Controlling Irrigation of Hydrangea Based on Plant Water Use

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Nature of work: The increase in water use in urban parts of Georgia likely will reduce the amount of water available for agriculture in the future. It will become increasingly important that water used for agricultural purposes is used as efficiently as possible. Currently, many nurseries irrigate based on a set schedule, without paying much attention to the actual water needs of the crop. This generally results in the application of much more water than what is needed to sustain plant growth, which may in turn result in runoff of water and fertilizer.

A better approach to efficient irrigation is to irrigate based on the actual water use of the plants. Plant water use can be determined from measurements of the moisture content of the substrate in the container. We are using fairly new and affordable soil moisture sensors (ECH_2O probe, Decagon, Pullman, WA) to measure the volumetric water content of the substrate. These probes are interfaced with a datalogger, which can turn on the irrigation when the substrate water content drops below a particular set point. In this study, we watered the plants with 35 ml of water (slightly over one fl. oz.), each time the substrate water content dropped below 8, 11, 14, 17, or 20%. The objective of this research is to quantify optimal substrate moisture levels for fully-automated irrigation systems that maintain a constant substrate moisture content.

On March 29, 2005 60 hydrangeas ‘Lady in Red’ were transplanted into 1 gallon containers. Each container was placed in a hole in the lid of a 5-gallon bucket, so that any leachate accumulated in the bucket (Picture 1). The plants were assigned to one of five treatments, in which plants got watered as the substrate moisture content dropped below a particular set point. Initially these irrigation set points were set to 10, 15, 20, 25, and 30%, but the higher set points exceeded the water-holding capacity of the substrate and set point were changed to 8, 11, 14, 17, and 20% on April 14. The water content in the substrate of four containers in each treatment was measured with 10-cm long ECH_2O probes, which were inserted diagonally into the containers. The probes were connected to a datalogger (CR10, Campbell Scientific, Logan, Utah) that functioned as the irrigation controller (picture 1). The probes were measured once every 20 minutes. The readings from the four probes in one treatment were averaged, and all plants in that treatment were irrigated for 30 seconds when the average water content dropped below the set point. Irrigation was provided by low volume (1 GPH) drip irrigation. Irrigation was controlled by the datalogger and a relay driver (SDM-CD16AC, Campbell Scientific). Although the ECH_2O probes are temperature-sensitive (the moisture reading goes up with increasing temperature), we did not correct for fluctuations in the substrate temperature.

The datalogger not only controlled irrigation, but also kept track of how often each treatment was irrigated. This allowed us to calculate the amount of water applied to each plant. Leachate from each container was measured throughout the experiment by weighing the water in the buckets collecting the leachate. Leaf chlorophyll was measured on June 16 with a handheld chlorophyll meter (SPAD-502, Minolta). The experiment was ended on July 11, at which time the shoots of the plants were harvested and their dry weight was determined. The water use efficiency, the amount of shoot dry matter produced per liter of water, in each treatment was calculated as shoot dry weight dived by the amount of water applied.

Results and Discussion: The irrigation system generally performed well. The substrate moisture content in the 14-20% treatments remained stable as can be seen from the daily minimum substrate moisture levels (Figure 1). The substrate was always maintained at or above the set point for irrigation. In the 8 and 11% treatments the differences between the daily minimum and maximum were much larger than in the 14 - 20% treatments. This may be an artifact related to the temperature sensitivity of the probes. Temperature fluctuations are larger in drier substrates, and this may result in larger fluctuations in the readings of the temperature-sensitive probes. Even so, the irrigation system was able to maintain distinct substrate moisture levels in the different treatments.

The volume of irrigation water applied per container ranged from 1.08 liters in the 8% water content treatment to 83 liters in the 20% treatment (Figure 2, Table 1). The amount and percentage of water leached from the containers varied greatly among treatments and was lowest in the 8 and 14% treatments. However, 8% volumetric water content was not sufficient to keep the plants alive. At the end of the study all plants in this treatment had died. Surprisingly, there was more leachate in the 11 than in the 14% treatment. Perhaps, the substrate in the 11% was too dry to readily absorb water, and channeling and subsequent leaching of the irrigation water may have occurred. A substrate water content of 11% also resulted in stunted plants, as is clear from their low dry weight (23 grams per plant). There was no difference in growth among the 14 and 17% treatments (39.5 g/plant), while the 20% treatment slightly reduced growth compared to that at 14 and 17%. Leaf chlorophyll, an indicator of leaf color was highest in the 11% treatment, but this treatment did not result in acceptable growth (Table 1). Representative plants from the different treatments are shown in picture 2.

Overall, the 14% treatment was optimal, since it resulted in relatively low water use (17.7 L total or on average 200 mL per day), good growth, and very little leaching (0.6 L or 3% of the applied water; Table 1). This treatment also resulted in the highest water use efficiency. Thus, by controlling irrigation based on the water content of the substrate, it is possible to provide plants with the needed water, while minimizing leaching.

From figure 2, it is clear that this approach to irrigation automatically adjusts the amount of water applied based on plant size and environmental conditions. During the first month of the growing period, plants did not get watered very often, but irrigation frequency increased as plants got larger, and temperatures increased during the summer. By maintaining a constant substrate water content, the irrigation system basically replaces the amount of water used by the plants, i.e. after the plant takes up 35 mL of water from the substrate, the irrigation comes on and adds another 35 mL of water to the substrate. Thus, irrigation is based on plant water use, and plants receive as much water as they use. A controller that can be interfaced with existing irrigation systems is now available, so that greenhouse and nursery growers can use this approach to irrigation.

