SUMMER GROWTH RESPONSE OF BERMUDAGRASS FERTILIZED WITH 12 DIFFERENT NITROGEN FORMULATIONS

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EXECUTIVE SUMMARY

The objective of this study was to evaluate 10 slowly-available nitrogen products, while comparing them to two quickly-available nitrogen products. The study was conducted on a 4-year-old stand of Arizona Common bermudagrass maintained similar to fairway conditions. Treatments included 9 products applied once at 4 lb N/1000 ft^2; one product applied twice at 2 lb N/1000 ft^2; and two products applied four times at 1 lb N/1000 ft^2. Each treatment was replicated four times and applied on 5- x 8-ft plots. The duration of this evaluation was 16 weeks, with the first application on June 18 and the last date of measurements on October 8. Biweekly measurements of visual turfgrass quality and color, and clipping yields were taken commencing 1 week after the first treatment application.

Results showed that there were significant differences among the treatments for quality and color on specific rating dates. Generally, most slow-release treatments produced acceptable quality and color (> 5.0, with 7.5 approximately the highest possible rating for Arizona Common bermudagrass) for an 11-week duration with a 2 week lag period following the first treatment application.

There was considerable variation for clipping yields among slow-release treatments on specific rating dates and for total clipping yield. Considering clipping yield as an indirect indicator of N release, Polyon, SulfurKote II, and Multicote II (24-8-16) showed relatively high N release among the slow-release products. The products applied monthly (Turf Supreme and K-Power) showed relatively low N release.

I. INTRODUCTION

The performance of numerous nitrogen (N) fertilizer formulations in turfgrass maintenance of landscapes and golf courses has been investigated since before 1948. As the technology progresses, so does the versatility by which a turf manager can supply nitrogen. Replicate studies are needed in order to quantify the performance of various N products and rates. The impact of nitrogen can be shown in root and shoot growth, pest susceptibility, reaction to temperature variation, and recuperative ability.

Nitrogen formulation differences are manifested in their release characteristics (Table 1). Such release characteristics can be shown to influence nitrogen uptake by the turfgrass as well as nitrogen loss from leaching, denitrification, volatilization, and inefficient plant use. Ammoniacal and nitrate N have immediate use potential to the turfgrass, but also are highly susceptible to loss. Slowing the release of these forms of nitrogen (through coating processes, etc.) has been shown to directly impact the plant usage.

The objective of this study was to evaluate several different types of both quickly- and slowly-available N sources. Visual ratings, as well as clipping yields, were taken to distinguish the performance of the N sources. A review is provided to summarize the role of nitrogen in turfgrass nutrition, characteristics of the major nitrogen formulations, characteristics of Common bermudagrass, and considerations involved in developing a nitrogen fertility program. This review can be found in the Appendix.

Table 1. Nitrogen formulations that are being tested and their mode of degradation.

Mode of degradation	Nitrogen source	Product (analysis)
Slow Release:		
Hydrolysis of an insoluble form of N	isobutylidene diurea (IBDU)	Par ex 31-0-0 Par ex 24-4-12
Physical rupturing of coating and hydrostatic pressure of coated water soluble N	sulfur-coated urea (SCU)	Best SCU 38-0-0 SulfurKote II 38-0-0
Dissolution-osmosis of coated water soluble N	polymer-coated urea	Polyon 40-0-0
	resin-coated urea	Osmocote 40-0-0 Multicote II 12-0-43 24-0-24 24-8-16 40-0-0
Quick Release:		
Dissolution of water-soluble N	ammoniacal N	Turf Supreme 16-6-8
	nitrate N	K-Power 13-0-44

II. MATERIALS AND METHODS

A summary of the study is shown in Tables 2 and 3. The study was conducted on a 4-year-old stand of Arizona Common bermudagrass maintained in a manner similar to fairway conditions. This study sought to determine the effect of fertilizer release on clipping yields and visual turfgrass quality, and color.

The study was a randomized complete block design with 4 replications. Initial treatments were applied in mid-June, with subsequent treatments applied per protocol (Tables 2 and 3). The duration of the study was 16 weeks, ending in mid-October.

Biweekly measurements of visual turfgrass quality and color and clipping yields were taken commencing 1 week after the initial treatment (Table 4). A total of 8 measurements were taken over the course of the study.

Environmental measurements were collected from a California Irrigation Management Information System (CIMIS) weather station located at the UCR Turfgrass Research Project (Table 5).

Analysis of variance was conducted using SAS version 6.03.

Table 2. Materials and methods outline.

Cultivar: Arizona Common bermudagrass (*Cynodon dactylon* (L.) Pers.).

Location: A mature field plot established at the UCR Turfgrass Research Project, Riverside, CA in 1989. The soil consisted of a Hanford fine sandy loam; pH 7.7.

Experimental Design: A randomized complete block design incorporated 52 plots, each 5- x 8-ft in dimension. An overall ANOVA was conducted at the end of the study utilizing a multiple measures design in which N treatments formed the main plots and measurement date was the repeated measures factor.

N Treatments:

N source (analysis)	Initial application (lb N/1000 ft^2)	*Subsequent applications (lb N/1000 ft^2)	Total N (lb N/1000 ft^2)
Slow release:			
Best SCU 38-0-0	2	2 (56 DPT)	4
Multicote II 12-0-43	4	0	4
Multicote II 24-0-24	4	0	4
Multicote II 24-8-16	4	0	4
Multicote II 40-0-0	4	0	4
Osmocote 40-0-0	4	0	4
Par Ex IBDU 31-0-0	4	0	4
Par Ex IBDU 24-4-12	4	0	4
Polyon 40-0-0	4	0	4
SulfurKote II 38-0-0	4	0	4
Quick release:			
K-Power 13-0-44	1	1 (28, 56 ,84 DPT)	4
Turf Supreme 16-6-8	1	1 (28, 56 ,84 DPT)	4
Check	0	0	0

*DPT (days post treatment) refers to the number of days after the initial treatment when follow-up treatments were applied.

Plots were irrigated following each application.

Mowing: The entire plot was mowed two times per week at 5/8 inch using Tri King riding reel mower.

Clippings were removed.

Irrigation: Water schedule was set according to CIMIS data. Plots were irrigated 1.8 inches/week.

Table 3. Calendar of the 1993 nitrogen product evaluation study.

