Title: Evaluating GreenActivator on putting green performance

Protocol: Field Study

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Objective:

Compare GreenActivator as a fertilizer to other commercially available fertilizers for putting green (turfgrass) health and performance in Florida, Iowa, Texas, and Virginia.

Methods & Materials:

Treatments were applied to an established putting green (creeping bentgrass in Virginia and Iowa and bermudagrass in Texas and Florida) in summer/fall 2023. Treatments were arranged in a randomized complete block design on 5' by 10' plots with 4 replications. Applications were applied every 14 days at a standard nitrogen rate (0.1 lbs. N/1000 ft^2 or based on the GreenActivator label). Turfgrass was maintained at putting green height and all normal agronomic practices were followed. Treatments included:

1. **GreenActivator (Label rate)**
2. **GreenActivator (2x label rate)**
3. **Industry Standard (Garys Green at 0.1 lbs. N/1000 ft^2)**
4. **Urea (at 0.1 lbs. N/1000 ft^2)**
5. **Industry Standard 2 (Foliar Pak at 0.1 lbs. N/1000 ft^2) – Only done in Iowa.**
6. **Untreated (non-fertilized control)**

Data Collection:

1. Bi-weekly pictures for cover – this allowed for tracking changes in growth over time (early-June-mid-Sept. or based on start date at various locations) pictures were weekly in IA and FL. Picture data is still being processed from VA.
2. Clippings (yield) were collected bi-weekly in June, July, and August to see if growth changes existed (data were taken as dry weight in grams at FL, IA, and TX, and as L of clippings per m^2 in VA).
3. Green speed was taken bi-weekly to judge the speed of greens (an indicator of playing surface quality).
4. NDVI ratings were taken bi-weekly to judge turfgrass health.
5. Green Firmness was also taken bi-weekly with the TruFrim (surface hardness device, excessive growth will be puffy and lower firmness).

Deliverables:

Executive report at the end of the study with data analysis. Additionally, we have a goal of producing research that is worthy of publication in a peer-reviewed journal.

Results:

Table 1. Analysis of Variance (ANOVA) for various fertilizers applied to golf course putting greens in FL, IA, TX and VA in summer/fall of 2023.

Source	NDVI	Firmness	Green Speed	Clipping Yield	Percent Green Cover
Location	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rep(Location)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Treatment	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Location*Treatment	<0.0001	0.0015	<0.0001	<0.0001	<0.0001
Rep*Treatment(Location)	<0.0001	<0.0001	<0.0001	NS	NS
Date	<0.0001	<0.0001	<0.0001	NS	<0.0001
Location*Date	<0.0001	<0.0001	<0.0001	NS	<0.0001
Treatment*Date	NS	NS	NS	NS	NS
Location*Treatment*Date	NS	NS	NS	NS	NS

All data (NDVI or plant health, putting green firmness, green speed, clipping yield, and percent green cover from digital image analysis) were analyzed in SAS for analysis of variance at the 0.05 level of significance for statistical differences. Means were separated with Fishers Least Significant Difference method. NS = not statistically different. There were differences for all variables between rating dates and locations, but that is expected as weather can change the stress on a plant and this data does not reflect how the treatments were actually doing. For clipping yield, only IA, FL, and TX were tested together as VA used a different measurement technique. There were treatment differences for every variable tested as well as location by treatment differences and those differences will be presented and discussed.

Table 2. Plant health (NDVI), putting green firmness (Firmness), green speed, clipping yield (in grams or L/m^2), and percent green cover for putting greens with various fertilizers applied to them in IA, FL, TX and VA in summer/fall 2023.