One potential problem with this irrigation approach is that the moisture probes are temperature sensitive; an increase in temperature will increase the reading of the probe and cause an overestimation of the true volumetric water of the substrate. To counteract such problems, it may be necessary to use a higher set point for irrigation during the hottest part of the year. New probes are under development that are likely to be less temperature sensitive, which may nullify this problem.

Subsequent, similar experiments in the summer and fall of 2005 were less successful. In these experiments, plants were transplanted in either mid summer or early fall, under much less favorable environmental conditions (higher temperatures and more light). The plants did not get established well in summer and fall, suggesting that higher substrate moisture set points may be necessary under less favorable conditions, at least shortly after transplanting.

Significance to the industry: More efficient irrigation strategies will be necessary in the future to conserve water and minimize runoff of nutrients. This can be achieved by irrigating plants based on the amount of water that is present in the containers. One approach to doing so, is to measure the substrate moisture content, and adding small amounts of water to the container as the moisture content drops below a grower-determined set point. In cooperation with Brower Electronics Laboratories, we have developed an irrigation controller that is designed as an add-on to existing irrigation systems, so no extensive redesign is needed. This controller allows growers to set a substrate moisture level at which the plants will be irrigated, the duration of each irrigation event, and a minimum interval between subsequent irrigations (to allow the water to get distributed within the container).

Table 1. Total irrigation volume, leachate volume, leachate percentage, plant dry weight, water use efficiency (g of plant dry weight per liter of water used for irrigation) and leaf chlorophyll content of hydrangeas as affected by the set point for irrigation.

Irrigation set point % water	Irrigation volume (Liters)	Leachate volume (Liters)	Leachate percentage %	Plant dry weight (g/plant)	Water use efficiency (g/L)	Leaf chlorophyll (SPAD units)
8%	1.08	0.13	12	dead	-	49.7
11%	14.98	5.97	40	23.02	1.54	56.4
14%	17.74	0.61	3	39.81	2.24	47.1
17%	36.44	16.66	46	39.38	1.08	45
20%	83.02	excessive	-	34.99	0.42	43.4

Picture 1. Plants were placed in the lids of 5-gallon buckets so that the leachate collected in the buckets. A datalogger (in the metal enclosure on the right) controlled solenoid valves, allowing for precise control of the substrate moisture level in five different treatments. The datalogger was connected to a laptop computer, allowing us to monitor the data.

Picture 2. Representative plants from the five irrigation treatments on June 16. Although most of the plants in the 8% treatment were still alive at this stage, all plants in this treatment would die in the coming month.

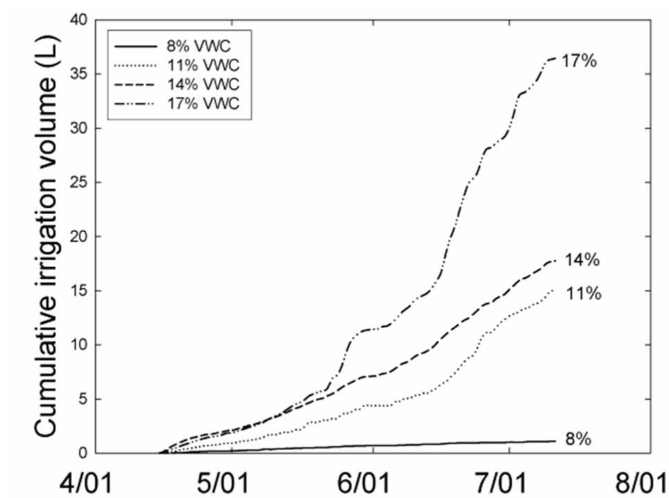

Figure 1. The daily maximum (closed symbols) and minimum substrate volumetric water content (open symbols) in the five irrigation treatments during the last two months of the growing period.

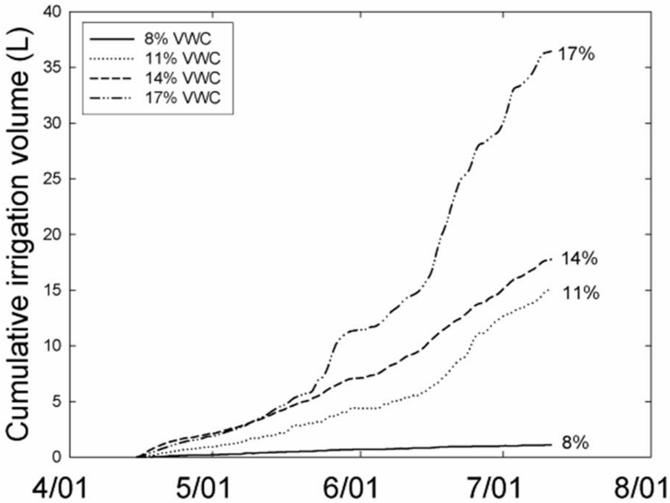

Figure 2. The cumulative amount of irrigation supplied to hydrangeas during an 87-day period. Plants received 35 mL of water each time the measured volumetric water content of the substrate dropped below 8, 11, 14, 17, 0r 20%. The 20% treatment resulted in excessive irrigation and data are not shown. Those plants received over 80 L of water during the 87-day period. In this figure, steeper parts of the curves indicate periods during which the plants received more water.