Date	Activity
June 18	Treatments applied.
June 25-October 8	Visual turfgrass quality, color, and clipping yield measurements taken biweekly from each plot.
July 16	Monthly applications of follow-up treatments.
August 13	Monthly applications of follow-up treatments.
September 10	Monthly applications of follow-up treatments.
October 8	Study is completed.

Table 4. Measurements taken during the 1993 nitrogen product evaluation study.

Visual Turfgrass Quality and Color
*June 25 to October 8

*Taken once every 2 weeks. Scale was 1-9, with 1 = poorest; 5 = acceptable; 9 = best. Note that the highest that Arizona Common bermudagrass could rate is approximately 7.5.

Clipping Yield
*June 25 to September 24

*Biweekly clipping yields were collected from 3 days' growth. Clipping consisted of stems, leaves, and seedheads. Plots were mowed twice a week, with yields collected on the same mowing day (Friday). Yield weights reflect a single lengthwise pass (8.44 ft^2) per plot from a Great States model push reel mower. Clippings were dried for 48 hours in a forced air oven maintained at 70 C. Clippings recovered represent a subsample of the entire plot (40.0 ft^2).

Table 5. Environmental conditions during the 1993 nitrogen product evaluation study, UCR Turfgrass Research Project, Riverside, CA.

Date	Accumulative Weekly ET_o (mm/week)	Average daily solar radiation (W/m^2 per day)	Average daily air temperature (ºC)	Average daily soil temperature[z] (ºC)
6/13-6/19	42.74	311	24	24
6/20-6/26	41.54	312	23	25
6/27-7/3	42.89	323	23	25
7/4-7/10	39.35	301	22	24
7/11-7/17	35.51	277	21	24
7/18-7/24	30.61	246	20	23
7/25-7/31	30.49	236	22	24
8/1-8/7	41.33	281	26	26
8/8-8/14	37.11	284	22	24
8/15-8/21	36.94	283	22	23
8/22-8/28	38.24	272	24	23
8/29-9/4	35.80	250	25	24
9/5-9/11	38.60	263	26	24
9/12-9/18	24.42	201	19	22
9/19-9/25	25.57	191	20	21
9/26-10/2	34.14	223	26	21
10/3-10/9	17.35	160	19	21

ET_o = reference evapotranspiration.

[z] Soil temperature at 10.2 cm depth.

III. RESULTS AND DISCUSSION

Fertilizer treatments significantly increased turfgrass quality and color (Tables 6 and 7). Quality and color ratings were generally similar for all slow-release treatments applied once at 4 lb N/1000 ft^2. (One can note significant differences among these treatments on specific rating dates.) Generally, these treatments produced acceptable quality or color (> 5.0) within 21 DPT (SulfurKote II and Par Ex 24-4-12 were within 7 DPT) and lasted until 98 DPT (SulfurKote II and Par Ex 24-4-12 lasted until 84 DPT, while Multicote II 12-0-43 lasted until 112 DPT). Therefore, most slow-release treatments produced acceptable quality and color for 11 weeks, with a 2-week lag period after the first treatment application.

The remaining treatments, applied monthly or bimonthly, produced generally acceptable turfgrass quality and color ratings for a duration of 11 to 13 weeks, with the overall average quality and color similar to treatments applied once.

Fertilizer treatments significantly increased clipping yields (Table 8). There was considerable variation for clipping yields among slow-release treatments on specific dates and for total clipping yield. In general, slow-release treatments produced higher yields than treatments applied monthly or bimonthly.

The variation for clipping yields among treatments can be related to the release characteristics of the nitrogen sources themselves, as well as the ability of the turfgrass plant to absorb the available nitrogen. Considering clipping yields as an indirect indicator of N release, it was shown that approximately halfway through the study (56 DPT), the slow-release treatments had released an average of 63% of their total nitrogen (63% of the total clippings had been collected) (Table 8). Par Ex (31-0-0), which depends upon hydrolysis for nitrogen release, falls below the average for all of the fertilizers (59%), whereas SulfurKote II, which depends on physical rupturing of the coated prill, has a nitrogen release well above the average (75%). Multicote II (24-8-16, 40-0-0), Polyon, and Osmocote are all very close to the overall average release percentages. The three treatments in which 2 pounds of N had been applied by 56 DPT averaged 52% release. Since this percentage is approximately what is expected, we may surmise that the method of calculating percent N release based on clipping mass is fairly representative.

The significant differences among treatments for clipping yield at various dates and for total clipping yield suggest differences among treatments for N release rates and the amount of N available for turfgrass growth. Therefore, among the slow-release treatments, Polyon, SulfurKote II, and Multicote II (24-8-16) showed relatively high

N release. The treatments applied monthly (Turf Supreme and K-Power) showed low N release and availability, according to the clipping yields collected. Turfgrass utilization efficiencies, as well as environmental factors, would also have an impact on clipping yield, and, therefore, would warrant further investigation when explaining significant treatment differences.

Table 6. The effect of N source on visual turfgrass quality of Arizona Common bermudagrass.

Nitrogen treatment	Days after application:	Visual turfgrass quality[z]								
		7	21	35	56	70	84	98	112	Overall
One application[y]:										
Multicote II (12-0-43)		4.4	5.6	5.5	6.0	6.3	6.3	5.5	4.9	5.5
Osmocote (40-0-0)		4.4	6.0	6.1	5.9	5.8	5.8	4.9	4.3	5.4
Multicote II (24-8-16)		4.0	5.5	6.0	5.8	6.1	6.0	5.1	4.3	5.3
Polyon (40-0-0)		4.0	5.8	5.9	5.8	5.8	5.8	5.0	4.4	5.3
Multicote II (24-0-24)		4.0	5.3	5.5	6.0	5.8	5.6	5.1	4.4	5.2
Multicote II (40-0-0)		4.0	5.4	6.1	5.9	5.5	5.5	4.9	4.3	5.2
Par Ex (31-0-0)		3.9	5.5	5.0	5.9	5.6	5.5	5.0	4.1	5.1
SulfurKote II (38-0-0)		5.6	6.8	5.4	5.4	5.1	4.8	4.1	3.4	5.1
Par Ex (24-4-12)		5.0	6.4	5.1	5.5	5.1	5.0	4.3	3.8	5.0
Two applications[x]:										
Best SCU (38-0-0)		5.0	5.8	4.8	4.9	5.5	5.8	5.0	4.4	5.1
Four applications[w]:										
Turf Supreme (16-6-8)		4.4	4.9	4.5	5.3	5.9	6.0	6.0	5.5	5.3
K-Power (13-0-44)		4.6	4.5	4.6	5.1	6.1	5.9	5.5	5.0	5.2
Check		4.0	3.6	3.5	3.4	2.8	3.0	3.0	2.8	3.3
LSD p = 0.05		0.5	0.9	0.5	0.5	1.0	0.7	0.7	0.6	0.5
CV (%)		7.4	11.1	6.7	6.0	12.6	8.9	10.6	10.4	7.9
Treatment effect[v]		***	***	***	***	***	***	***	***	***

[z] Scale = 1 to 9, with 1 = poorest; 5 = acceptable; 9 = best; note that the highest that Arizona Common bermudagrass could rate is approximately 7.5.

