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Comparison of Controlled-release Nitrogen Fertilizers on Turfgrass in a Moderate Temperature Area

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Abstract. **Coating of conventional urea with polymers is designed to improve N availability to crops. A field experiment was conducted from 1993 to 1994 on turfgrass at Ellerslie, Alta., Canada, to determine release rates of coated urea applied on turfgrass thatch surface, and the effect of coated urea application on growth, color, and N uptake of turfgrass. The experiment was established on existing stands of a mixture of 'Merion' Kentucky bluegrass (*Poa pratensis* L.) and 'Gennuina' creeping red fescue (*Festuca rubra* L.) growing on a Black Chernozemic (Typic Cryoboroll) soil. The annual rate of N application was 100 kg·ha^{-1} in 1993 and 1994. The release rate of urea fertilizers was determined by the weight loss of the fertilizer granules after application in polyvinyl chloride (PVC) cylinders inserted into the turfgrass thatch. Some coated urea fertilizers released most of their N within the growing season (e.g., Sherritt-G, Polyon 4%, and SulfurKote), while others released only half their N (e.g., Esso T-90 and Meister 7), probably because of the cool ambient summer temperature in the area. The growth and color of turfgrass were more uniform in some controlled-release fertilizer treatments (e.g., Esso T-90, Meister 7, Polyon 4%, and SulfurKote) than in noncoated urea and NH_4NO_3 treatments. Promotion of growth in 1994 as a residual effect of the 1993 controlled-release urea fertilizer application was also noted. The results suggest that the application of some controlled-release urea fertilizers (with 70- to 90-day release rates) can produce the most consistent quality turfgrass.**

Controlled-release urea fertilizers with a polymeric membrane coating can supply N to plants over a long period of time. Because of this, they have frequently been used in turfgrass fertilization. Other research results indicated that the prolonged release of N from controlled-release fertilizer minimized the potential loss of N (nitrate or nitrite) from leaching (Petrovic, 1990), reduced the flush of spring growth, and increased the green color of grass in the fall (Waddington and Duich, 1976).

The dissolution rate of controlled-release N fertilizers is dependent on soil temperature and coating thickness (Christianson, 1988; Kochba et al., 1990; Zhang, 1994). After evaluating the response of 'Merion' Kentucky bluegrass to three controlled-release fertilizers with N dissolution rates of 70, 100, and 270 d, Hummel (1989) concluded that the 100-d product generated a uniform growth. Peacock and DiPaola (1992) obtained the best turf quality (turf color, density, texture, uniformity, and smoothness) by applying blended fertilizers with different dissolution rates, including noncoated urea. They also showed that the gradual improvement of turf quality from initial application to peak quality at 8 weeks coincided with the rise in summer temperatures. In evaluating the performance of polymer-coated sulfur-coated urea, and polymer-coated and sulfur-coated compound fertilizers on burmudagrass (*Cynadon dactylon*) in Georgia, Carrow (1997) concluded that greater turf quality at 61 to 95 d was related to the thicker sulphur or polymer coating in the products. However, all aforementioned research was conducted in warm climates.

The objectives of our research were to determine in a moderate temperature area the response of turfgrass to several controlled/slow-release N fertilizers in 1) the first year of fertilizer application and 2) the year following application.

Materials and Methods

The research was conducted on the Univ. of Alberta research farm at Ellerslie, 10 km south of Edmonton (lat. 54°N, long. 114°W) in 1993 and 1994. The turfgrass was a mixture of 'Merion' Kentucky bluegrass and 'Gennuina' creeping red fescue grown on an Orthic Black Chernozemic (Typic Cryoboroll) soil (pH 5.7, total C 6.2%, total N 0.5%, texture clay loam). To our knowledge, the turfgrass had not been fertilized for 10 years prior to 1993.

Irrigation was scheduled so that the plots would receive a total of 40 mm water (irrigation + rain) in each 2-week period. In 1994, three instances occurred when they received more than 40 mm of water because rainfall exceeded that amount. Rain and air temperatures above the turfgrass surface during the experimental period were recorded, and are reported as weekly rainfall totals and averages of maximum and minimum temperature (Fig. 1).

