Kentucky Bluegrass Response to Slow-Release Fertilizer Treatments: Comparisons of Nitrogen & Potassium Availability, Nutritional Quality, and Color

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<u>Introduction</u>:

More slow-release fertilizer products are currently available to turfgrass mangers than ever before. Fertilizer producers employ one or two general mechanisms to regulate nutrient availability following application of their product. The first is use of slowly-degradable coatings to encapsulate immediately available nutrient forms (e.g. sulfur-coated urea N). The second is synthesis of urea, formaldehydes, and/or salts into polymers of various length, solubility, and stability/persistence (e.g. methylene urea N).

Though simplistic, disadvantages of using coats to regulate quickly-available fertilizers are stark. Foremost, coatings add weight to the prill, diluting nutrient content and increasing requisite material application rates. Likewise, coating integrity can be compromised by ‘rough handling’ inherent to bulk fertilizer transport and application. These undesirable traits of coated fertilizers continue to increase interest in homogenous, organic N fertilizer formulations. Considering claims of consistent N-release over an entire season, it has become increasingly important to verify fertilizer performance through replicated and statistically-scrutinized field research.

<u>Experimental Objective:</u>

To evaluate and compare the release patterns of several commercially-available fertilizers over an 85-day (~12 week) field trial by measuring canopy color, growth rate, and nutrient uptake; following a typical, one-time application (1.8 lbs N per 1000 ft^2) to an intensively-maintained Kentucky bluegrass sports turf field (or showcase home lawn).

<u>Field Experimentation and Methods:</u>

<u>Treatments:</u> On April 20, 2006, six similar fertilizer products [Exalt, Expo, MethEx, IBDU, PCU/SCU (coated), and StaGreen (coated)] were applied at a rate of 1.8 lbs N per 1000 ft^2 to four replicated plots (4 x 8 ft, 32 ft^2) of ‘Park’ Kentucky bluegrass, in a randomized complete block design. A control plot was maintained in each block to calculate N recoveries. Associated nutrient delivery rates are presented in Table 1 below.

							Fertilizer					
	N	P_2O_5	K_2O	Fe	S	Fertilizer	N	WIN*	P_2O_5	K_2O	Fe	S
	Fertilizer % mass					lbs applied / 1000 ft^2						
Exalt	25	0	12	0	10.2	7.20	1.8	0.41	0.0	0.86	0.00	0.73
Expo	20	0	25	0	8.5	9.00	1.8	0.59	0.0	2.25	0.00	0.77
IBDU	31	0	0	0	0.0	5.81	1.8	1.61	0.0	0.00	0.00	0.00
MethEx	40	0	0	0	0.0	4.50	1.8	0.56	0.0	0.00	0.00	0.00
PCU/SCU	39	0	0	0	12.0	4.62	1.8	1.71	0.0	0.00	0.00	0.55
StaGreen	29	2	5	1	1.2	6.21	1.8	0.45	0.1	0.31	0.06	0.08

*WIN, water insoluble N

Figure 1. The 2006 Slow-Release Granular Fertilizer Field Trial conducted at the Joseph Valentine Turfgrass Research Center, Penn State University, University Park, PA. Image captured 8 days following experiment initiation (April 28).

Data Collection: Clipping yields (CY) were collected 12, 20, 27, 34, 41, 48, 55, 62, 69, 77 and 85 days after treatment (DAT). Relative clipping yield (RCY; 0-1) was calculated for each plot CY by dividing the observed CY by the maximum CY reported for any given DAT. Tissue collected from plots at 12 and 20 DAT were pooled, ground, and analyzed for nutrient content (henceforth referred to as 16 DAT). This process was repeated on pooled tissue samples from the 41 and 48 DAT yields, and the 69 and 77 DAT yields (henceforth referred to as 44 and 73 DAT, respectively). Clippings collected 55 or 85 DAT were analyzed for tissue N only. Nitrogen uptake (NUP) was calculated as the product of biomass production and mean tissue N (when available). Tissue N was estimated for 27 and 34 DAT clipping yields, and NUP estimated for inclusion in total net NUP estimates. Potassium uptake (KUP) was calculated from data for the 16, 44, and 73 DAT CYs only (KUP estimates were not calculated). High resolution digital images were collected 5, 14, 18, 20, 24, 31, 34, 41, 57, 62, 70, 77 and 85 DAT. Turfgrass color index ratings were calculated using the dark green color index (DGCI) method (Karcher and Richardson, 2003). Relative DGCI (rDGCI) was calculated as described for RCY above.

Field Results:

Initial Nutrient Content, Growth, and Quality:

Nutritional status of Kentucky bluegrass tissue collected 12 to 20 days after treatment (DAT) generally resided within established ranges of sufficiency (data not shown). In the first 3 weeks of the study, nutrients showing the greatest variability in tissue by fertilizer treatment were potassium (K) and sulfur (S). This is not surprising considering IBDU was the only fertilizer devoid of S, while only Exalt, Expo, and StaGreen contained K_2O (Table 1).

Bluegrass Shoot Growth (i.e. Clipping Yield/Biomass Production):

Because several environmental factors (other than nutrient availability) influence shoot growth (e.g. light intensity/quality, soil water availability, temperature), repeated measures of shoot growth over time are best standardized on a per-date basis. Thus, relative clipping yield (RCY) data are used to most clearly represent shoot growth patterns observed over the study. Experiment-wide mean relative clipping yield (RCY) data are shown below (Figure 2).

