

Lebanon Performance Study Report

Tom Fermanian, University of Illinois

January, 7 2013

Experimental Layout

This experiment was designed to comparatively evaluate the performance of several fertilizer products on a stressed putting green turf. The study was conducted at the University of Illinois Landscape Horticulture Research Facility on a soil-based putting green growing 'L-93' creeping bentgrass (Figure 1.). Soil at the site is a Flanagan silt loam soil (fine, montmorillonitic, mesic Aquic Argiudoll). The experimental design was a completely randomized block with four replications. Plot size was '5' x 6'. A list of treatments is shown in Table 1. The description of fertilizer schedules and dates of application are further expanded in Table 2. The experiment was initiated on May 23, 2012. All treatments were weighed for an individual plot and applied by hand through shaker jars. Treatments were watered in with 20 min. of irrigation immediately after all treatments were applied. This same process was used for all subsequent applications. There were no pesticides applied to the greens during the course of the experiment. Irrigation was applied by schedule due to the sparse rainfall this summer. All plots were irrigated at night approximately 7 days per week. No other routine cultural practices were applied to the green during the experiment. The green was mowed 5 times per week at 0.125 inches.



Figure 1. Overall view of plot area. Bentgrass putting green maintained at 0.125 inches cutting height. Image taken at initiation of study on May 23rd, 2012.

Simulated Traffic

To apply some degree of stress to the experimental area all plots were periodically rolled with a smooth, unweighted roller. The roller was drawn by a EZ-Go golf cart, which also added some wear stress. All plots were initially rolled twice per week with two replications. This stress treatment began on May 29 one week after the initial treatments. After five weeks, the replications were increased to four until September 1 when all stress treatments were stopped to allow for evaluation of turf recovery.

Table 1. List of treatments.

No.	Treatment	Rate
		lb N / 1000 ft ²
1.	Country Club 18-0-18 + seaplant	Schedule A 0.25
2.	Country Club 18-0-18 + seaplant	Schedule B 0.5
3.	Country Club 18-0-18 + seaplant	Schedule C 0.75
4.	Country Club 18-3-18	Schedule A 0.25
5.	Country Club 18-3-18	Schedule B 0.5
6.	Country Club 18-3-18	Schedule C 0.75
7.	Andersons DG 17-0-17	Schedule A 0.25
8.	Andersons DG 17-0-17	Schedule B 0.5
9.	Andersons DG 17-0-17	Schedule C 0.75

Results

Data was collected weekly for a visual evaluation of turfgrass quality, color and/or injury. Additionally, a field scout TCM 500 NDVI turf color meter was used to measure the reflective light energy on a weekly basis. During the first month of the study clippings were collected 24 and 48 hours after treatment application and measured for dry clipping weights and any collected fertilizer particle weight.

Table 2. Fertilizer application schedules.

Schedule	Description	Dates Applied
Schedule A	0.25 lbs. nitrogen/ 1,000 sq. ft. applied on the 1st and 15th plus or minus one day of each month beginning May 15th and concluding on October 1st.	May 23, June 6, July 9, July 26, Aug. 6, Aug. 20, Sept. 6, Sept. 16, Sept. 28
Schedule B	0.50 lbs. nitrogen/ 1,000 sq. ft. applied on the 1st and 15th plus or minus one day of each month beginning May 15th and concluding on October 1st.	May 23, June 6, July 9, Aug. 6, Sept. 6, Sept. 28
Schedule C	0.75 lbs. nitrogen/ 1,000 sq. ft. applied on May 15, July 15 and September 15 plus or minus one day.	May 23, June 6, July 9, Aug. 20, Sept. 16,

Phytotoxicity ratings

No phytotoxicity or injury was observed across the entire experimental area during the course of the experiment. Injury, however, did occur from the stress treatments and is reflected in the quality ratings.

Quality Ratings

All plots were rated for turf quality on 20 dates during the experiment. Statistically significant differences among the error mean squares were found on only 4 dates of rating evaluation as shown in Table 3. The first date with a significant error mean square was on May 29, which was one week after the initial application of treatments. As expected the highest rate of application displayed the highest rated quality. The one exception was the 0.5lb/1000 sq ft rate of Country Club + seaplant, which was also rated as having best quality among treatments. (Figure 2.)

Plots receiving the highest rate of fertilizer (0.75lb/1000 sq ft) from any of the three evaluated sources continued to be rated with the highest quality for the remaining three significant dates of evaluation. Additionally, plots receiving 0.5lb/1000 ft.² from any of the three fertilizer sources were also rated of highest quality. Plots receiving fertilizer in Schedule A (0.25lb/1000 ft.²) were generally rated at a lower quality except those receiving the Country Club + seaplant source, which were also rated of highest quality in the last two dates of evaluation.

When the data was analyzed as a factorial arrangement (Table 5.) plots receiving fertilizer in programs B & C showed significantly higher quality on June 26. This was expected because they had received a higher rate of nitrogen in the study at this point in time. This effect was also apparent on July 24 & 31 for program C, but was not observed during the remainder of the study. There were very little differences among the 3 sources of fertilizer with the exception of the Country Club + seaplant source on July 17 that had significantly higher quality. This difference was not of any practical value, however.