Treatment	NDVI (0-1)	Firmness (mm)	Green Speed (ft)	Clipping Yield	Percent Green Cover (%)
GreenActivator at label rate	0.711a	156c	8.7b	4.4a	91.0b
GreenActivator at 2x label	0.709a	157c	8.5b	3.8b	91.4b
Urea (0.1 lbs. N/1000 ft^2)	0.718a	166b	8.6b	4.5a	92.2b
Foliar Pak (0.1 lbs. N/1000 ft^2)	0.693b	201a	8.3b	3.6b	95.0a
Garys Green (0.1 lbs. N/1000 ft^2)	0.716a	162bc	8.7b	4.5a	90.9b
Unfertilized Control	0.717a	77d	9.5a	3.8b	93.7ab
LSD (0.05)	0.009	6.7	0.5	0.5	1.4

Means with the same letter after them in a column are not different from each other.

NDVI- Is a measurement in which plant health is often scored on a 0-1 scale with a higher number being a healthier plant, it is based off the green color of the plant. There were no differences in all of the products tested for plant health in TX, FL, and VA, while in IA the addition of the Foliar Pak (0.693) resulted in a lower plant heath than GreenActivator (0.711), GreenActivator 2x (0.709), Urea (0.718), Garys Green (0.716) and the unfertilized control (0.717). All of these values in are in the upper end of the scale suggesting that plant health was good at every location in the experiment and that none of the products had a detrimental harm on the plants health.

Firmness or Putting Green Firmness- The TruFirm is a device used to measure how far a plunger depresses a surface indicating a thatch issue. The greater the number the larger the impact and softer the surface. The Foliar Pak (201) had the greatest impact into the surface, which was greater than all other treatments tested in IA. The unfertilized control (77) had the firmest surface compared to all other treatments at every location. GreenActivator (156) and GreenActivator 2x (157) had similar firmness values which were more than the unfertilized control but less than urea (166). While Garys Green (162) had a similar firmness to both rates of GreenActivator and urea. It was not surprising that the control was the firmest surface as it will often have little to no growth making it a firm surface. The other treatments were very similar in range and were not surprising as the addition of any nutrients will cause some growth which will cause the firmness values to decrease some with additional growth even with the daily mowing.

Green Speed- Green speed is a common measure of how far a golf ball will roll across a putting green surface. The larger the number the faster the surface. The highest green speed was the unfertilized control (9.5), which was greater than GreenActivator (8.7), GreenActivator 2x (8.5), urea (8.6), Foliar Pak (8.3), and Garys Green (8.7). There were no differences in green speed for any of the fertilizer treatments in this study. Much like firmness, the addition of nutrients will cause some growth of the plant and slow the speed of the green compared to a surface that is not growing.

Clipping Yield- The weight of clippings can give an indication of how much growth will occur from a given product. Excessive growth will result in thatch content and scalping on the putting greens. Garys Greens (4.5), urea (4.5), and GreenActivator (4.4) had the greatest clipping yield during the study with GreenActivator 2x (3.8) and unfertilized control (3.8) having fewer clippings collected. In Iowa, Foliar Pak (3.6) was less than Grays Green, GreenActivator, and urea but not GreenActivator 2x and the unfertilized control. The lower amount of clippings from the GreenActivator 2x rate could be due to a plant growth regulating response, which has been seen in some humic containing products.

Percent Green Cover- Digital images were scanned for green pixels and then divided by the total pixels for a percent green cover value. A loss of green cover would indicate a decrease in plant cover and poor performing green. There were no differences in the percentage green cover for all locations except Iowa. In Iowa, Foliar Pak (95%) had greater green cover than all treatments except the unfertilized control (93.7%). The above 90% average of percent green cover indicated that enough green cover remained for all treatments during this experiment and no detrimental effects were present.

Table 3. Plant health (NDVI), putting green firmness (Firmness), green speed, clipping yield (in grams or L/m2), and percent green cover for putting greens with various fertilizers applied to them in IA, FL, TX and VA in summer/fall 2023.