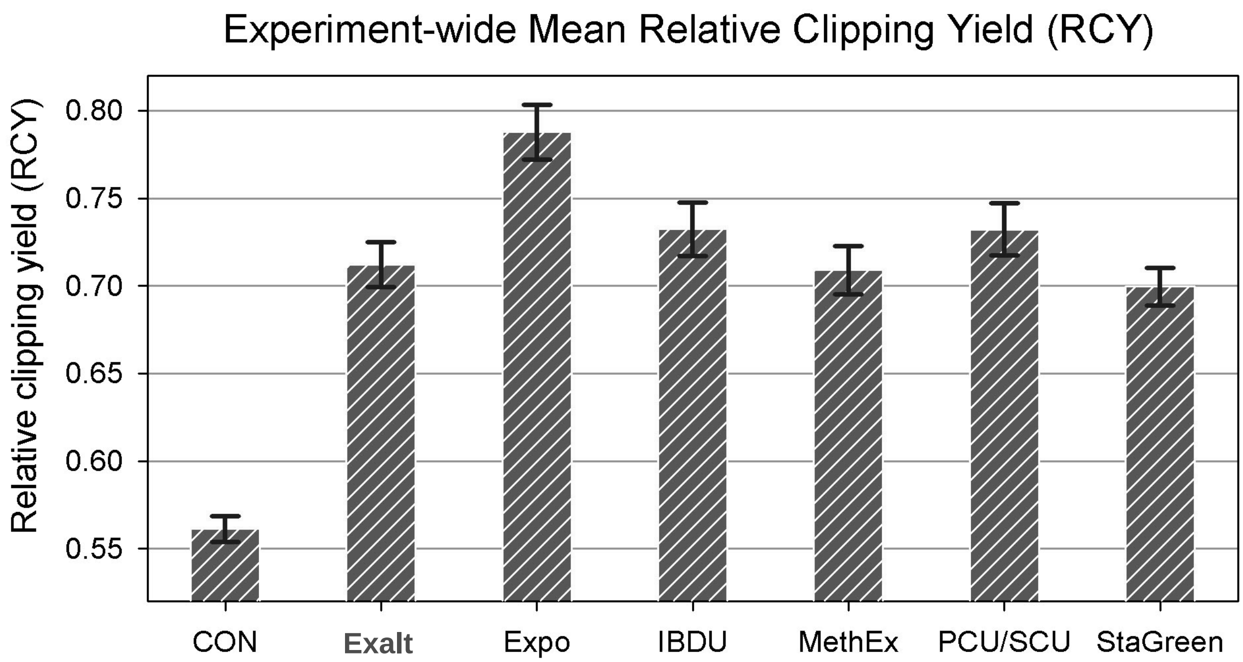


Figure 2. Relative clipping yields (RCY) shown by fertilizer over the 85-day study. Error bars represent the statistically significant range of RCY response for each fertilizer treatment (alpha level = 0.05).

Obvious differences in shoot growth are observed in the mean RCY values. Plots fertilized with Expo demonstrated significantly more growth than all other treatments. Plots treated with IBDU or PCU/SCU demonstrated statistically similar RCY, while a significantly greater rate of shoot growth than StaGreen. Regarding mean RCY across the study, all fertilizer treatments fostered significantly more vigorous shoot growth than the control plots (Fig. 2).

Relative clipping yields (RCY) by DAT are displayed in Figure 3 (next page). In the 12-days following fertilizer application (1.8 lbs N / 1000 ft^2); N release from IBDU or PCU/SCU fertilizers was relatively limited. All other treatments resulted in shoot growth significantly greater than the unfertilized control plots (Fig. 3). MethEx and StaGreen showed identical growth rate 12 and 20 DAT. Shoot growth in all fertilized plots (except IBDU) statistically exceeded that observed in the control plots, 20 DAT. Exalt and Expo plots demonstrated significant growth increases (Fig. 3), a desirable early-season response to N fertilization. Once turfgrass has broken dormancy, shoot growth thickens the canopy, increases area-based photosynthetic assimilation, and facilitates early season weed resistance. Growth-induced canopy thickening and enhanced aesthetic appeal are important late spring season management goals.

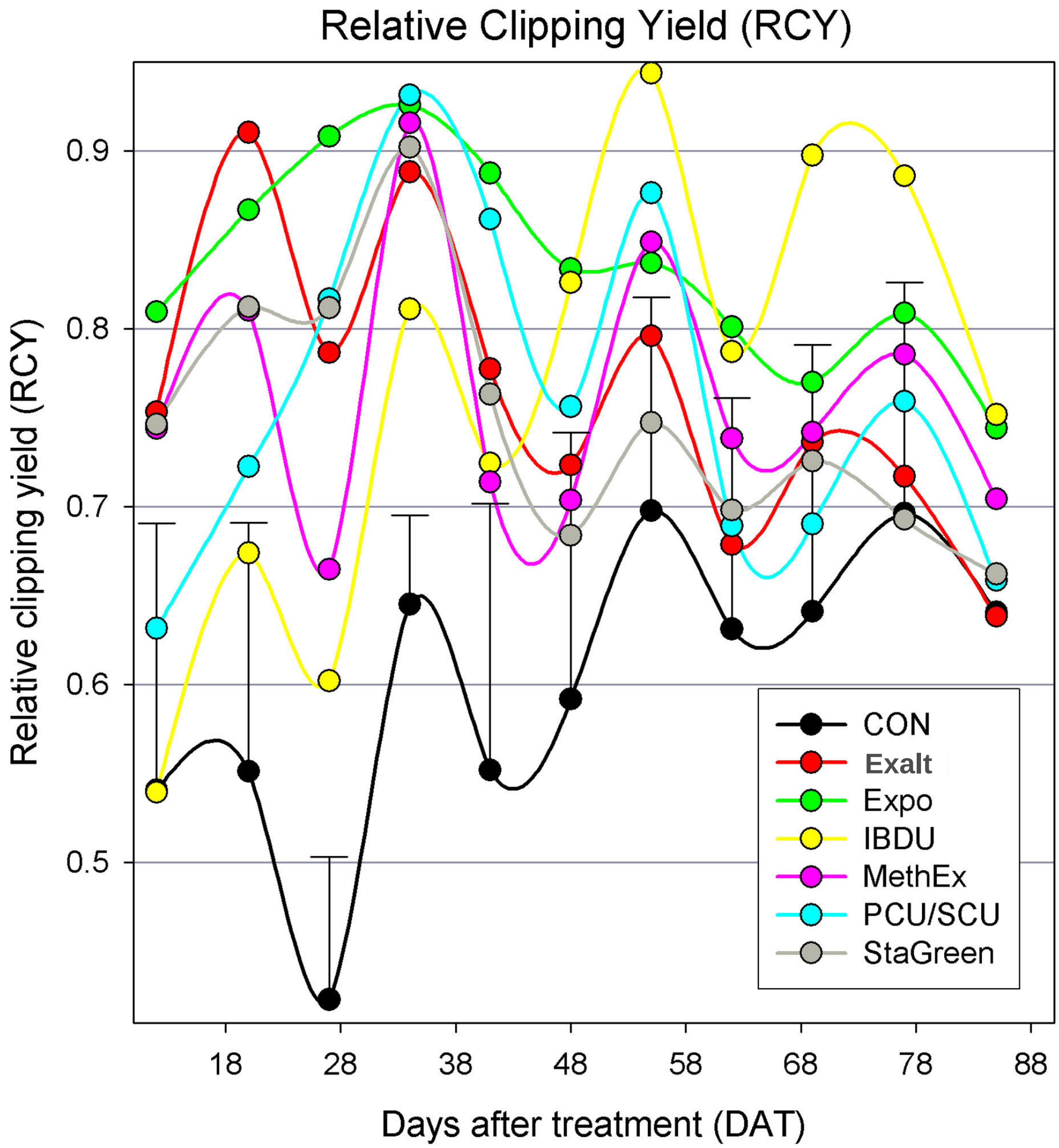


Figure 3. Relative clipping yield (RCY) by fertilizer and day after treatment (DAT). Error bars on control (0 lbs N) symbols represent a range of RCY response NOT significantly different from the control RCY response, for any DAT (alpha level = 0.05). No fertilizer treatment RCY was significantly different from the control RCY at 85 DAT (far right).