[y] Treatment applied at 4 pounds of actual nitrogen per 1000 ft^2.

[x] Treatment applied at 2 pounds of actual nitrogen per 1000 ft^2, second application 56 DPT.

[w] Treatment applied at 1 pound of actual nitrogen per 1000 ft^2, follow-up application 28, 56, 84 DPT.

[v] *** Significant at *P* = 0.001.

The effect of N source on visual turfgrass quality of Arizona Common bermudagrass.

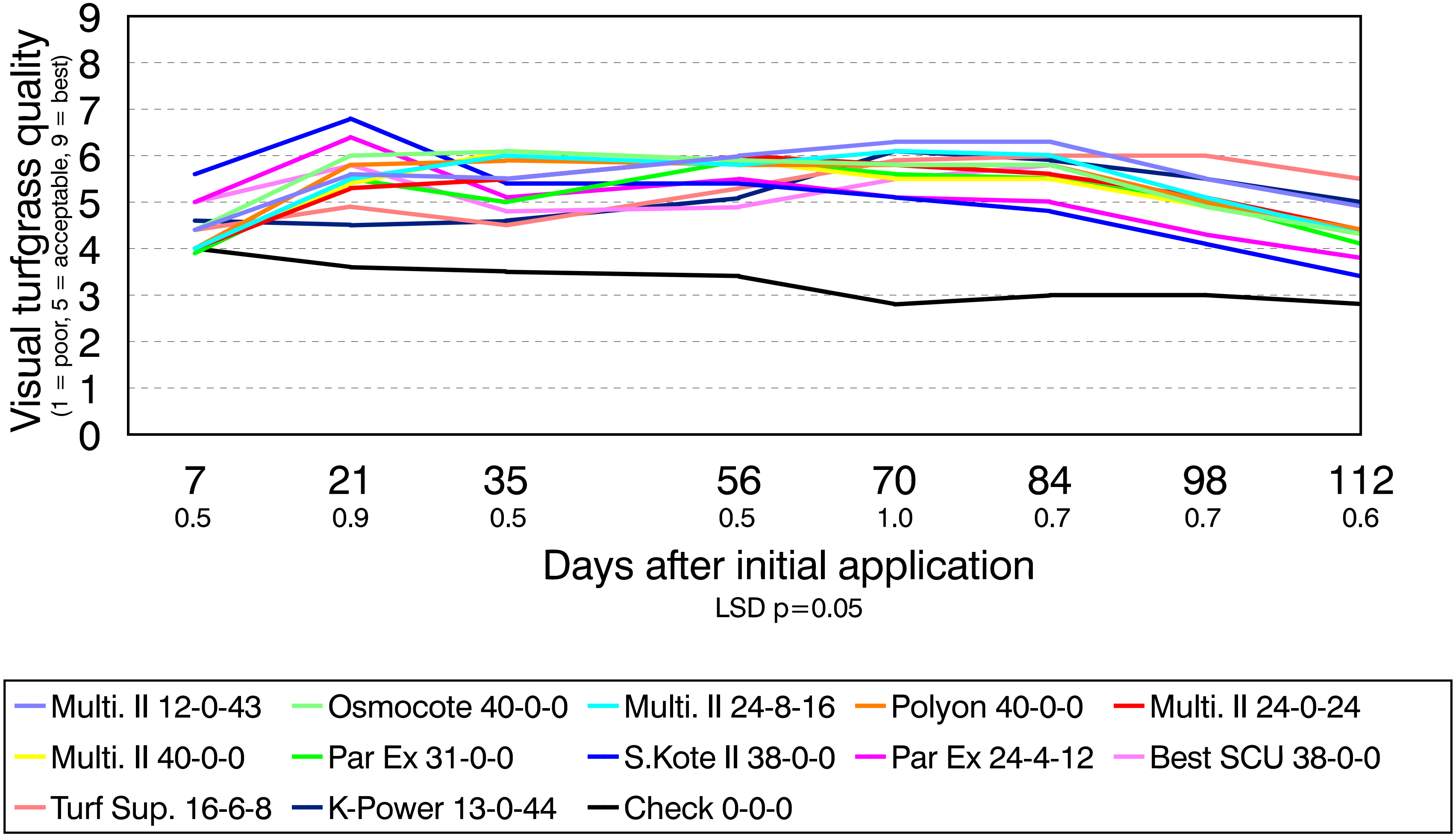


Table 7. The effect of N source on visual turfgrass color of Arizona Common bermudagrass.

Nitrogen treatment	Days after application:	Visual turfgrass color[z] 7	21	35	56	70	84	98	112	Overall
One application[y]:										
Multicote II (12-0-43)		4.1	5.8	5.5	6.0	6.3	6.3	5.5	4.9	5.5
Osmocote (40-0-0)		3.9	6.4	6.1	5.9	5.8	5.8	4.9	4.3	5.4
Multicote II (24-8-16)		3.6	5.5	5.9	5.8	6.1	6.0	5.1	4.3	5.3
Polyon (40-0-0)		3.5	5.9	6.0	5.8	5.8	5.8	5.0	4.4	5.3
Multicote II (24-0-24)		3.8	5.8	5.5	6.0	5.8	5.6	5.1	4.4	5.2
Multicote II (40-0-0)		3.5	5.5	6.3	5.9	5.5	5.5	4.9	4.3	5.2
Par Ex (31-0-0)		3.5	5.5	5.1	5.9	5.6	5.5	5.0	4.1	5.0
SulfurKote II (38-0-0)		5.6	7.0	5.3	5.4	5.1	4.8	4.1	3.4	5.1
Par Ex (24-4-12)		5.1	6.5	5.1	5.5	5.1	5.0	4.3	3.8	5.0
Two applications[x]:										
Best SCU (38-0-0)		4.9	5.8	4.8	4.9	5.5	5.8	5.0	4.4	5.1
Four applications[w]:										
Turf Supreme (16-6-8)		4.3	4.9	4.6	5.3	6.0	6.0	6.0	5.5	5.3
K-Power (13-0-44)		4.5	4.5	4.8	5.3	6.1	5.9	5.5	5.0	5.2
Check		3.5	3.6	3.5	3.4	2.8	3.0	3.0	2.8	3.2
LSD p = 0.05		0.5	0.9	0.5	0.5	1.0	0.7	0.7	0.6	0.5
CV (%)		8.0	10.6	6.7	6.0	12.6	8.9	10.6	10.4	7.7
Treatment effect[v]		***	***	***	***	***	***	***	***	***

[z] Scale = 1 to 9, with 1 = poorest; 5 = acceptable; 9 = best; note that the highest that Arizona Common bermudagrass could rate is approximately 7.5.

