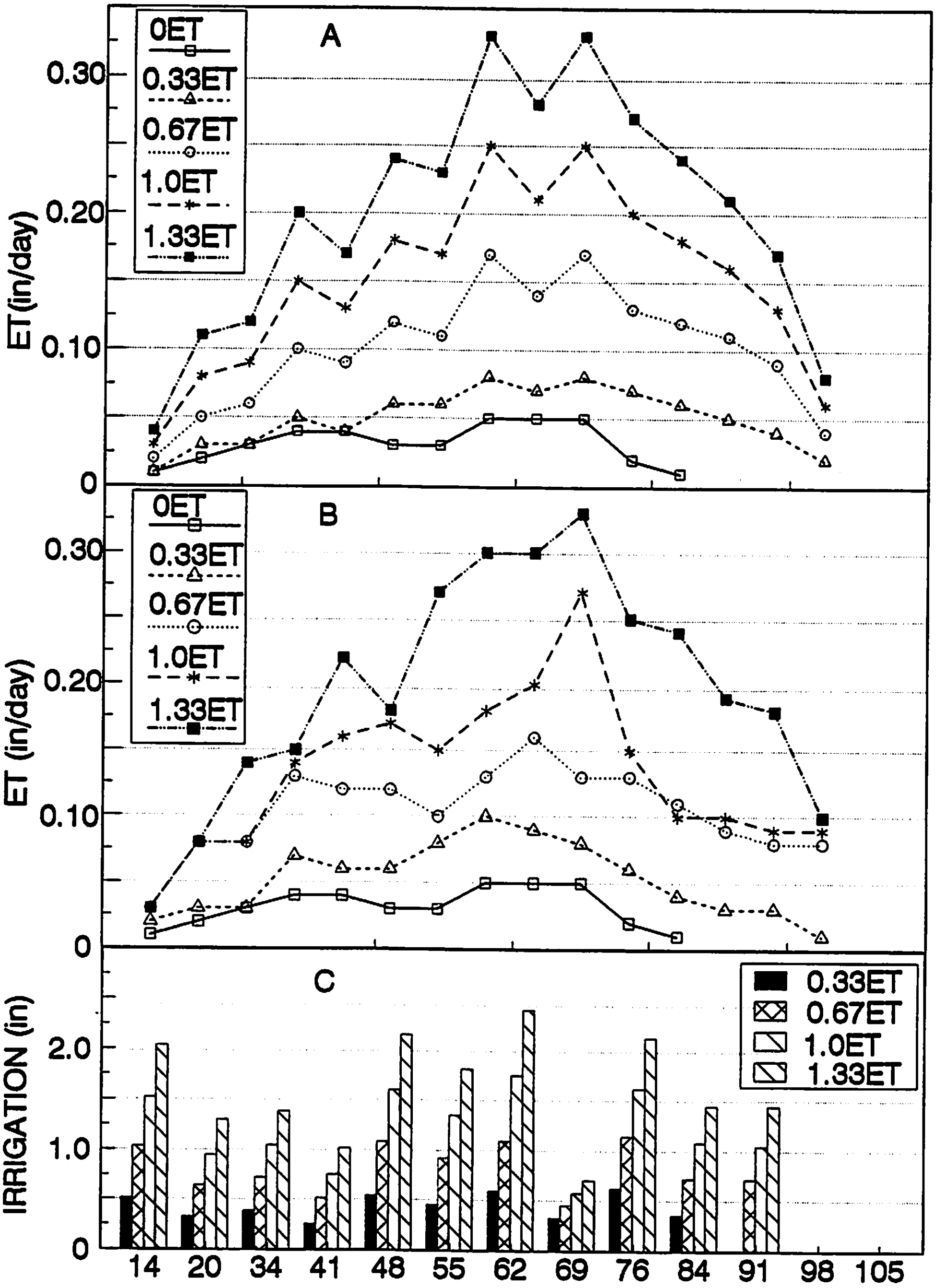

Fig.1. (A) Predicted ET. (B) Actual ET calculated using water balance approach (C) Irrigation during growing season.

