Quantifying Water and Nutrient Losses with Hose Irrigation[1]

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Abstract

The amount of water, nitrogen (N), phosphorous (P), and iron (Fe) lost from potted impatiens (*Impatiens wallerana* Hook. f.) plants fertilized with either controlled-release fertilizer (CRF) of varying longevities or a water-soluble fertilizer (WSF), with irrigation provided with a hose in all treatments, was quantified. The plants were grown in a sphagnum peat-based soilless substrate containing either CRF [Osmocote Plus 16-9-12 (16-3.9-10-0.46 N:P:K:Fe), 5 to 6 month and or 8-to 9 month longevities] incorporated (6.8 kg·m^{-3} or 11.5 lb·yd^{-3}) throughout the substrate and compared with plants fertigated with a WSF [Peters Professional 20-10-20 (20-4.4-1.66-0.1 N:P:K:Fe) at 150 mg·L^{-1} (150 ppm) N]. The container-grown plants were placed on top of plastic cups and located inside a plastic box. Municipal water or mineral nutrient solution leached from each container and lost between containers was captured, quantified and analyzed for N, P, and Fe concentrations. As an average for the three treatments, 25.6% of the total water applied was leached out of the pots and 34% fell between the pots. Six weeks after starting the experiment, leachate from pots fertilized with WSF had approximately a 92% higher concentration of N, 96% more P, and 69% more Fe than the concentrations in leachate from CRF-fertilized pots. These results quantify the assumed inefficiencies of using a hose as the primary fertilizer delivery method.

Index words: *Impatiens wallerana*, slow-release fertilizers, fertilization, bedding plants, irrigation, leachates.

Species used in this study: 'Xtreme Scarlet' impatiens (*Impatiens wallerana* Hook. f.).

Significance to the Horticulture Industry

Many nursery and floriculture producers of container-grown plants use a hose moved by hand from plant to plant to irrigate or fertigate (watered with dissolved mineral nutrients) some or all their crops. This method is more common among small growers who cannot afford more efficient delivery methods of water or water-soluble fertilizer. This research quantifies and confirms the inefficiency of this irrigation and fertilization management method. Although each grower may use a hose for irrigation differently from the way we used it in this research, it nevertheless shows that growers should avoid using this irrigation method as much as possible to minimize waste of water and mineral nutrient resources.

Introduction

High nitrate-nitrogen in runoff contributes to algal blooms in estuaries and marine environments while high phosphate/phosphorus levels can cause eutrophication and subsequent algal blooms in fresh water and estuaries (Entry and Sojka 2007, Pennsylvania Fish and Boat Commission 2001). Other water body contaminants include aluminum, iron and manganese. These heavy metals can be toxic to aquatic life, causing stress and possible death of young fish (Pascoe et al. 1986). Iron can settle downstream causing water to appear yellow, eliminating fish habitat and indirectly increasing water temperatures (Pennsylvania Fish and Boat Commission 2001). Reduction of nutrient losses becomes important to minimize environmental impact and maximize effectiveness of costly fertilizers. In some watersheds, the amount and makeup of nonpoint runoff is strictly monitored, making excess runoff punishable by fines (Torres 2012) or limits in business practices. Reduction in water and nutrient losses from greenhouse and nursery growing operations can be achieved by the proper selection of fertilizer and water delivery systems.

Using controlled-release fertilizer (CRF) instead of water-soluble fertilizer (WSF) for container-grown plant production has been reported to effectively limit the loss of nutrients (Haver and Schuch 1996, Medina et al. 2008). CRFs have been identified as a best management practice because they produce a localized supply of nutrients to the surrounding substrates over time, increasing the probability of root interception and uptake (Cabrera 1997, Colangelo and Brand 2001, Simonne and Hutchinson 2005). CRF use may also reduce nutrient runoff and improve nutrient use efficiency in greenhouses (Klock-Moore and Broschat 1999, Cabrera 1997, Wright 1992). Fernandez-Escobar et al. (2004) found that use of a CRF product reduced nitrate losses by at least 50% compared to traditional fertilizers such as ammonium nitrate or calcium nitrate, especially during the first month after application.