[y] Treatment applied at 4 pounds of actual nitrogen per 1000 ft^2.

[x] Treatment applied at 2 pounds of actual nitrogen per 1000 ft^2, second application 56 DPT.

[w] Treatment applied at 1 pound of actual nitrogen per 1000 ft^2, follow-up application 28, 56, 84 DPT.

[v] *** Significant at *P* = 0.001.

The effect of N source on visual turfgrass color of Arizona Common bermudagrass.

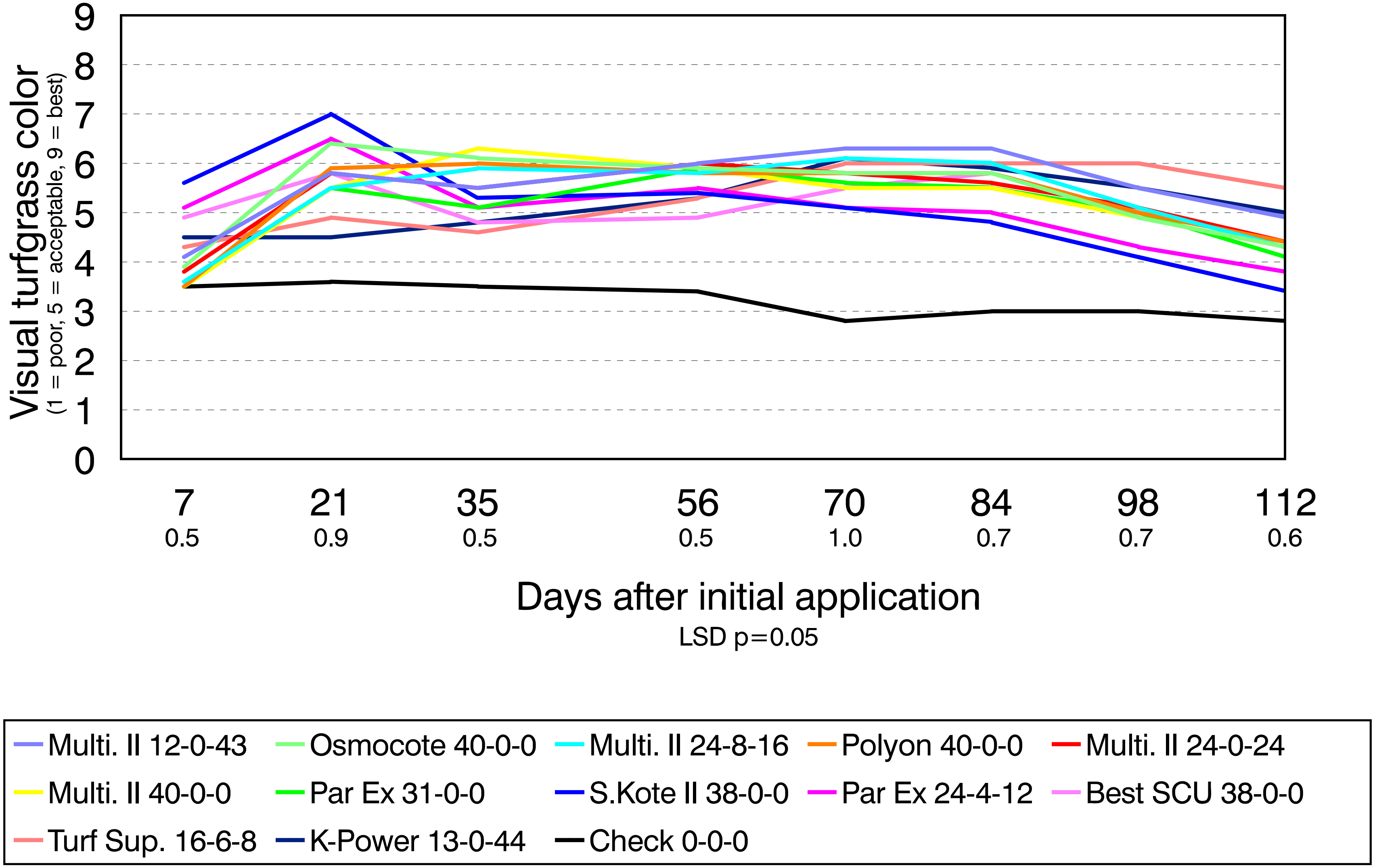


Table 7. The effect of N source on clipping yields of Arizona Common bermudagrass.

Nitrogen treatment	Days after application:	Clipping yield (g/18.44 ft^2 per 3 days)								
		7	21	35	56	70	84	98	Total	%[z]
One application[y]:										
Multicote II (12-0-43)		3.9	3.8	8.9	9.2	8.0	8.8	5.3	48.0	53.2
Osmocote (40-0-0)		4.1	7.3	10.6	8.3	5.8	6.3	4.2	46.7	65.5
Multicote II (24-8-16)		4.7	5.9	9.7	10.0	7.1	8.1	4.2	49.7	61.5
Polyon (40-0-0)		4.1	5.5	12.8	12.2	7.5	5.4	4.6	52.0	66.5
Multicote II (24-0-24)		3.4	3.8	8.9	8.1	5.2	9.3	3.6	42.2	57.0
Multicote II (40-0-0)		3.5	4.7	12.0	9.6	5.9	5.5	4.1	45.4	65.7
Par Ex (31-0-0)		4.2	3.3	6.0	8.7	6.0	6.0	4.1	38.3	57.9
SulfurKote II (38-0-0)		7.5	14.5	8.4	6.8	4.0	5.6	2.9	49.6	75.0
Par Ex (24-4-12)		4.5	4.7	5.9	6.8	3.7	5.1	2.4	33.0	66.0
Two applications[x]:										
Best SCU (38-0-0)		4.4	3.7	4.5	4.1	5.7	7.4	3.0	32.8	52.0
Four applications[w]:										
Turf Supreme (16-6-8)		4.1	2.1	4.5	4.2	5.2	5.5	3.7	29.3	50.6
K-Power (13-0-44)		3.4	2.6	5.5	5.1	5.4	5.3	3.0	30.3	54.3
Check		3.6	1.8	1.9	2.5	1.7	2.1	1.4	15.2	66.0
LSD p = 0.05		1.5	2.2	3.1	2.3	2.7	2.3	2.0	11.5	7.3
CV (%)		24.0	30.6	28.5	21.8	34.6	25.3	39.7	19.9	8.2
Treatment effect[v]		***	***	***	***	***	**	*	***	***

