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This field study examined the impact of six products that contained cytokinians and other plant extracts, N or Fe and/or various combinations thereof for their impact on creeping bentgrass putting green color and summer quality. These products were compared to urea (N) and evaluated in Lemont, IL and College Park, MD in 2007 and 2008.

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## PURPOSE

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# Evaluation of Cytokinian Plant Extract Biostimulants, Iron, and Nitrogen Products for Their Effects on Creeping Bentgrass Summer Quality

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## SUMMARY

The summer quality of creeping bentgrass research greens in Lemont, IL and College Park, MD was monitored in response to six liquid fertilizer and biostimulant products, and urea. The treatments included IronRoots, Roots Concentrate, Knife, PanaSea Plus, Lesco's 12-0-0 Chelated Iron Plus Micronutrients (hereafter Lesco 12-0-0), Ultraplex, urea, IronRoots + urea, Roots Concentrate + urea, and PanaSea Plus + urea.

- Early in the season in MD, Ultraplex, IronRoots, Knife, Lesco 12-0-0 and treatments containing urea improved turf color and quality compared to the control and often provided for enhancement of color and quality to a high level. In IL, the effects began in July and both Ultraplex and Lesco 12-0-0 consistently improved turf quality and color compared to the control, whereas Knife did not.
- When data were averaged over the season in both IL and MD, urea alone and treatments containing urea generally provided for best summer quality. There were, however, no significant differences among urea alone, IronRoots + urea, Roots Concentrate + urea, or PanaSea Plus + urea at either site.
- Treatments containing urea were judged to have provided acceptable quality on every rating date in IL, but not in MD where scalp injury occurred in August 2008.
- When data were averaged over the 2008 season, Lesco 12-0-0 and Ultraplex provided an acceptable level of quality in both IL and MD, whereas, PanaSea Plus, IronRoots, Roots Concentrate and Knife did not improve quality compared to the control.
- Urea alone and treatments containing urea helped to mitigate injury from scalping leading to improved turf quality in August in MD.
- IronRoots generally provided better color than Roots Concentrate, but the iron in the former product did not darken turf as much as the other iron products.
- Any potential visual benefits from cytokinian-plant extract products (i.e., biostimulants) were masked by the presence of iron or nitrogen in Knife and IronRoots or by the nitrogen in urea when tank-mixed with Roots Concentrate or PanaSea Plus.
- PanaSea Plus and Roots Concentrate, which do not contain iron or nitrogen, had only a small impact on turf color and quality, and did not improve quality above the minimum acceptable level in most of July and August in MD, or most of August and September in IL.
- Iron darkens foliage within an hour after application. Darkening of foliage can take the form of a blackish, grayish, or purplish-gray color, which can be objectionable from a distance.
- When viewing iron-treated turf closely, however, iron improved color and quality. In the presence of scalping, iron intensified the visual appearance of injury in MD by darkening foliage and creating a sharp, reddish-colored contrast.
- NDVI (Normalized Difference Vegetative Index) color ratings were consistently highest in plots treated with urea, IronRoots + urea, Roots Concentrate + urea, and PanaSea Plus + urea in IL (2007 and 2008) and MD (2008). There were, however, no significant NDVI rating differences among treatments containing urea.
- Iron had little or no effect on color as measured by NDVI in IL or MD when data were averaged over the season. On selected dates, however, plots treated with Ultraplex and Lesco 12-0-0 (both contain iron and nitrogen) had higher NDVI readings versus the control at both sites.
- Chelated iron darkens the cuticle/mesophyll, but does not enhance green color. The mechanism by which chelated iron darkens leaves is unknown.


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Golf course superintendents often limit nitrogen fertility on greens for the purpose of improving green speed. To maintain acceptable turf color and plant health under conditions of limited nitrogen input, superintendents often apply liquid biostimulants during the summer. Numerous companies market products containing cytokinians and other plant extracts in liquid forms for use on golf greens.

Cytokinians are considered biostimulants, which have been shown to improve shoot and root health of creeping bentgrass in controlled environment studies (2, 3, 5). Biostimulant is a broad term and refers to products that may contain one or more purported active ingredients. Ingredients can include cytokinians, humates, nutrients, organic acids, hormones, vitamins, microbial inoculants, plant extracts, and others. Often biostimulant products contain either iron (Fe), nitrogen (N), or both.

Manufacturer labels state that these products improve turf color, root growth, plant development, and environmental stress tolerance. Generally, the plant extract components of these products, as well as the amounts of Fe, N and other nutrients or biostimulants, are not specifically stated. While N and Fe are known to improve turf color and quality, it remains unclear if products containing cytokinians and/or other biostimulants provide any additional benefits in the field (4). Marine algae represent the primary source of phytohormones used in products marketed for golf green use. When analyzed, low levels of plant nutrients occur in seaweed or kelp (*Ascophyllum nodosum*) extracts and may include 1-2% N, 1-2% P, 15-20% K, 1-7% Na, and trace levels Ca, Mg, S, Fe, Cu, Mn, Zn, and B (1).

Chlorophyll levels influence turf color and normalized difference vegetation index (NDVI) readings were obtained as a means of assessing color. The color meter was a Field Scout TCM 500 Color Meter (Spectrum Technologies Inc., Plainfield, IL). Five (MD) or six (IL) measurements were taken using a spaced pattern across each plot throughout the study period.

Superintendents are eager for this kind of side-by-side product evaluation in an effort to obtain performance data that they can use in purchasing decisions.

This field study examined the impact of six products that contained cytokinians and other plant extracts, N or Fe and/or various combinations thereof for their impact on creeping bentgrass putting green color and summer quality. These products were compared to urea (N) and evaluated in Lemont, IL and College Park, MD in 2007 and 2008.

Lessons learned in 2007 resulted in a change in the treatment structure in 2008. A major goal of the effort in 2007 was to determine if the cytokinian plant extract, Fe, and N products would have an impact on dollar spot (*Sclerotinia homoeocarpa*) severity. In 2007 in IL and MD, IronRoots, Knife, Lesco's 12-0-0, PanaSea Plus, Ultraplex, urea and Daconil Ultex were evaluated for their ability to suppress dollar spot. Except for Daconil Ultrex, none of the these products claim disease suppression on their labels.

As expected, plots treated with Daconil Ultrex exhibited the best summer quality in both IL and MD since it effectively controlled the disease. Urea was the next best treatment, but urea-treated plots eventually were severely damaged by

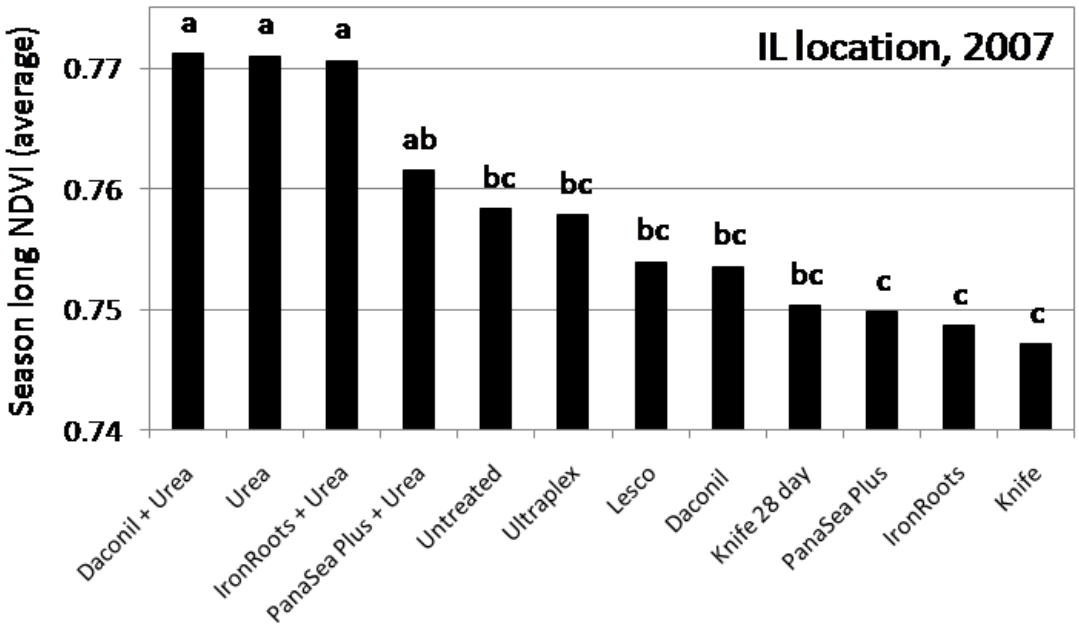



**Figure 1.** Normalized Difference Vegetation Index (NDVI) for all treatments when data were averaged over the 2007 season in IL. Bars with the same letter are not significantly different according to Fisher's protected LSD, $P < 0.05$.

dollar spot. Except as noted below, none of the other treatments reduced dollar spot and plots treated with the biostimulants and liquid fertilzer products were damaged severely, resulting in poor turf quality in both IL and MD.