Color Ratings

Ratings of turf color were also recorded on 20 dates during the experiment. On 15 of the 20 dates the ANOVA error means square was found to be significant. The first eight dates are displayed graphically in Figure 3 and the last seven dates are displayed in Figure 4. Generally, for ratings obtained in May or June only the 0.75lb/1000 ft.² rates of any of the fertilizer sources were judged to have the deepest green color. In July as the season became more stressful the 0.5lb/1000 ft.² were rated the same as the higher rate.

Figure 4 continues with ratings for August, September and October. These ratings are similar to earlier rating results, however, they generally reflect the effect of a recently applied schedule. By the conclusion of the study (October 10) only the 0.5lb/1000 ft.² rate of either Country Club source had significantly greener color than the other treatments.

When the data was analyzed as a factorial arrangement (Table 5.) Plots receiving fertilizer in program C were

Table 3. ANOVA error mean square significance for evaluations of turf quality, color and NDVI.

Date	Quality	Color	NDVI
22-May	NS	NS	NS
29-May	*	**	**
5-Jun	NS	**	**
12-Jun	NS	**	**
19-Jun	NS	**	**
26-Jun	**	**	**
11-Jul	NS	*	**
17-Jul	**	**	**
24-Jul	**	**	**
31-Jul	NS	NS	**
7-Aug	NS	NS	**
14-Aug	NS	**	NS
21-Aug	NS	**	**
1-Sep	NS	*	missing ¹
4-Sep	NS	**	**
11-Sep	NS	**	NS
18-Sep	NS	**	**
24-Sep	NS	NS	**
4-Oct	NS	NS	**
11-Oct	NS	**	NS

NS = not significant, * = significant at alpha = 0.05, ** = significant at alpha = 0.01.