In the 25 to 40-days following treatment, all fertilized plots show significantly greater growth than the control plots. Most fertilizers are supplying more N to the Kentucky bluegrass in this period than at any other throughout the study (excepting MethEx and IBDU). Though StaGreen treatment showed identical RCY to MethEx at 12 & 20 DAT, shoot growth of StaGreen treated plots exceeds MethEx at 27 DAT. Between 34 and 40 DAT, availability of N from the Exalt and StaGreen fertilizers appear to wane (Fig. 3). Over the next 45-days, shoot growth in the Exalt and StaGreen treated plots were not significantly different than the control plots; indicating very little N availability from those fertilizers 6 weeks following a 1.8 lbs N / 1000 ft^2 application.

From 48 to 62 DAT, only Expo and IBDU demonstrate significantly greater shoot growth than the control. Compared to Exalt and StaGreen, both PCU/SCU and MethEx treatments demonstrate improved slow-release formulation (delayed N release) during this period, but not with as consistent growth as the Expo and IBDU treatments (Fig. 3). At 68 and 78 DAT, only the IBDU treatment delivers significant levels of N to the Kentucky bluegrass plots, as all other fertilizer treatments fail to stimulate greater growth than no fertilizer treatment at all.

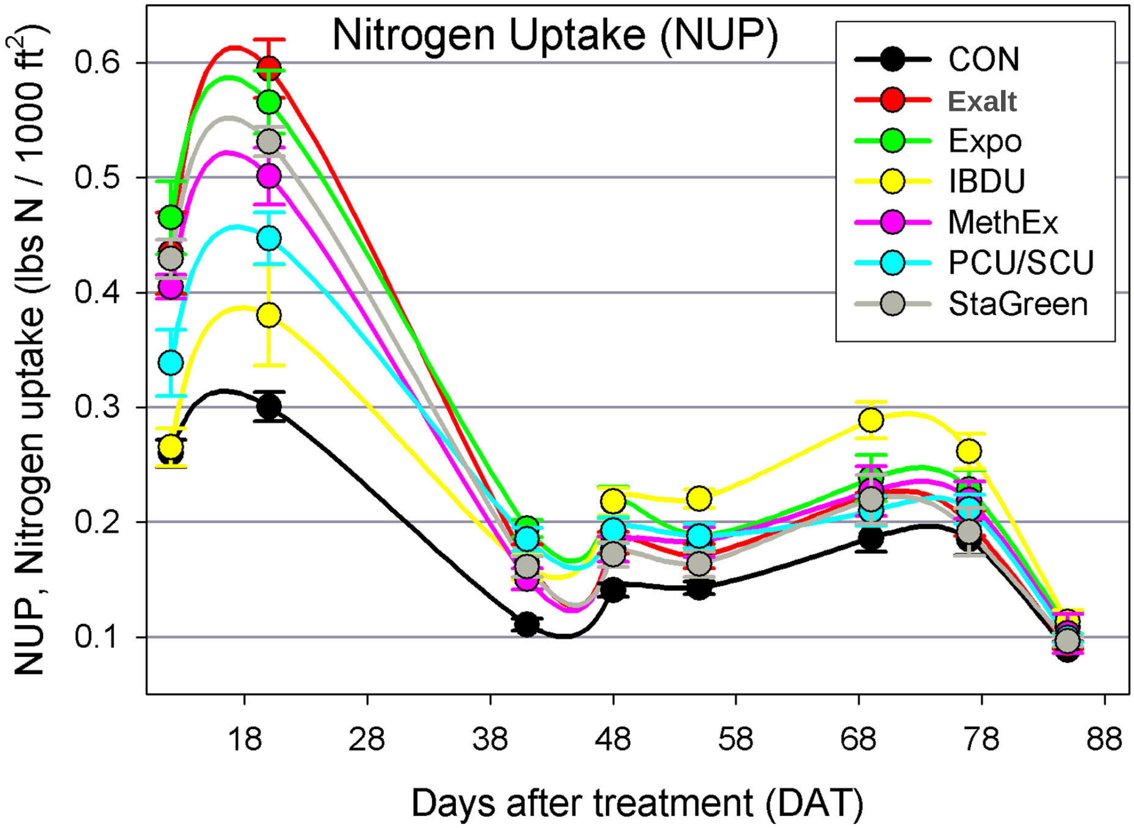


Figure 4. Nitrogen uptake (NUP) by fertilizer and days after treatment (DAT). Error bars represent the statistically significant range of NUP response for each fertilizer treatment (alpha level = 0.05), at any given collection date.

<u>Kentucky Bluegrass Nitrogen Uptake (NUP):</u>
The critical objective of a fertilizer program is consistent, metered N availability through the post application interval. Although most fertilizers demonstrated twice the N availability and uptake during the first 40 days of the trial than in the next 40 days, IBDU was the only fertilizer that demonstrated nearly equally-metered uptake over the 85-day experimental period (Figure 5b).

The fertilizers showing the most NUP (0.65 to 0.85 lbs N / 1000 ft^2) in the first 41 DAT were Exalt, Expo, and StaGreen. This NUP demonstrated by Exalt and StaGreen correlate well with their water-soluble N (WSN) fractions of 77.2 and 75 % (of total N), respectively. However, the comparatively lesser NUP of MethEx at 12 and 20 DAT (Figure 4) did not result in much lesser RCY, yet will likely result in greater N recovery later.