In MD, however, some slight reduction in dollar spot was observed in plots treated with Knife, but the effect was temporary and did not result in acceptable quality at any time. In MD, where visual color ratings were obtained in 2007, IronRoots, Knife, Lesco's 12-0-0, and Ultraplex consistently improved color. PanaSea Plus sometimes improved color, but ratings always were unacceptable and usually similar to the control.

In IL, color ratings were taken on three dates in 2007. When averaged, Lesco 12-0-0 and Ultraplex improved color in IL and were similar to urea alone, whereas other biostimulants did not, and color was similar to untreated turf. Among urea treatments, IronRoots + urea had a tendency to be best on the dates rated. Weekly color measurements were obtained electronically using a color meter (NDVI, normalized difference vegetative index) in IL. Across the 2007 season, NDVI data indicated that urea and treatments combined with urea had enhanced foliar green color as shown by Figure 1.

The presence of dollar spot in both IL and MD sites in 2007 made it impossible to determine if any of the products had impacted summer quality. The IL NDVI measurements were taken to avoid *S. homoeocarpa* infection centers and showed promise to detect differences as Figure 1 illustrates. In 2008, both IL and MD sites utilized NDVI to supplement visual turf color and quality ratings. Hence, the study was repeated, but dollar spot was controlled across both study sites so that the effect of the aforementioned products on summer quality could be more effectively assessed. To this end, the Daconil Ultrex treatment was eliminated and was replaced with Roots Concentrate alone or mixed with urea in 2008.

## Materials and Methods

The products evaluated are described in Table 1. Since PanaSea Plus, Roots Concentrate, and IronRoots contain no N they were compared with and without N from urea. Therefore, urea was applied alone or tank-mixed with IronRoots, Roots Concentrate, and PanaSea Plus at 0.15 lb N/1000 $ft^2$. All treatments were applied on a 14-day interval, except Knife which was evaluated at two

| Treatment and analysis | Application rate (per 1000 ft$^2$) | Application cost ($/acre) | Manufacturer | Additional Micronutrients or Other Biostimulant(s) |
|---|---|---|---|---|
| Ultraplex 5-0-3 | 6.0 fl oz | $170.00 | Grigg Brothers | 0.05% B, 0.05% Cu, 2.0% Fe, 0.4% Mn, 0.4% Zn |
| IronRoots 0-2-4 | 2.0 fl oz | $79.00 | Novozymes | 4.0% Fe |
| Knife 12-0-0 | 1.5 fl oz | $43.00 | Floratine | 4.0% S, 6.0% Fe, extracts of kelp and terpenoids |
| Knife 12-0-0 (every 28 days) | 2.5 fl oz | $57.00 | Floratine | 4.0% S, 6.0% Fe, extracts of kelp and terpenoids |
| PanaSea Plus 0-2-2 | 3.0 fl oz | $75.75 | Emerald Isle | Unspecified sea plant extracts |
| Urea 46-0-0 | 0.15 lb N | $7.50 | N/A | None |
| LESCO's 12-0-0 | 4.0 fl oz | $29.00 | Lesco | 4.0% S, 6.0% Fe, 2.0% Mn Chelated Iron + Micro |
| Roots Concentrate 0-0-0 | 2.0 fl oz | $43.00 | Novozymes | 4.6% humic acids, 3.9% kelp extract, 3.0% vitamin C, 1.0% amino acids, 0.5% myo-inositol, 0.3% vitamin B1, 0.1% vitamin E |

**Table 1.** Cytokinian plant extract biostimulant, iron and nitrogen products evaluated in IL and MD on creeping bentgrass research greens. Application costs are estimates based on the purchase of small amounts of product, which may vary from year to year in different markets.

rates applied on either a 14-day or 28-day interval as specified on the label. All products were tested at rates and application intervals as specified on product labels. Both study sites were treated with Chipco 26GT, Daconil Ultrex, or Emerald every two weeks during the study period to control dol-

Dr. Mike Kenna, USGA's Director of Research, closely examines the field-plot performance of several cytokinian-plant extract biostimulant, iron, and nitrogen treatments evaluated in this two-state study.

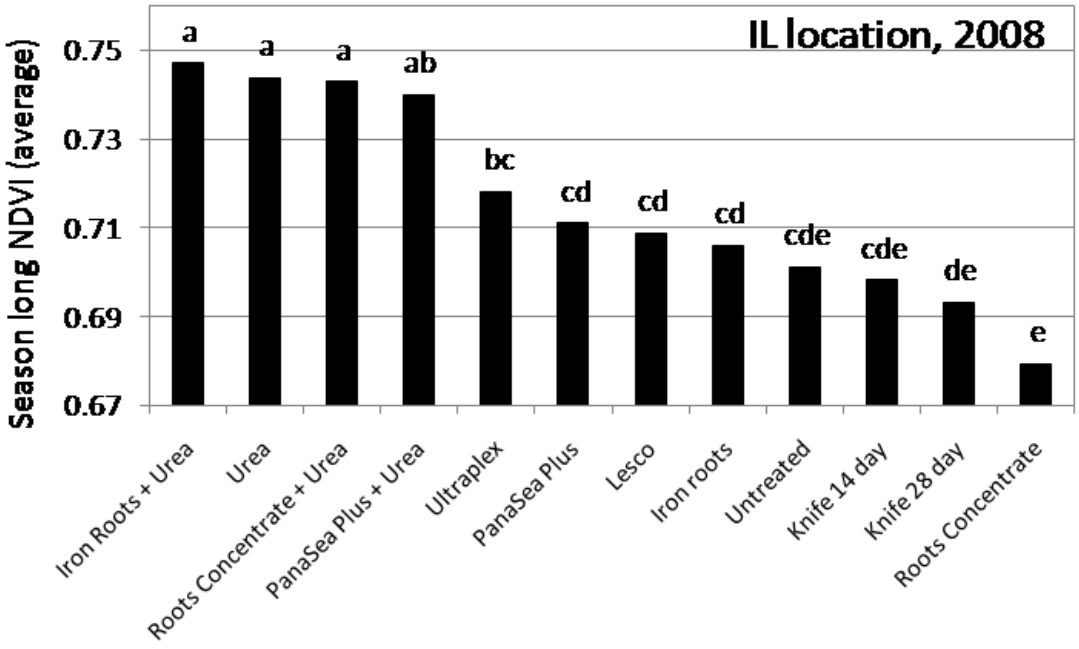



**Figure 2.** Normalized Difference Vegetation Index (NDVI) for all treatments when data were averaged over the 2008 season in IL. Bars with the same letter are not significantly different according to Fisher's protected LSD, P < 0.05.

lar spot and brown patch (*Rhizoctonia solani*).

