METHOD OF FERTILIZER APPLICATION AFFECTS NUTRIENT LOSSES OF CONTROLLED-RELEASE FERTILIZER

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Abstract

An experiment with two controlled-release fertilizers (CRF) and two methods of fertilizer application (surface-applied or incorporated) was conducted to evaluate the impact of method of fertilizer application on nutrient losses and efficacy. Rooted cuttings of *Cotoneaster dammeri* 'Skogholm' were potted into 3.8 liter containers in an 8 pine bark: 1 sand (by vol) substrate. Each plant was fertilized at potting with 5.0 g N from Nutricote 18N-2.6P-6.6K or Meister 18N-2.6P-9.7K. The experiment, a RCBD with four replications was conducted for 100 days on a plant production area subdivided into 16 separate plots that allowed for the collection of all irrigation water leaving each plot. Twenty containers were placed on each plot. Irrigation water (total volume = 800 ml) was applied daily in two equal applications with a two hr interval between irrigation allotments via pressure compensated spray stakes. Volume of effluent from each plot was measured daily and analyzed for NO_3-N, NH_4-N, and PO_4-P. Nitrate losses increased 105% or 258% when Nutricote or Meister, respectively was incorporated compared to surface-applied. Phosphorus losses increased 33% or 88% when Nutricote or Meister, respectively was incorporated compared to surface-applied, respectively. Nitrogen efficiency was 39% to 53% for Meister incorporated and surface-applied, respectively, whereas N efficiency was 34% to 43% for Nutricote incorporated and surface-applied, respectively. Phosphorus efficiency with Meister fertilizer was greater for surface-applied (57%) compared to incorporated (38%). Phosphorus efficiency (32%) with Nutricote was unaffected by the method of application.

1. Introduction

Concerns with water quality places pressure on growers to develop "best management practices" to reduce or eliminate nutrient contamination in irrigation effluent (Urbano, 1989). Thus, any production technique that improves efficiency and reduces nutrient losses could be advantageous. Recently, it was recommended that the initial application of controlled-release fertilizer (CRF) should be incorporated into the growth medium at potting in lieu of applying the CRF to the surface of the medium (Southern Nurserymen's Assoc., 1997). This recommendation infers that adjustments in method of fertilizer application may provide a management tool for increasing nutrient efficiency yielding environmental as well as monetary paybacks for growers.

Several studies have been conducted to determine whether surface application or incorporating CRF produces larger plants. Plant growth varies depending on the method of application, nutrient release characteristics of the CRF, rate of fertilization, container medium and plant species (Eakes *et al*., 1990, Yeager *et al.*, 1989). However, little is known concerning the effect of method of fertilizer application on nutrient losses and efficiency. Therefore, the objective of this study was to evaluate the method of fertilizer application (surface or incorporation) of two commercial CRFs on plant growth and

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mineral nutrient content, and nutrient losses.

2. Materials and methods

2.1. Experimental design, CRFs, and cultural practices

The experiment, a randomized complete block design with four replications and treatments arranged in factorial combinations of two CRFs and two methods of fertilizer application (surface or incorporation), was conducted for 100 days at the North Carolina State University Horticulture Field Laboratory, Raleigh from June to September. Rooted cuttings of *Cotoneaster dammeri* 'Skogholm' were potted into 3.8 liter containers in an 8 pine bark: 1 sand (by vol) substrate amended with 1.8 kg/m^3 dolomitic limestone. Each plant was fertilized at potting with 5.0 g N from Nutricote 18N-2.6P-6.6K (18-6-8, Nutricote Inc., Tampa, Fla.) composed of polymer coated ammonium nitrate, ammonium phosphate, calcium phosphate, and potassium nitrate; or Meister 18N-2.6P-9.7K (18-6-12, Helena Chemical Co., Memphis, Tenn.) containing polymer coated urea, calcium phosphate, potassium sulfate, and potassium-magnesum sulfate. Micronutrients were contained in both CRFs. Plants were grown in a plant production area subdivided into 16 separate plots that allowed for collection of all irrigation water leaving each plot. Plots were 8 x 2 m with a 2% slope and were lined with black plastic. Twenty containers were placed in each plot for a total of 80 containers in each treatment. A daily irrigation volume of 800 ml was applied in two equal applications with a two hr interval between irrigation allotments via pressure compensated spray stakes (Acu-Spray Stick, Wade Mfg. Co., Fresno, Calif.) at a rate of 200 ml/min.