Richards and Reed (2004) reported that of the K released from Osmocote CRF prils (14-6.1-11.6, N:P:K, 3 to 4 month release), 77 and 83% were recovered in the plant shoots for sub-irrigation and top watering, respectively. This indicates a high fertilizer use efficiency by CRF, which has also been reported by others (Holcomb 1980). Andiru (2010) found that a 5 to 6 month (5–6) longevity CRF had relatively high losses of nutrients early in the plant life cycle while WSF applied with a leaching fraction of 25 to 30% leached similar amounts of nutrients as a 8 to 9 month (8–9) CRF. That research did not quantify, however, the amount of leachate that

[1]Received for publication July 1, 2014; in revised form February 18, 2015. Ohio State Journal Article Number HCS14-15. Funding for this research was provided by The Cooperative State Research, Education and Extension Services (CSREES), U.S. Department of Agriculture (USDA). Greenhouse Ohio project. Award # 2009-38897-19894. Salaries and research support were provided in part by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center (OARDC), The Ohio State University. Mention of trade names implies no endorsement by the authors. We thank The Scotts Company for supplying the fertilizers used in this research. Journal Article Number HCS14-15.

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occurs from containers fertilized with WSF using irrigation methods with a higher leaching fraction such as those used for producing container-grown crops.

A common method for delivery of fertigation (defined as applying fertilizer mixed with irrigation water) or irrigation used by container-grown ornamental plant producers is a watering device at the end of a hose. During fertigation, growers move the hose end from plant to plant and from one bench to another. Some water/fertilizer solution falls onto leaves and drains either inside or outside the container, while the rest falls outside the container. It has been estimated that up to about 74% of the solution in overhead irrigation systems falls outside the containers (Colangelo and Brand 2001), and if fertigation is utilized as a fertilizer delivery method, then a similar proportion of the fertilizer never reaches the target plants.

The objective of this experiment was to quantify the amount of water, nitrogen (N), phosphorous (P), and iron (Fe) lost when plants are fertilized with CRF or fertigated with a hose. Particular emphasis was placed on the amount of these nutrients leached from container-grown plants because these elements have a high algae growth potential (Kuffner and Paul 2001).

Materials and Methods

The experiment was conducted in plants growing in a substrate consisting of a 3:1 (by vol) ratio of Canadian sphagnum peat moss (Sunshine PeatMoss; SunGro Horticulture, Bellevue, WA) and perlite (Therm-ORock East, New Eagle, PA). A total of 3 $kg \cdot m^{-3}$ (5.1 $lb \cdot yd^{-3}$) carbonated lime was added to correct the pH to 5.8 to 6.4 (Argo and Biernbaum 1996). This substrate was hydrated by adding a solution of 11.2 ml of surfactant (Aqua-Gro L, Scotts Company, Marysville, OH) per liter of water (1.5 fl oz per gal). This solution was added to the substrate at a rate of 10 $L \cdot m^{-3}$ (2 $gal \cdot yd^{-3}$). The substrate was then placed in a 100-L plastic container and left to equilibrate for 24 h.

'XTREME Scarlet' impatiens, 288-plugs per tray, were obtained from a commercial producer (Green Circle Growers, Oberlin, OH) and planted individually in 770 ml (4.5 in diam) plastic containers. The CRF 16N-3.9P-10K-0.46Fe (Osmocote Plus 16-9-12, Everris International, Geldermalsen, The Netherlands) in the 5 to 6 month and 8 to 9 month longevity formulations were incorporated throughout the substrate at 6.8 $kg \cdot m^{-3}$ (11.5 $lb \cdot yd^{-3}$). The fertigation treatment was based on a 20N-4.4P-16.6K-0.1Fe WSF (Peters Professional 20-10-20, Everris International, Geldermalsen, The Netherlands) applied at a rate of 150 $mg \cdot L^{-1}$ (150 ppm) N. All CRF-treated plants were watered with a hose supplying tap-water only, while the WSF-treated plants were fertigated using a hose as needed based on environmental conditions and plant size. The color of the substrate surface and the container weight (sensed by lifting the containers) were checked in order to determine if irrigation was needed. Water applied per container was not measured. When the volume of the container between the surface of the substrate and the rim of the container was full with water, the hose was moved to another container. The goal was to imitate what many growers do with hose irrigation.