The studies were conducted on mature stands of either 'G-2' + 'L-93' blend (IL) or 'Providence' (MD) creeping bentgrass grown on a sand-based rootzone constructed to USGA recommendations. The research greens were mowed five to six times weekly to a height of 0.156 inches. The MD site received 1.75 lb N/1000 $ft^2$ between April 19 and May 30, 2008, and an additional 0.25 lb N/1000$ft^2$ was applied on August 6, 2008. The IL site received 0.5 lb N/1000$ft^2$ during May 2008. Otherwise both sites did not

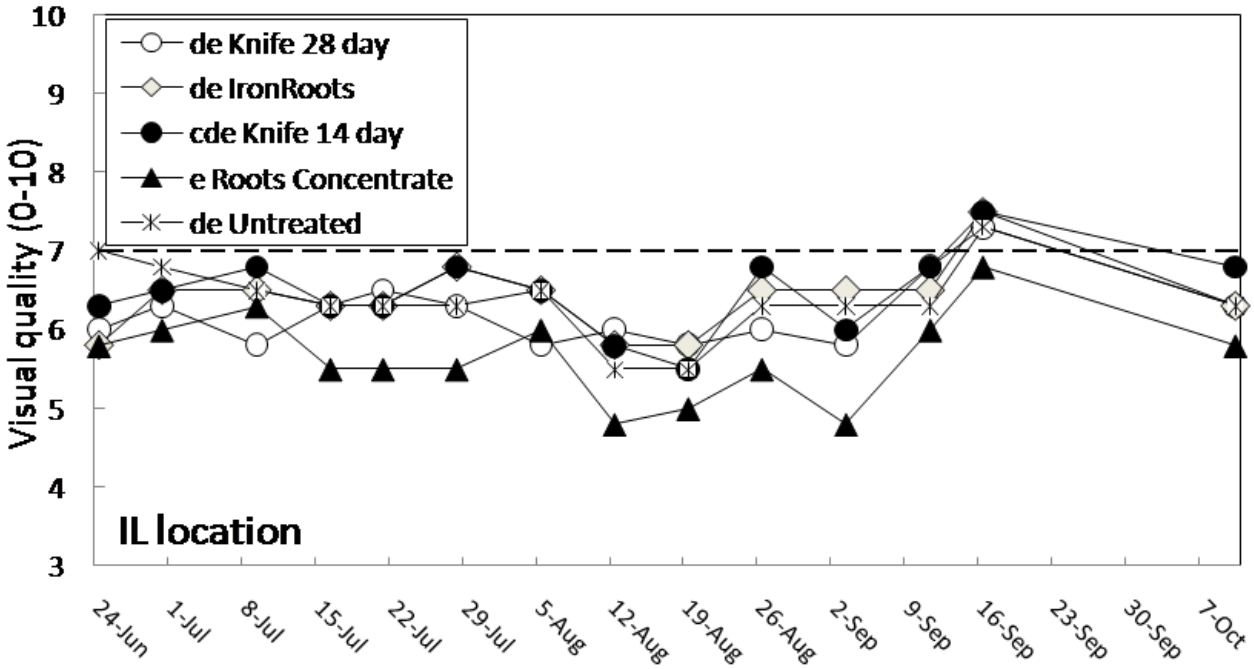



**Figure 3.** Effect of Knife, IronRoots, and Roots Concentrate on summer quality of G-2/L-93 creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

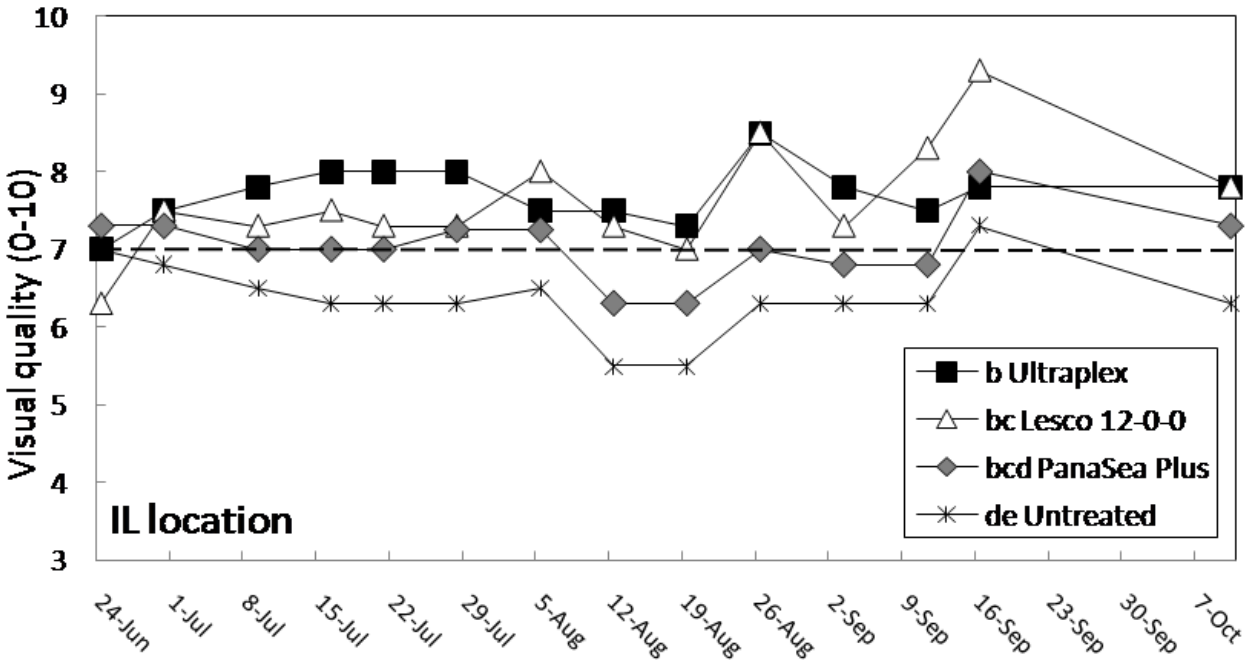



**Figure 4.** Effect of Ultraplex, Lesco 12-0-0, and PanaSea Plus on summer quality of G-2/L-93 creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

receive any supplemental N during the study period. All treatments were applied in 50 (MD) or 87 (IL) gallons per acre of water using a $CO_2$ pressurized (35 psi) backpack sprayer equipped with an 8004 Tee Jet flat-fan nozzle. Plots were 4 ft by 6 ft (IL) or 5 ft by 10 ft (MD) and arranged in a randomized complete block with four replications.

Turfgrass color and quality were assessed visually on a 0 to 10 scale where 0 = entire plot area brown or dead; 7 = minimum acceptable color and quality for a putting green in summer; 8 = very good summer color and quality; and 10 = optimum greenness, texture and uniformity. Chlorophyll levels influence turf color and normalized difference vegetation index (NDVI) readings also were obtained as a means of assessing color. The color meter was a Field Scout TCM 500 Color Meter (Spectrum Technologies Inc., Plainfield, IL).

Five (MD) or six (IL) measurements were taken using a spaced pattern across each plot throughout the study period. Data were downloaded as a notepad document in MD or recorded by hand in IL, and the five/six measurements per plot were averaged prior to statistical analyses. Scalping injury also was evaluated in MD on a 0 to 5 visual scale where 0 = no scalping; 2.5 = objectionable levels of scalping; and 5.0 = severe injury and loss of >20% cover. Data were subjected to the analysis of variance and significantly different means were separated using Fisher's protected least significant difference (LSD) test at P = 0.05.