¹ Scanner not available

Turf Visual Quality Analysis

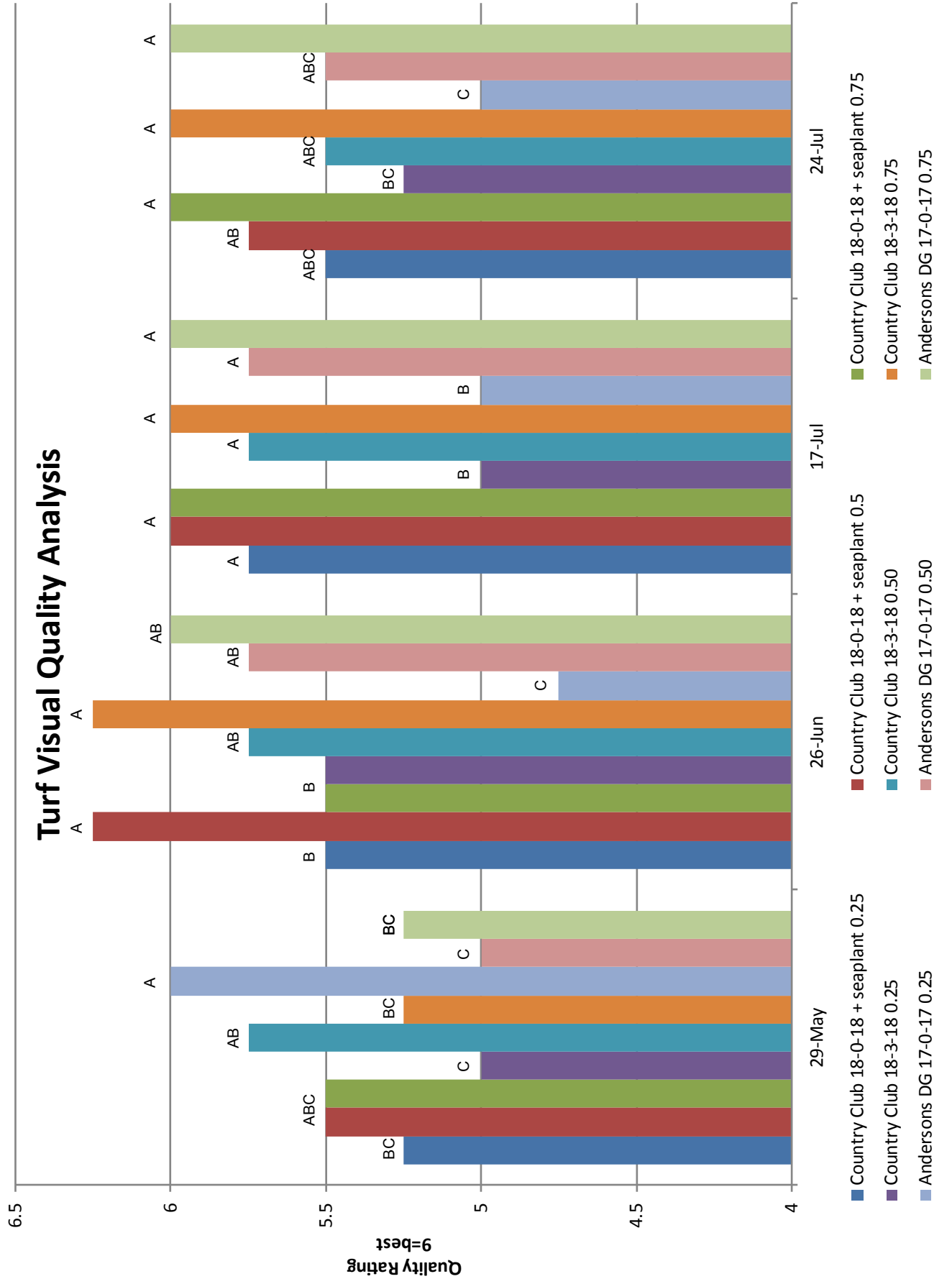


Figure 2. Mean quality ratings for 4 dates of evaluation in Lebanon Performance Study. All plots were rated for quality on 20 dates, but only 4 dates had significantly different mean square values.

Table 5. Means of subjective quality or color evaluation of a bentgrass putting green fertilized with 3 fertilizer sources applied in 3 application programs. Each value is the mean of 9 observations.

Date	Quality						Color					
	Program			Source			Program			Source		
	A	B	C	Anderson DG	Country Club	Country Club + seaplant	A	B	C	Anderson DG	Country Club	Country Club + seaplant
May 22	5.00 NS	5.00	5.00	5.00 NS	5.00	5.00	5.00 NS	5.00	5.00	5.00 NS	5.00	5.00
May 29	5.42 NS	5.42	5.33	5.42 NS	5.33	5.42	5.75 b	6.17 b	6.75 a	6.42 NS	6.08	6.17
June 5	5.00 NS	5.00	5.00	5.00 NS	5.00	5.00	4.83 c	5.50 b	5.92 a	5.42 NS	5.33	5.50
June 12	5.92 NS	6.00	5.83	5.92 NS	5.92	5.92	5.00 c	6.17 b	7.00 a	6.08 NS	6.00	6.08
June 19	5.25 B	5.67 AB¹	6.00 A	5.58 NS	5.58	5.75	5.25 c	6.17 b	7.17 a	6.33 NS	6.00	6.25
June 26	5.25 b	5.92 a²	5.92 a	5.50 NS	5.83	5.75	6.08 b	6.33 a	6.50 a	6.75 a	6.00 b	6.17 b
July 11	5.17 NS	5.50	5.75	5.50 NS	5.42	5.50	5.92 b	6.17 b	6.75 a	6.42 NS	6.17	6.25
July 17	5.25 b	5.83 a	6.00 a	5.58 b	5.58 b	5.92 a	6.42 b	7.33 a	7.58 a	7.08 NS	7.08	7.17
July 24	5.25 b	5.58 b	6.00 a	5.50 NS	5.58	5.75	5.67 c	6.25 b	6.75 a	6.17 NS	6.08	6.42
July 31	5.33 B	5.67 B	5.83 A	5.67 NS	5.50	5.67	6.25 NS	6.25	6.58	6.42 NS	6.17	6.50
Aug 7	5.67 NS	5.83	5.83	5.75 NS	5.75	5.83	6.67 NS	6.58	6.33	6.67 NS	6.50	6.42
Aug 14	5.42 NS	5.92	5.75	5.67 NS	5.58	5.83	7.25 b	7.75 a	6.67 c	7.25 NS	7.17	7.25
Aug 21	5.50 NS	5.50	5.42	5.42 NS	5.42	5.58	6.42 a	6.25 a	5.83 b	6.17 NS	6.25	6.08
Sept 1	5.17 NS	5.08	5.58	5.33 NS	5.17	5.33	6.92 a	6.25 b	6.75 a	6.75 NS	6.67	6.50
Sept 4	5.17 NS	5.08	5.25	5.08 NS	5.08	5.33	6.58 b	6.17 c	6.92 a	6.50 NS	6.75	6.42
Sept 11	5.25 NS	5.08	4.92	5.17 NS	5.00	5.08	6.58 a	6.67 a	6.08 b	6.50 NS	6.58	6.25
Sept 18	5.58 NS	5.33	5.17	5.50 NS	5.17	5.42	6.83 a	6.92 a	6.33 b	6.67 NS	6.67	6.75
Sept 24	5.58 NS	5.33	5.33	5.58 NS	5.17	5.50	6.08 NS	6.08	5.92	5.67 b	6.42 a	6.00 ab
Oct 4	5.50 NS	5.42	5.25	5.33 NS	5.42	5.42	6.75 NS	7.17	6.50	6.58 NS	7.08	6.75
Oct 11	5.25 NS	5.08	4.75	5.17 NS	4.92	5.00	6.08 b	6.92 a	6.33 b	6.33 NS	6.58	6.42

NS = not significant

¹values followed by the same capital letter within the same row of a single data set are not significantly different ($P > 0.05$).

