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Controlled-release Potassium Fertilizers for Turfgrass

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Abstract. **Field and laboratory studies were conducted to evaluate the K retention properties of several resin-coated (RC), sulfur-coated (SC), and plastic-coated (PC) K fertilizers. Substantial differences in K release were found among the controlled-release K materials, based both on the K content of 'Tifgreen' bermudagrass *[Cynodon dactylon* (L.) Pers. × C. *transvaalensis* Burt-Davvy] clippings and on direct measurement of K remaining in fertilizer granules in the field over time. One SC material appeared to release K too rapidly, and one RC material appeared to release K too slowly to be useful for providing extended plant-available K to turfgrass. The other sources appeared to have release characteristics that would be favorable for turfgrass maintenance. Because differences in K release were observed among the sources, a laboratory method for assessing K release would be useful. Toward this-end, models were developed relating K retention of sources in hot water (70C) to K retention under field conditions.**

Potassium is used in comparatively large quantities by turfgrasses (Turgeon, 1985). It has been associated with resistance to many stress conditions, including those imposed by disease, drought, and traffic (Beard, 1973). Soils having significant amounts of clay minerals may supply appreciable plant-available K. However, sandy soils contain much less K than clays and have considerably less ability to retain K against leaching.

Sandy soils often are used for turfgrass to facilitate drainage, so that rainfall has minimum impact on use of turfgrass for sporting events. Sandy soils, along with irrigation and clipping removal, make it difficult to efficiently provide a steady supply of plant-available K. One method of achieving this goal is to use controlled-release K fertilizers, but such materials have only recently been manufactured for use on turfgrass. Controlled release of K generally is accomplished by coating soluble K salts with materials such as sulfur, plastic, or resins. The objective of the present study was to determine the K-release properties of several controlled-release K fertilizers, both through direct measurement of K release from the materials in the field and in the laboratory, and indirectly by determining K in 'Tifgreen' bermudagrass clippings.

Materials and Methods

Potassium fertilization of turfgrass. Six controlled-release K fertilizers were evaluated in each of two year-long experiments. Two additional materials were evaluated in the second experiment (Table 1). In the first experiment, the K fertilizers were applied on 20 July 1989, to provide 15 g K/m^2 to four replications of established 'Tifgreen' bermudagrass plots (1 × 2 m). Potassium from KCl or K_2SO_4 was applied at the same rate to other plots, and a control that received no K was included. The plots were arranged in a randomized complete-block design on a Margate fine sand soil (Siliceous, hyperthermic Mollic Psammaquent) at the Ft. Lauderdale Research and Education Center, Univ. of Florida.

The plots in the first experiment were fertilized with ammonium sulfate to provide 5 g N/m* at the start of the study and at the same rate monthly, thereafter. The area was mowed weekly to a 13-mm height from July to mid-October, and biweekly thereafter. Irrigation maintained adequate soil moisture for turfgrass growth.

Turfgrass clippings were taken from each plot beginning 2 weeks after K application and again near the middle of each month through Jan. 1990. Thereafter, clipping collection was continued bimonthly from Feb.–July 1990. The clippings were oven-dried at 70C, weighed, and analyzed for K by atomic absorption spectrometry following wet-acid digestion (Lowther, 1980). For the first 6 months, before each tissue sampling, the plots were rated for quality (a combination of color and density) using a 1 to 10 scale (10 = best possible, 6 = minimum acceptability).

The second experiment was similar to the first, using an established sward of 'Tifgreen' bermudagrass on a Hallandale fine sand (Siliceous, hyperthermic Lithic Psammaquent) at the Ft. Lauderdale Research and Education Center. On 30 Jan. 1990, the controlled-release K fertilizers provided 30 g K/m^2 in six replications to 2 × 3-m plots. A control that received no K and plots that received KCl or K_2SO_4 also were included in the experiment. The plots were fertilized with ammonium sulfate to provide 10 g N/m* on 17 Jan. 1990 and at the same rate at monthly intervals, thereafter. Mowing, irrigation, visual ratings, and tissue sampling were conducted as described above, except that the quality ratings and tissue samplings were initiated 1 month after the K fertilization (2 weeks after N fertilization), and the quality ratings were conducted throughout the 12-month study period. Potassium in clippings from the final two samplings (Nov. 1990 and Jan. 1991) was determined in water extracts, which is equivalent to that in acid digestates (Snyder and Kretschmer, 1986). The clipping-weight and K-analysis data were processed by analysis of variance (SAS, 1985).