## Results

### Illinois Site

*Turf Quality*

In 2008, all biostimulant treatments were applied every 14 days and began June 11 with last application done on September 3. Between the period of June 24 and October 10, untreated control plots (hereafter control) exhibited symptoms of nutrient deficiency and often appeared both chlorotic and thin. The control was without acceptable quality on every date rated except June 24. Urea alone, urea mixed with biostimulants, or biostimulants alone were tested for two attributes:

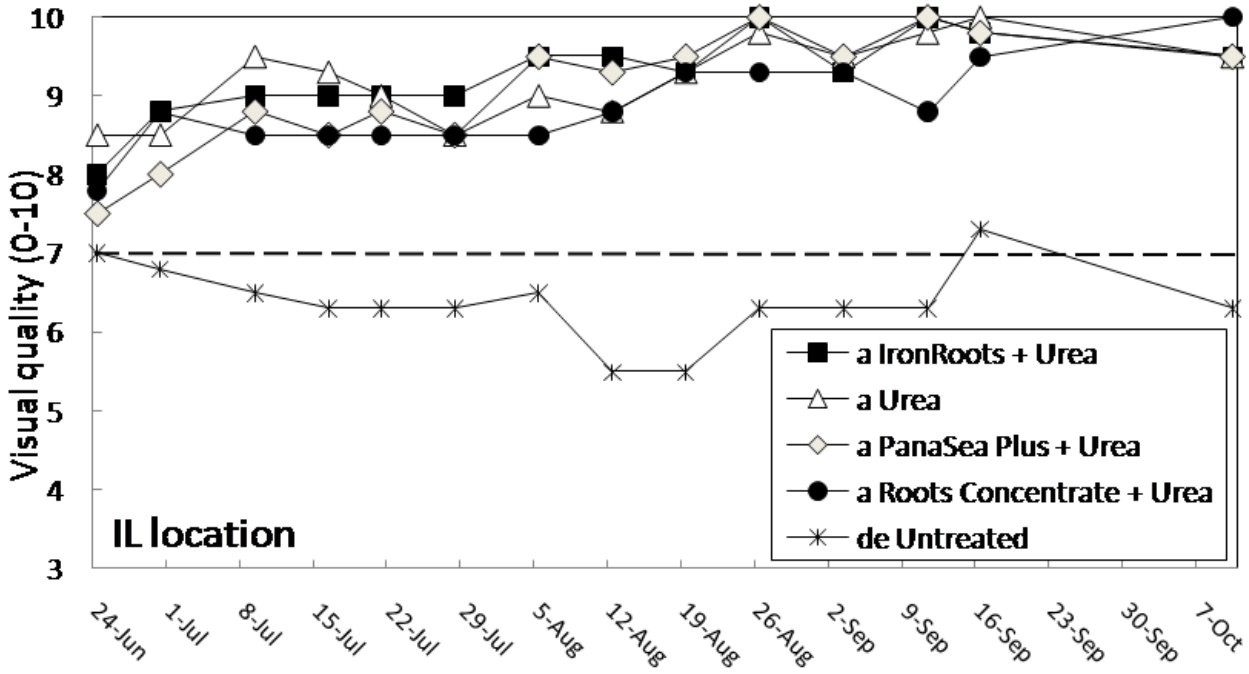



**Figure 5.** Effect of urea treatments on summer quality of G-2/L-93 creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

1) ability improve visual quality and color over the control, and 2) ability to provide acceptable quality necessary for a golf green.

In IL, NDVI was an effective method to evaluate treatment differences by quantifying color and indirectly allowed estimation of leaf chlorophyll content. NDVI in 2007 captured differences otherwise obscured for visual quality that year because dollar spot disease was allowed to develop. NDVI color data was enhanced only by treatments receiving urea compared to the control in both 2007 (Figure 1) and 2008 (Figure 2). In 2008, without interference of foliar disease development, visual quality, NDVI, and visual color data generally agreed and were largely similar in describing effects.

In IL, visual quality at study start was telling of treatment performance the entire season. For example, Knife (both treatments), IronRoots, and Roots Concentrate displayed poor visual quality during the first two weeks, and thereafter were never different than the control on any date rated (Figure 3). Averaged over the entire season, visual quality was similar to the control for the same four treatments which included Knife (both treatments), IronRoots, and Roots Concentrate (Figure 11). IronRoots and Roots Concentrate do not contain nitrogen whereas Knife is 12% nitrogen (Table 1). Season-long color by NDVI showed results similar to visual quality ratings and Knife (both treatments), IronRoots, and Roots Concentrate were not different from the control.

With one exception, the four individual biostimulant treatments were unable to provide the acceptable visual quality needed for golf green surface. In June, plots treated with Knife (both treatments), IronRoots, and Roots Concentrate were off-color and chlorotic. As summer progressed, Roots Concentrate tended to have poorest quality on every date rated visually or by NDVI. In June, as plots were greening up, an obvious pattern of greener bentgrass directly above a grid of core aerification holes was common. The pattern was likely due to enhanced root growth and nutrient uptake via the sand-filled channels. Based on IL field observations of golf greens, this pattern is usually associated with the use of low or inadequate levels of N in summer and is indicative of nutrient deficiency.

Of the four products consistently associated with unacceptable visual quality, Roots Concentrate showed a trend of poorest visual

quality, and rating values were less than the control on September 3. Similarly, visual color of Roots Concentrate was lower than the control on two dates, September 11 and October 10. Overall, NDVI color measurements were better than either visual ratings in detecting subtle differences between Roots Concentrate and the control because it detected a reduction on five of 16 dates (August 12, September 3, 11, 16, and October 10).

Over the 2008 season, intermediate visual quality was associated with Ultraplex, Lesco 12-0-0, and PanaSea Plus (Figure 11). Across individual rating dates, intermediate visual quality was associated with Ultraplex, Lesco 12-0-0, and PanaSea Plus because they generally fluctuated near the minimum acceptable threshold (i.e., 7.0), and did not provide a high a level of quality compared to the urea treatments (Figure 4). The products associated with intermediate visual quality, however, were not different than control plots during early summer (June to mid-July). Ultraplex was better than the control beginning July 16, and Lesco 12-0-0 was better beginning July 21. From July 28 on, plots treated with Ultraplex and Lesco 12-0-0 displayed better visual quality than the control.

Overall, the performance of PanaSea Plus was questionable because its visual quality was no different than control plots on 87% of the rating dates. Quality of plots treated with PanaSea Plus largely mirrored the control, but plots achieved slightly higher quality ratings (Figure 4). Except for three instances, color measurements by NDVI were unable to discern differences between the control and the intermediate visual quality group of Ultraplex, Lesco 12-0-0, and PanaSea Plus. The color of plots treated with Ultraplex was better on August 19, and Lesco 12-0-0 was better on September11 and 16, while the color of PanaSea Plus plots was never better than the control as measured by NDVI.

Comparisons to the minimum acceptable threshold for visual quality were made (Figure 11). Percent acceptable visual quality across all 17 dates rated from June 11 to October 10 was 100% for Ultraplex, 93% for Lesco 12-0-0, and 73% for PanaSea Plus. Visual color also suggested that Ultraplex and Lesco 12-0-0 could improve plots late in the season because one or both products had higher ratings than the control from July 28 on. Both Ultraplex and Lesco 12-0-0 required three applications before having a positive impact

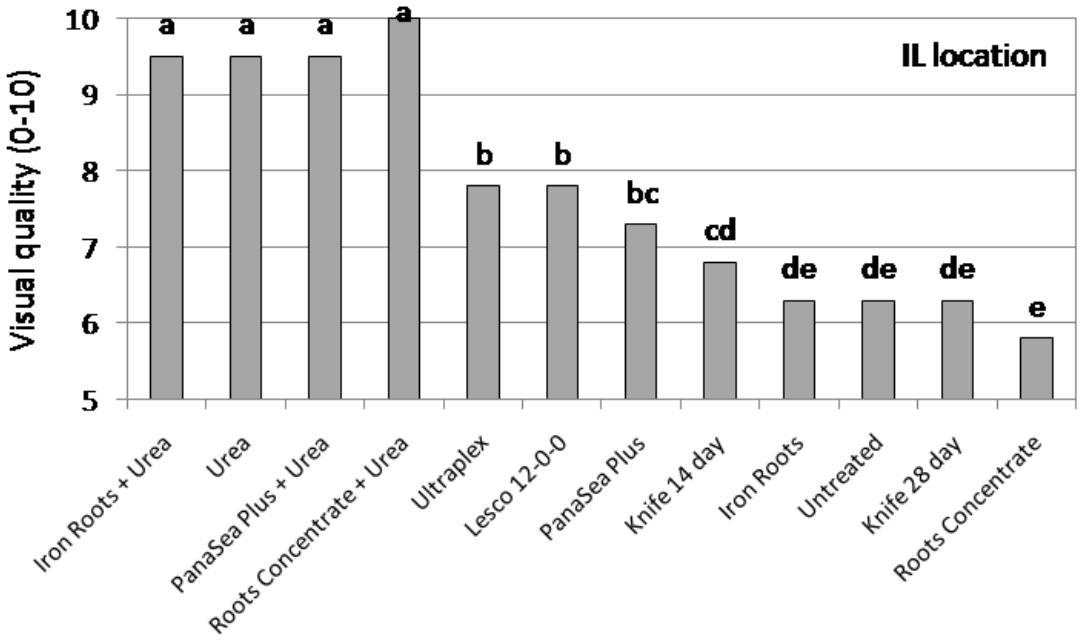



**Figure 6.** Effect of treatments with and without urea on quality of G-2/L-93 creeping bentgrass on October 10 in IL with final application September 3, 2008. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