The experimental design was a randomized complete block with four replications. Each plot was 10 m^2 (2 m × 5 m), and received 100 kg·ha^{-1} N on 25 June 1993, from one of the following: two quick-release N fertilizers (urea or NH_4NO_3); four polymer-coated ureas [Sherritt-G (44% N, 30-day release, Sherritt, Edmonton), Esso T-90 (44.5% N, 90-day release, Imperial Oil, Edmonton), Polyon 4% (44% N, Pursell Industries, Sylacaugah), Meister 7 (40% N, 70-day release, Chisso Co., Kitakyusya, Japan)]; one sulfur-coated urea [SulfurKote (39% N, Pursell Industries)]; and one synthetic slow-release N fertilizer [IBDU (31% N, Vigoro, Toronto)]. Some of the plots on which controlled/slow-release fertilizers were applied in 1993 were divided into two subplots (2 m × 2.5 m) in 1994 and another 100 kg·ha^{-1} N was applied to one subplot on 22 May. The residual effect of the 1993 fertilizer addition was determined by measuring the dry-matter yield of clippings from both subplots.

Release rates of controlled-release fertilizers applied to the turfgrass thatch surface were determined in 1993 by adding preweighed fertilizer granules in PVC cylinders (15-cm diameter, 15-cm height, 0.5-cm thickness) inserted 5 cm deep into the turfgrass thatch, and then recovering them 20, 40, 67, and 83 d later. Recovered granules were air-dried and weighed.

Dry-matter yield of clippings, leaf color, and N uptake were the parameters used to evaluate response to the fertilizer application. Turfgrass was clipped with a rear bagging mower set at a 2-cm height, at 20, 40, 60, and 83 d after fertilizer application in 1993, and at 24, 44, 64, 84, and 104 d in 1994. Samples of clippings were also taken on 22 May 1994 before fertilizer addition to measure the early spring growth generated by the 1993 fertilizer application. The sampling area for each plot was 2.55 m^2 (0.51 × 5 m). The samples were placed in paper bags, dried at 65 °C, and weighed. A portion of each sample was ground to pass a 0.5-mm sieve for total N analysis. Ground samples were digested in concentrated H_2SO_4 and H_2O_2 (Clifford et al., 1985, 1987) and their total N content was determined with a Technicon Autoanalyzer II (Technicon Autoanalyzer II, 1973a, 1973b). The N uptake of the turfgrass was calculated

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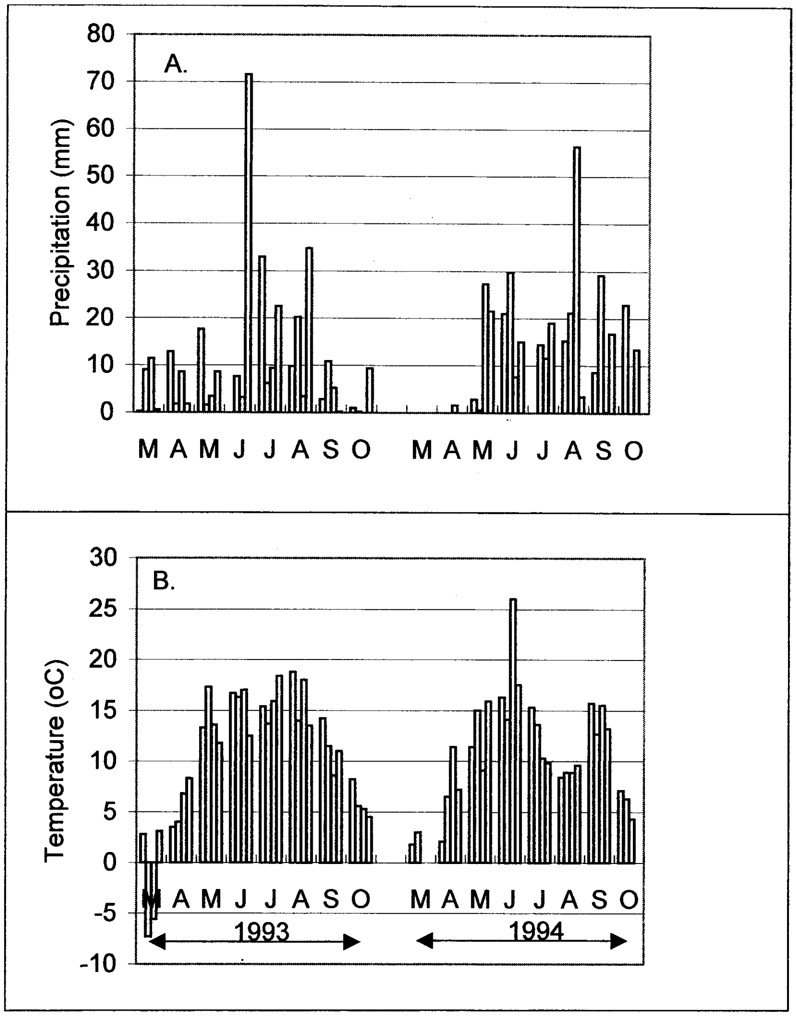