[z] % = (Accumulative mass through 56 DPT/total mass) x 100.

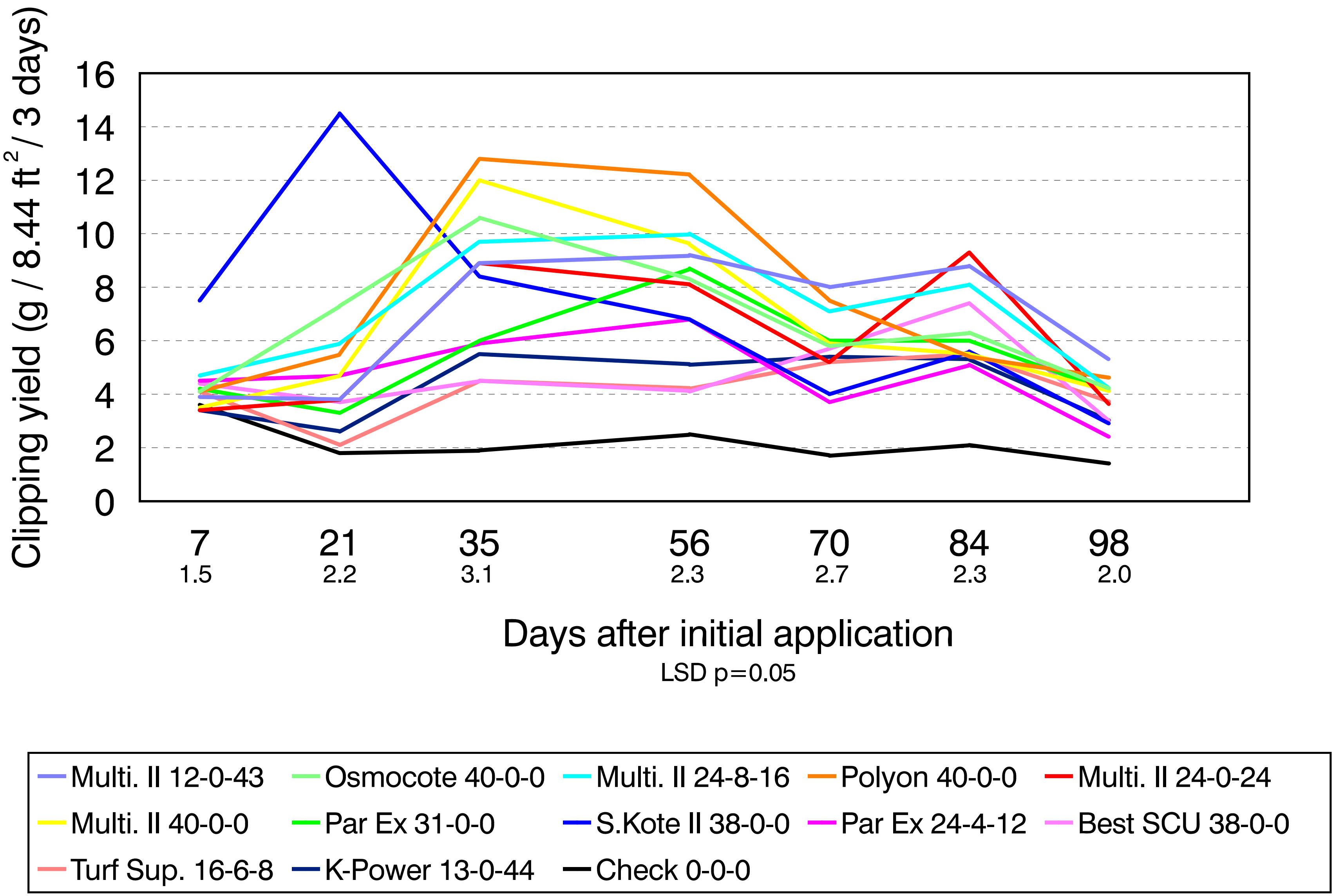
[y] Treatment applied at 4 pounds of actual nitrogen per 1000 ft^2.

[x] Treatment applied at 2 pounds of actual nitrogen per 1000 ft^2, second application 56 DPT.

[w] Treatment applied at 1 pound of actual nitrogen per 1000 ft^2, follow-up application 28, 56, 84 DPT.

[v] *, **, *** Significant at *P* = 0.05, 0.01, and 0.001, respectively.

The effect of N source on clipping yields of Arizona Common bermudagrass.



APPENDIX

A REVIEW OF LITERATURE
INVOLVED WITH TURFGRASS
NITROGEN NUTRITION

Role of Nitrogen in Turfgrass Nutrition

Understanding the role of nitrogen in turfgrass nutrition is dependent upon a basic understanding of energy dynamics and carbohydrate partitioning in turfgrasses. Nitrogen conversion in the soil environment to a plant-usable form (NH_4 or NO_3) is the initial, but plant response limiting, step in a series of complex physiological processes. These biological processes are utilized mainly to grow and maintain roots, tillers, and foliage. Urban turfgrass management is such that the energy expended on seed germination, flowering, seed production or dormancy is a small fraction of the total expended energy. A general discussion of photosynthesis and carbohydrate use will aid in the discussion of the impact of nitrogen on turfgrass nutrition.

Photosynthesis is the reduction of CO_2, in the presence of light, to form energy-rich carbohydrate units to be utilized by the plant during respiration. Two pathways, the C-3 and C-4, exist to accomplish this initial energy capture and conversion. The differences between the two pathways, besides leaf structure, reside mainly in the superior ability of the C-4 pathway to capture CO_2 and concentrate it for assimilation. Carbon dioxide fixed by the bundle sheath cells of the C-4 pathway is ultimately utilized in the C-3 pathway.