²values followed by the same lowercase letter within the same row of a single data set are not significantly different ($P > 0.01$).

Visual Color Analysis

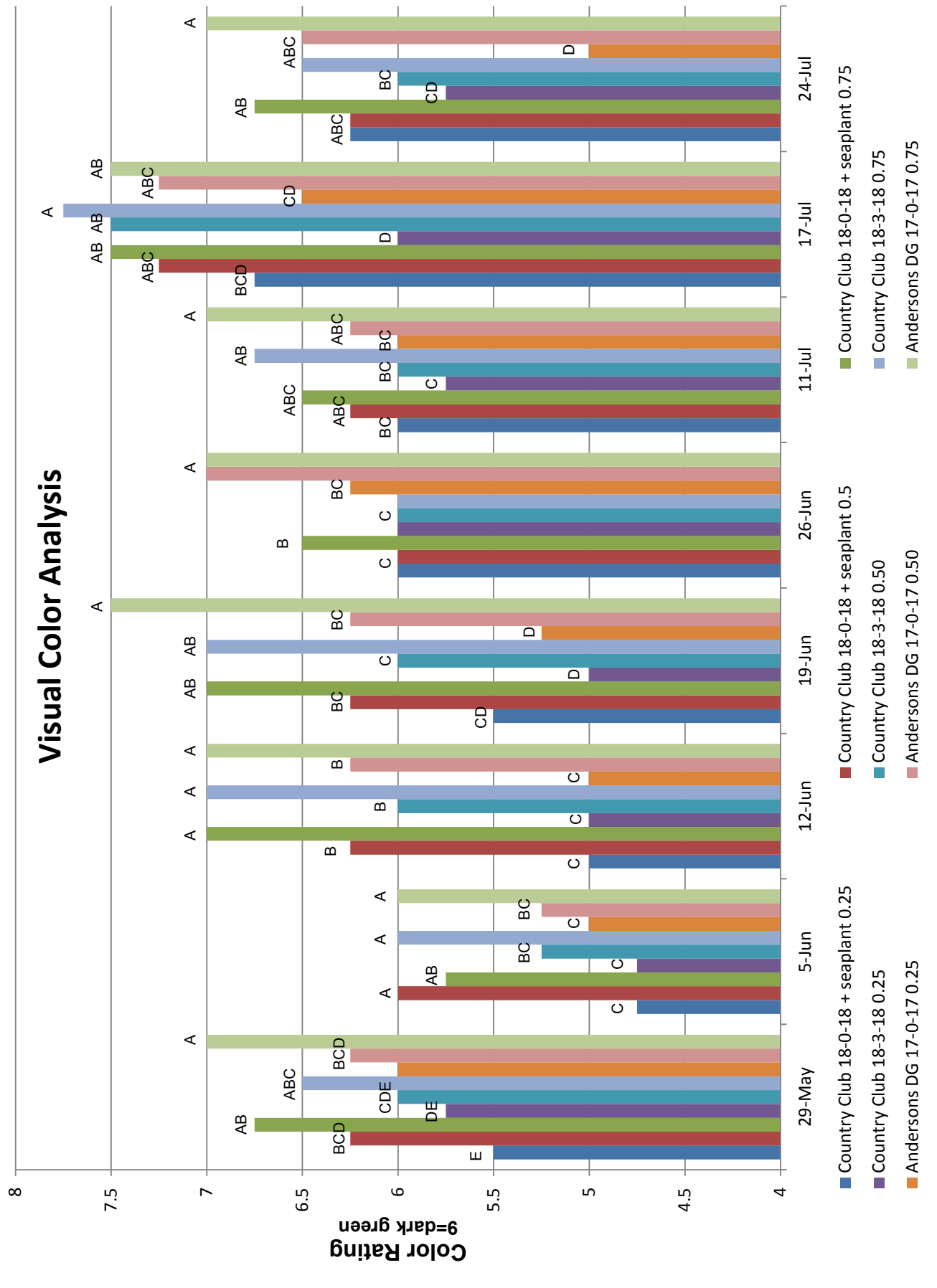


Figure 3. Mean color ratings for 8 dates of evaluation in Lebanon Performance Study. All plots were rated for quality on 20 dates, but only 15 dates had significantly different mean square values.

Visual Color Analysis (continued)