Potassium retention–field evaluation. A fiberglass screen, fertilizer packet technique was used to directly measure K remaining in the fertilizer granules over time. Packets (4 × 6 cm) were made by folding fiberglass window screening in half, add-

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Abbreviations: PC, plastic-coated; RC, resin-coated; SC, sulfur-coated.

Table 1. Controlled-release K sources evaluated.

Designation	Description	K (%)	Manufacturer
RC-1	Resin-coated K_2SO_4, 3–4 month release[z]	38	Grace/Sierra, Milpitas, Calif.
RC-2	Resin-coated K_2SO_4, 5–6 month release[z]	39	Grace/Sierra, Milpitas, Calif.
RC-3	Resin-coated K_2SO_4, 8–9 month release[z]	38	Grace/Sierra, Milpitas, Calif.
SC-1	Sulfur-coated KCl	37	ICI Canada, London, Ottawa
SC-2	Sulfur-coated K_2SO_4	35	ICI Canada, London, Ottawa
SC-3	Sulfur-coated KCl (experimental)	42	LESCO, Rocky River, Ohio
PC-1[y]	Plastic-coated (polyvinyl chloride) K_2SO_4	36	Vigoro Industries, Winter Haven, Fla.
RC-4	Resin-coated KNO_3	28	Vigoro Industries, Winter Haven, Fla.

[z]Based on manufacturer's literature.
[y]PC-1 and RC-4 were used in the second experiment only.

ing fertilizer (2 and 1 g/packet for the first and second experiments, respectively), folding the screen around the edges, and securing the perimeter with a stapler. At the start of each field experiment, 12 packets of each fertilizer source were placed randomly on the turf surface at two locations adjacent to the turf-response experiments, for a total of 24 packets per" fertilizer material. Small paint spots were placed on the packets to color code each fertilizer source. Additionally, a map was made to show the location of each source. The two groups of packets in each experiment were covered with a coarse wire screen to press them against the turf surface and to secure them in place. In a few weeks, leaf blades and stolons grew around and through the packets. The turf in the vicinity of the packets was clipped by hand.

Two packets of each fertilizer source at each location were removed monthly. The packets were emptied into 50-ml tubes that then were covered with small funnels and placed in a muffle furnace at 550C for 1 h. After cooling, 2 ml concentration HNO_3 was added to each tube. After standing for 30 rein, two 25-ml portions of demineralized water were added to each sample with each addition followed by vortex stirring. The samples were filtered through Whatman no. 2 paper and analyzed for K by atomic absorption spectrophotometry. The data were calculated as a percentage of the K originally in the packets, based on chemical analysis of the fertilizer materials by the same technique. Retention over time was evaluated for linearity by the general linear models statistical procedure (SAS, 1985).

Potassium retention–laboratory evaluation. Portions (1 g) of each controlled-release K fertilizer were weighed in triplicate into 50-ml Erlenmeyer flasks. Following addition of 50 ml demineralized water, the flasks were placed in a rotating (100 rotations/rein) hot-water bath at either 30 or 70C. Samples (0.5 ml) of the liquid phase were removed from each flask at 1, 3, and 7 days. An additional sample was removed from the 70C bath at 6 h. The samples were analyzed for K by atomic absorption spectrophotometry. Potassium remaining in the fertilizer granules was calculated as the original amount minus K detected in the liquid phase and was expressed as a percentage of the original content of the granules. General linear models statistical procedures (SAS, 1985) were used to relate K retention by the K sources in the laboratory to K retention by the K sources in the second field experiment, which used all eight sources.

Results and Discussion

Potassium fertilization of turfgass. Fertilization with K produced few significant *($P \leq 0.05$)* effects on turf quality ratings or on clipping weights in either of the two experiments (data not presented), even though in certain treatments, tissue K was found to be < 1.0% (Tables 2 and 3).

In each experiment, only on the 12th month after K fertilization were clipping weights from control plots significantly lower than those from the others (data not presented). Clipping weights in the control plots were 78% and 47% of the average of the K-fertilized treatments in the first and second experiments, respectively. In the second experiment, clippings from controlled-release K-fertilized plots (excluding RC-4 and SC-3) weighed more than those from plots fertilized with the water-soluble K sources. Only 12 months after K fertilization did control plots in the second study receive lower ratings than any of the plots fertilized with controlled-release K fertilizers. Thus, for most of the study, quality and growth were good for all treatments.