Turfgrasses can be identified as either C-3 or C-4 plants, based upon their CO_2 compensation concentration and leaf anatomy. In general, warm-season turfgrasses are classified as C-4 plants and cool-season turfgrasses as C-3. Herein lies the mechanism by which general characteristics of each group can be explained. C-4 plants exhibit a higher carbon exchange rate (CER), lower evapotranspiration (ET) rate, and a higher nitrogen use efficiency than C-3 plants. C-3 plants are susceptible to photorespiration and, therefore, a decreased CER. It is this flow in the C-3 pathway which allows for cool-season turfgrass to become physiologically stressed during periods of elevated temperatures.

Increased N efficiency, as exhibited by C-4 plants, can be explained by the commitment of smaller amounts of leaf N to the enzymes required for CO_2 reduction. An additional model proposed by Moore and Black in 1979 suggested N efficiency can be explained by a greater division of labor for the reduction and assimilation of NO_3 in C-4 plants. Regardless of the physiology involved, N efficiency has been linked to N availability. Essentially, C-4 plants are the most nitrogen efficient when the element is abundant and less efficient when availability is limited. For any rate of N supply, an optimum leaf N content exists that supports maximum growth and that optimum N level is lower for C-4 plants.

Carbohydrates are the energy source utilized by turfgrasses for growth, development and maintenance. Carbohydrates are the by-product of photosynthesis; the conversion of light energy into chemical energy. Carbohydrates in C-4 plants exist as glucose or sucrose polymers, whereas C-3 plants contain mostly fructose polymers. The total nonstructural carbohydrate (TNC) content of tissues is often used as an indicator of the physiological status of turfgrasses. Levels of carbohydrate content in turfgrasses have been shown to be influenced by nitrogen fertility, supra-optimal temperature, and partial defoliation. Rapid growth and high metabolic activity normally results in lower TNC levels, whereas conditions which encourage near maximum photosynthetic rates with decreased growth allows for increased levels of TNC. Nitrogen fertility and the subsequent increased shoot growth create demands on the plants' carbohydrate supply by increasing the demand of photosynthetic energy required to reduce and assimilate nitrogen.

The role of nitrogen in turfgrass nutrition can be summarized as a factor in both carbohydrate production and photosynthesis. The role of nitrogen can be said to be defined by use efficiency and availability versus quantity of the actual nitrogen molecule.

Nitrogen Formulations

The growth and development of turfgrass is dependent on 17 essential elements. Of the 17 elements, nitrogen is required in the greatest quantity by turfgrass, excluding oxygen, carbon, and hydrogen. Nitrogen is an important element in many aspects of turfgrass plant growth, including chlorophyll, proteins, nucleic acids, enzymes, vitamins, and amino acids. It has been shown to affect color, density, shoot growth, root growth, recuperative ability, stress management, and pest susceptibility (resistance). A wide spectrum of nitrogen sources exist for use in the turfgrass industry. The current technology which exists to produce these sources is progressive by nature, and, therefore, product enhancement is an ongoing process.

Classification of nitrogen sources can be simply accommodated by dividing the products into either quick- or slow-release formulations. Quick-release nitrogen fertilizers are those which are water soluble and, therefore, readily available to the plant. Slow-release nitrogen fertilizers have insoluble forms of nitrogen or have water soluble nitrogen encapsulated by a coating process. The readily-available formulations of nitrogen exist as either nitrate (NO_3) or ammoniacal (NH_4). However, nitrate nitrogen is the form most readily utilized by plants and can be made available from ammoniacal nitrogen through a bacterial conversion process which occurs in the soil. Uptake of nitrogen proceeds rapidly, with translocation to the leaf tissue occurring within 15 hours (Beard, 1973). Ammoniacal and nitrate nitrogen which is not used by the plant can be lost to the environment through leaching and/or volatilization. Leaching occurs most readily with nitrate nitrogen due to like charges between the nitrogen molecule and the soil micelle. Commonly available quick-release nitrogen sources are those which contain inorganic salts, urea, or urea formaldehyde products. Fertilizers produced from inorganic salts include ammonium nitrate, ammonium sulfate, and ammonium phosphates (several). The K-Power (13-0-44) and Turf Supreme (16-6-8) formulations included in this study belong to this group. Inorganic salt nitrogen sources (N sources) can be characterized by rapid initial growth, high N efficiency, high foliar burn potential (high salt index), and short nutrient duration (4-6 weeks). Use of these fertilizers is targeted to situations which require a fast greening of the turf with excess growth.

Urea-based N sources are formed by combining atmospheric nitrogen with methane to produce ammonia gas, which, in turn, through a pressurized, high temperature system, reacts with CO_2 to form urea (46-0-0). Turfgrass reaction to urea fertilization is much the same as an inorganic salt nitrogen source. Urea is hydrolyzed to ammoniacal nitrogen prior to uptake by the plant.

Urea formaldehyde (UF) products are products of a condensation reaction of urea with formaldehyde. The product of this reaction is methylol urea, which contains about 50% N from methylol and about 50% from urea. Both forms are water soluble and, therefore, readily available for conversion to a plant usable form of nitrogen. Turfgrass response to methylol ureas is similar to inorganic salt nitrogen sources as well. Methylol ureas can be converted to long-chain methylene urea polymers, through condensation, to produce a slowly-available N source.

Slowly-available N sources can be classified into three categories: (1) natural organics, (2) synthetic organics, and (3) coated materials. General characteristics of slowly-available N sources include low water solubility, lower salt index, and slow initial turfgrass response of longer duration than quick sources.

Natural organic N sources were the first slow-release products available to turf managers. Most of these products were waste or by-products, and include bone and blood meal, cottonweed meal and activated sewage. These products typically contain a low percentage of nitrogen and, therefore, a higher cost per acre per unit of the material. Activated sewage sludge accounts for the highest use from these sources. Complex organic compounds contain the N in these products and must be microbially digested for release to the plant. Microbial activity is dependent on factors such as soil moisture, pH and temperature.