Fig. 1. Weekly precipitation (**A**) and average turfgrass surface temperatures (**B**) from March to October in 1993 and 1994 at Ellerslie, Alta., Canada.

Table 1. Percentage urea released on turfgrass thatch by fertilizers, and turfgrass surface air temperatures during the 83-d experimental period in 1993.

	Urea released (%)			
Treatment	20 d[z]	40 d	67 d	83 d
Sherritt-G	91 a[y]	98 a	102 a	95 a
Esso T-90	9 d	37 c	47 c	47 b
Polyon 4%	58 b	104 a	104 a	93 a
SulfurKote	35 c	71 b	83 b	94 a
Meister 7	14 d	7 d	28 d	36 b
Mean temp. (°C)[x]	16	16	19	17

[z]Days after fertilizer application on 25 June 1993.
[y]Mean separation within columns by LSD ($P \leq 0.05$).
[x]Means of minimum and maximum temperatures each day.

as: N uptake ($kg \cdot ha^{-1}$) = N content of turfgrass (% N) × clipping dry-matter yield ($kg \cdot ha^{-1}$)/100. Leaf color was estimated on a scale from 1 (light green) to 9 (dark green) by two independent technicians at each time prior to sampling.

Thatch and soil samples were taken to a depth of 30 cm after the last turfgrass sampling on 13 Sept. 1994. The samples were divided into three parts: thatch (≈2 to 5 cm thick) and soil (0 to 15 cm and 15 to 30 cm). Mineral N was extracted from the samples with 2 M KCl, in a 1 soil : 5 solution ratio, and determined with a Technicon Autoanalyzer II.

The data on dry-matter yield of clippings, leaf color and N uptake, and mass of recovered granules were analyzed with analysis of variance and $LSD_{0.05}$.

Results and Discussion

Release rate of N from the controlled-release urea fertilizers. All fertilizer products used released urea into water at 23 °C in 30 to 90 d. When the fertilizers were placed on the turfgrass thatch, their release rates (average temperature: 17 °C from 15 June to 8 Sept.) paralleled those in water. For example, Esso T-90 (90-d product) released only half of the encapsulated urea over the 83-d growing period (Table 1), whereas Sherritt-G (30-d product) released 91% in the first 20 d. Peacock and DiPaola (1992) reported that, regardless of the coating thickness and release rate, the Reactive Layer Coated urea (RLCU) gradually increased turf quality from the day of fertilization to a peak at 8 weeks after application. They suggested that this was caused by increased coating permeability due to higher summer temperatures. Fry et al. (1993) showed that turf growth response was related to the release rate of RLCU and sulfur-coated urea. Even though we did not have urea products with different thicknesses of the same coating material, our results showed that, under our climatic conditions, the dissolution rate of the coated urea on turfgrass thatch paralled that in water (23 °C).

Clipping dry-matter yield. In 1993, during the first 20 d after application, the noncoated urea and noncoated NH_4NO_3 produced the highest clipping dry-matter yield among the treatments (Table 2). At 40 d, NH_4NO_3, Sherritt-G, urea, Polyon 4%, and SulfurKote had stimulated more growth than had the other fertilizers. At 60 d, Polyon 4% and SulfurKote tended to give the most clipping dry-matter yield. Later in the season, Esso T-90 and Polyon 4% tended to produce more clipping dry matter than did the other fertilizers. Throughout the 83-d growing season, Meister 7 generated little growth, in agreement with the release rate found on the thatch, where only 36% of its coated urea was released (Table 1). Isobutylidene diurea (IBDU) also had produced little effect.