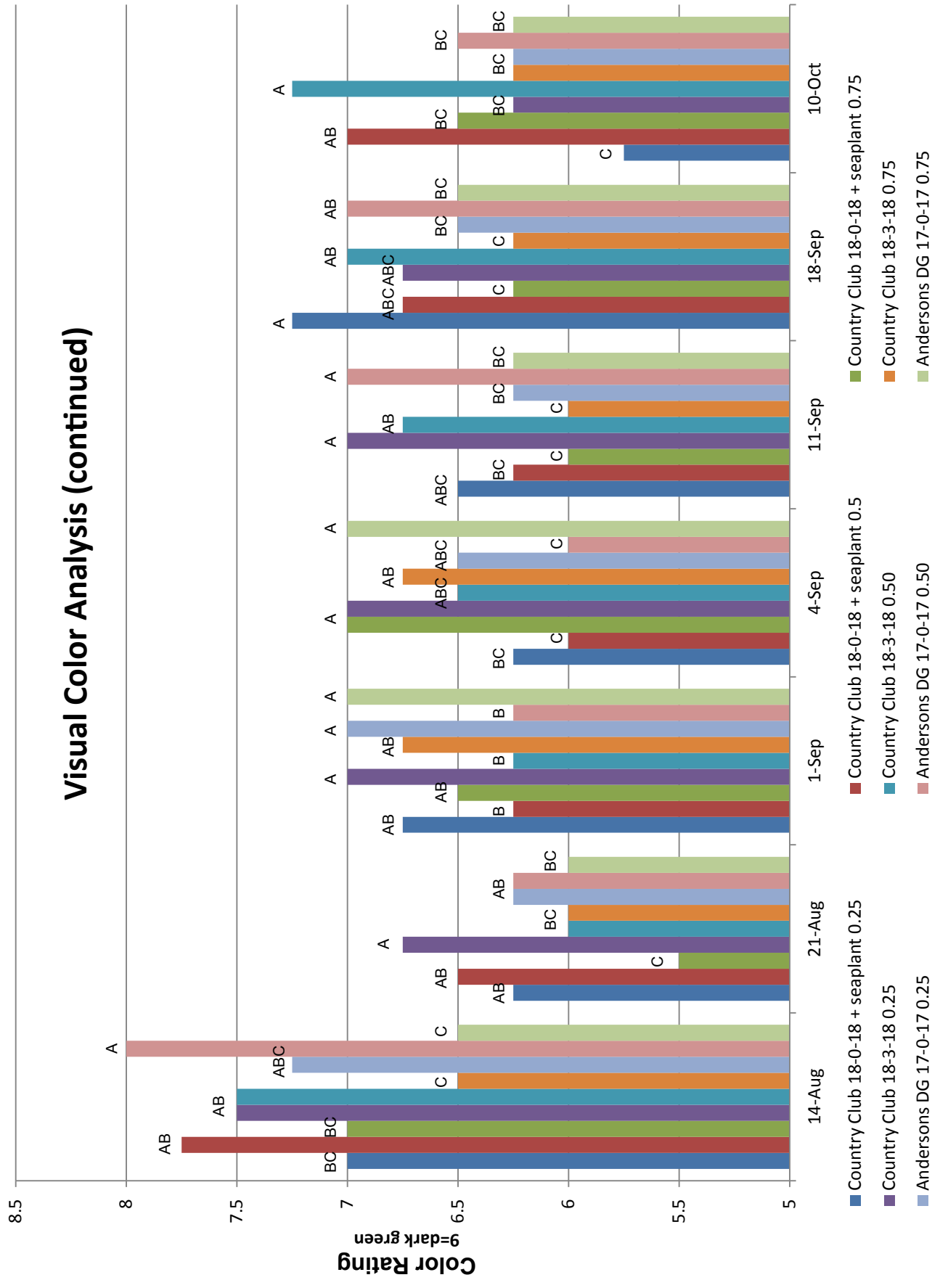


Figure 4. Continued mean color ratings for 7 dates of evaluation in Lebanon Performance Study. All plots were rated for quality on 20 dates, but only 15 dates had significantly different mean square values.

consistently greener in color than plots in program A until the beginning of August. This was expected since they had received more nitrogen up to this point in time in the study. This trend reversed in the second half of the study, but was somewhat inconsistent. On June 26, plots receiving the Anderson DG source were significantly greener than either Country Club source. While this may have some practical implications it was not observed during the remainder of the study. In fact, on September 24, both Country Club sources were significantly greener or equal to the Anderson DG source.

NDVI

At the same time subjective data was collected, evaluations of the Normalize Difference Vegetation Index (NDVI) were obtained by measurement with a



Figure 10. Overview of Experiment on August 23 showing injury from rolling treatments.

Table 4. ANOVA error mean square significance for evaluations of clipping weights, article weights and particle pickup.

Date	Clipping weights	Particle Weight	Particle Pick-up
23-May	NS	*	NS
24-May	NS	**	**
7-Jun	**	NS	**
8-Jun	**	NS	*
23-Jun	*	**	**
24-Jun	**	NS	**
10-Jul	**	*	**
11-Jul	**	*	**

NS = not significant, * = significant at alpha = 0.05, ** = significant at alpha = 0.01.

FieldScout TCM 500 NDVI Turf Color Meter from spectrum technologies, Inc. Three readings were taken from each plot and the mean of the 9 readings for each treatment are presented in Figures 5 & 6 by date.

Figure 5 shows NDVI measurements for the first nine weeks of the experiment ending on July 24. Generally, the 0.75lb/1000 ft.² rate of all three fertilizer sources had the highest mean NDVI value similar to the results of visual color ratings. It is interesting to note a similarly high value for all rates of Country Club + seaplant treatments from the end of June through July. This trend continued almost to the end of the study, but was not observed on the final date of evaluation. By late August the rolling treatment across experimental area was reducing turf quality for all treatments, but particularly severely for the high rate of Country Club and all rates of Anderson DG. (Figure 10.)