Urea formaldehyde reaction products and isobutylidene diurea (IBDU) are two formulations found in the synthetic organics classification. As mentioned previously, the initial reaction of urea with formaldehyde produces water soluble, quick-release sources of N (methylol). Further condensation of this N source results in methylene urea polymers of varying molecular weight. Mineralization and nitrification of UF fertilizers is dependent upon the molecular size of the methylene ureas, the rate decreasing with increasing length. The molecular weight is controlled by the ratio of urea to formaldehyde. Essentially, as the rate of urea increases, the molecular weight decreases. The resulting N source consists of mainly shorter-chained polymers and unreacted urea. Mineralization and nitrification can be slowed, therefore, by decreasing the ratio of urea to formaldehyde and increasing the percentage of longer-chain polymers. These long chain polymers represent the water-insoluble nitrogen (WIN) portion of the product, which is responsible for the slower initial response and longer duration. Currently, minimally accepted standards of UF sources contain 35% N, which have at least 60% WIN and an activity index of not less than 40%.

Mineralization of UF nitrogen sources is completed by microbial degradation. This process has been shown to be influenced by soil moisture and pH (Watschke and Waddington, 1974). In addition, microbial activity necessary to complete the conversion to nitrate nitrogen is also dependent upon soil temperatures.

Isobutylidene diurea (IBDU) is another urea condensation product, this time with isobutyraldehyde. The resulting product contains 31% N, with 90% of the total N available from WIN in the coarse material. Nitrogen release from IBDU is accomplished by hydrolysis and can be influenced by temperature, moisture, particle size and soil pH. Optimum conditions for these four parameters are 25 C (80% N availability), well-watered soil conditions, finer grade (fines), and pH 5.7, respectively. Nitrogen efficiency appears to be higher with the finer IBDU grades versus the coarser grades. Two formulations of IBDU are currently involved in this study (31-0-0, 24-6-12). Both are coarse grade materials.

Turfgrass response to IBDU is typically delayed due to the time required to dissolve the IBDU and subsequent hydrolysis of this product. Good residual response of turfgrass to nitrogen fertilization has been observed with continued use of the material. Satisfactory low temperature response of IBDU has also been observed.

The third classification of slowly-available nitrogen sources is coated materials. Release of the urea or other water-soluble forms of nitrogen is controlled by an impermeable or semi-permeable membrane. Membranes are typically made from sulfur or a resin-type material. Release of nitrogen is accomplished either by degradation of the coating or the physical characteristics inherent to the coat.

Sulfur-coated urea is produced by spraying molten on urea prills or granules which have been heated. In most cases, the coated urea is then sealed with a thin coating of wax and conditioned with diatomaceous earth to decrease tackiness (clumping) and increase hydrophilicity. The final SCU product consists of 32-38% N, 13-22% S, 2-3% sealant, and ~ 2% conditioner.

Coating thickness and coating defect can influence the release of nitrogen from SCU. A typical SCU product has three classes of granules: (1) unobstructed holes or cracks in the coating to allow for unimpeded movement of nitrogen as soon as the material is wetted, (2) defects in the coating are plugged by the sealant and nitrogen is released upon sealant degradation, (3) no defects exist in the S coat, and, therefore, release is dependent upon degradation of the sealant (if used) and S coating by hydrolysis. The 7-day dissolution (7-d DR) is a laboratory quantification of the release of nitrogen from SCU. The 7-d DR is the amount of SCU N that can be hydrolyzed by water @ 38 C in a 7-d period. Typical 7-d DR are 25-35%. Greater initial turfgrass responses have been observed using SCU materials with higher 7-d DR.

Field response to SCU is dictated indirectly by a variety of parameters including coating thickness, particle size, soil water tension, temperature, and soil aeration. In general, increased turfgrass response has been observed with the use of thinner coatings with a wax sealant (vs. thicker S coating with no sealant), when temperatures are elevated, and when soil moisture is adequate or better. This type of turfgrass response was not noted when soil aeration was significantly reduced. Particle size was shown to be inconclusive regarding field response. Coarser materials demonstrated faster release rates due to thinner coating per unit weight when compared to finer materials (due to the reduced surface area of the coarse material). Finer materials also exhibited faster release rates due to increased degradation of the coating. This can be explained by the increase in surface area to volume and, therefore, greater exposure. Soil pH and microbial activity were shown to have little to no effect on SCU N release.

High quality bermudagrass turf, similar to that produced with multiple applications of ammonium sulfate, resulted from two applications of prilled SCU. Volk and Horn found that a SCU with a 9% dissolution rate gave more favorable results than IBDU, UF, and activated sewage sludge. Hummel and Waddington found that two applications of SCU produced superior quality turf more uniformly through the season that several other slow- and quick-release N sources.

Resin-coated fertilizers (RCU) are made by spraying a thin plastic coating onto a urea prill. Talcum is added to alter the physical characteristics of the coating, namely the pore size. Release is believed to be controlled by an osmotic gradient. Water entering the prill causes the sphere to swell. Urea is released through cracks in the sphere or forced out into solution through the pore spaces. Plant uptake of nitrogen would begin after mineralization and nitrification of the urea.

Common Bermudagrass Characteristics

Common bermudagrass (*Cynodon dactylon* (L.). Pers.), belonging to the Chlorideae tribe, subfamily *Festucoideae,* can be characterized as medium in both texture and color, with an intermediate shoot growth rate and density. Benefits of Common bermudagrass include rapid establishment and growth rate, excellent recuperative potential, good wear tolerance, a lower water requirement, and the capability of establishment with seed. Detractions from this turf include winter dormancy, poor shade tolerance, and excessive seedhead formation.

Common bermudagrass is widely utilized as a playing surface due to its adaptability and inherent culture. The heat and drought tolerance of this plant is well-documented, as is the ability to tolerate a wide range of soil types and textures. Optimum growing conditions include relatively fine-textured soils with good drainage, adequate soil moisture, moderate fertility, and a pH range of 5.5-7.5. Bermudagrass requires a high intensity cultural program to produce moderately acceptable turf. Current practices such as close (0.5-1.5 inches) mowing, vertical mowing (dethatching), frequent fertilization (0.8-1.8 lb N/month per growing season), and adequate irrigation are necessary to produce optimum field conditions. Cultural practices below this level of intensity will produce proportionally inferior turfgrass.

A Nitrogen Fertilizer Strategy

The study of the response of common bermudagrass to nitrogen fertilization would also include an overview of a fertility strategy such that an understanding of the interactions of the turfgrass environment is gained. Vital aspects of this strategy can be developed around parameters such as: (1) the growing season, (2) growth response to nitrogen, (3) plant vigor, (4) nitrogen loss (i.e., volatilization, inefficient plant utilization, denitrification, and leaching), (5) soil environment, and (6) cost vs. benefit. Central to this discussion is the designated use of the turfgrass. Turfgrass, as described by Beard (1973), can have functional, recreational or ornamental uses. For purposes of this study our discussion will be limited to recreational uses.