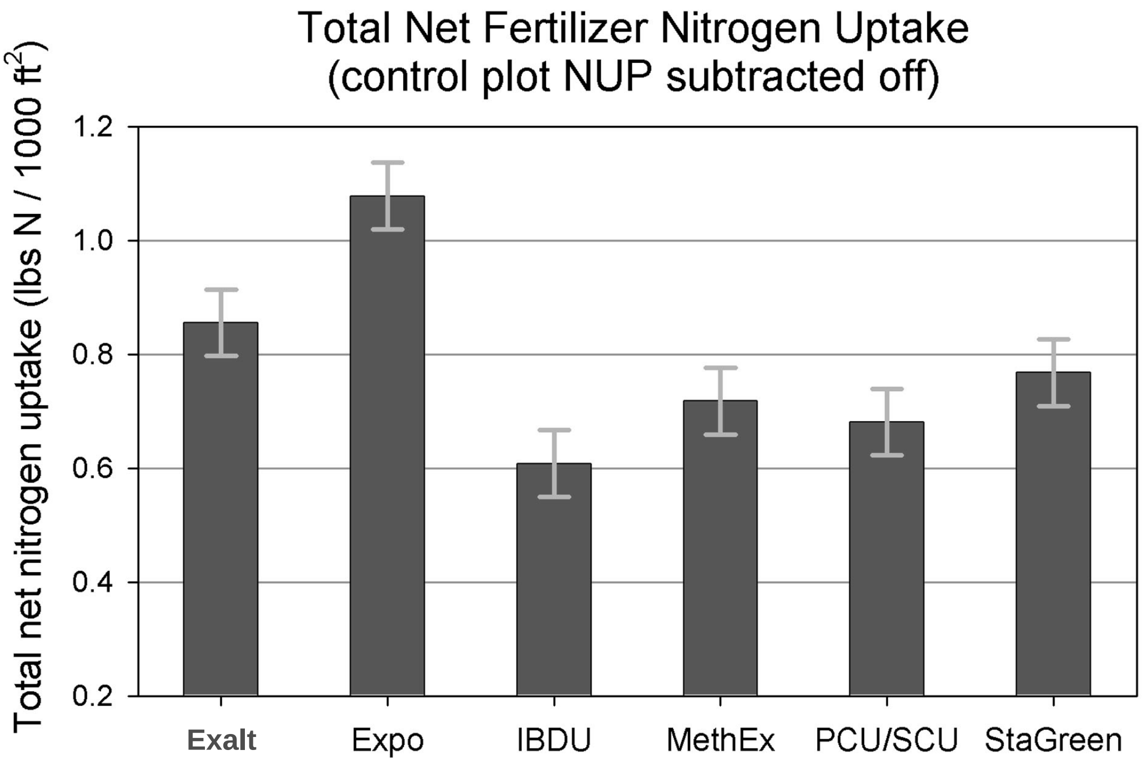
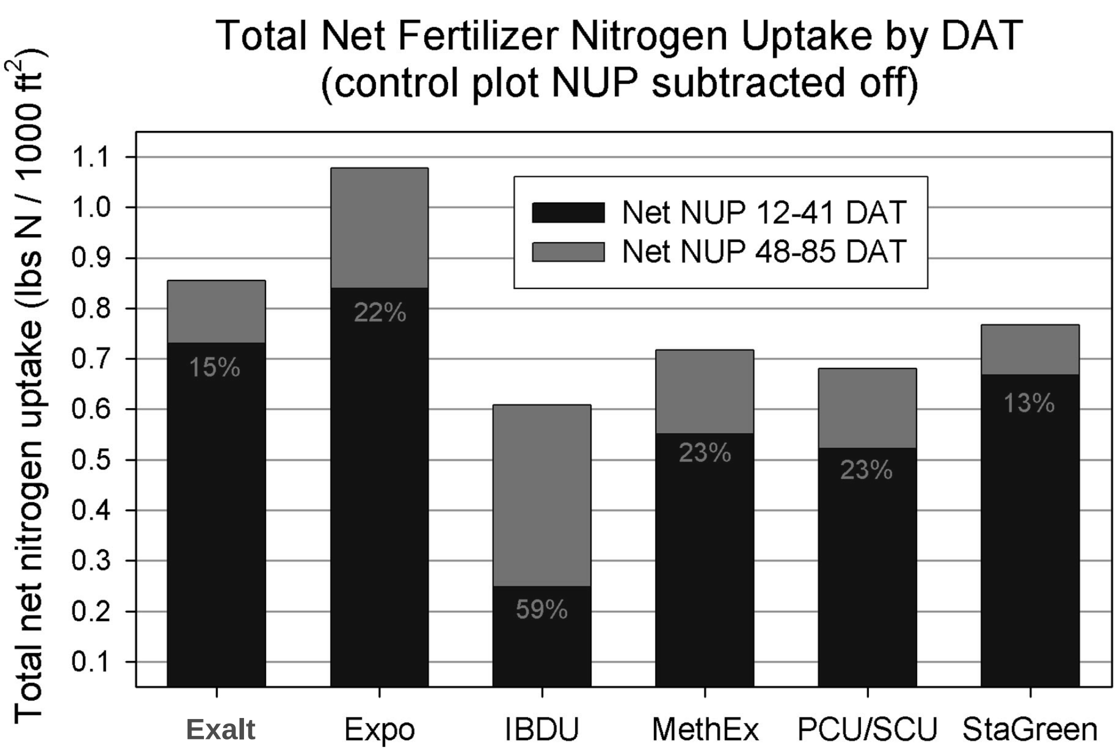


Figure 5. (a; above) Total (experiment-wide) net nitrogen uptake (net NUP) by fertilizer treatment. Error bars represent the statistically significant range of NUP response for each fertilizer treatment (alpha level = 0.05). (b; below) Total NUP by fertilizer by experimental period; where percent NUP occurring 48 to 85 DAT relative to total is shown in light blue.