			Iowa		
Treatment	**NDVI (0-1)**	**Firmness (mm)**	**Green Speed (ft)**	**Clipping Yield (g)**	**Percent Green Cover (%)**
GreenActivator at label rate	0.708b	54.8b	9.4c	3.7	99.3
GreenActivator at 2x label	0.712ab	56.5ab	9.4c	3.2	98.9
Urea (0.1 lbs. N/1000 ft2)	0.717a	57.1a	9.5bc	3.8	98.7
Foliar Pak (0.1 lbs. N/1000 ft2)	0.716ab	57.0a	9.6abc	3.3	99.5
Garys Green (0.1 lbs. N/1000 ft2)	0.713ab	55.4ab	9.9a	3.7	99.7
Unfertilized Control	0.709ab	56.1ab	9.8ab	3.6	99.5
LSD (0.05)	0.009	20	0.3	1.0	1.1
			Texas		
Treatment	**NDVI (0-1)**	**Firmness (mm)**	**Green Speed (ft)**	**Clipping Yield (g)**	**Percent Green Cover (%)**
GreenActivator at label rate	0.676	6.4	10.7	5.2	83.3
GreenActivator at 2x label	0.679	6.4	10.8	4.6	82.9
Urea (0.1 lbs. N/1000 ft2)	0.675	6.4	10.9	5.7	82.4
Garys Green (0.1 lbs. N/1000 ft2)	0.686	6.5	10.8	6.1	82.9
Unfertilized Control	0.677	6.2	11.0	4.3	84.0
LSD (0.05)	0.06	.03	0.7	2.1	12.7
			Florida		
Treatment	**NDVI (0-1)**	**Firmness (mm)**	**Green Speed (ft)**	**Clipping Yield (g)**	**Percent Green Cover (%)**
GreenActivator at label rate	0.684	400b	6.7a	5.2	85.9b
GreenActivator at 2x label	0.661	406b	6.3b	4.2	88.0ab
Urea (0.1 lbs. N/1000 ft2)	0.679	425a	6.4ab	4.5	91.4a
Garys Green (0.1 lbs. N/1000 ft2)	0.655	397b	6.4ab	4.4	89.0ab
Unfertilized Control	0.660	404b	6.6ab	3.7	85.3b
LSD (0.05)	0.033	16	0.4	1.6	4.5
			Virginia		
Treatment	**NDVI (0-1)**	**Firmness (mm)**	**Green Speed (ft)**	**Clipping Yield (L/m^2)**	**Percent Green Cover (%)**
GreenActivator at label rate	0.766c	171b	8.0a	40.7c	N/A
GreenActivator at 2x label	0.771bc	169b	7.6ab	44.4bc	N/A
Urea (0.1 lbs. N/1000 ft2)	0.786ab	187a	7.5ab	54.5ab	N/A
Garys Green (0.1 lbs. N/1000 ft2)	0.791a	194a	7.3b	58.5a	N/A
Unfertilized Control	0.760c	164b	7.8ab	41.5bc	N/A
LSD (0.05)	0.016	11.9	0.5	13.1	N/A

Due to the significant interaction of location and treatment, each location is presented with means for those treatments at that location in Table 3. Different letters after a value indicate differences between treatments for that column.

Iowa:

NDVI- Differences in plant health existed in Iowa between treatments. Urea (0.717) had a higher NDVI value than GreenActivator (0.708). While there were no differences between any other products tested for NDVI.

Firmness- The firmest surface was GreenActivator (54.8 mm) which was less than Foliar Pak (57.0 mm) and urea (57.1 mm). All other treatments were similar in firmness.

Green Speed- The greatest green speed was Garys Green (9.9 ft), which was greater than GreenActivator (9.4 ft), GreenActivator 2x (9.4 ft) and urea (9.5 ft). The unfertilized control (9.8 ft) was not different from Garys Green, urea, and Foliar Pak (9.6 ft), but was greater than both rates of GreenActivator. GreenActivator and GreenActivator 2x had similar green speeds to urea and Foliar Pak.

Clipping Yield- There were no differences between treatments for clipping yield in Iowa with a range of 3.2 g of clippings up to 3.8 clippings. It is interesting to note that GreenActivator 2x (3.2 g) had the lowest amount of clippings in that range.

Percent Green Cover- There were no differences between treatments for percent green cover with a range of 98.7 to 99.7% green cover.