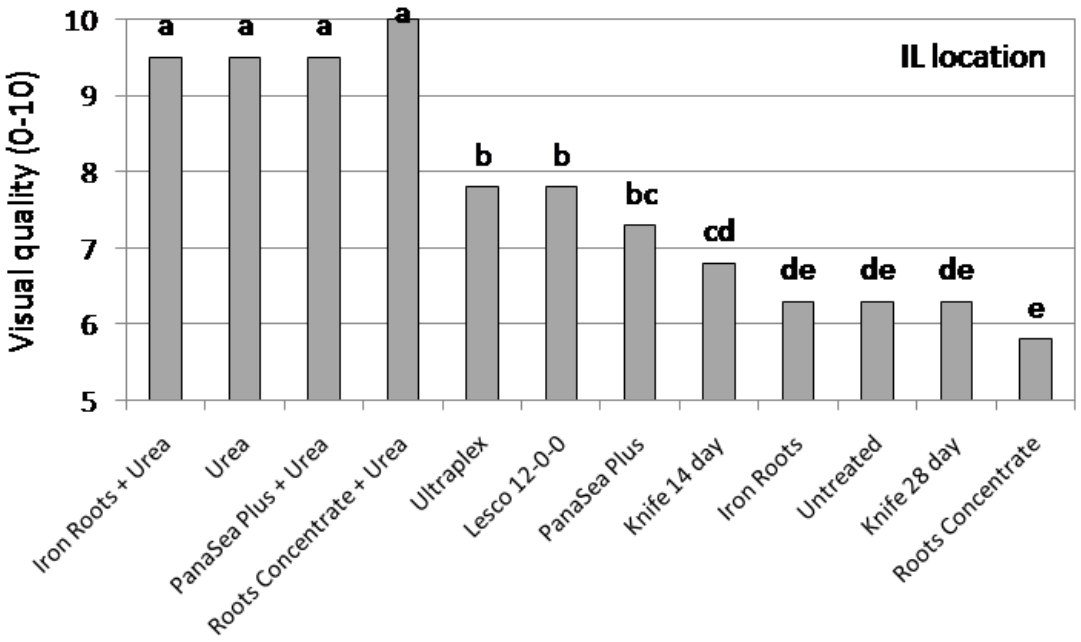



**Figure 7.** Effect of treatments with and without urea on color of G-2/L-93 creeping bentgrass two days after treatment on August 7. Bars with the same letter are not significantly different (P < 0.05) by Fisher's LSD mean separation test.

on visual color. In contrast, PanaSea Plus never improved color visibly compared to the control on any date rated.

Over the 2008 season, best visual quality was associated with urea alone or urea mixed with biostimulant products with cytokinians (Figure 11). Beginning in July, plots treated with urea, IronRoots + urea, PanaSea Plus + urea, Roots Concentrate + urea grouped together with best quality on every date rated (Figure 5). June was the only period that plots receiving urea were not different than the control. This was likely due to delayed bentgrass growth caused by cooler than normal spring/early summer temperatures in 2008. With initial treatments on June 11, urea or urea mixed with biostimulants were similar to the control until June 24. By June 30, all urea treatments except PanaSea Plus + urea had improved visual quality versus the control.

Since plots were never rated immediately after product application, all measurements utlilized by the study represented effects after a minimum of 7 days in IL. Urea masked all other nutrients at this measurement interval because at no time were biostimulant products mixed with urea able to improve visual quality to levels greater than urea alone. For example, IronRoots, PanaSea Plus, and Roots Concentrate did not improve visual quality over urea alone as illustrated in Figures 5 and 8. Beginning in July, all plots given urea had a similar dark green color on every date rated with one exception: Roots Concentrate + urea had slightly lower visual color on September 11. NDVI found differences of urea and urea + biostimulants a week earlier on June 30, but was otherwise identical to visual quality with high color levels all season.

*Residual Urea Effect*

Treatments were last applied on September 3, and a final visual quality rating was made on October 10 (Figure 6). On October 10 (i.e., 5 weeks post-application), plots treated with urea and urea mixed with biostimulants still retained superior visual quality (range 9.5 to 10.0). In contrast, visual quality of control plots remained unacceptable (6.3), while plots treated with Ultraplex, Lesco 12-0-0, and PanaSeaPlus were intermediate (7.6).

On October 10, NDVI data also showed urea and urea + biostimulant products provided highest color meter readings. All other treatments were similar to the control except Roots Concentrate which had the lowest NDVI value. At study end, the final NDVI measurement continued to closely match visual assessments. Urea was capable of long-term enhancement of color and density which greatly contrasted the chlorotic and thin plots of certain treatments without nitrogen input since June (e.g., Roots Concentrate).

*Transient Iron Effect*

In IL, a minimum rating interval of 7 days post-treatment always found urea effects were dominant across all measurements taken. Nitrogen by urea likely masks effects by iron because it has a quick release effect and a systemic physiological activity that causes increased chloroplast synthesis in plant cells. However, it was apparent during the study that certain other treatments created visible color responses within hours of application. On August 7, plots were rated 48 hours after application to capture those effects. Both UltraPlex and Lesco 12-0-0 showed enhanced color deemed as good as urea plots (Figure 7). Those two biostimulant products contain iron (Table 1). Knife also contains 6% Fe, a level identical to Lesco 12-0-0, but did not enhance color compared to the control on August 7, although both Knife treatments were applied.

Color by iron was somewhat different than the dark green color urea provides. On treated plots, the two iron treatments influenced existing bentgrass color by the addition of purple, gray, or brown hues. Lesco 12-0-0 had a purple-gray color and is typical of what superintendents generally expect following iron applications on golf greens. UltraPlex was slightly different, a brownish-gray color. On all weekly visual rating dates iron's colorant activity was never visible by day 7. It indicated this is a temporary or transient effect. The inability of iron to enhance color for the duration of one week was probably due to removal of leaves contacted by chelated iron by necessary frequent mowing.

**Maryland Site**

All treatments were applied initially on June 11, and the last application of the products