In 1994, dry-matter yield in the first clipping was associated with the N release rate of the fertilizers. On 16 June (24 d after fertilizer application), urea, NH_4NO_3, and Sherritt-G had produced significantly greater clipping dry-matter yield than did the control treatment (Table 2). These fertilizers either have 100% readily available N or they released their coated urea at a slightly faster rate than did the other coated products. The treatments that did not differ from the control were coated urea with slow or moderate N release rates, including Esso T-90, Meister 7, Polyon 4%, SulfurKote, and IBDU. On the 44th d after application, the yield from noncoated urea was greater than that from Esso T-90, Meister 7, and IBDU, but similar to that from SulfurKote, Sherritt-G, and Polyon 4%. From then on, the yield from urea decreased relative to that from all controlled/slow-release fertilizers except Polyon 4% and IBDU. The highest yields were from Meister 7 and SulfurKote at 64 d and from Esso T-90 and Meister 7 at 84 and 104 d after application.

Leaf color. In 1993, leaf color of the turfgrass usually paralleled clipping dry-matter yield. Noncoated fertilizers and Sherritt-G produced the highest color scale in the first 20 d (Table 2), whereas Sherritt-G, SulfurKote, Polyon 4%, urea, and NH_4NO_3 and noncoated fertilizers produced the darkest leaf color in the second 20 d of growth. However, Meister 7 and Esso T-90 gradually increased the color scale of sward with a peak at 83 d after application. Sherritt-G, SulfurKote, and NH_4NO_3

Table 2. Effects of fertilizers on clipping dry matter and leaf color of turfgrass thatch.

	1993					1994					
Treatment	20 d^z	40 d	60 d	83 d	Total	24 d	44 d	64 d	84 d	104 d	Total
					Clipping dry-matter yield (kg·ha^{-1})						
Control	177 f^y	266 e	212 g	85 d	740 f	1167 c	402 d	382 de	232 b	129 c	2312 d
Urea	562 b	668 b	343 de	167 bc	1740 b	2396 a	761 a	506 bc	273 b	136 c	4072 a
NH_4NO_3	679 a	865 a	414 bc	160 bc	2110 a	2248 ab	788 a	492 bc	233 b	113 c	3894 a
Sherritt-G	467 c	705 b	379 cd	165 bc	1716 bc	1998 b	821 a	573 ab	270 b	151 c	3813 a
Esso T-90	204 ef	418 cd	395 bcd	228 a	1245 d	1297 c	642 b	579 ab	478 a	238 ab	3234 b
Polyon 4%	363 d	666 b	487 a	223 a	1739 b	1344 c	849 a	355 e	281 b	117 c	2946 bc
SulfurKote	263 e	595 b	456 ab	192 ab	1506 c	1348 c	772 a	622 a	306 b	176 bc	3224 b
Meister 7	182 f	346 de	310 ef	198 ab	1036 e	1148 c	518 c	627 a	443 a	269 a	3041 bc
IBDU	212 ef	320 de	263 fg	129 c	924 e	1287 c	435 cd	462 cd	261 b	189 abc	2634 cd
					Leaf color rating^x						
Control	1 d	1 d	---^{w}	1 d		1 c	1 d	1 d	1 e	1 e	
Urea	8 a	8 a	---	3 c		9 a	8 a	4 bc	2 de	2 de	
NH_4NO_3	9 a	8 a	---	4 c		9 a	8 a	5 b	3 cd	2 de	
Sherrit-G	8 a	8 a	---	4 c		8 a	8 a	5 b	3 cd	3 cd	
Esso T-90	3 c	6 b	---	8 a		5 b	8 a	7 a	5 ab	4 bc	
Polyon 4%	6 b	9 a	---	7 ab		5 b	9 b	7 a	4 bc	2 de	
Sulfurkote	6 b	8 a	---	6 b		5 b	9 a	7 a	4 bc	2 de	
Meister 7	2 cd	4 c	---	7 ab		4 b	4 c	8 c	6 a	6 cd	
IBDU	3 c	3 c	---	3 c		4 b	4 c	3 c	3 cd	3 cd	

^{z}Days after fertilizer application on 25 June 1993 and on 22 May 1994.
^{y}Mean separation within columns by LSD ($P \leq 0.05$).
^{x}Color rated from 1(light green) to 9 (dark green).
^{w}Color data not collected in 1993.