2.2. Physical properties of growing medium

Physical properties of the medium (percent volume at drainage) were total porosity 78%, air space 16%, container capacity 62%, unavailable water 31%, and available water 30%. Physical properties were determined as described in Tyler et al. (1993).

2.3. Data collected

2.3.1. Effluent collection and analysis: At 9:00 AM daily, volume of effluent from each plot (four per treatment) was measured and a sub-sample of effluent was collected, filtered, and analyzed for $N0_3$-N (Calaldo *et al*., 1975), NH_4-N (Chaney *et al*., 1962), and PO_4-P (Murphy *et al.*, 1962) using a spectrophotometer (Spectronic 1001 Plus, Milton Roy Co., Rochester, N.Y.*)*. Urea in effluent was hydrolyzed to NH_4 with urease (Sigma Chemical Company, St. Louis, MO.) prior to NH_4-N analysis (Chaney *et al.*, 1962).

2.3.2. Nutrient analysis: At harvest, all fertilizer prills from two containers per plot (total of 8 containers / treatment) were removed and a sample of the substrate was collected. Fertilizer prills were mixed in a blender with 100 ml distilled water for one minute. This solution was diluted to 500 ml total volume with distilled water. Nitrate-N, NH_4-N, and $P0_4$-P analyses were conducted as described for effluent analysis. Substrate samples were dried at 62ºC for 5 days, ground in a hammer mill and sieved through a 18 mesh (1 mm) screen. Each substrate sample (1.25 g) was combusted at 490ºC for 6 h. The resulting ash was dissolved in 10 ml 6 N HC1 and diluted to 50 ml with distilled water. Phosphorus concentrations were determined with a inductively coupled plasma emissions spectrophotometer (P-2000, Perkin Elmer, Norwalk, Conn.). Nitrogen concentrations were determined using 10 mg samples in a CHN elemental analyzer (Perkin Elmer 2400).

2.3.3. Plant response: At harvest, shoots (aerial tissue) from five randomly chosen containers per plot (total of 20 containers / treatment) were removed and roots were placed over a screen and washed with a high pressure water stream to remove substrate.

Shoots and roots were dried at 62ºC for 5 days and weighed. After drying, shoots and roots were ground in a Wiley mill to pass a 40 mesh (0.425 mm) screen. At treatment initiation (Day 0), 10 plants were harvested and separated into shoots and roots. These plants were handled as previously described to determine initial shoot dry weight, root dry weight and nutrient concentration. Tissue analyses were conducted as described for substrate analysis.

2.4. Statistical analysis

Data were subjected to analysis of variance procedures (ANOVA) (SAS, 1985). Treatments means were separated by LSD, $P = 0.05$. The following variables were determined as follows: plant nutrient content = plant part dry weight (g) x plant part nutrient concentration (% dry weight); nutrient efficiency = [plant nutrient content (g) ÷ (nutrient content (g) in effluent + plant + substrate)]. Nutrient content of fertilizer prills was not included since this is related to remaining nutrient supplying power of the fertilizer. Initial N and P contents of cotoneaster roots and shoots were subtracted from plant nutrient content data prior to nutrient efficiency calculations.

3. Results and Discussion

3.1. Plant response

Total dry weight (shoots + roots) of cotoneaster grown with surface-applied Meister was 20% greater compared to incorporated Meister (Table 1). In contrast, total dry weight (shoots + roots) of cotoneaster grown with incorporated Nutricote was 35% greater than plants grown with surface-applied Nutricote. Previous studies have reported similar contrasting results. *Rhododendron* sp. 'Coral Bells' had 31% greater shoot dry weight when Osmocote 18N-2.6P-10K was surface-applied compared to incorporated (Eakes *et al*., 1990). However, shoot dry of *Ligustrum japonicum* and *Rhododendron* sp. 'Mrs G.G. Gerbing' fertilized with Osmocote 18N-2.6P-1OK were unaffected by method of fertilizer application (Yeager *et al.,* 1989). Eakes *et al.(*1990) reported incorporated Nutricote 16N-4.4P-8.3K produced greater dry weight of *Juniperous conferta* 'Blue Pacific' compared to surface-applied.

3.2. Plant mineral nutrient content

Nitrogen, P, and K content of cotoneaster were greater when the CRF was incorporated compared to surface application regardless of CRF (Table 2). This supports the hypothesis that incorporated CRF may be more accessible to the plant's root system resulting in increased uptake. If accumulation of nutrients by the plant increased this could increase fertilizer efficiency and decrease the content of nutrients in the effluent.

