Rates of Ammonium-nitrogen, Nitrate-nitrogen, Phosphorus, and Potassium from Two Controlled-release Fertilizers under Different Substrate Environments

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SUMMARY. Five-gram (0.18 oz) samples of two controlled-release fertilizers (CRFs), Osmocote 15N-3.9P-10K (8-9 month) (OSM) and Nutricote 18N-2.6P-6.7K (type 180) (NUTR), were sealed into polypropylene mesh packets that were placed on the surface of a 5 pine bark:4 sedge peat:1 sand (by volume) potting substrate (PS), buried 10 cm (3.9 inches) deep below the surface of PS, buried 10 cm below the surface of saturated silica sand (SS), or in a container of deionized water only. Containers with PS received 120 mL (4.1 fl oz) of deionized water three times per week, but the containers with SS or water only had no drainage and were sealed to prevent evaporation. Samples were removed after 2, 5, or 7 months of incubation at 23 °C (73.4 °F) and fertilizer prills were crushed, extracted with water, and analyzed for ammonium-nitrogen ($\text{NH}_4\text{-N}$), nitrate-nitrogen ($\text{NO}_3\text{-N}$), phosphorus (P), and potassium (K). Release rates of $\text{NO}_3\text{-N}$ were slightly faster than those of $\text{NH}_4\text{-N}$ and both N ions were released from both products much more rapidly than P or K. After 7 months, OSM prills retained only 8% of their $\text{NO}_3\text{-N}$, 11% of their $\text{NH}_4\text{-N}$, 25% of their K, and 46% of their P when averaged across all treatments. Nutricote prills retained 21% of their

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$\text{NO}_3\text{-N}$, 28% of their $\text{NH}_4\text{-N}$, 51% of their K, and 65% of their P. Release of all nutrients from both fertilizers was slowest when applied to the surface of PS, while both products released most rapidly in water only. Release rates in water only exceeded those in SS, presumably due to lower rates of mass flow in SS.

Controlled-release fertilizers have been used in the production of a wide variety of horticultural crops (Maynard and Lorenz, 1979; Sharma, 1979). Container production of ornamental plants normally utilizes well-aerated potting substrates, with CRFs applied either to the surface of the substrate, or incorporated, layered, or dibbled within the substrate. The method of applying CRFs is known to affect their release rates of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ (Lunt and Oertli, 1962).

Production of aquatic plants, both for the aquarium trade, and for restoration of wetlands, is a relatively new industry, with its production methods still evolving. Many of these plants are grown in largely sand substrates submerged under water. CRFs, incorporated into such sand-based substrates have been shown to be effective nutrient sources for aquatic plants grown under water or in flooded sand substrates (Sutton, 1991, 1993, 1994, 1995). Release of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ from Osmocote into the surrounding sand substrate has been demonstrated by Sutton and Latham (1996).

The release rates of N and K from several CRFs have been determined in sand columns (Broschat, 1996; Holcomb, 1981; Huett and Gogel, 2000; Lunt and Oertli, 1962; Prasad and Woods, 1971;). Release rates of nutrients from CRFs in water have also been determined (Harbaugh and Wilfret, 1981), but their relevance to the production substrate environment has not been determined. Release rates of nutrients from Osmocote have been shown to be strongly temperature dependent, but intermittent drying that occurs when CRFs are surface-applied can also affect nutrient release rates (Lunt and Oertli, 1962; Oertli and Lunt, 1962). Differences in release rates due to substrate environment could influence application rates recommended for these products. The purpose of this study was to determine the release rates of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, P, and K from two CRFs applied under

substrate environments varying in their drying potential and diffusion rates.

Materials and methods

Five-gram (0.18 oz) samples of Osmocote 15N-3.9P-10K, 8 to 9 month (The Scotts Co., Marysville, Ohio) and Nutricote 18N-2.6P-6.7K, type 180 (Florikan ESA, Sarasota, Fla.) were sealed into 5- × 6-cm (2.0 × 2.4 inches) packets made from 55% shade woven shade cloth (Chicopee Manufacturing, Cornelia, Ga.). One packet was added to each of the following treatment containers: 1) packets were laid on the surface of a 5 pine bark:4 sedge peat:1 sand (by volume) potting substrate (PS) in a 2.4-L (0.63 gal) polypropylene nursery container; 2) packets were laid horizontally, 10 cm below the surface of PS in the same containers; 3) packets were laid horizontally, 10 cm below the surface in a medium-grade silica sand substrate (SS) in a holeless 2-L (0.53 gal) polystyrene container filled to the top with deionized water and sealed with Parafilm (American National Can, Chicago) to prevent evaporation; and 4) packets were placed in the same 2-L polystyrene containers filled with deionized water only and sealed with Parafilm. All containers were placed in a room maintained at $23 \pm 1^\circ\text{C}$ ($73.4 \pm 1.8^\circ\text{F}$). Deionized water was added to the surface of the nursery containers used in treatments 1 and 2 at a rate of 120 mL per container three times per week to simulate irrigation under nursery conditions. The sealed containers used for treatments 3 and 4 were not disturbed for the duration of the experiment to prevent any agitation of the water.