Table 3. Nitrogen uptake by turfgrass.

	N uptake (kg·ha^{-1})												
	1993						1994						
Treatment	20 d^z	40 d	60 d	83 d	Total N uptake	Net N uptake^y	24 d	44 d	64 d	84 d	104 d	Total uptake	Net N uptake
Control	3 f^x	6 d	6 d	2 e	17 f	---	20 d	9 e	9e	6 b	3 c	47 c	---
Urea	19 b	16 b	9 cd	4 cd	48 bc	31 bc	69 a	20 bc	12 cd	6 b	3 c	110 a	63 a
NH_4NO_3	26 a	23 a	11 bc	4 cd	64 a	47 a	67 a	20 bc	11 de	7 b	3 c	107 a	60 a
Sherritt-G	15 c	18 b	10 bc	4 cd	47 bc	30 bc	56 b	23 b	14 bc	7 b	4 c	104 a	57 a
Esso T-90	5 ef	11 c	12 ab	7 a	35 de	18 d	28 cd	18 c	15 ab	14 a	6 b	81 b	34 b
Polyon 4%	10 d	20 ab	15 a	6 ab	51 b	34 b	31 c	27 a	9 e	6 b	3 c	76 b	29 b
SulfurKote	7 e	17 b	13 ab	5 bc	42 cd	25 c	30 c	22 b	15 ab	8 b	4 c	79 b	32 b
Meister 7	4 f	8 cd	10 bc	6 ab	28 e	11 e	24 cd	14 d	17 a	13 a	8 a	76 b	29 b
IBDU	4 f	7 cd	6 d	3 de	20 f	3 f	24 cd	11 de	11 de	8 b	4 c	58 c	11 c

^{z}Days after fertilizer application on 25 June 1993, and on 22 May 1994.
^{y}Net N uptake = Treatment – control.
^{x}Mean separation within columns and parameters by LSD ($P \leq 0.05$).

maintained color of leaves at or above 4, an acceptable leaf color level, throughout the growing season. Esso T-90, Polyon 4%, and Meister 7 also maintained the color at or above that level from mid-July until late August.

Leaf color showed a similar trend in 1994, but the application of controlled-release fertilizers on the same area in 1993 and 1994 generated better color than in 1993 (Table 2). The time during which leaf color was greater than 4 increased where Esso T-90 and Meister 7 were applied in both 1993 and 1994.

Nitrogen uptake. In 1993, the highest N uptake occurred with NH_4NO_3 in the 83-d period (47% net N uptake), the lowest with IBDU (3% net N uptake) (Table 3). The N uptake with urea, Sherritt-G, Polyon 4%, or SulfurKote was similar, and was higher than that with the other controlled-release products. Nitrogen uptake over the growing season tended to be more even with coated than with the noncoated urea.

In 1994, more N was taken up in the first clipping (16 June) than in any subsequent cutting (Table 3). The amount of N uptake was associated with the N released by the fertilizers. For example, in the first clipping the net N uptake was 49% from noncoated urea, but only 8% from Esso T-90. After the 16 June sampling, the amount of N uptake declined. On 16 Aug., 84 d after fertilizer application, N uptake in the plots treated with urea, NH_4NO_3, Sherritt-G, IBDU, SulfurKote, and Polyon 4% was similar to that in the control plots, but N uptake from Esso T-90 and Meister 7 was significantly greater than the control, and this was maintained up to the last clipping on 5 Sept. (i.e., 104 d after fertilizer application).

Residual effects from 1993 fertilizer application. From the application on 25 June 1993, 331 d passed until the first clipping on 22 May 1994. The growth of turfgrass generated by the 1993 fertilizer addition was still visible at that time, but the dry-matter yield, color of the turfgrass, and duration of the residual effect varied among fertilizers (Table 4). The effect disappeared with SulfurKote on 16 June 1994. At the 6 July clipping, the effect had also disappeared with the Polyon 4% and Esso T-90 application; their dry-matter yields were no higher than that of the control. The residual effect for Meister 7 and IBDU lasted until 6 July 1994. The residual effects of Polyon 4% and SulfurKote were attributed to the mineralization-immobilization N turnover in soil during the fall to spring period, because they had released almost 100% of their N in 1993 (Table 1). The residual effect of Esso T-90 and Meister 7 was probably caused by the late release of N not released at the end of the growing season in 1993.