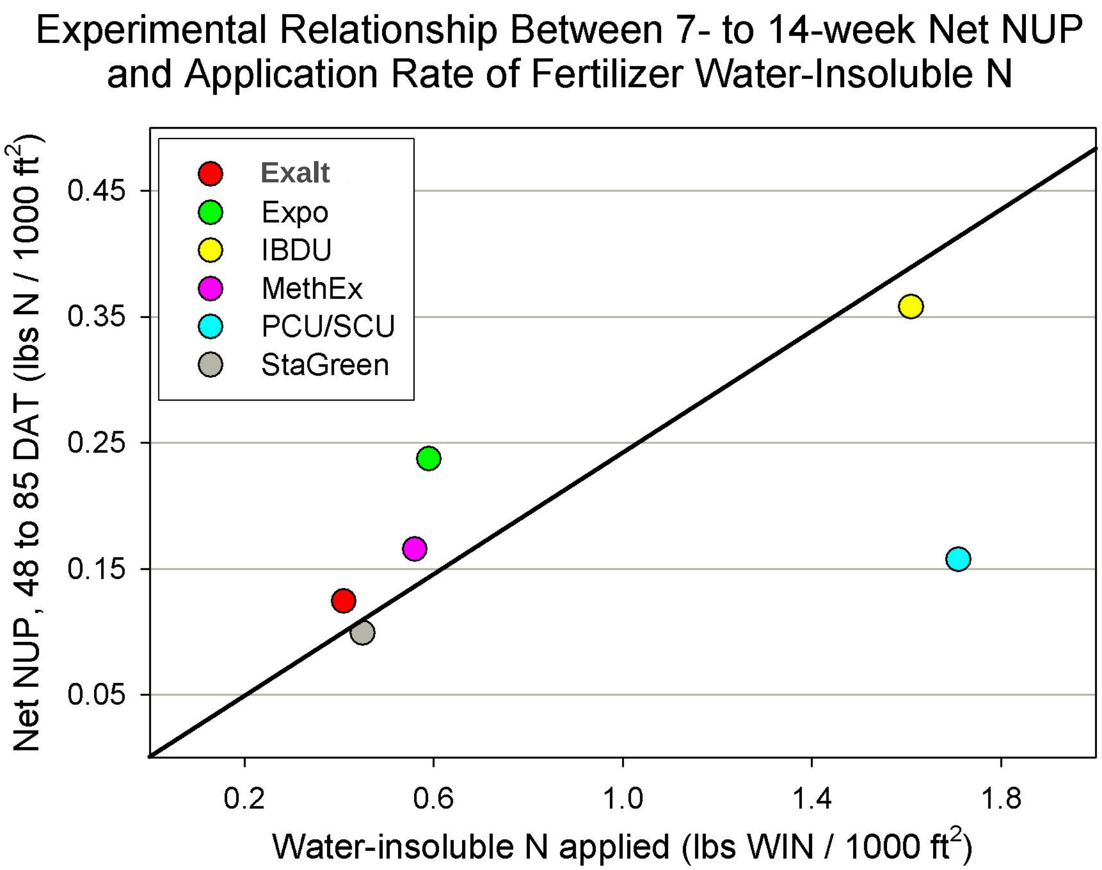


Figure 6. Net nitrogen uptake (NUP, control subtracted) by fertilizer treatment in the 48- to 85-DAT experimental period as related to lbs of water-insoluble N (WIN) applied per 1000 ft^2. The solid black line statistically predicts 48- to 85-day NUP by label WIN (48- to 85-DAT NUP = [0.24314 X lbs WIN applied], r^2=0.737). Fertilizers reporting 'controlled-release N' instead of WIN were not used to calculate the prediction (PCU/SCU and StaGreen).

Although total levels of NUP were similar for PCU/SCU, MethEx, and StaGreen (over the 85-d experiment duration), NUP from the PCU/SCU and MethEx fertilized plots in the 2nd half of the study accounted for 23% of their total, whereas StaGreen treatment resulted in significantly greater 1st half NUP (87%) and lesser N recovery in the 2nd half of the study (Fig. 5b).

Data shown in Figure 6 clearly demonstrates the trend between fertilizer WIN and NUP in the 48 to 85 days after fertilizer application. Kentucky bluegrass recovered 29.5, 30.3, or 40.2 % of WIN from the MethEx, Exalt, or Expo fertilizer applications 48 to 85 DAT, respectively. Only 9 % of PCU/SCU-'controlled release N (CRN)', or 22 % of either IBDU-WIN or StaGreen-CRN was recovered over identical time periods. Net total 85-d recovery of the Expo and Exalt fertilizer treatments are impressive (Figure 5a). Significantly greater fertilizer N was recovered (net NUP) from Expo than any other fertilizer treatment. Exalt fertilization resulted in significantly higher experiment-wide net NUP than IBDU, MethEx, or PCU/SCU (Figure 5a).