Plants were grown in a greenhouse with a double-layer acrylic roof at The Ohio State University, Columbus. The experiment lasted six weeks (42 days), conducted between the months of September and November. The greenhouse low and high temperatures set points were 18 and 21 C (64 and 70 F), respectively. The experimental setup for the nutrient leached from containers and lost when moving the hose from container to container (water that fell outside the container) during hose irrigation was a randomized complete block design consisting of three treatments with 18 plants per plot (one plant per container) grown in three blocks.

During weeks 1, 3, and 6, the flow rate of the irrigation water for each treatment was determined. To collect leachates during irrigation, containers with plants were placed on top of 11.5 cm (4.5 in) diameter by 8.5 cm (3.3 in) height plastic cups in such a way that all container's drainage holes would drain inside the plastic cup. This setup (containers on top of plastic cups) was placed inside a plastic 88.3 × 41.9 × 15.2 cm (2.9 ×1.4 × 0.5 ft) box (Sterilite Corp. Townsend, MA) to collect water lost during irrigation when the hose was moved among containers. The box initially fitted 18 plants 'pot-to-pot' (week 1). As plants grew larger, the box fit fewer containers: 12 containers in week 3 and eight in week 6. This setup imitated plant spacing that growers would use during container plant production. The boxes with the plants inside were placed next to each other and one empty box (with no containers with plants) was placed between treatments to collect water lost when moving the hose from one treatment to another. The water collected in the empty box represented the water lost when growers move the hose from one bench to another.

The time to complete the watering of each treatment was recorded. This time and the previously measured flow rate allowed the calculation of the total volume of water used to irrigate each treatment (here called 'Total'). Thirty minutes after irrigation, plants were removed from the boxes. The total volumes of water leached from the plants ('Leached') and water collected inside the boxes with and without plants 'Missed') were measured. Six plants from each treatment were randomly selected and a sample of 50 mL per plant of the leachates was stored in 50 ml plastic cylindrical tubes at 2 C (36 F) for future analysis of N using an ion selective electrode (ISE) (Scotts Testing Laboratory, Lincoln, NE). P and Fe were analyzed using inductively coupled plasma-optimal emission spectroscopy (Iris Intrepid II, Thermo Electron, Waltham, MA).

The total volume of water used for irrigation was determined by multiplying the measured flow rate by the time it took to water all the plants for each treatment. Because the width of the empty box was half of the distance between benches, the water collected in this box was doubled to simulate the water lost when the hose is moved between benches. The total volume of water leached was determined by pooling the water collected in all the plastic cups placed under the containers with the plants. Total volume of water 'Missed' was determined by pooling the water collected in all the plastic boxes. The results of N, P and Fe leached were analyzed using mixed models (proc mixed) and mean separation by Fisher's least significant difference (LSD) at $P \leq 0.05$ using SAS version 9.2 (SAS Institute, Cary, NC).