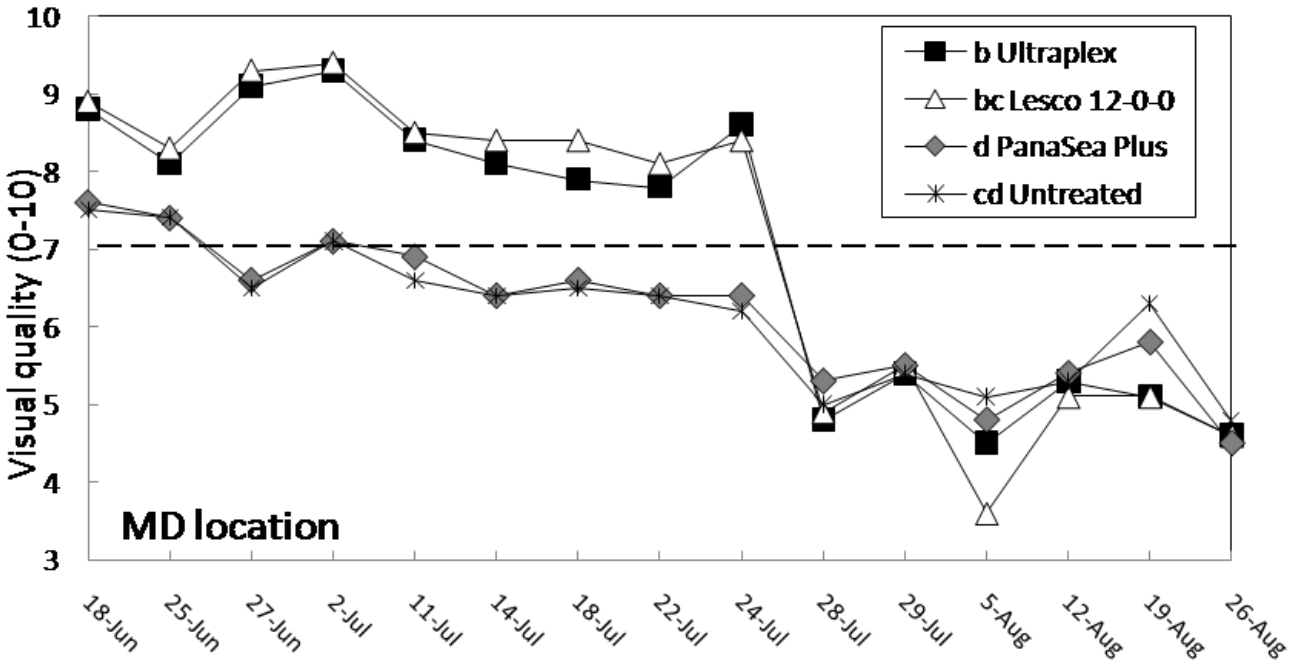



**Figure 8.** Effect of Lesco 12-0-0, PanaSea Plus and Ultraplex on summer quality of Providence creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

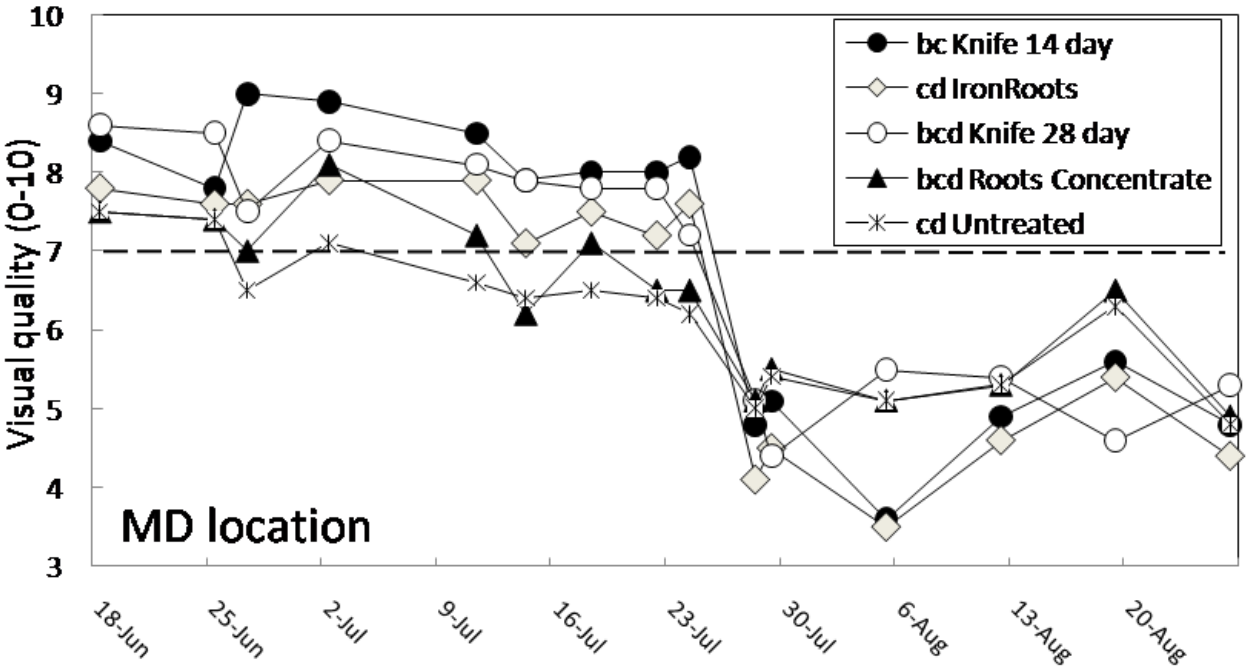



**Figure 9.** Effect of Knife, IronRoots and Roots Concentrate on summer quality of Providence creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P <0.05.

was made on August 6, 2008. Only turf quality data for MD are shown in Figures 8, 9 and 10. Visual turf color as well as NDVI ratings also were obtained, and while these data are not shown, they are discussed. Between the period of June 18 and July 2, most treatments improved color and quality significantly compared to the control. Plots treated with Ultraplex, IronRoots + urea, Roots Concentrate + urea, Knife (both treatments), PanaSea Plus + urea, Lesco 12-0-0, and urea generally exhibited very high quality (i.e., > 8.0), and ratings generally were superior to those of the untreated control (hereafter control).

Conversely, there generally were no significant improvements in quality between the control and plots treated with IronRoots, Roots Concentrate, or PanaSea Plus during this period. During the period between July 11 and 24, only plots treated with IronRoots + urea and Lesco 12-0-0 had quality ratings above 8.0 on all dates. There were, however, no significant color/quality differences between the aforementioned treatments and plots treated with Ultraplex, Knife (1.5 fl. oz., 14-day interval), PanaSea Plus + urea, or urea alone, which had provided acceptable color/quality ratings on all but one date during the July 11 to 24 period. During the period from July 11 to 24, IronRoots improved quality (ratings 7.1 to 7.9) on all dates compared to the control, but Roots Concentrate (ratings 6.2 to 7.2) only improved quality on July11. Bentgrass treated with PanaSea Plus alone had color/quality ratings equivalent to the control on all dates between July 11 and 24.

Most of June and July was marked by frequent thunderstorm activity. With higher night temperatures, humidity, and a wet thatch layer in mid-to-late July, the bentgrass became puffy, and the study area was uniformly scalped throughout the remainder of the study. During the period between July 28 and August 26, turf color (data not shown) was improved to at or above the minimum acceptable level by Ultraplex, IronRoots + N, Knife (14-day treatment), PanaSea Plus + urea, Lesco 12-0-0, and urea. IronRoots improved color significantly compared to the control on all dates, but the ratings were consistently below the minimum acceptable level.

Very poor color ratings similar to the control on most dates were associated with Roots

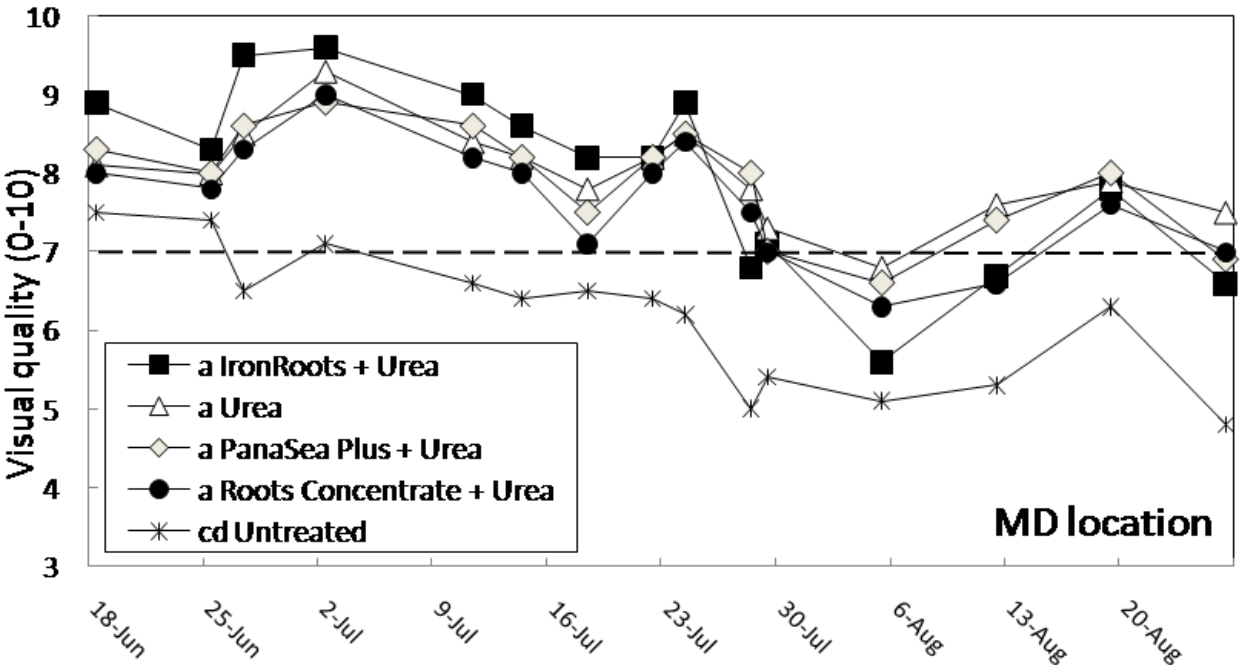



**Figure 10.** Effect of urea treatments on summer quality of Providence creeping bentgrass. In the inset box, treatments marked by the same letter are not significantly different when data were averaged over the 2008 season according to Fisher's protected LSD, P < 0.05.