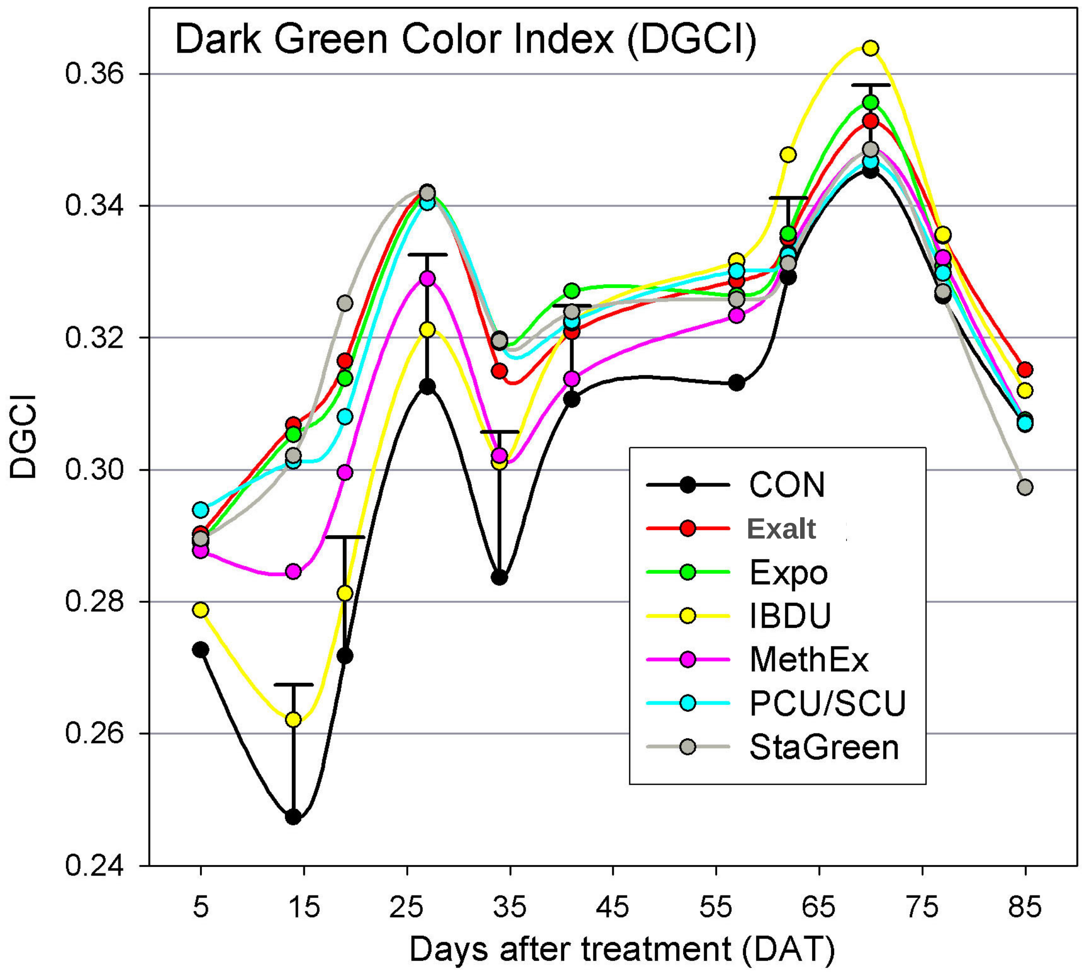


Figure 7. Dark green color index (DGCI) by fertilizer and day after treatment (DAT). Error bars on control (0 lbs N) symbols represent a range of DGCI response NOT significantly different from the control DGCI response, for any DAT (alpha level = 0.05). No fertilizer treatment DGCI significantly differed from the control at 5, 57, 77 or 85 DAT.

<u>Dark Green Color Index (DGCI):</u>
While 13 digital image collections were made over the 12 week study, statistical analysis of DGCI data showed no significant experiment-wide differences between treatments. Daily significant differences in dark green leaf coloration from 5 to 62 DAT are summarized briefly:

- 14 DAT; Exalt, Expo, PCU/SCU, and StaGreen showed significantly better DGCI than IBDU and MethEx.
- 19 DAT; Exalt and StaGreen showed significantly better DGCI than IBDU, MethEx, and PCU/SCU.
- 27 DAT; Exalt, Expo, PCU/SCU, and StaGreen had significantly better DGCI than IBDU.
- 27 DAT; Only PCU/SCU and StaGreen had significantly better DGCI than MethEx.
- 41 DAT; Exalt, Expo, IBDU, PCU/SCU, and StaGreen all showed significantly better DGCI than the MethEx fertilizer treatment.

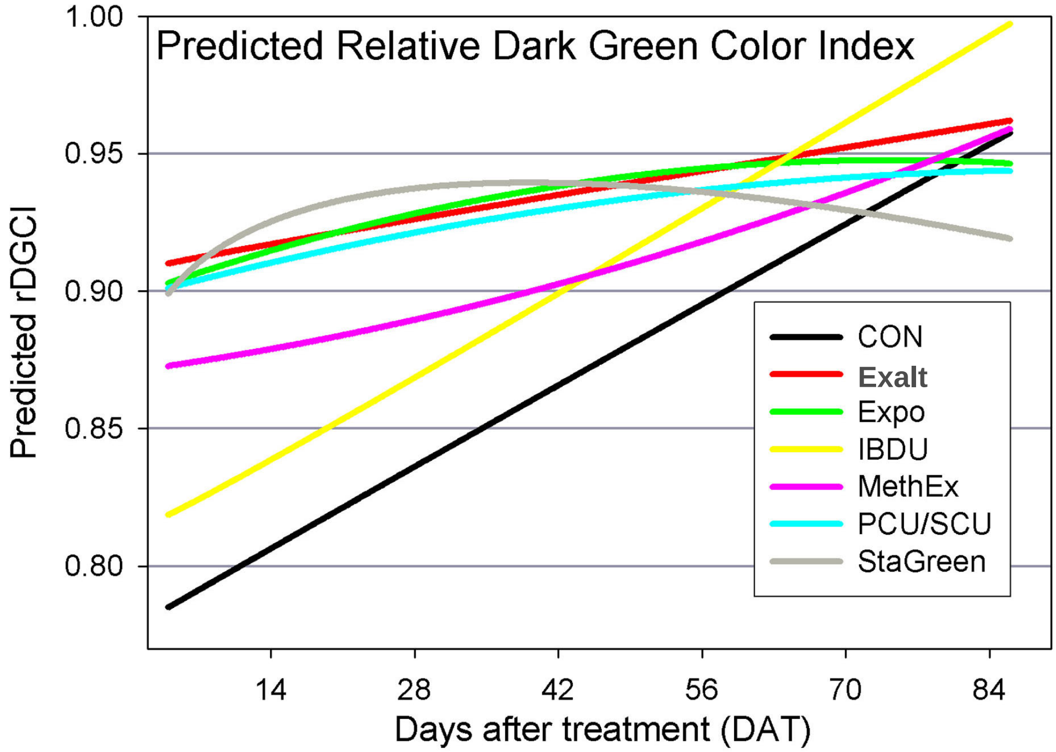
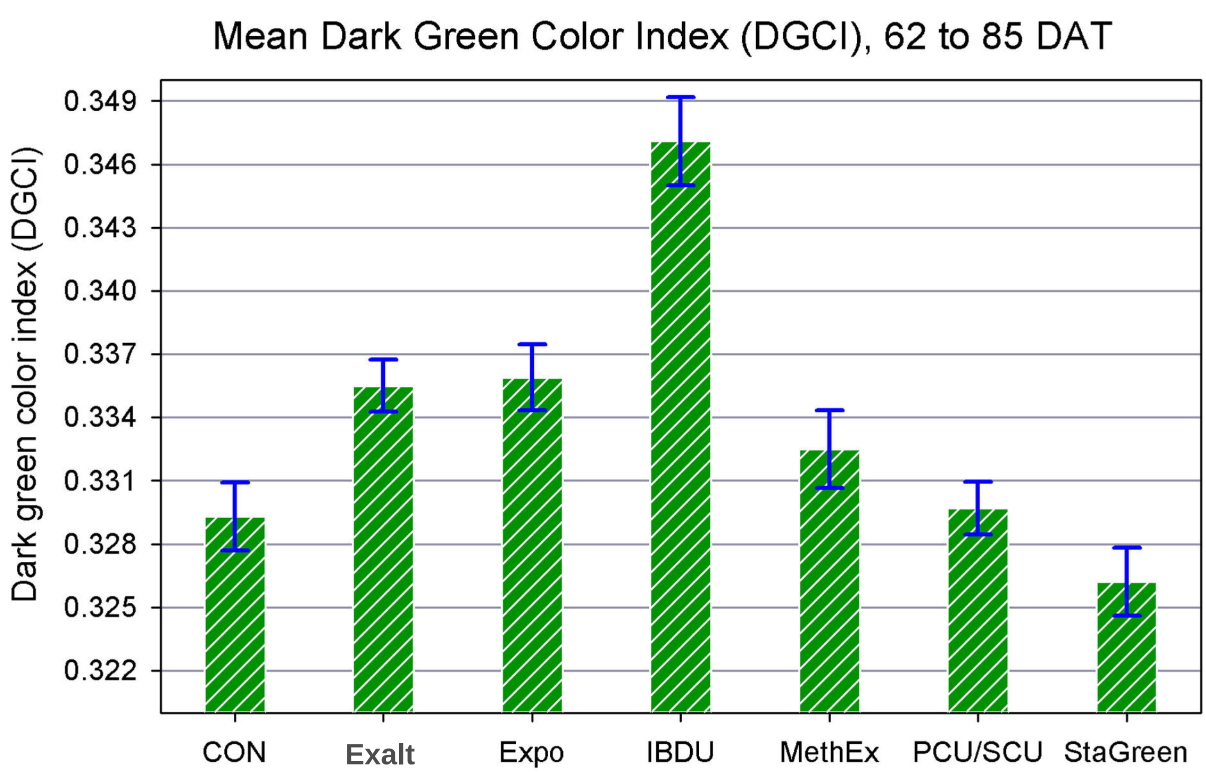