Results and Discussion

The total volume of water or fertilizer-solution applied during irrigation or fertigation, and the volumes of water 'Leached' and 'Missed' increased over time (Table 1). This increase may be the consequence of plants being larger, having different shapes over time and the movements with

Table 1. **Total water applied, leached and lost (missed) per treatment during irrigation using a hose.**

Treatments[y]	Amount of water (L)[z]		
	Total applied	Total leached	Total missed
		Week 1	
CRF (5–6 mo.)	13.1	5.1	3.6
CRF (8–9 mo.)	11.3	4.0	2.6
WSF	11.9	4.3	3.5
		Week 3	
CRF (5–6 mo.)	23.2	5.2	8.1
CRF (8–9 mo.)	22.4	5.0	7.5
WSF	25.5	4.6	9.1
		Week 6	
CRF (5–6 mo.)	28.6	8.2	10.4
CRF (8–9 mo.)	27.9	7.6	10.7
WSF	29.6	5.5	10.5
		Total	
CRF (5–6 mo.)	64.9	18.5	22.1
CRF (8–9 mo.)	61.6	16.6	20.8
WSF	67.0	14.4	23.1

[z]Total applied is the total amount of water used during irrigation of a given treatment, total leached is the amount of water leached from all the containers of a treatment and total missed is the amount of water lost while moving the hose from one container to another within a treatment.

[y]Plants were grown with Osmocote 16-9-12 of 5–6M or 8–9M longevity incorporated in the substrate. WSF plants were grown with a 150 mg·L^{-1} N solution of 20-10-20 Peter's Professional WSF.

the hose end the person irrigating had to make to reach each plant. Different fertilizer treatments may have also produced plants of different sizes and shapes affecting how they were irrigated by the person applying the water or fertilizer-solution. As an average for the three treatments, 25.6% of the total water applied was leached and 34% was missed.

In week 1, the leachate solution from the 5–6 month CRF had a concentration of N that was approximately 34% higher than the N concentration in the leachate from WSF or 8–9 month CRF (Table 2). Similarly, a higher concentration of Fe was found in the leachate solution from the 5–6 month CRF or the 8–9 month CRF. These results were unexpected and we hypothesize that it is the consequence of the higher level of Fe (0.46%) in the CRF versus the WSF (0.1%). The concentration of P in the leachate solution of week 1 was similar for the three treatments.

By week 3, the concentration of N, and P in the WSF leachate solutions were higher than those in the leachate solutions from the other two treatments (Table 2). During week 6, the concentrations of N, P, and Fe in the WSF leachate solution were about 92, 96, and 69% higher, respectively, than concentrations in the leachate solutions from the other two treatments. These results are consistent with those reported by Andiru (2010) when measuring the nutrients in the leachates of CRF-fertilized impatiens when CRF was placed at different locations inside the container.

The concentrations of N missed from the WSF pots in weeks 1, 3, and 6 were higher than what was in the applied nutrient solution applied (150 ppm). The water lost by falling outside the containers ('Missed') during irrigation of CRF-treated plants had a smaller concentration of nutrients than the water wasted during fertigation with WSF (Table 2). This difference increased in weeks 3 and 6. The concentration of N in the 'Missed' water of the three fertilizer treatments on week 1 was higher than expected; we speculate that it was contamination from residues in the irrigation hose or from CRF prills falling into the bin from the containers.

The volume of water that fell outside the containers increased over time because there was additional space between containers to accommodate the larger plants. An increased area of fertigation requires more time to apply the irrigation. Therefore, more water will be lost when moving the hose end from container to container.

Hose fertigation with WSF can lead to high nutrient losses due to fertilizer falling outside the containers (Colangelo and Brand 2001). In our experiment, using CRF resulted in significant reductions of nutrients in the water that fell outside the containers. For example, the N concentration in the Missed water from the WSF treated pots on week 1 was 10.4 times higher than in the Missed water of the CRF treated pots. On week 6, such concentration of N was 94 times higher. After the first week, the amounts of N and P concentrations in water leached from WSF-treated plants were greater because these nutrients were continuously added to the substrate through irrigation.