3.3. Nutrient losses

Even though the nutrient release characteristics and N source varied by CRF product, both CRFs lost greater quantities of NO_3-N and PO_4-P when incorporated compared to surface-applied (Table 3). Nitrate losses increased 105% or 258% when Nutricote or Meister was incorporated compared to surface-applied, respectively. Phosphorus losses increased 33% or 88% when Nutricote or Meister was incorporated compared to surface-applied, respectively. Similarly, Meister when incorporated lost greater quantities of NH_4-N compared to surface application. Nutricote had similar NH_4-N losses regardless of method of application. This difference in NH_4-N losses may have resulted from differing sources of N.

Yeager *et al*. (1989) working with Osmocote 18N-2.6P- 10K reported that K and NO_3-N leachate levels were generally higher when incorporated compared to surface-

applied. Eakes *et al*. (1990) also reported higher medium solution electrical conductivity (EC) when CRFs were incorporated compared to surface-applied. This suggests that nutrients released from incorporated CRF may be more easily leached since the fertilizer is dispersed uniformly throughout the medium in contrast to surface application. Another possibility would be that incorporated fertilizer might have a faster release rate compared to surface-applied fertilizer due to differences in medium temperature and water content. A faster nutrient release rate, if not subsequently absorbed by the plant could result in higher nutrient losses in the effluent.

3.4. Nitrogen and phosphorus budgets

Ninety-one percent to 101% of the 5.0 g of N from each CRF was recovered (Table 4). Nitrogen from rainfall and mineralization of organic substrate was not deducted from N recovery calculations which may have resulted in percentages > 100. Nitrogen efficiency was significantly ($P<0.05$) higher for surface-applied fertilizer compared to incorporated fertilizer regardless of the CRF. Nitrogen efficiency was 39% to 53% for Meister incorporated and surface-applied, respectively, whereas N efficiency was 34% to 43% for Nutricote incorporated and surface-applied, respectively. Using our defination of N efficiency and data collected by Stewart *et al*. (1981), a 15% N efficiency was calculated when *Ligustrum japonicum* was grown with liquid fertilization. In a simulated nursery with 1.2 cm of water applied daily by overhead irrigation, Warren *at al*. (1995) reported surface-applied resin-coated NH_4NO_3 and urea, both CRFs, provided a 56% N efficiency for azalea *(Rhododendron* sp. 'Sunglow'). Tyler *et al*. (l996b) working with cyclic irrigation, reduced leaching fractions, and surface-applied CRF reported N efficiencies form 56% to 69%. Nitrogen efficiency will vary depending upon irrigation volume (Tyler *et al*., 1996b), method of irrigation application (Tyler *et al*., l996a), form of nutrient and fertilizer applied (Warren *et al*., 1995), effectiveness of controlled release technology (Warren *et al*., 1995), and efficiency of plant uptake.

Of the N released from the fertilizer prills Meister lost 36% from surface-applied and 53% from incorporated, whereas Nutricote lost 45% and 57%, respectively. Of 6.0 g N surface-applied as Osmocote l7N-3P-1OK, Fare et al. (1994) lost 46% as NO_3-N in the effluent. Rather *et al*. (1989) reported an average of 24% of the surface-applied N was recovered in the effluent.

In contrast to N, P recovery ranged from 31% to 57% of the 0.73 g P from each CRF (Table 5). This was somewhat surprising, since P does not volatilize and has been reported to leach rapidly from pine bark substrates which have low P fixation capacities (Marconi and Nelson, 1984). However, Warren et al. (1995) and Tyler *et al*. (1996b) also reported low P recovery percentages. Of the P released from the fertilizer prills, Meister lost 43% and 62% from surface-applied and incorporated, respectively in the effluent, whereas Nutricote lost 73% and 65% from surface-applied and incorporated, respectively in the effluent. Similar to N, P efficiency with Meister fertilizer was greater for surface-applied (57%) compared to incorporated (3 8%). Phosphorus efficiency (32%) with Nutricote was unaffected by the method of application. Tyler *et al*. (1996a) working with uncoated monoammonium phosphate reported a P efficiency of 29%. Warren *et al*. (1995) reported 43% P efficiency with ammonium and calcium phosphates where P sources were contained in a resin-coated prill. Tyler *et al*. (1996b) demonstrated that P efficiency (56% to 69%) can be improved by reducing irrigation volume.

Even though plant nutrient content was greater when both CRFs were incorporated, incorporating CRFs increased NO_3-N and PO_4-P losses in irrigation effluent an average of 61% and 36%, respectively compared to surface application. A single study does not necessarily mandate changes in the choice of fertilizer application. However, growers should be aware that method of fertilizer application can affect nutrient losses in the irrigation effluent depending on fertilizer, medium, and irrigation management. Therefore, if growers incorporate CRFs, irrigation practices such as cycled irrigation or monitoring irrigation volume to decrease leaching could be critical.