Turfgrasses may not respond to K in terms of shoot color, density, or growth, except under conditions of stress (Beard, 1973). Stress conditions were minimized in the present study, which included irrigation, N fertilization, and minimal imposition of traffic. The general lack of visual and growth response to K was not of major importance, since the turf was mainly being used as a biological indicator of K availability, and turfgrasses are capable of accumulating K in excess of that required for normal growth (Beard, 1973).

For both field experiments, there were highly significant *(P 0.01)* effects of K source, time after application, and the interaction between the two factors on the K content of turf clippings. For this reason, each factor must be examined independently at each level of the other factor (Tables 2 and 3). In the first field experiment, at 1 month after fertilization, clippings from most of the K-fertilized plots had higher concentrations of K than did clippings from the control plots (Table 2). Three months after fertilization, clippings from the RC-1 and SC-2 treatments contained significantly ($P \pm 0.05$) more K than clippings from plots fertilized with KCl or K_2SO_4 sources. Six months after fertilization, clippings from the RC-1 treatment contained more K than those from any of the other treatments. All of the controlled-release products, except SC-3, produced clippings with K concentration exceeding that in clippings from plots receiving the water-soluble fertilizers. Twelve months after fertilization, the RC-2 and RC-3 products produced clippings with higher amounts of K than clippings from any of the other treatments.

The second field experiment produced many results similar to the first. As in the first experiment, 1 month after fertilization K-fertilized plots produced clippings with more K than that found in control plots (Table 3). Three months after K fertilization, clippings from plots fertilized with SC-2, but not with RC-1, contained more K than clippings from plots fertilized with the water-soluble K fertilizers. The RC-4 product, which was not included in the first study, also provided higher K concentration in the clippings 3 months after fertilization than the water-soluble K fertilizers. In both studies, the SC-3 source generally produced clippings with less K than was produced by most of the other controlled-release sources 3 or more months after application. As in the first experiment, 6 months after fertilization, clippings from the RC-1 plots contained more K than those from most of the other sources. Potassium also was high in clippings from the SC-1 and PC-1 treatments. Six months after fertilization, all but one (RC-3) of the sources produced clippings with

Table 2. Effect of K fertilizer on bermudagrass leaf tissue K, Expt. 1.

	Time after application (months)										
Source	0.0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0
RC-1	0.92	1.36	1.67	1.36	1.08	1.83	1.72	1.45	1.51	0.93	0.75
RC-2	0.79	1.40	1.48	1.06	0.83	1.51	1.54	1.20	1.35	0.94	0.89
RC-3	1.08	1.32	1.55	0.98	0.70	1.38	1.38	1.12	1.24	0.85	0.87
SC-1	0.88	1.54	1.73	1.24	0.95	1.79	1.62	1.20	1.39	0.78	0.70
SC-2	0.91	1.34	1.53	1.20	1.06	1.74	1.57	1.21	1.26	0.72	0.70
SC-3	1.00	1.62	1.63	1.23	0.86	1.44	1.31	1.03	1.11	0.60	0.65
KCl	0.74	1.49	1.65	1.08	0.75	1.28	1.21	0.88	0.91	0.51	0.58
K_2SO_4	0.74	1.48	1.48	0.99	0.82	1.18	1.07	0.90	0.90	0.63	0.57
Control	0.95	0.86	1.05	0.60	0.56	0.96	0.78	0.61	0.66	0.54	0.48
$LSD_{(0.05)}$	0.31	0.24	0.41	0.23	0.26	0.34	0.17	0.18	0.14	0.14	0.10

Table 3. Effect of K fertilizer on bermudagrass leaf tissue K, Expt. 2.

	Time after application (months)								
Source	1	2	3	4	5	6	8	10	12
RC-1	1.58	1.46	1.56	2.58	1.74	2.11	1.40	0.80	1.27
RC-2	1.63	1.38	1.57	2.52	1.63	1.94	1.41	0.81	1.34
RC-3	1.60	1.30	1.33	2.32	1.50	1.77	1.41	0.86	1.43
RC-4	1.72	1.59	1.87	2.62	1.67	1.95	1.24	0.67	1.09
SC-1	1.70	1.39	1.58	2.70	1.70	2.25	1.40	0.80	1.24
SC-2	1.68	1.44	1.73	2.73	1.77	2.03	1.24	0.73	1.11
SC-3	1.78	1.52	1.55	2.45	1.51	1.86	1.21	0.67	1.07
PC-1	1.63	1.24	1.66	2.77	1.75	2.08	1.34	0.73	1.12
KCl	1.70	1.56	1.53	2.35	1.41	1.61	1.06	0.59	0.89
K_2SO_4	1.80	1.53	1.51	2.43	1.33	1.59	1.01	0.54	0.86
Control	1.40	1.03	0.96	1.68	1.05	1.22	0.82	0.42	0.72
$LSD_{(0.05)}$	0.15	0.15	0.16	0.12	0.17	0.18	0.05	0.10	0.07