Fifteen replicate containers of each substrate environment and fertilizer were used. After 2, 5, and 7 months, five replicate containers from each treatment were removed from the incubation room. The fertilizer packets were removed from each container and were rinsed for 10 s under running deionized water. These packets were then opened and the fertilizer prills were crushed with a mortar and pestle. The crushed prills were dissolved in 50 mL (1.7 fl oz) of deionized water and were shaken for 30 min at 250 oscillations/min. After filtration, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ concentrations were determined by ion selective electrodes (Greenberg, et al., 1985), P by the ascorbic acid method (Greenberg et al., 1985), and

K by atomic absorption spectroscopy. Fresh samples of each fertilizer were similarly extracted to determine their total $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, P, and K contents. The percentage of each nutrient element remaining in the incubated fertilizer samples was determined by dividing the sample nutrient content by the average total elemental content for each product.

Analysis of variance, with mean separations by the Waller-Duncan k-ratio method, was performed on the data using SAS (SAS Institute, Cary, N.C.).

Results and discussion

Fertilizer type and substrate environment, as well as their interaction, had highly significant effects on $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, P, and K release rates (Tables 1 and 2). OSM released all of these nutrients more quickly than NUTR under comparable substrate environments. In all cases, CRFs applied to the surface of the PS released their nutrients the most slowly, while water only incubation resulted in the most rapid release. Both fertilizers usually released these four nutrients at similar rates, or more rapidly, when placed 10 cm deep in SS than in PS at a similar depth.

The much slower release of all nutrients from both OSM and NUTR when applied to the surface of PS could be due to the intermittent drying that occurred between irrigations and the short period of time when the prills were completely immersed in water (Lunt and Oertli, 1962). Although prill temperature was not monitored, it is possible that evaporative cooling may have resulted in lower average temperatures for surface-applied fertilizers, which could in turn reduce the rate of nutrient release (Lunt and Oertli, 1962; Oertli and Lunt, 1962).

Release of nutrients from the CRFs presumably occurs when the surface of the prills is merely moist, since both PS environments experienced only brief periods of complete immersion in water, followed by a much longer period of moist to nearly dry conditions in buried and surface-applied CRFs, respectively. That the CRFs buried in SS released only slightly faster, if at all, than when buried in PS, suggests that complete and continuous immersion in water is not a necessary condition for rapid release of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, P, and K from these products.

Table 1. Percentage of total ammonium-nitrogen (NH₄-N) and nitrate-nitrogen (NO₃-N) remaining in prills of Osmocote 15N-3.9P-10K [8-9 month (OSM)] and Nutricote 18N-2.6P-6.7K Type 180 (NUTR) incubated at 23 °C (73.4 °F) in various substrate environments.

Fertilizer	Substrate environment ^z	NH ₄ -N (% total)			NO ₃ -N (% total)		
		2 months	5 months	7 months	2 months	5 months	7 months
OSM	PS/surface	55.3 a ^y	24.7 a	19.6 a	55.4 a	27.1 a	17.2 a
OSM	PS/10 cm deep	47.3 b	12.9 c	7.9 b	46.4 b	13.8 b	4.9 b
OSM	SS/10 cm deep	47.3 b	17.1 b	8.8 b	44.1 c	9.7 b	4.8 b
OSM	Water	41.3 c	12.1 c	8.2 b	38.6 d	8.6 b	4.6 b
NUTR	PS/surface	86.8 a	58.3 a	47.1 a	84.3 a	48.4 a	37.5 a
NUTR	PS/10 cm deep	77.5 b	39.9 b	25.3 b	73.4 b	33.9 ab	18.1 b
NUTR	SS/10 cm deep	75.8 b	35.6 bc	23.9 b	68.0 c	30.2 ab	16.2 b
NUTR	Water	72.7 c	33.5 c	17.3 c	68.7 c	27.0 b	11.8 c

^zPS = potting substrate, SS = saturated sand, 1 cm = 0.39 inch.

^yMean separation within columns and fertilizers by the Waller-Duncan k-ratio method, *P* = 0.05.