Concentrate and PanaSea Plus. Roots Concentrate and PanaSea Plus improved color relative to the control (ratings 5.3-5.4) on August 5 and 26, but turf color was poor (ratings 6.0-6.6). Hence, Roots Concentrate and PanaSea Plus did positively impact turf summer color on a few dates, but were not as effective as the other products evaluated.

While Ultraplex, Lesco 12-0-0, Knife (14-day treatment) and treatments including urea improved color, there was a marked reduction in turf quality in all plots not receiving routine applications of urea from July 28 through August 26 (Figures 8, 9, and 10). This precipitous drop in quality was due in large part to scalping, as well as heat stress and lack of sufficient N for bentgrass

| Treatments | Timing* | Rate (oz/1000 ft$^2$) | Scalping injury (0 - 5; >2.5 = objectionable) July 28 | Aug 5 | Aug 12 | Aug 19 | Aug 26 |
|---|---|---|---|---|---|---|---|
| Ultraplex 5-3-0 | 14 Days | 6.0 | 3.9 abc** | 4.5 ab | 3.6 a | 3.5 a | 3.8 a |
| IronRoots 0-2-4 | 14 Days | 2.0 | 4.6 a | 4.8 a | 4.0 a | 3.6 a | 4.1 a |
| IronRoots 0-2-4 + urea | 14 Days | 2.0+0.15 lb N | 2.8 cd | 3.4 b-e | 2.5 bc | 0.6 d | 2.1 b |
| Roots Concentrate | 14 Days | 2.0 | 3.3 bc | 2.8 def | 2.0 cde | 1.5 bc | 3.8 a |
| Roots Concentrate + urea | 14 Days | 2.0+0.15 lb N | 1.4 e | 2.8 def | 2.1 cde | 0.4 d | 1.6 bc |
| Knife 12-0-0 | 14 Days | 1.5 | 4.3 ab | 4.6 a | 3.9 a | 3.4 a | 3.6 a |
| Knife 12-0-0 | 28 Days | 2.5 | 4.3 ab | 4.0 abc | 3.4 ab | 3.4 a | 3.9 a |
| PanaSea Plus 0-2-2 | 14 Days | 3.0 | 3.0 bc | 3.8 a-d | 2.3 cd | 1.9 b | 3.9 a |
| PanaSea Plus 0-2-2 + urea | 14 Days | 3.0+0.15 lb N | 1.5 de | 2.4 ef | 1.3 ef | 0.8 cd | 1.6 bc |
| Urea 46-0-0 | 14 Days | 0.15 lb N | 1.3 e | 1.8 f | 1.0 f | 0.8 cd | 1.1 c |
| Lesco's 12-0-0 | 14 Days | 4.0 | 4.0 abc | 4.7 a | 3.6 a | 3.8 a | 3.9 a |
| Untreated | 14 Days | -- | 3.1 bc | 3.3 cde | 1.5 def | 1.5 bc | 3.4 a |

*Treatments on the 14-day interval were applied June 11 and 25, July 9 and 23, and August 6, 2008. Treatment on the 28-day interval was applied June 11, July 9, and August 6, 2008.
**Means in a column followed by the same letters are not significantly different according to Fisher's protected LSD, P = 0.05.

**Table 2.** Scalping injury in 'Providence' creeping bentgrass as influenced by cytokinian-plant extract products, iron and urea. College Park, MD, 2008.

grown on sand.

Some treatments produced quality levels inferior to the control. This was especially true for treatments containing Fe. For example, scalp ratings sometimes were significantly higher in plots treated with Ultraplex, IronRoots, Knife (both rates), and Lesco 12-0-0 versus the control (Table 2). The darkening of the canopy by Fe made scalping damage more conspicuous. Scalping injury appeared as a reddish discoloration and thinning in Fe-treated plots. Scalping was made less conspicuous by the lighter green canopy color in the control. During this period, all treatments that did not include urea generally exhibited extremely poor quality. Except on August 5, plots treated with urea alone had acceptable quality on all dates between July 28 and August 26. PanaSea Plus + urea and Roots Concentrate + urea had acceptable quality on four of six rating dates over the same period. IronRoots + urea produced acceptable quality on only July 29 and August 19.

NDVI readings have been correlated with visual color ratings and chlorophyll levels. Only plots receiving N from urea had higher NDVI ratings versus the control. On only two dates did NDVI show an increase in color in plots treated with Ultraplex (July 14) and Lesco 12-0-0 (August 20). Ultraplex, Lesco 12-0-0, and Knife contain N, but apparently the N delivered to plants from these products had little or no impact on chlorophyll production. Significantly higher NDVI ratings were not consistently detected in urea-treated plots until July 2 (i.e., after two applications). After July 2, NDVI ratings invariably were higher in plots receiving N from urea versus the control, but the meter readings were essentially the same among all urea treatments.

## Discussion

The performance of treatments were similar in both IL and MD. Quality data were averaged over the 2008 season and shown in Figure 11. Average quality ratings were lower in MD due to bentgrass scalping which was not a problem in IL. Average quality data show that in both IL and MD urea alone and urea tank-mixed with biostimulants provided for best summer quality. Ultraplex and Lesco 12-0-0 improved quality significantly compared to the control. Plots treated