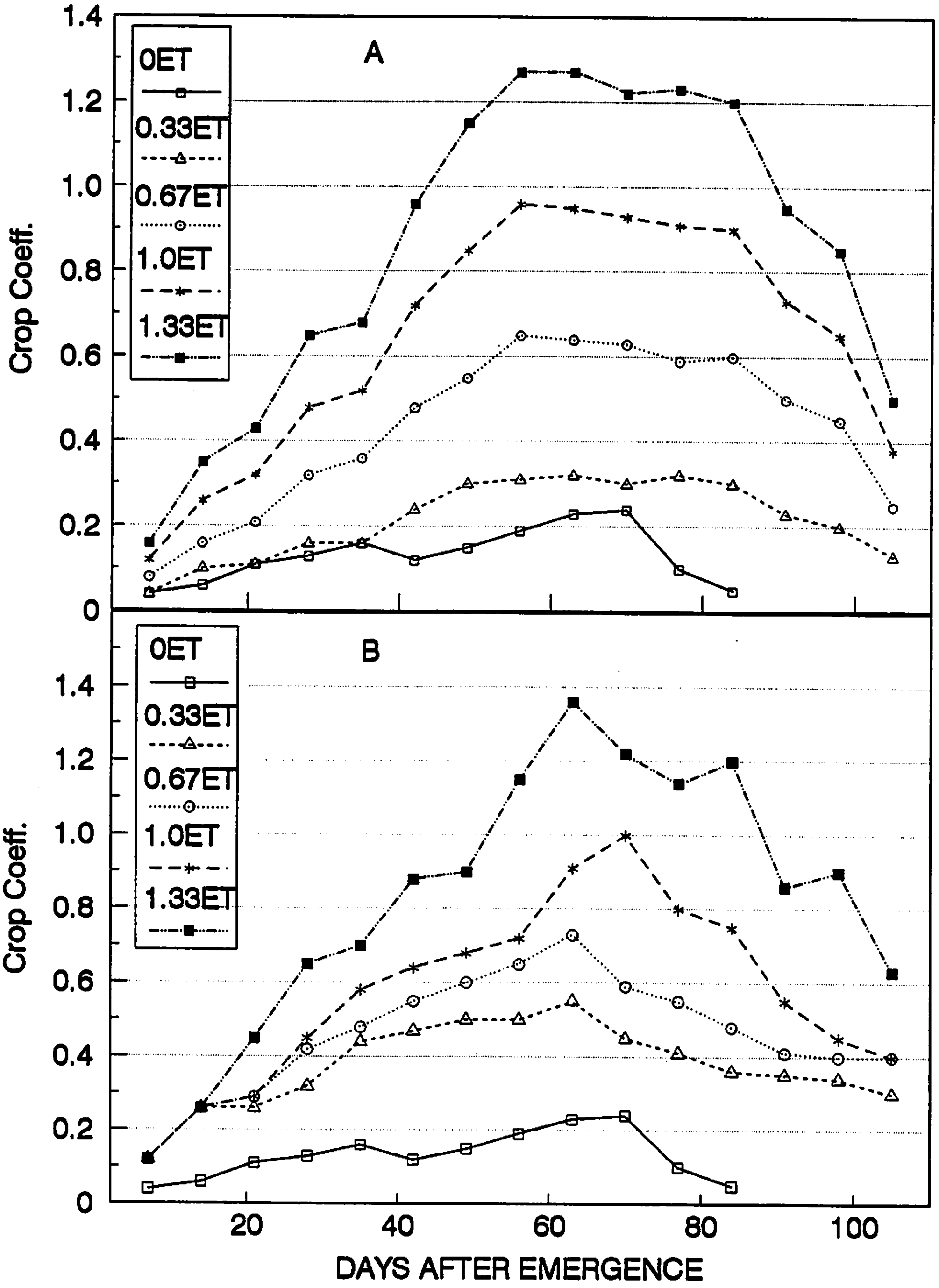

Fig. 2. (A) Crop coefficient from actual ET and Penman Equation. (B) Crop coefficient from ET water balance approach and Penman Equation.

