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A COMPUTER CONTROLLED IRRIGATION OF POTTED CHRYSANTHEMUM GROWN AT OUTDOOR CONDITIONS

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Abstract
A rapid and reliable method to estimate water requirements for chrysanthemum production with practical applications to commercial operations was developed to promote water conservation. A water-requirement prediction equation (R^2 = 0.71) that used class A pan evaporation along with plant-canopy height and width as input variables was generated. Equation verification was carried out by comparing vegetative growth and quality of crops irrigated according to the generated water-requirement equation to crops irrigated based on demand and conservative fixed daily irrigation regimes. Vegetation growth of the plants irrigated with the generated equation was smaller than plants grown by demand irrigation, but plant quality was not significantly different. Applied water was significantly lower for plants irrigated with the generated equation than would normally be applied in a commercial operation using a conservative fixed daily irrigation rate. The study showed that there was a close relationship between chrysanthemum water requirements and the plant and evaporative data. A simplified ET equation involving plant characteristics and evaporative data could be used in the irrigation scheduling of chrysanthemum grown under restricted root volume.

Keywords: Evapotrasnpiration, automation,potted plants, soil moisture

1. INTRODUCTION

Conservation of water and nutrient resources have become increasingly important to horticultural operations due to cost and environmental pollution. In recent years, the use of water-saving irrigation systems has increased the producer's ability to reduce the amount of water used to grow a crop. To properly conserve water while producing a high-quality commercial crop, regardless of irrigation system used, information on actual plant water requirements under specified conditions is necessary. Evapotranspiration of potted plants is affected by many factors, either environmental (e.g., ambient temperature, radiation, humidity, air speed) and plant related characteristics (e.g., the stage of growth, leaf area, fresh weight, leaf water potential) and kind of growing medium or size of container. The irrigation frequency of plants growing on pots can be based on measured or calculated evapotranrpiration. Any method used to accurately estimate plant water requirements must account these environmental and plant factors (Treder et al., 1997; Schuch et al., 1998; Lucia, 2010).

The supply of high-quality water for the production of greenhouse crops is decreasing, requiring creative approaches to the conservation of water during the irrigation of ornamental plants. Several methods have been developed for the controlled application of irrigation water to greenhouse crops. The most widely used system in commercial greenhouse ornamental production employ timers to control irrigation frequency (water applied for a given time at a given frequency). Many studies

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showed that higher frequencies of irrigation could improve plant growth in restricted root volume by improving effciencies of soil moisture and nurient uptake (Lieth and Burger, 1989; Taweesak et al., 2014).

There are several methods used to determine when and how much to irrigate. Growers may decide when to irrigate based on visual observation of their crops. However, this visual observation is based on water stress levels that are often not optimal for crop production and the quantity of water applied usually exceeds crop needs. Recent advances in sensors to measure the soil moisture tension of container media have resulted in the development of solid-state, electronic tensiometer units for measuring soil water status. Changes in soil moisture status can be monitored and the amount of water applied can be controlled by a computer used in combination with these tensiometers. With such a system, water use may be minimized without affecting crop quality and yield. However, many commercial producers do not have instrumentation, technical expertise, or desire to use such models. A simplified method with practical application to commercial operations is required for commercial horticultural operations (Kirnak, 1998; Lucia, 2010).

The objective of this research was to develop a simple water-requirement prediction equation for chrysanthemum and test the effectiveness of this equation for irrigation of potted chrysanthemum.

2. MATERIALS AND METHODS

Developing a simple ET model

Experiment was conducted in a computer-controlled, double-polyethylene greenhouse located at the Ohio Agricultural Research and Development Center (OARDC), Wooster, Ohio (41° 30' N latitude) USA. The experimental study was separated into two parts. In the first part of the experiment, a simplified ET model including plant canopy height, width, and pan evaporation was developed. In the second part of the study, this developed ET model was tested for another group of plants.

In the first experiment, designed to develop the prediction equation, a total of 25 plants (cv., snapper) were used and measurements were taken for 25 consecutive days from 10th of July through 5th of August when greenhouse air temperatures ranged from 16 to 34 ºC. The specific greenhouse compartment used in this experiment was 5 m wide and 30 m long with an evaporative-pad and fan ventilation system across the long dimension. Twenty five container-grown chrysanthemum of similar size and appearance were obtained from a local grower on 10th of July and used until 5th of August. The plants were in pots 30 cm diameter. The spacing used between pots was 25 cm in all directions. The potting medium used in the experiment was metromix 360 (The Scotts Company, Marysville, OH). A slow release fertilizer called osmocote 14-14-14 was used to fertilize the plants by using a fertigator system developed at Wooster, OH, USA.