Texas:

NDVI- There were no differences between treatments for plant health in Texas with a range of 0.675 to 0.686.

Firmness- There were no differences in firmness between treatments in Texas with a range of 6.2 up to 6.5 mm for TruFirm values.

Green Speed- There were no differences between treatments for green speeds in Texas with a range of 11.0 to 10.7 ft.

Clipping Yield- There were no differences in clipping yield between treatments in Texas with a range of 4.3 up to 6.1 grams.

Percent Green Cover- There were no differences between treatments for percent green cover with a range of 84.0 to 82.4% green cover.

Florida:

NDVI- There were no differences in NDVI values between treatments in Florida with a range of values from 0.655 to 0.684.

Firmness- Urea (425) had a softer surface than GreenActivator (400), GreenActivator 2x (406), Garys Green (397) and the unfertilized control (404) which were all similar in value.

Green Speed- The greatest green speeds were on GreenActivator (6.7 ft) which was greater than GreenActivator 2x (6.3 ft). There were no differences between urea (6.4 ft), Garys Green (6.4 ft), and the unfertilized control (6.6 ft).

Clipping Yield- There were no differences between treatments for clipping yield in Florida with a range of 5.2 to 3.7 grams of clippings.

Percent Green Cover- Percent green cover differed between treatments with urea (91.4%) having greater precent green cover than GreenActivator (85.9%) and the unfertilized control (85.3%). There were no differences in percent green cover for GreenActivator 2x (88.0%) and Garys Green (89%).

Virginia:

NDVI- Garys Green (0.791) had a greater NDVI than GreenActivator 2x (0.771), GreenActivator (0.766), and the unfertilized control (0.760) but not urea (0.786). Urea had a higher NDVI value than GreenActivator and the unfertilized control. There were no differences between GreenActivator 2x and urea, GreenActivator, and the unfertilized control.

Firmness- GreenActivator (171) and GreenActivator 2x (169), and the unfertilized control (164) had a greater surface firmness than urea (187) and Garys Green (194).

Green Speed- GreenActivator (8.0 ft) had a greater green speed than Garys Green (7.3 ft). While GreenActivator 2x (7.6 ft), urea (7.5 ft), and the unfertilized control (7.8 ft) did not differ with any treatment tested.

Clipping Yield- Garys Green (58.5 L/m^2) offered greater clipping yield than GreenActivator (40.7 L/m^2), GreenActivator 2x (44.4 L/m^2), and the unfertilized control (41.5 L/m^2). While there were no differences between urea (54.5 L/m^2) and Garys Green. Urea, GreenActivator 2x and the unfertilized control also did not differ. Whereas GreenActivator was less than urea.

Percent Green Cover- Percent green cover data will be added once the data is available to be analyzed.

Overall Conclusions:

This study was conducted across two very different turfgrass species as well as in four unique climates. The lack of differences for many of the variables indicates that GreenActivator will perform like the current industry standard fertilizers in those climates as well as urea. When differences did exist, GreenActivator at the label rate was often in the better statistical grouping for that variable, while GreenActivator 2x was often in the similar grouping as well indicating that doubling the rate does not help with growth. Although there was an indication that the 2x rate may increase green cover in Florida. Additional research should investigate if there are differences in field tested soil organic matter with the use of these treatments. Another research aspect should also investigate how mixing with a low rate of urea could affect the performance of the treatments in the field studies.

Additional Ames, IA location fall images:

At the ISU Turf Field Day, it was discussed to continue the digital images and treatments of the plots on monthly fertilizer applications through the end of the growing season. The plots were aerated and topdressed on October 2, 2023, hence the drop in color and cover around that date.

Table 4. Creeping bentgrass percent green cover with various fertilizers applied in the fall of 2023 in Ames, IA.