Table 2. **Average concentrations of nitrogen, phosphorus and iron in leachate solutions from containers and lost when moving hose from container to container (water that fell outside the container) during hose irrigation.**

Treatment[y]	Nutrient concentration (mg·L^{-1})[z]								
	Week 1			Week 3			Week 6		
	N	P	Fe	N	P	Fe	N	P	Fe
					Nutrients in leachates				
CRF (5–6 mo)	205.4a	10.3a	1.0a	122.2b	4.6b	1.0a	12.2b	1.1b	0.6b
CRF (8–9 mo)	154.6b	9.0a	0.6b	106.7b	4.7b	0.8a	9.8b	0.9b	0.5b
WSF	153.1b	10.9a	0.3c	149.6a	25.5a	0.9a	137.2a	27.5a	1.6a
					Nutrients lost between pots (Missed)				
CRF (5–6 mo)	24.7b	0.55b	0.02b	7.0b	0.8b	0.0b	2.1b	0.68b	0.0b
CRF (8–9 mo)	22.2b	0.53b	0.01b	10.2b	1.3b	0.02b	1.8b	0.52b	0.0b
WSF	256.6a	30.1a	0.36a	165.0a	30.1a	0.45a	196.7a	37.5a	0.51a

[z]Values are means of 18 plants in 3 blocks. Means separation by LSD. $P = 0.05$. Means with the same letter in a column are not significantly different.

[y]Plants were grown with Osmocote 16-9-12 of 5–6M or 8–9M longevity incorporated in the substrate. WSF plants were grown with a 150 mg·L^{-1} N solution of 20-10-20 Peter's Professional WSF.

Table 3. **Nitrogen, phosphorous, and potassium leached, missed, and lost from containers during hose irrigation. Plants were grown with Osmocote 16-9-12 of 5–6M or 8–9M longevity applied as incorporated. WSF plants were grown with a 150 mg·L^{-1} N (150 ppm N) solution of a 20-10-20 Peter's Professional WSF.**

Treatment[z]	Nutrients recovered (mg)								
	Week 1			Week 2			Week 3		
	N	P	Fe	N	P	Fe	N	P	Fe
				Nutrients in leachates					
CRF (5–6 mo)	1047.5	52.5	5.1	635.4	23.9	5.2	100.0	9.0	4.9
CRF (8–9 mo)	618.4	36.0	2.4	533.5	23.5	4.0	74.5	6.8	3.8
WSF	658.3	46.9	1.3	688.2	117.3	4.1	754.5	151.2	8.8
				Nutrients missed					
CRF (5–6 mo)	88.9	2.0	0.07	56.7	6.5	0.0	21.8	7.1	0.0
CRF (8–9 mo)	57.7	1.4	0.03	76.5	9.8	0.2	18.7	5.6	0.0
WSF	898.1	105.3	1.3	1,501.5	273.9	4.1	2065.4	393.8	5.4
				Total nutrients lost (leached + missed)					
CRF (5–6 mo)	1136.4	54.5	5.2	629.1	30.4	5.2	121.8	16.1	4.9
CRF (8–9 mo)	676.1	37.4	2.4	610.0	33.3	4.2	93.2	12.4	3.8
WSF	1,556.4	152.2	2.6	2,189.7	391.2	8.2	2,820.0	545.0	19.1

[z]Plants were grown with Osmocote 16-9-12 of 5–6M or 8–9M longevity incorporated in the substrate. WSF plants were grown with a 150 mg·L^{-1} N solution of 20-10-20 Peter's Professional WSF.

During the three weeks of measurement, total nutrient lost (Leached + Missed) was greatest for WSF, intermediate for CRF (5–6 mo), and smallest for the CRF (8–9 mo) treated containers (Table 3). The total nutrients lost from CRF-treated pots were reduced over time, while the total nutrients lost from WSF-treated containers increased.

Different growers use the hose in slightly different ways, and most likely different from the way it has been used in this experiment. Nevertheless, the results obtained in our research can be considered a clear indication of the inefficiencies of a hose as an irrigation method. Employing irrigation systems using drippers or emitters may increase water and nutrient efficiencies.

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