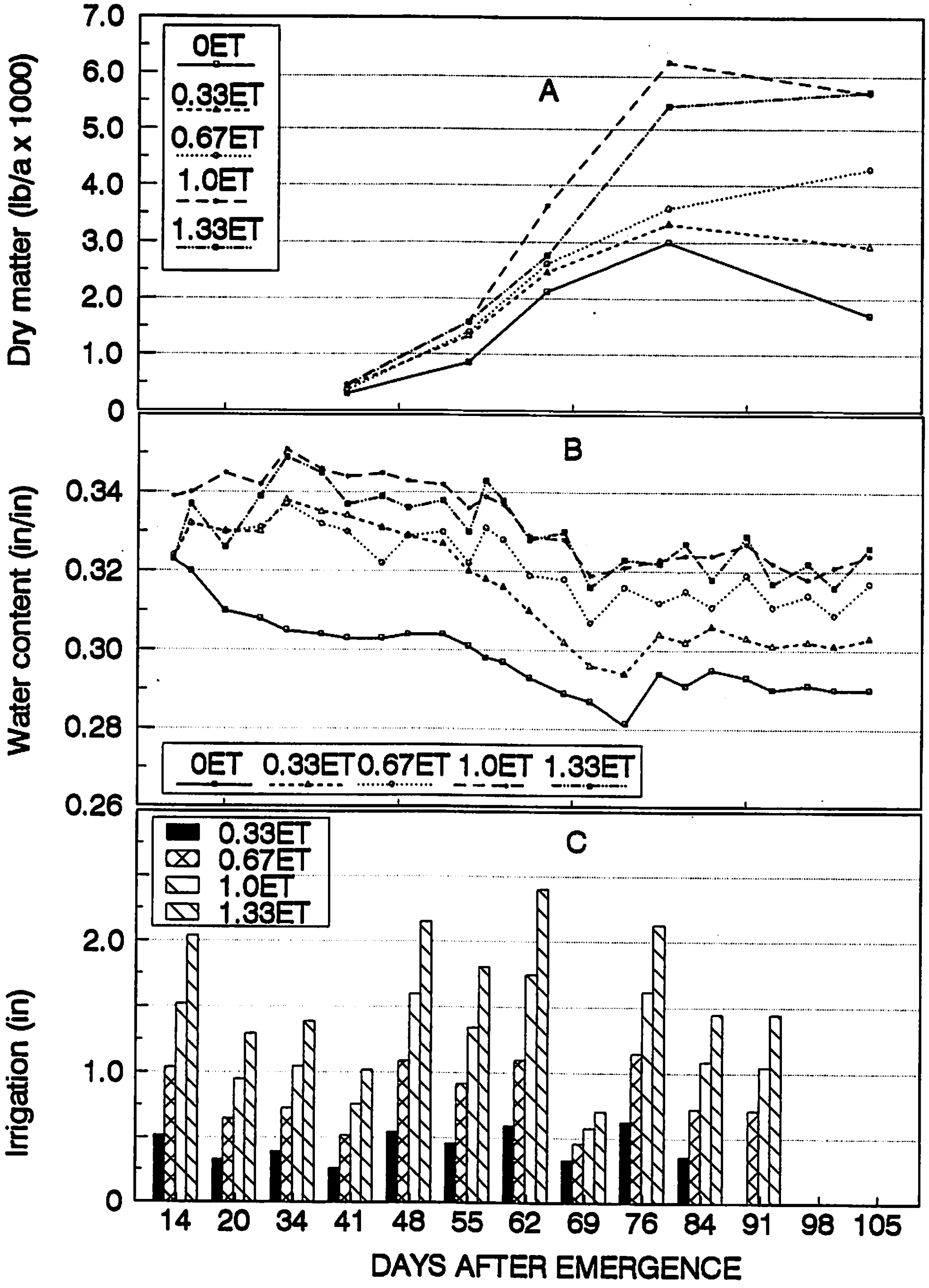

Fig. 3. (A) Dry matter. (B) Soil water content average for the top 3 ft. (C) Irrigation amount during the growing season.

GREENHOUSE IRRIGATION AND FERTILIZATION OVERVIEW

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INTRODUCTION

Greenhouse irrigation is just one of many systems which the grower uses to control growth, development, and timing of crop production. Overall control relies on the interaction of all systems: watering, fertilization, heating, cooling, ventilation, humidity control, lighting, and carbon dioxide supplementation. Water cycles throughout the plant and its environment, and plays an important role in total environmental control.