more K than was contained in clippings from plots fertilized with the water-soluble materials. Twelve months after fertilization, the RC-2 and RC-3 products produced clippings with higher amounts of K than clippings from the other treatments. These results were similar to those. found in the first study. Thus, from these two studies it is apparent that certain controlled-release K sources out-performed water-soluble K sources in terms of providing plant-available K over an extended time. However, significant differences also were observed among the slow-release K fertilizers.

Potassium retention–field evaluation. Retention of K (or the corollary: K release) by the controlled-release fertilizers under field conditions provided a basis for explaining variations in the K content of clippings among treatments. For example, in each of the two experiments, 3 and 6 months after being placed in the field, K retention by RC sources was in the order RC-3 > RC-2 > RC-1 (Figs. 1 and 2), which also was the order of K retention stated by the manufacturer (Table 1). Four, 5, and 6 months after fertilization, the K concentration of clippings was in the order RC- 1 > RC-2 > RC-3; i.e., the source providing the greatest retention of K within the fertilizer granule resulted in the lowest level of K in the clippings, and the source providing the least retention provided the highest clipping K. The SC-3. source appeared to retain less K than any of the other controlled-release sources during the first 3 months after application (Figs. 1 and 2). This source resulted in clippings with among the highest amounts of K for the first few months after application, but with among the lowest concentrations thereafter (Tables 2 and 3). Retention by the RC-3 source decreased little beyond 2 months after application, and clippings from the RC-3 plots contained relatively little K 3 to 6 months after

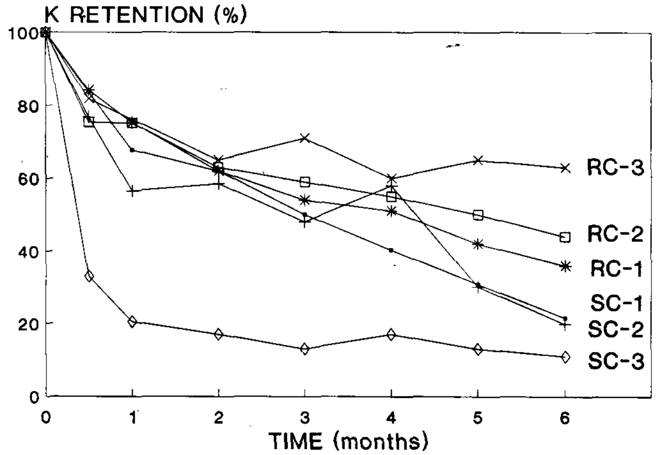

Fig. 1, Potassium retained by RC and SC fertilizers during 6 months following application in July 1989, expressed as a percentage of the original amount. $LSD_{0.05}$ = 13.8, 14.8, 6.7, 8.1, 10.1, 12.3, and 9.2 for 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 months, respectively. For linear regression, r^2 = 0.92, 0.84, 0.66, 0.95, 0.81, and 0. 41 for RC-1, RC-2, RC-3, SC-1, SC-2, and SC-3, respectively.

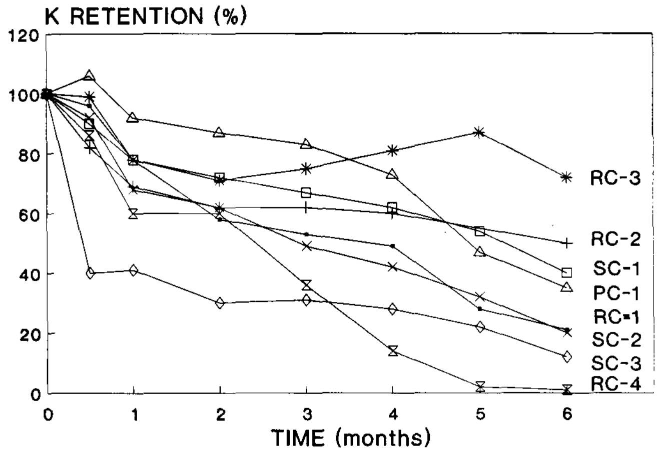

Fig. 2. Potassium retained by RC, SC, and PC fertilizers during 6 months following application in Jan. 1990, expressed as a percentage of the original amount. $LSD_{0.05}$ = 9.1, 10.5, 8.1, 9.9, 11.8, 21.2, and 11.0 for 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 months, respectively. For linear regression, r^2 = 0.92, 0.48, 0.13, 0.93, 0.85, 0.93, 0.53, and 0.81 for RC-1, RC-2, RC-3, RC-4, SC-1, SC-2, SC-3, and PC-1, respectively.