This is reflected in significantly lower NDVI measurements for these treatments on September 24. (Figure 6)

Some of the same trends observed with subjective color evaluations were also measured with NDVI readings when the data was analyzed as a factorial arrangement (Table 6.). For the first half of the study plots receiving fertilizer in program C had consistently higher NDVI readings than those fertilized in programs A & B. In the second half of the study this trend reversed with programs A & B generally having higher NDVI readings than program C.

The more significant finding in this analysis was for the source factor. Both Country Club sources and particularly the source containing seaplant had significantly higher NDVI readings than Anderson DG on 37% of the dates of evaluation. This was particularly apparent during the final weeks of the study.

Fertilizer Particle Retention

Twenty-four and 48 hours after treatment application on may 22nd, June 6, June 22 and July 9 a representative sample of clippings were collected. During this collection process a visual examination of the mowing basket was conducted to rate the quantity of collected visible fertilizer particles.

Results of an analysis of this visual examination is presented in Figure 7. Since the Country Club source was light colored while the other two sources were dark the results may be skewed due to the easy recognition of Country Club fertilizer particles. Generally, the plots receiving the 0.5lb/1000 ft.² and 0.75lb/1000 ft.² rates of Country Club fertilizer were rated to have significantly more collected particles in the mowing basket for 7 of the 8 dates of evaluation.

Collected clippings were then dried and included fertilizer particles were separated using a forced air research