Computer controlled irrigation

A Q-COM Inc., Irvine, CA computer controlled drip-irrigation system with GEM-III software was used to water all plants simultaneously. One emitter was placed in a flask to measure the total amount of irrigation water applied and one emitter was used for each plant. The irrigation timing was controlled by a Q-COM soil water tension control system where a tensiometer was placed half way down into the growing media of each of the containers. For this study, irrigation was started at 10 kPa and continued until the soil tension reached 5 kPa. This particular regimen was chosen based on works conducted by Stanly and Harbaugh (1981), Hansen et al., (1997) and Fynn et al. (1993) since it provided good soil moisture conditions while avoiding drainage from the bottom of the container for the most of the ornamental plants. The computer-controlled microirrigation system consisted of a soil tension sensor with a solid state pressure transducer attached, a spray stake emitter, a solenoid valve, an analog-to-digital converter (A/D), and a PC computer with GEM3V2 software (Figure 1).

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Measurements

An electronic weighing scale (Satorius, F330S) was placed beneath one of the plants to measure actual transpiration. There was only one lysimeter and it was placed in the center of the experimental area. Transpiration measurements and related parameters were collected from the pot on this lysimeter. The weighing lysimeter was connected to a datalogger.

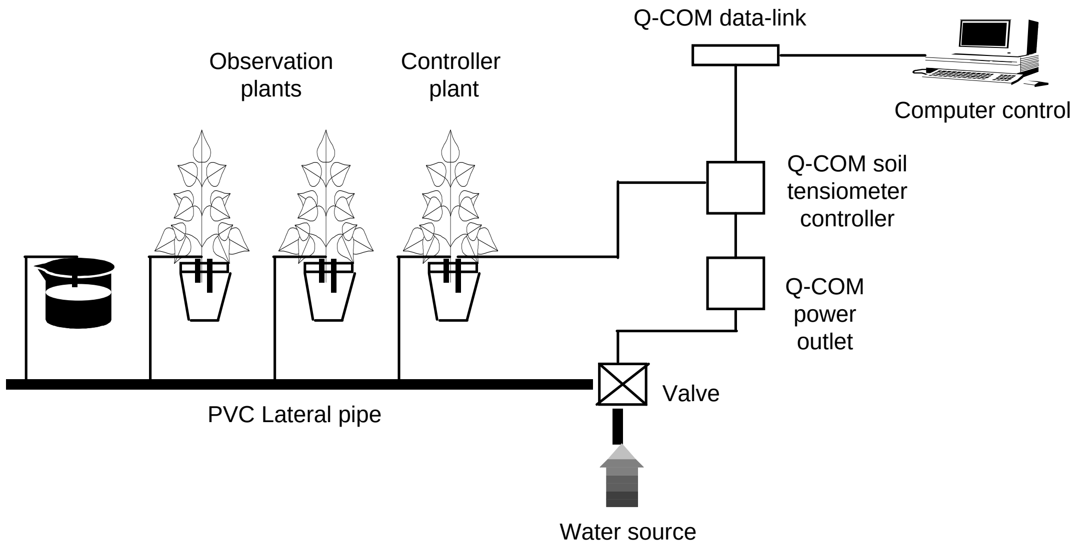

Figure 1. Schematic representation of computer controlled demand irrigation system

The data logger recorded the sensor reading in 30 minute intervals. The plant vegetative growth characteristics such as canopy height and width were measured weekly intervals. In order to measure evaporation, a standard class A pan was replaced same growing area in the greenhouse and daily measurements were taken manually. Data collected during this period were analyzed by a stepwise multiple-regression technique. This method allowed addition or substitution of potential independent variables in the model to observe changes in the statistical significance and improvement in the coefficient of determination for each model. The resulting regression equation, significant at $P < 0.01$ with an R^2 of 0.71 was:

$$ET = -94 + 1.6\,H + 0.9\,W + 62.1\,PE \quad (1)$$

Where: ET = total water use (mm), H = plant canopy height (cm), W = plant canopy width (cm), and PE = measured pan evaporation (mm).

Validation of the developed ET model

In the second series of the experiment, a new 30 potted plants were used to verify the usefulness of the water use prediction equation developed earlier. Thirty container-grown chrysanthemums of similar size and appearance were obtained from a local grower on 10^{th} of September and used until 10^{th} of October. All treatments received fertilization in the same manner, as was used in the plants used in the development of the prediction equation. Besides, layout of the experiment in the greenhouse, medium and size of container were same as the previous experiment. Plants were divided into three equal groups (10 plants for each of them) in the model verification study. Crops were irrigated using: (I) one third of the potted plants (10 plants) were irrigated based on computer controlled irrigation at the same tension level used in the first experiment, (II) the other 10 plants

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were irrigated using the prediction equation developed earlier considering average plant characteristics and pan evaporation, (III) the rest of the plants were irrigated using a daily fixed irrigation amount used by local growers. These simultaneous experiments were conducted to compare above irrigation treatments with each other in terms of plant growth, quality and water usage. Each experiment included same specific chrysanthemum cultivar with 10 replications, using one potted plant as the experimental unit. Average amounts of water applied were recorded in each treatment. The experimental design was completely randomized design. All data were analyzed using a statview computer program. Means were separated by Duncan's test at P<0.01 level. At the end of experiment, overall plant quality rating was done with a group of local commercial producers by considering inflorescence size, leaf color and maturity. These rating were ranged from 1 (poor) to 5 (excellent). Plant height was measured weekly from the media surface to the shoot apex. Plant width on the top of the canopy was measured at weekly intervals too. Leaf area was measured with a LI-3100 leaf area meter weekly intervals. Leaf and stem dry mass were determined at the time of final harvest.