fertilization. However, 1 year after fertilization, clippings from these plots contained among the highest levels of K, indicating

Table 4. Observations (Ohs.) of K retention by the controlled-release K sources as determined in the field and laboratory (70C incubation) experiments, and field retention calculated (Calc.) on the basis of laboratory retention, all expressed as a percentage of the original concentration.

K source	Lab obs. 3 days	Field, 3 months Obs.	Field, 3 months Calc.[z]	Lab obs. 7 days	Field, 6 months Obs.	Field, 6 months Calc.[y]
RC-1	58.8	53.5	56.7	49.5	20.5	21.6
RC-2	63.3	61.8	64.2	55.6	50.0	48.2
RC-3	67.0	74.9	70.4	59.8	72.0	72.8
RC-4	45.6	35.7	34.6	36.5	1.4	1.2
SC-1	69.1	66.7	68.0	67.7	39.6	39.6
SC-2	56.7	49.1	47.2	53.0	19.9	19.9
SC-3	47.3	30.9	31.5	44.3	12.6	12.6
PC-1	47.4	82.6	82.6	28.5	35.7	35.7

[z]Field = 3.169 + A + 1.676 × Lab, $r^2 = 0.981$, $P \leq 0.01$, where A = – 45.019 for RC sources, – 50.960 for SC sources, and 0.0 for PC source.

[y]Field = 71.165 + A — 1.244 × Lab + B × Lab + C × Lab^2, $R^2 = 0.999$, P 0.07, where for RC sources, A = 137.911, B = – 9.801, and C = 0.147; for SC sources, A = –45.461, B = 0.0, and C = 0.021; for PC sources, A, B, and C = 0.0.

that K release by the RC-3 material occurred beyond 6 months. Nevertheless, tissue K was low in all plots 12 months after fertilization, and release by RC-3 probably is too slow for successful use as a turfgrass K fertilizer. Sources such. as RC-1, RC-2, SC-1, SC-2, and PC-1 released K in a fairly linear pattern over the 6-month study periods (Figs. 1 and 2), and RC-2 release was fairly linear for 5 months. Clippings from plots fertilized with these sources generally contained the highest or nearly the highest amounts of K 3 to 6 months after fertilization (Tables 2 and 3).

Potassium retention–laboratory evaluation. Potassium retention in the field 3 and 6 months after application (second experiment) was related more closely to retention in the laboratory following 3 and 7 days of immersion in 70C water, respectively, than to any other combination of immersion time and temperature. Nevertheless, field retention at 3 months also was closely related to laboratory retention at 7 days (comparative data not presented). Potassium retention by the RC materials in the field 3 and 6 months after application was in the same order as was determined in the laboratory following 3 and 7 days immersion at 70C, respectively, i.e., RC-3 > RC-2 > RC-1 > RC-4 (Table 4). A similar relationship occurred for the SC sources, i.e., SC-1 > SC-2 > SC-3 for both field and laboratory studies. However, when the sources are considered together, differences in the order of K retention are observed. For example, the order for the field study 6 months after application was RC-3 > RC-2 > SC-1 > PC-1 > RC-1 > SC-2 > SC-3 > RC-4, whereas retention in the laboratory at 7 days was in the order SC-1 > RC-3 > RC-2 > SC-2 > RC-1 > SC-3 > RC-4 > PC-1. Release by dissolution probably predominated in the laboratory studies. In the field, microbial decomposition and other factors may have influenced K retention in addition to dissolution. The changes in the order of K retention between the laboratory and field evaluations indicate that factors other than dissolution had varying effects on the different types of K sources.

Nevertheless, by using coefficients for the three types of controlled-release K sources evaluated in this study, equations were developed that can be used to very closely calculate field-observed K retention on the basis of laboratory-observed retention (Table 4). The usefulness of the laboratory procedure for predicting K release in the field should be explored further in studies involving additional data sets. The model presented herein may need additional refinement to account for such factors as the effect of climatic conditions on K release.

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