Treatment	20-Sep	27-Sep	4-Oct	11-Oct	18-Oct	24-Oct	1-Nov	Mean
GreenActivator at label rate	99.9	99.9	25.5	28.3	93.1	63.8b	59.5c	67b
GreenActivator at 2x label	100	99.9	23.9	25.1	94.3	64.5b	60.8bc	67b
Urea (0.1 lbs. N/1000 ft^2)	100	99.9	27.6	32.1	95	76.9a	72.9ab	72a
Foliar Pak (0.1 lbs. N/1000 ft^2)	100	99.9	23.3	29.7	95.1	71.7ab	74.7a	71ab
Garys Green at 0.1 lbs. N/1000 ft^2)	100	99.8	27.8	25.9	94.3	70.4ab	64.1abc	69ab
Unfertilized Control	100	99.9	22.4	23.6	93.2	63.3b	62.4abc	66b
LSD (0.05)	NS	NS	NS	NS	NS	9.7	13.3	4.6

Percent green cover differed by rating date for treatment on two rating dates for the average percent green cover (mean) during the fall. On October 24th, urea (76.9%) had greater percent green cover than GreenActivator (63.8%) and GreenActivator 2x (64.5%) as well as the unfertilized control (63.3%). There were no differences between Foliar Pak (71.7%) or Garys Green (70.4%) and any treatments. On the final rating date, Foliar Pak (74.7%) had greater precent green cover than GreenActivator (59.5%) and GreenActivator 2x (60.8%). Garys Green (64.1%) and the unfertilized control (62.4%) did not differ in cover with any treatment. Neither rate of GreenActivator were different from each other. The mean percent green cover differed with urea (72%) having greater cover than GreenActivator (67%) GreenActivator 2x (67%) and the unfertilized control (66%), while Garys Green (69%) and Foliar Pak (71%) were not different from each other. Differences in percent green cover could have been due to differing amounts of nitrogen present in the treatments. The GreenActivator plots had lower rates of nitrogen which slowed the recovery from aeration and topdressing more than a higher rate of nitrogen would have such as those in urea, Foliar Pak and Garys Green. It should be noted that in the future additional nitrogen is needed for recovery from topdressing.

Table 5. Creeping bentgrass color with various fertilizers applied in the fall 2023 in Ames, IA.

Treatment	20-Sep	27-Sep	4-Oct	11-Oct	18-Oct	24-Oct	1-Nov	Mean
GreenActivator at label rate	9	8.9	2.3	3.3	7.3	3.2b	5.8c	5.7b
GreenActivator at 2x label	9	8.8	2.1	2.8	7.9	3.4b	5.9bc	5.7b
Urea (0.1 lbs. N/1000 ft2)	9	8.8	2.7	3.9	8.2	5.7a	7ab	6.5a
Foliar Pak (0.1 lbs. N/1000 ft^2)	9	8.8	2	3.5	8.2	4.7ab	7.2a	6.2ab
Garys Green at 0.1 lbs. N/1000 ft^2)	9	8.6	2.7	2.9	7.8	4.5ab	6.2abc	6.0ab
Unfertilized Control	9	8.7	1.8	2.6	7.3	3.1b	6.1abc	5.5b
LSD (0.05)	NS	NS	NS	NS	NS	1.8	1.2	0.7

Like percent green cover, there were two rating dates and the mean turfgrass color that differed in the fall. October 24th, urea (5.7) had greater turfgrass color than GreenActivator (3.2), GreenActivator 2x (3.4), and the unfertilized control (3.1). Garys Green (4.5) and Foliar Pak (4.7) did not differ from any treatment on this rating date. On the final rating date, Foliar Pak (7.2) had a higher turfgrass color than GreenActivator (5.8) and GreenActivator 2x (5.9), while Garys Green (6.2) and the unfertilized control (6.1) did not differ from any treatment. The mean turfgrass color also differed with urea (6.5) having greater turfgrass color than GreenActivator (5.7), GreenActivator 2x (5.7) and the unfertilized control (5.5). Garys Green (6.0) and Foliar Pak (6.2) did not differ from any other treatment. This indicates that GreenActivator will perform as well as other industry standard fertilizers as they did not differ for the mean of the fall values.