In our two-consecutive-year experiment, no controlled/slow-release fertilizers caused a spring flush of growth and all generated a long-lasting growth response as compared with ordinary urea. Similar results have been reported primarily by Carrow (1997), Fry et al. (1993), Hummel (1989), Peacock and DiPaola (1992), and Waddington and Duich (1976), but those studies were conducted in warmer regions than the Edmonton area. Our results showed that the time during which the turf quality improved was related to the N release rate on the thatch surface. This differs from the results of Peacock and DiPaola (1992), who reported that high quality of turf was associated with an increase in summer temperature, but not with the release rate of coated urea. This difference, however, is related to the

Table 4. Dry-matter yield and leaf color of turfgrass in 1994 as affected by fertilizer application in 1993.

Treatment[z]	Date of clipping in 1994					
(1993)	22 May	16 June	6 July	26 July	16 Aug.	5 Sept.
	Dry-matter yield ($kg \cdot ha^{-1}$)					
Control	116 d[y]	1167 c	402 b	382 a	232 a	129 ab
Esso T-90	270 ab	1661 ab	482 ab	421 a	220 a	99 b
Polyon 4%	242 bc	1543 ab	490 ab	396 a	240 a	135 ab
SulfurKote	223 bc	1348 bc	447 ab	429 a	254 a	119 ab
Meister 7	299 a	1760 a	519 a	411 a	271 a	152 a
IBDU	211 c	1445 bc	542 a	399 a	246 a	150 a
	Leaf color rating[x]					
Control	1 c	1 b	1 c	1 a	1 a	1 a
Esso T-90	5 a	3 ab	2 bc	2 a	1 a	1 a
Polyon 4%	3 b	3 ab	3 ab	1 a	1 a	1 a
SulfurKote	2 bc	3 ab	2 bc	1 a	1 a	1 a
Meister 7	5 a	4 a	3 ab	1 a	1 a	1 a
IBDU	3 b	4 a	4 a	2 a	1 a	1 a

[z]Turf growth from treatments of urea, NH_4NO_3 and Sherritt-G was similar to the control in the early Spring 1994; therefore, their carryover effects were not determined.
[y]Mean separation within columns by LSD ($P \leq 0.05$).
[x]Color rated from 1 (light green) to 9 (dark green).

lower summer temperatures at our experimental site as compared with Raleigh, N.C., where Peacock and DiPaola's experiments were conducted. Our results show that the first year's fertilization promotes growth on the second year, especially with those fertilizers that have a long N release time. Therefore, the best turf quality in our experiment resulted from a single annual application of coated urea (70 to 90 d release time).

The use of IBDU did not generate much turfgrass growth in 1993, but it stimulated moderate growth in 1994. Available N is released from IBDU by hydrolysis and dissolution. The cool and dry climatic conditions in the Edmonton area probably decreased the rate of N release. Turfgrass growth in 1994 was probably simulated by the IBDU applied in 1993.

We did not sample the thatch and soil in the plots until Fall 1994. At 104 d after fertilizer application in 1994, mineral N in the soil, mainly NH_4-N, was greater with controlled-release urea (e.g., 44 and 47 $mg \cdot kg^{-1}$ N with Esso T-90 and Meister 7 treatments, respectively) on thatch and at 0- to 30-cm soil depth than with noncoated urea (25 $mg \cdot kg^{-1}$ N soil). With this amount of N in the thatch and soil, growth was stimulated early in the succeeding year.

In conclusion, some controlled-release fertilizers (e.g., Esso T-90, Meister 7, Polyon 4%, and SulfurKote) produced uniform turfgrass growth and an acceptable green color over a longer period of time than did the noncoated urea. Turfgrass growth was associated with the rates of N release from coated urea products in a moderate temperature area. The results suggest that in our region, a single annual application of controlled-release fertilizers (with 70- to 90-d release rates) will produce the most consistent turf quality. The findings also imply that a suitable mixture of controlled-release fertilizers with various release rates would benefit turfgrass growth.

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