It is important to understand the impact water has not only on plant growth, but also on plant environment. Plants evaporate water from their leaves in order to keep cool under the constant heat of the sun. Often, the best approach to greenhouse temperature control is to encourage the plant's own evaporative cooling system. Once water evaporates, it adds to the humidity of the air. The lighter moist air rises through heavier dry air, helping to create natural air currents which moves hot air away from the plants, and fresh, carbon dioxide-rich air to the plants. Another water cycle occurs beneath the soil. Water added through irrigation reaches roots, which absorb the water needed to meet the needs of leaf evaporation. This water also carries nutrients to the plant roots much faster than roots are able to grow toward new nutrient supplies, offering a distinct advantage over field crop root uptake strategies. The type of potting media must be selected with this water movement in mind.

This paper discusses the common methods of greenhouse irrigation and fertilization. An overview of the benefits and costs of each system as well as general operational guidance is provided. Finally, an integrated approach to water and nutrient management is presented. This approach is based on current research of greenhouse irrigation systems. Only recently have researchers focused on the importance of precise water and nutrient control for optimal greenhouse crop production. In the future, as crop nutrient requirements are determined with increasing precision, growers using all types of irrigation systems will be able to tailor fertilizer applications to better meet crop needs.

IRRIGATION SYSTEMS

No matter what irrigation system is used, the goal is the same: apply the proper amount of water to each plant. The proper amount is defined by the amount of water the plant uses in the process of evapotranspiration (ET). ET can be predicted for a given plant based on several key environmental factors: light, temperature, humidity, and wind. However, each plant responds to the environment in a slightly different way to give a different water requirement. General guidelines can be found in most horticultural production manuals. For example, poinsettia uses 7 to 9 quarts over the 15 weeks of the crop. This range is relatively narrow since poinsettias are grown at a specific controlled temperature and predominately at one time of year (to meet the Christmas rush). The low side of the limit would be for a season with mostly cloudy conditions, and the high side for when most sunny conditions occur. Once you know how much water the plant needs, you can calculate how much water is needed at each irrigation by knowing how many times you will irrigate over the growing period. This is largely determined by the type of irrigation system used.

Hand watering has inexpensive up-front equipment but expensive labor costs. Often, uniformity is difficult to maintain. However, training operators in a few simple concepts will greatly improve the effectiveness of this system. This method can be adapted for both flats and potted plants. It is best to operate under low flow rates (2-4 gallons per minute) and to apply a know amount (by amount of time in one location with a know flow rate) directly to each pot or bedding flat. One simple method is to determine how many ounces of water it takes to fill a pot, and leave space at the top of the pot for only that much volume. Then, filling the pot with water will provide the precise amount of water needed. Plants with well established root systems should be watered thoroughly and allowed to dry between waterings. As long as water quality is acceptable, there is no need for leaching.

Sprinkler/mist systems use stationary nozzles to distribute water across the growing area. These systems are best used for flats, but can be used for potted plants with a loss of efficiency due to water falling between pots. Though complete uniformity is rarely attained, proper placement of sprinklers can provide more consistent, uniform watering than hand systems, particularly when nozzles are cleaned and maintained. The goal is the same as discussed with hand watering: allow media to dry before returning to water thoroughly. Systems can be fully automated. Equipment costs can be significant.

Watering booms are simply sprinklers or mist heads placed on moveable central units, either mounted on carts or on overhead framework. Again, uniformity depends on proper nozzle placement and maintenance. Lower initial costs compared to stationary systems are offset by increased maintenance. These systems can also be controlled by computer for increased flexibility and control.

Drip irrigation can be used for hanging baskets and potted plants. Precise amounts of water are applied through low-flow emitters in each pot. Filtration is often required to minimize clogging. Again, water amounts should be determined to completely wet media without leaching. Because water is applied directly to the soil, foliage is kept dry, reducing the chance of several diseases.

Ebb-flood systems water plants from below by periodically filling a trough-like bench to a shallow depth and letting water wick into the potting soil. Irrigation water is used again and again in a closed system. As with the drip system, some diseases which need moist foliage to thrive are minimized. Up-front costs can be high, but the system is