Figure 8. (a; above) Predicted relative dark green color index (rDGCI) by fertilizer and days after treatment (DAT). (b; below) Mean DGCI by fertilizer over the last 3 weeks of the 12 week study (62 to 85 DAT). Error bars represent the statistically significant range of DGCI response for each fertilizer treatment (alpha level = 0.05).



While StaGreen treatment demonstrated significant color improvement over IBDU and MethEx in the 14 to 41 DAT period, the resulting DGCI decreased rapidly over the experimental remainder (Figure 7). Relative DGCI can be a more useful tool for comparing fertilizer treatments over time. The data in Figure 8a shows predictive rDGCI (relative to all fertilizers, for 5-85 DAT) over the experiment period. All fertilizers but PCU/SCU and IBDU show a rapid response to the fertilizer application (5 DAT). However, StaGreen shows a maximum rDGCI near 40 DAT, followed by an exponential decrease in rDGCI. From this data it can be inferred that N availability in the plots treated by StaGreen has significantly decreased compared to all other fertilizer treatments. Expo and PCU/SCU treatments show an asymptotic increase in the second half, with predicted rDGCI falling below the control plots only in the last week of the 85-day trial. Exalt, IBDU, and MethEx were the only fertilizer treatments that demonstrated continual relative DGCI improvement, fostering darker green color than the control plots over the entire trial (Figure 8a).

Statistical evaluation of fertilizer treatment effects on DGCI across all dates can sometimes obscure significant differences that would be apparent over pooled dates. Data in Figure 7 show few significant differences between fertilizer treatments 62, 70, 77, or 85 DAT. However, Figure 8b shows DGCI levels of fertilizer treatments pooled across the last 4 dates (final 3 weeks). The data from this period show DGCI of MethEx, PCU/SCU, and StaGreen treatments to be statistically equivalent to plots receiving no fertilizer treatment at all (control). In this same period, DGCI levels in IBDU treated plots were significantly greater than the control plots as well as all other fertilizer treatments (Figure 8b). Likewise, DGCI of Exalt and Expo treatments were significantly darker in green color than all fertilized and control plots, except IBDU and MethEx (Figure 8b).

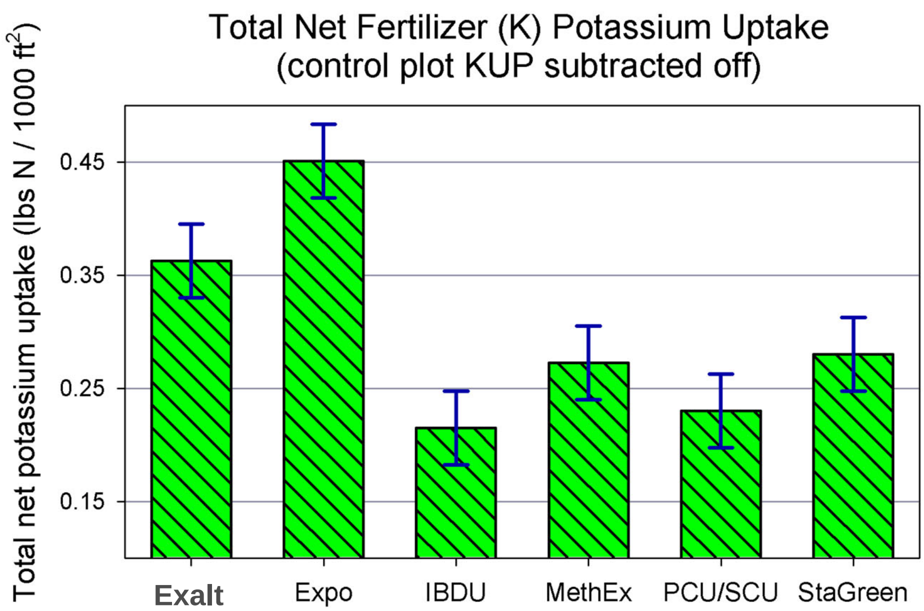
<u>Nutrient Concentration and Uptake:</u>

General nutritional status of Kentucky bluegrass was maximized in the initial weeks of the study (data not shown). Tissue N, P, Ca, S, Fe, Mn, and Zn levels decreased over the course of the study for all fertilizer treatments. From 69 to 85 DAT, leaf N levels rapidly decreased from a range of 3.6–4.0 % tissue N to levels generally considered inadequate for optimal bluegrass performance (3.1–3.3 % tissue N). Most micronutrient tissue levels were also comparatively depleted, with iron deficiencies pending.

Leaf potassium (K), the essential nutrient accumulation second only to nitrogen in necessary turfgrass tissue abundance, has been highly correlated to NUP by turfgrass researchers in recent period. Leaf K increased in Kentucky bluegrass with time only in plots fertilized with IBDU, MethEx, or PCU/SCU. Regardless, leaf K levels remained above 2.4 % in all fertilized plots over the course of the study. Leaf K levels in plots fertilized with Expo were significantly greater than all fertilizers except Exalt (16 DAT), and IBDU (73 DAT). At 16 DAT, leaf K levels in Exalt treated plots were significantly greater than all other plots except Expo and StaGreen.