3. RESULTS AND DISCUSSIONS

Plant height and width were the greatest for plants grown with tension based irrigation treatment (Table 1). Plants irrigating using prediction equation were 12% shorter than those plants irrigating with demand irrigation. Irrigation with developed ET equation reduced leaf area, leaf dry mass and stem dry mass by an average of 8% compared to demand irrigation. Plant vegetative parameters mentioned above affected by used irrigation regimes significantly at P <0.01 level. There were no differences inflorescence diameter (range 6 to 8 cm) due to irrigation method for any test. No differences in overall quality were observed among between treatments. Plants irrigated with the prediction equation were slightly and of lower quality than plants irrigated tension based irrigation. But, it was not statistically significant. The plants, irrigated with the prediction equation, wilted occasionally during periods of combined rapid plant growth and high evaporative demand, which indicated that the equation was not adequately predicting the necessary water requirements on such days. These results were in agreement with the studies conducted by Stanly and Harbaugh (1989), Karlovich and Fonteno (1986), Schuch and Burger (1997).

If underestimation and subsequent under-application of water occurred, soil moisture in pot would have been depleted, because irrigation based on the prediction equation only replaces estimated water used the previous day. The results show that additional information or some compensation coefficient is required to make the equation more responsive during the high demand periods. A common irrigation practice in commercial operations consists of applying a constant amount of water daily (e.g., 250 to 350 ml per pot per day). If these amounts were used and compared in any of the studies using treatments I or II, they would show substantial water savings (30% for experiment I, and 35% for the experiment II). Figure 2 shows the total water use under different irrigation treatments. Total applied water was between 6 L and 9.5 L depending on treatments. In the application of developed ET model, water for leaching was not considered because usage of the developed prediction equation was based on applying the minimum amount of water required to grow. Leaching might not be required with proper fertilization and adequate-quality irrigation water. However, reducing volume of water applied to pots and thereby lowering the leaching fraction can be resulted in accumulation of high EC levels in the medium and decreases in chrysanthemum dry mass with increasing root media EC. Therefore, necessary precautions should be made in the use of the developed ET model for commercial purposes. Leieth and Burger (1989) said that soil moisture tensions between 7.5 and 15 kPa caused significant reductions over the time-

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based treatment in fresh and dry weights of leaves, stems, and inflorescences and total leaf area, but had no influence on inflorescence diameter.

Table 1. Plant height-weight[1], leaf area[1], leaf-stem dry mass[1], inflorescence diameter[1] and overall quality of chrysanthemum[1] under three irrigation regimes for the verification stage of the experiment

Irrigation	Plant height (cm)	Plant width (cm)	Leaf area (cm^2)	Leaf dry mass (g)	Stem dry mass (g)	Inflorescence diameter (cm)	Plant quality rating
Tensioned based Demand	44.5a[2]	28.5a	4000a	34.5a	25.1a	8.0a	3.4a
Developed ET eq.	39.8b	25.1b	3755b	31.4b	23.4b	7.5a	3.1a
Traditional, fixed	35.4c	22.8c	3610c	28.6c	22.8b	7.0a	3.2a

Note. [1]Within each column, means followed by the same letter indicates no significant difference between treatments by Duncan's test at $P<0.01$. [2]Means of ten plants.

Plant growth can be limited by insufficient amounts of water but, is generally not adversly affected by excessive irrigation because of the well-drained root medium used by many growers. Overall, it can be said that the growth of chrysanthemum and water saving in the nursery production can be enhanced using developed specific ET models.

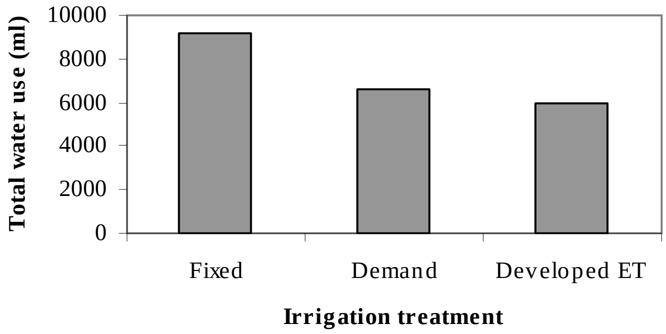

Figure 2. Total amount of water applied under different irrigation regimes

4. CONCLUSIONS

The study showed that a close relationship exists between chrysanthemum water requirements and the plant and evaporative data that were used to estimate those requirements. It is obvious that this simplified ET equation is important for commercial purposes in practice. However, this ET equation should be evaluated for all growing conditions, and necessary precautions should be given in its use. Besides, necessary calibration for the developed equation should be done with additional data in order to respond to high evaporative demand conditions.

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