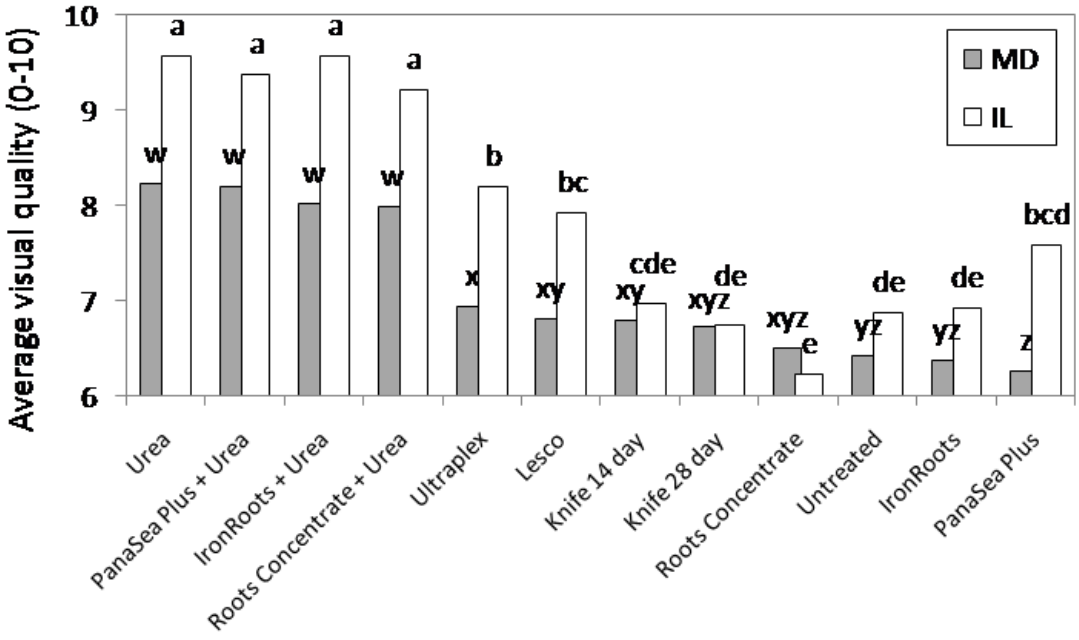


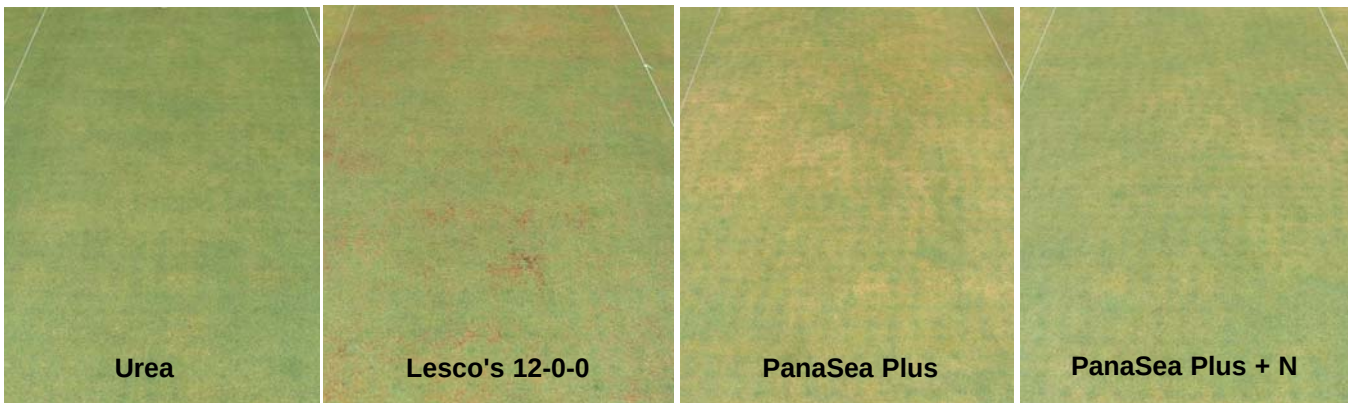

**Figure 11.** Visual quality ratings for all treatments when data were averaged over the 2008 season in IL and MD. Minimum acceptable quality was = 7.0. Bars with the same letter are not significantly different according to Fisher's protected LSD, P < 0.05.


Applications of Fe appear to improve turf color and quality by eliciting a darkening of foliar color. That is to say, the canopy does not appear greener, but darker.

with Knife, Roots Concentrate, IronRoots, and PanaSea Plus had summer quality equivalent to the control.

There was a trend for IronRoots + urea to provide the best combination of color and summer quality in both IL and MD, especially early in the season in MD. However, at both sites there were no significant quality differences in plots treated with urea alone compared to plots treated with IronRoots + urea, Roots Concentrate + urea, or PanaSea Plus + urea. Hence, little or no benefit was observed by tank mixing any of the biostimulant products with urea. Furthermore, urea alone provided equal or better quality when compared to any other treatment on most rating dates at both locations. Indeed, urea was a consistently good performer, and only treatments containing urea mitigated scalping in MD.

Visual turf color often was enhanced by the products containing Fe and/or N in both IL and MD. The only exceptions were in MD during late July and August when the bentgrass became puffy and was scalped. Scalp injury sometimes was made more conspicuous by the darkening of foliage in Fe-treated plots in MD. Color, as determined by NDVI, also was similar between sites. In both IL and MD, highest NDVI ratings were observed in plots treated with urea alone or mixed with IronRoots, Roots Concentrate, or PanaSea Plus.




On the University of Maryland, scalping was a major issue. Some treatments produced quality levels inferior to the control. Scalping injury appeared as a reddish discoloration and thinning in iron-treated plots. During this period, all treatments that did not include urea generally exhibited extremely poor quality.

In MD, there were no other treatments that consistently improved color as measured by NDVI. In IL, plots treated with Ultraplex and Lesco 12-0-0 registered NDVI ratings equivalent to urea-treated plots when monitored three days, but not seven days after application. However, when data were averaged over the season, only treatments containing urea registered higher NDVI ratings versus the control in IL in 2007 and 2008. This brings into question the nature of the improvement in color and quality accorded by the chelated Fe products evaluated, which had almost no impact on NDVI in MD and limited impact in IL.

Since NDVI measures color as influenced by chlorophyll and turf density, it appears likely that the Fe applied did not impact chlorophyll levels. Applications of Fe appear to improve turf color and quality by eliciting a darkening of foliar color. That is to say, the canopy does not appear greener, but darker. From a distance, the Fe products induce a purpling, blackening, and shades of grayish purple, and, as a result, the study sites appeared checkerboarded by the various shades of black and purple-gray which were objectionable in appearance. However, when standing close to the plots, and without the benefit of the checkerboard pattern, the visual result was positive in the absence of scalping.

To our knowledge, the mechanism by which chelated Fe darkens turf has not been described. With iron sulfate, a grayish-black residue forms on leaves or appears as a staining effect. With chelated (EDTA) Fe there is no residue. Under high magnification, one can see a uniform darkening of tissue treated by chelated Fe. Perhaps tissue darkening is the result of a chemical reaction with Fe in the cuticle or within mesophyll cells. The darkening is not a greening, but merely a grayish-black darkening of tissue.

Iron is a component of the chlorophyll molecule and is a cofactor in the synthesis of chlorophyll. Since foliage darkens in color within 1 to 2 hours of Fe application it is highly unlikely that we are seeing an increase in chlorophyll and, as previously noted, NDVI readings showed that color levels remain unaffected by Fe alone (e.g., IronRoots). Regardless, products containing Fe improve color and quality in summer in the absence of mechanical injury. Furthermore, products containing Fe, cytokinians and/or other plant extracts are overwhelmingly impacted by the Fe component. Therefore, any possible beneficial effect from a cytokinian-plant extract product is not observed, but is masked by the darkening of tissue elicited by Fe.

In products that contain cytokinian plant extracts but no Fe (i.e., Roots Concentrate and PanaSea Plus), there was some improvement in summer quality compared to the control on some dates in MD and several dates in IL. However, PanaSea Plus and Roots Concentrate seldom improved quality to an acceptable level throughout July and August in either IL or MD. It is possible that the somewhat improved quality accorded by PanaSea Plus in IL was related to the creeping bentgrass cultivars involved.

In the final analysis, the visual benefits provided by PanaSea Plus and Roots Concentrate generally were negligible and were not nearly as effective as urea or the Fe or N components of the products evaluated in improving visual summer quality. It should be noted that many biostimulant products are said to improve rooting, which was not quantified in this study. Future field studies should consider subjecting treated plots to wilt stress to determine if biostimulants improve creeping bentgrass tolerance to drought stress.

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## Literature Cited


1. Ervin, E., and X. Zhang. 2008. Applied physiology of natural and synthetic plant growth regulators on turfgrasses. Pp. 171-200. *In* M. Pessarakli (Ed.). Handbook of Turfgrass Management and Physiology. Taylor and Francis, London, United Kingdom. (TGIF Record 128330)

2. Liu, X., and B. Huang. 2002. Cytokinin effects on creeping bentgrass responses to heat stress II. Leaf senescence and antioxidant metabolism. *Crop Sci.* 42:466-472. (TGIF Record 79201)

3. Liu, X., B. Huang, and G. Banowetz. 2002. Cytokinin effects on creeping bentgrass response to heat stress I. Shoot and root growth. *Crop Sci.* 42:457-465. (TGIF Record 79200)

4. Munshaw, G., E. Ervin, D. Parrish, C. Shang, S. Askew, X. Zhang, and R. Lemus. 2006. Influence of late-season iron, nitrogen, and seaweed extract on fall color retention and cold tolerance of four bermudagrass cultivars. *Crop Sci.* 46:273-283. (TGIF Record 109577)

5. Schmidt, R., E. Ervin, and X. Zhang. 2003. Questions and answers about biostimulants. *Golf Course Management* 71(6):91-94. (TGIF Record 86525)