NDVI Analysis by Date

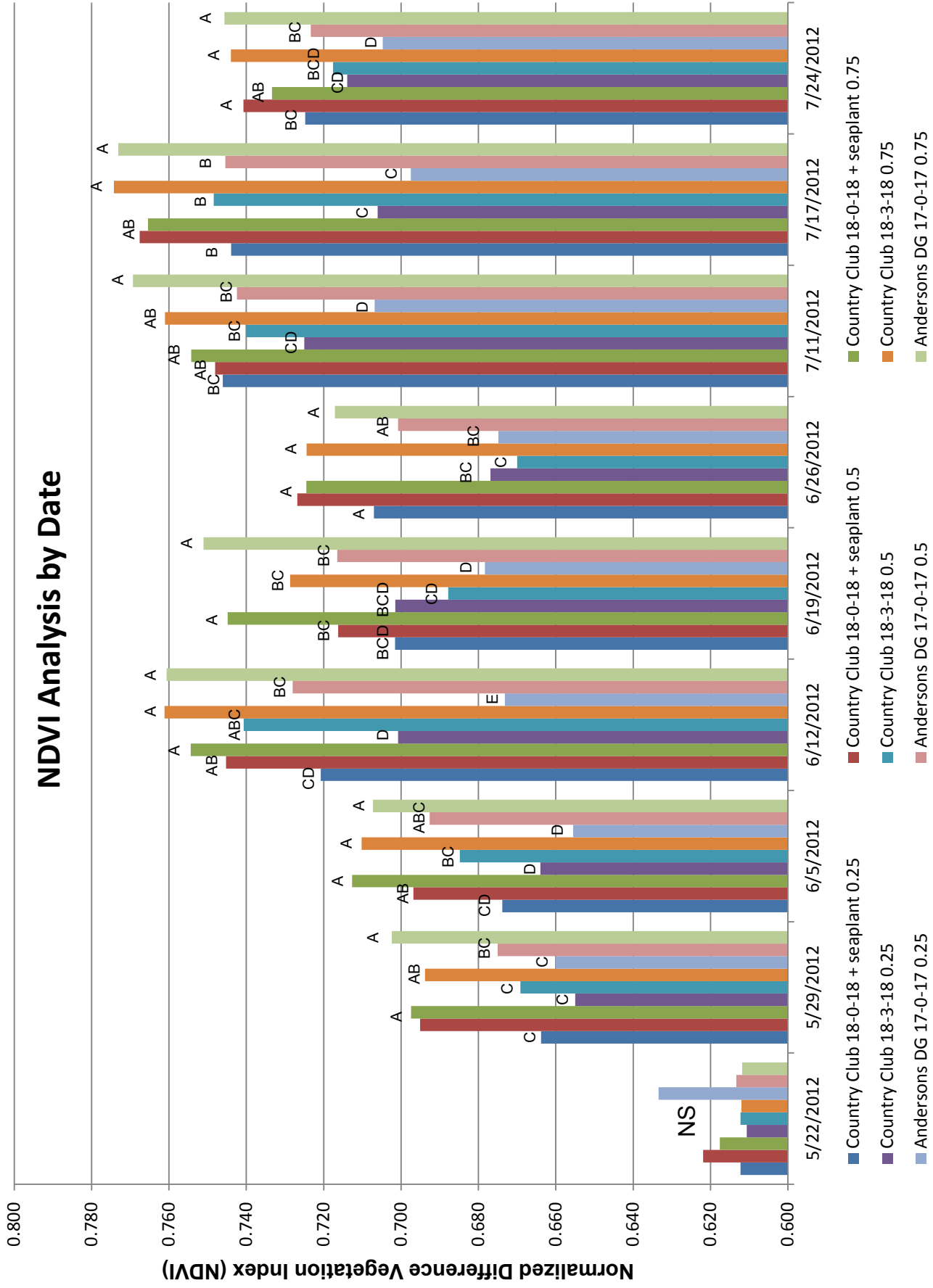


Figure 5. Mean Normalize Difference Vegetation Index (NDVI) measurements of turf receiving three fertilizer sources for 8 dates of evaluation in Lebanon Performance Study. All plots were rated for quality on 20 dates, but only 15 dates had significantly different mean square values.

NDVI Analysis by Date (continued)

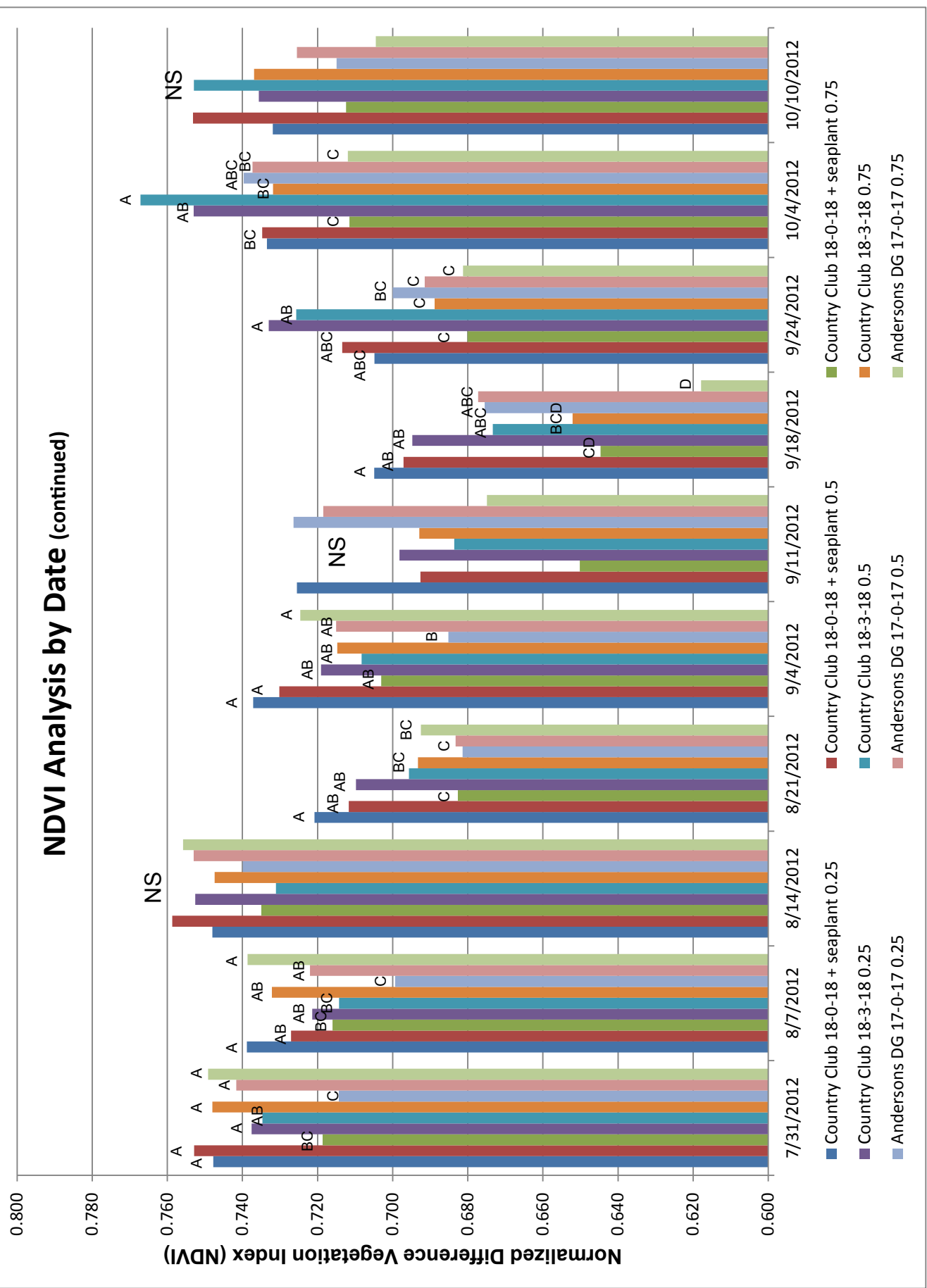


Figure 6. Continued mean Normalized Difference Vegetation Index (NDVI) measurements of turf receiving three fertilizer sources for 7 dates of evaluation in Lebanon Performance Study. All plots were rated for quality on 20 dates, but only 15 dates had significantly different mean square values. Normalize Difference Vegetation Index (NDVI) measurements of turf receiving three fertilizer sources.