Growing season is a function of species, climate and photoperiod. Nitrogen fertilization has the greatest opportunity to optimize turfgrass growth and development when applied during optimum N efficiency periods. Common bermudagrass has a temperature optimum of 80-95 F, and thrives under high light intensity conditions. Therefore, nitrogen fertilization (0.8-1.8 lb N/1000 ft^2), which occurs during the summer months, would deliver the optimum benefit to a monostand of bermudagrass. Over-fertilization, and, in turn, over-stimulation of shoot growth during the summer months, will likely increase the level of photosynthesis required to reduce and assimilate nitrogen. TNC content would also be depleted. This study was conducted during the optimum growing season.

Growth response to nitrogen fertilization is a function of several factors, including, but not limited to, species, growing season, nitrogen rate, and formulation. A strategy for nitrogen fertilization which would produce even-growth response in Common bermudagrass might include the following: (1) a coated slow-release nitrogen source applied at a rate which would release 1.0 lb N/1000 ft^2 per month, (2) the application timed so that the nitrogen source is available to the plant (via mineralization and nitrification) when daytime temperatures are between 80-95 F, (3) conditions which limit growth response are minimized, such as poor cultural practices, irrigation level below field capacity, etc., (4) soil chemical, physical and biological conditions are optimized. Alternative strategies, such as the use of quick-release fertilizers more frequently during the growing season, have been shown to produce a less even growth response, as well as reduced management efficiencies. The effects of such a strategy are presently being compared to alternative strategies in the course of this study.

Plant vigor is influenced by turfgrass quality. The most visible determinants of quality include density, texture, uniformity, color, growth habit, and smoothness. Nitrogen fertilization can be proved to affect all determinants, but it most directly influences uniformity, density and color. Therefore, a nitrogen fertility strategy would target the enhancement of uniformity, color and density, thereby increasing the overall turfgrass quality and vigor. A quantification of vigor is accomplished by measuring turfgrass yield (clippings), with quality evaluations occurring at a more subjective level based on color and uniformity.

A fertility strategy which safeguards against nitrogen loss is needed in order to manage the turfgrass environment efficiently. Volatilization, which is a phase change from a solid to a gas with subsequent loss to the atmosphere, occurs during conditions of high moisture or humidity, warm temperatures, and excessive rates of nitrogen. Fertilization using coated materials minimizes the amount of nitrogen exposed to the environment.

N efficiency of turfgrass is critical in minimizing loss. Common bermudagrass nitrogen efficiencies are greatly decreased during N deficient conditions. Conditions which favor physiological stress (drought, pest invasion, elevated temperatures) will also decrease the ability of the turfgrass to absorb the nitrogen through its roots. Nitrogen use efficiencies are also influenced by the N formulation: soluble sources = sulfur-coated urea (SCU) > methylene urea = IBDU > activated sludge > ureaform (UF). Denitrification of nitrate or nitrite sources of nitrogen are caused by anaerobic biological reduction to gaseous forms of nitrogen (N_2, N_2O). Conditions which favor anaerobic bacterial growth (compaction and over-watering) should be corrected or avoided. Leaching of NO_3-N from the rootzone is common on sandy, irrigated soils. Loss of nitrogen due to leaching can be controlled through the use of finer-textured soils or soil mixes, slow-release fertilizers, and proper irrigation. The greatest loss of nitrogen in this study would be caused by N formulation due to the consistency of irrigation and soils.

Soil environment, including the physical, chemical and biological parameters, requires careful consideration when developing a fertilizer strategy. Although many complex interactions affect the strategy of a fertilizer program, a simplified overview will suffice for this study.

Soil physical properties are governed by soil texture. Soil texture is one of the limiting factors which influence compaction and drainage. Nitrogen utilization will be optimal with physical properties such that 50% of the soil volume is consumed with air and water, in equal amounts. Changes in physical properties (compaction) alter the biological and chemical properties, as well. Essentially, compacted soils increase bulk density, heat conductivity, mechanical impedance to roots, CO_2 levels, and water retention. Compaction also causes air porosity, infiltration, percolation and oxygen diffusion to decrease (Waddington et al., 1992). Soil temperature, a physical property, influences many chemical and biological reactions, including microbial activity and N transformation.

Soil reaction (pH) refers to the acidity or alkalinity of the soil environment. The soil pH affects soil physical properties, nutrient forms and availability, toxic substances, and microbial activity (Waddington et al., 1992). Individual turfgrass cultivars have pH optimums, with bermudagrass preferring soils with acidity levels of 6.0-7.0. N release from slow-release sources has been shown to be dependent upon pH.

In addition to soil reaction, salts and sodium levels also affect soil chemistry. Decreased water availability and subsequent plant decline is the result of high osmotic pressure from excess salts. Excess sodium causes deflocculation of soil and, thereby, erodes soil structure. Bermudagrass has been shown to be tolerant of excessive slat, but has shown reduction in growth at elevated sodium levels.

Biological properties of soils have arguably the most demanding (limiting) role of the soil parameters in developing a nitrogen strategy. N conversion into plant-usable forms occurs by microbial degradation. Soils limited in their ability to support these organisms will require basic forms of nitrogen (NO_3, NH_4) more frequently. Soils constructed using a high sand profile, such as putting greens and sports fields, fall into this category. N source fertility options with these types of soils are greatly decreased, and, subsequently so are management efficiencies. In addition to soil microbes, fungi, earthworms and nematodes all play a vital role in the overall health of the soil environment.

All of the scientific parameters notwithstanding, a nitrogen fertilizer strategy requires a cost vs. benefit analysis. This process would allow the turfgrass manager to evaluate the individual turf site and base the decision-making process not only on scientific evidence, but on budgetary constraints. The cost per unit of N in a slow-release form is considerably higher than in a quick-release form, although the costs incurred (from increased labor, excess clipping removal, and irrigation scheduling changes when using a quick-release fertilizer) help to negate the higher costs of the slow-release fertilizers. Other cost considerations are timing of application to maximize plant response, individual turfgrass species N efficiencies, and quality of turf desired for the type of use demanded. Efficient use of resources will be required as the demand for turfgrass performance increases in the recreational use industries such as golf and football.

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