Table 2. Percentage of total phosphorus (P) and potassium (K) remaining in prills of Osmocote 15N-3.9P-10K [8-9 month (OSM)] and Nutricote 18N-2.6P-6.7K Type 180 (NUTR) incubated at 23 °C (73.4 °F) in various substrate environments.

Fertilizer	Substrate environment ^z	P (% total)			K (% total)		
		2 months	5 months	7 months	2 months	5 months	7 months
OSM	PS/surface	95.0 a ^y	50.1 a	49.2 a	73.9 a	49.8 a	40.7 a
OSM	PS/10 cm deep	92.1 b	45.3 b	44.9 b	64.9 b	27.0 b	19.9 b
OSM	SS/10 cm deep	85.8 c	45.5 b	45.2 b	65.7 b	31.2 b	19.3 b
OSM	Water	86.2 c	44.6 b	44.5 b	57.9 c	25.8 b	18.8 b
NUTR	PS/surface	100.0 a	79.8 a	64.4 a	95.3 a	77.4 a	76.2 a
NUTR	PS/10 cm deep	99.6 a	72.9 a	57.9 ab	91.5 ab	66.6 ab	49.4 b
NUTR	SS/10 cm deep	99.4 a	58.7 b	54.0 b	88.6 bc	61.3 b	44.0 b
NUTR	Water	97.1 b	56.7 b	50.7 b	86.6 c	57.3 b	33.2 c

^zPS = potting substrate, SS = saturated sand, 1 cm = 0.39 inch.

^yMean separation within columns and fertilizers by the Waller-Duncan k-ratio method, *P* = 0.05.

Release rates for all four elements were similar, or were slightly more rapid, in pure water than in SS. Although the containers with both of these substrate environments were not disturbed (e.g., moved or bumped) until they were harvested, we believe that the slightly more rapid release of these nutrients from water than in SS is due to the slightly higher rates of mass flow in the water than in the SS. This could result in steeper concentration gradients across the prill membrane in water and, therefore, more rapid diffusion of ions out of the prill.

There were highly significant differences in the release rates of NH₄-N, NO₃-N, P, and K from OSM and NUTR when evaluated across all substrates (Table 3). NO₃-N generally was released more rapidly than the other three ions, although NH₄-N was only slightly slower. Potassium was generally released more rapidly than P, with the differences between the two ions slightly greater for OSM than for NUTR. Huett and Gogel (2000) also found that P and K were

Table 3. Percent of total ammonium-nitrogen (NH₄-N), nitrate-nitrogen (NO₃-N), phosphorus (P), and potassium (K) remaining in prills of Osmocote 15N-3.9P-10K [8-9 month (OSM)] and Nutricote 18N-2.6P-6.7K Type 180 (NUTR) incubated at 23 °C (73.4 °F) across all substrate environments.

Element	Remaining (% total)					
	2 months		5 months		7 months	
	OSM	NUTR	OSM	NUTR	OSM	NUTR
NH ₄ -N	47.8 c ^z	77.7 c	16.7 c	41.8 b	11.1 c	28.4 c
NO ₃ -N	46.1 d	73.1 d	14.8 c	34.9 c	7.9 d	20.9 d
P	89.8 a	99.0 a	46.3 a	64.4 a	46.0 a	65.2 a
K	65.6 b	90.5 b	33.4 b	65.4 a	24.7 b	51.0 b

^zMean separation within columns by the Waller-Duncan k-ratio method, *P* = 0.05.

released more slowly than N from CRFs. After 7 months, OSM prills contained about 8% of their NO₃-N, 11% of their NH₄-N, 25% of their K, and 46% of their P, compared to 21% of their NO₃-N, 28% of their NH₄-N, 51% of their K, and 65% of their P for NUTR (Table 3).

The practical implications of these results will vary with the application. For container-grown ornamental crops that are typically grown in organic substrates similar to our PS, N is usually

the most limiting element (Ogden, et al., 1987). Since about 90% of the total N is released within 7 months for OSM and about 72% to 79% of the N from NUTR is released, this presents little problems for these crops. However, most aquatic plants are grown in SS type environments, where deficiencies of other elements such as K are often more common than those of N (T.K. Broschat, unpublished data). The more rapid release of N than K from these products could contribute to K

deficiency problems by increasing the effective N:K ratio in the substrate. Since N tends to promote plant growth, this higher N:K ratio could result in a dilution of K within the plant and thus an accentuation of K deficiency symptoms.

Although plant P requirements are usually much lower than are applied in these CRFs, the retarded release of P from these products means that only about half or less of the total P content of OSM and NUTR will be released by the time that the N supplies are largely exhausted. Thus, these higher percentages of P in these products may be justified due to the very slow release of this element into the substrate solution.

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