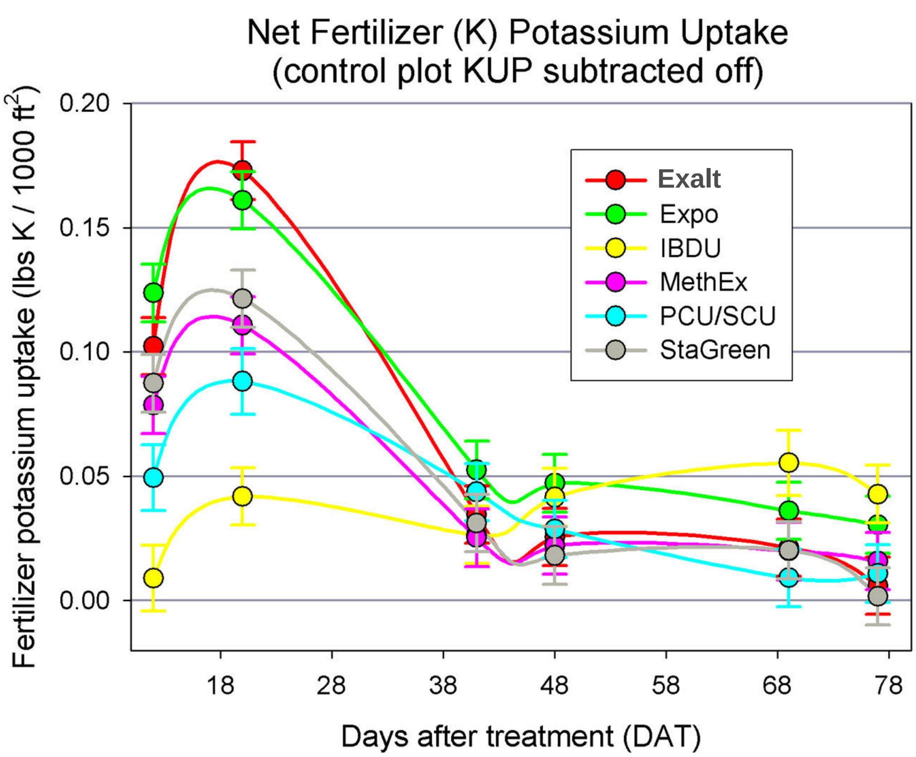
Of greater application than evaluation of tissue K levels by time, is evaluation of total K uptake (KUP) over the experimental period (Figure 9). Potassium sufficiency is an integral component of stress resistant turfgrass, and K_2O application equivalent to N rate (e.g. 5-1-5 analysis ratio) is a recommended practice for maximizing K availability in low organic matter mineral soils and/or low CEC, porous, sand rootzones.

Figure 9. Total (experiment-wide) net potassium uptake (net KUP) by fertilizer treatment. Error bars represent the statistically significant range of KUP response for each fertilizer treatment (alpha level = 0.05).



Data shown in Figure 9 above illustrate significant enhancement of KUP with treatment by fertilizers containing K_2O (Exalt and Expo). A more specific examination of KUP by DAT is presented in Figure 10 (below), and shows the majority of the experiment-wide differences in KUP were gained by Expo and Exalt in the first 3 weeks of the study (Figures 9 and 10). Because K plays an osmoregulative role in turfgrass leaf tissue, it is not found in the more recalcitrant components of leaf clippings. This is significant because the elevated KUP in the early season resulting from the Exalt and Expo fertilizer treatments would be liberated from returned leaf clippings, and cycle in the upper soil profile over the course of the season. However, this nutrient-cycling benefit was not observed in our experimentation, as all leaf clippings were collected and disposed off site.

Figure 10. Net potassium uptake (KUP) by fertilizer and days after treatment (DAT). Error bars represent the statistically significant range of KUP response for each fertilizer treatment (alpha level = 0.05), at any given collection date.



Summary of Kentucky Bluegrass Field Study:

Recent research has shown frequent, yet light application of plant-available nitrogen to optimize turfgrass growth/recuperation, stress resistance, and overall plant health; when compared to turfgrasses receiving equal N rates in greater doses on a less frequent basis (Bowman, 2003). Turfgrasses that cycle through alternate periods of nitrogen feast or famine demonstrate short periods of unabated shoot growth, followed by subsequent chlorosis and stunting. In conjunction with proper turfgrass culture, consistent maintenance of N sufficiency in Kentucky bluegrass (3.6-4.6 % leaf N) is likely to facilitate maximum carbohydrate reserves, root-to-shoot ratios, leaf chlorophyll concentrations, and photosynthetic efficiencies.

There are at least two ways to achieve this objective: One is to fertilize turfgrass with available N forms every 3 to 4 days, while the second is to apply a proven slow-release fertilizer product on a pre-determined interval that reliably releases plant-available N forms as they are needed. In management of a showcase home or commercial lawn system, the second is the more cost-effective option. The reported data show variously-formulated fertilizers demonstrate various N release patterns, but one thing that can be agreed upon is the fertilizer treatment that maximizes color and supports moderate growth, consistently over a 3-month period, is the best fertilizer for periodic application to showcase home or commercial lawn systems.

The fertilizers that performed best in this study did not show signs of rapid, intense N release; often indicated by unsustainable, short-term, nitrogen-stimulated shoot growth. The more-effective fertilizer treatments showed total net NUP levels in excess of 0.6 lbs N / 1000 ft^2, yet also resulted in 48-85 DAT NUP levels exceeding 15 % of the total measured net NUP. Moreover, the fertilizer treatments that resulted in elevated RCY and DGCI values in the last month of this study indicate a reliable slow-release formulation compared to those which did not.

These things considered, Expo and Exalt are identified as the primary outperforming fertilizers evaluated. These two fertilizers fostered significantly greater Kentucky bluegrass lawn quality than common alternatives in the 12-weeks following application. Plots treated with StaGreen did show excellent color response in the first month, yet subsequent decreases in growth and color response indicated an abrupt depletion of N supply. While MethEx and IBDU demonstrated consistent growth and NUP across the study duration, the canopy color of the bluegrass treated with these fertilizers fell below acceptable levels in the first 6 weeks of the study.

The top performer of the trial, residing within the top statistical grouping for experiment-wide RCY, NUP, KUP, DGCI (all dates, yet most importantly 62-85 DAT), and having released 40 % of fertilizer WIN between 48 and 85 DAT, was the Expo (20-0-25) granular fertilizer (LebanonTurf Products, Lebanon Seaboard Corp.).

References:

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