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Tables

1. Effect of method of fertilizer application, onshoot, root, and total (shoot + root) plant dry weights of *Cotoneaster dammeri* 'Skogholm', 100 days after treatment initiation

Fertilizer Application	Controlled-release fertilizer Meister 18-6-12	Nutricote 18-6-8
	Top dry weight (g)	
Incorporated	39.3 b[z]	27.5 a
Surface	42.8 a	20.0 b
	Root dry weight (g)	
Incorporated	5.3 b	5.1 a
Surface	10.7 a	4.2 b
	Total dry weight (g0	
Incorporated	44.6 b	32.6 a
Surface	53.5 a	24.2 b

[z]Means within columns followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05

2. Effect of method of fertilizer application on nutrient content of *Cotoneaster dammeri* 'Skogholm'

Fertilizer Application	Controlled – release fertilizer					
	Meister 18-6-12			Nutricote 18-6-8		
	N	P	K	N	P	K
	Total plant nutrient content (mg)					
Incorporated	1030.0 a	102.9 a	671.0 a	807.4 a	28.5 a	352.0 a
Surface	910.5 b	60.2 b	558.6 b	669.2 b	16.1 b	231.1 b

[z]Means within columns followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05.

3. Effect of method of fertilizer application, on total nutrient content (g) in effluent, 100 days after treatment initiation. All data presented on a per 3.8 liter container basis.

Fertilizer Application	Controlled-release fertilizer Meister 18-6-12	Nutricote 18-6-8
	NH_4-N	
Incorporated	0.48 a[z]	0.15 a
Surface	0.36 b	0.11 a
	NO^3-N	
Incorporated	0.93 a	1.21 a
Surface	0.26 b	0.59 b
	PO_4-P	
Incorporated	0.150 a	0.032 a
Surface	0.080 b	0.024 b

[z]Means within columns followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05

4. Effect of method of fertilizer application on grams of N recovered in effluent, substrate, cotoneaster shoots and roots, and fertilizer prills, 100 days after treatment initiation. All data presented on a per 3.8 liter container basis.

	Controlled – release fertilizer							
	Meister 18-6-1				Nutricote 18-6-12			
Variable	Incorporate		Surface		Incorporate		Surface	
	Nitrogen recovered							
	g	%[z]	g	%[z]	g	%	g	%
Effluent[y]								
NH_4-N	0.48	18	0.36	21	0.15	6	0.11	7
NO_3-N	0.90	35	0.26	15	1.21	51	0.59	38
Substrate	0.19	7	0.19	11	0.19	8	0.19	12
Cotoneaster	1.03	39	0.91	53	0.81	34	0.67	43
Fertilizer prills								
NH4-N	2.41		3.27		1.41		1.54	
NO3-N	0.0		0.0		1.30		1.46	
Recovered N[x]	5.04		4.99		5.07		4.56	
N efficiency[w]	39%		53%		34%		43%	

[z]Percentage based on N recovered in the effluent + substrate +plant.
[y]Nitrogen in rainfall included.
[x]Recovered N = N contained in effluent ± substrate ± plant + fertilizer prills.
[w]N efficiency = [g N in plant χ (g N in effluent + substrate ± plant)] x 100.

5. Effect of method of fertilizer application on grams of P recovered in effluent, substrate, cotoneaster shoots and roots, and fertilizer prills, 100 days after treatment initiation. All data presented on a per 3.8 liter container basis.

	Controlled – release fertilizer							
	Meister 18-6-12				Nutricote 18-6-12			
Variable	Incorporate		Surface		Incorporate		Surface	
	P recovered							
	g	%[z]	g	%	g	%	g	%
Effluent[y]	0.150	55	0.080	34	0.032	40	0.024	40
Substrate	0.020	7	0.020	9	0.020	25	0.020	33
Cotoneaster	0.103	38	0.132	57	0.029	36	0.016	27
Fertilizer prills	0.140		0.080		0.250		0.165	
Recovered P[x]	0.413		0.312		0.331		0.225	
P efficiency[w]	38%		57%		36%		27%	

[z]Percentage based on N recovered in the effluent + substrate +plant.
[y]Nitrogen in rainfall included.
[x]Recovered P = P contained in effluent + substrate + plant + fertilizer prills.
[w]N efficiency = [g N in plant χ (g N in effluent + substrate ± plant)] x 100.