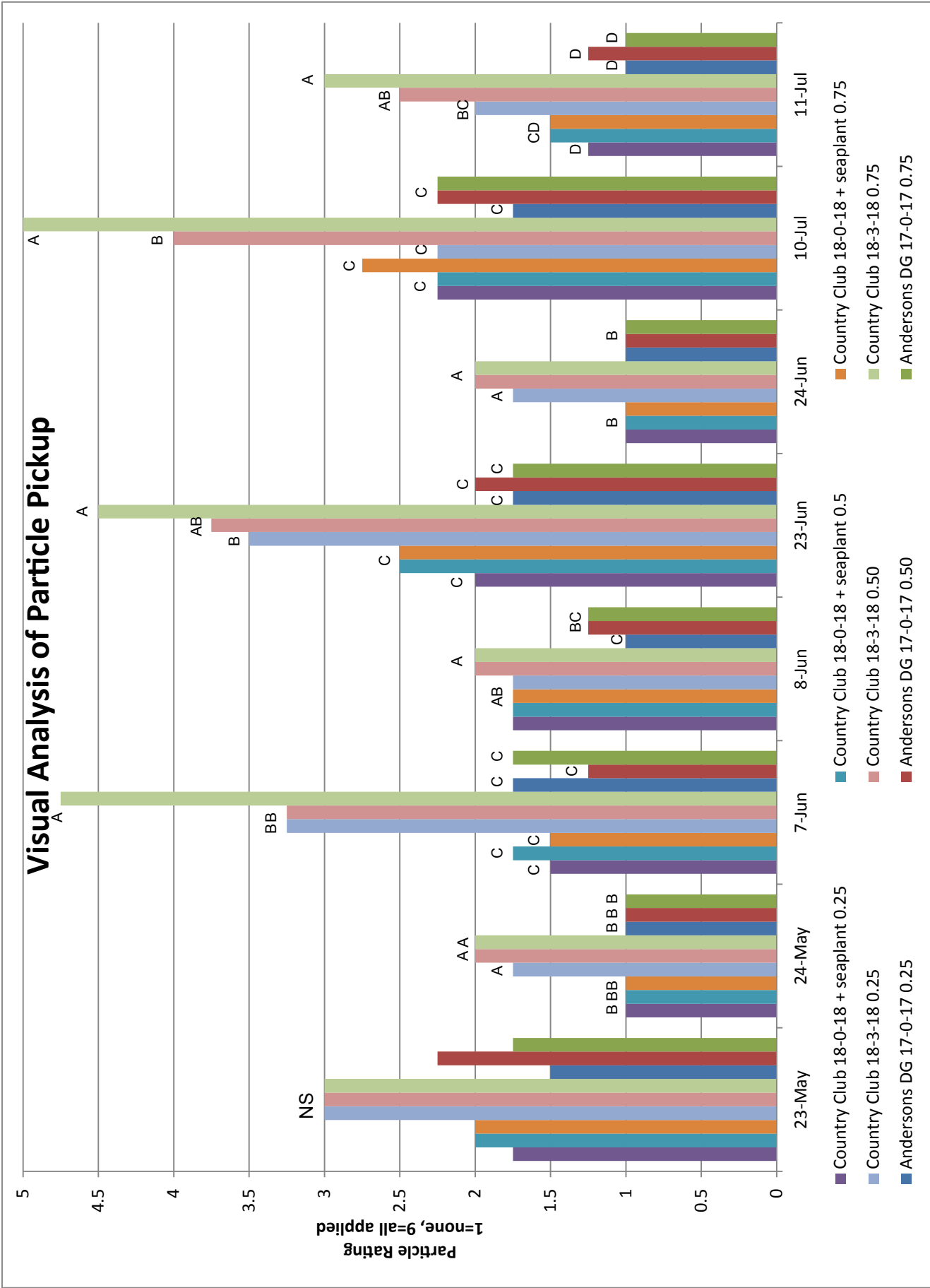


Figure 7. Visual analysis rating of collected fertilizer particles during mowing following first 4 dates of treatment application. 1 = no visible particles in mowing basket, 9 = all surface fertilizer particles applied collected in basket.

Table 6. Mean Normalize Difference Vegetation Index (NDVI) measured¹ from a bent-grass putting green fertilized with 3 fertilizer sources applied in 3 application programs. Each value is the mean of 9 observations.

Date	NDVI					
	Program			Source		
	A	B	C	Anderson DG	Country Club	Country Club + seaplant
May 22	0.619 NS	0.616	0.614	0.620 NS	0.612	0.617
May 29	0.660 c²	0.680 b	0.698 a	0.679 NS	0.673	0.685
June 5	0.664 c	0.691 b	0.710 a	0.685 NS	0.686	0.694
June 12	0.698 c	0.738 b	0.759 a	0.721 b	0.734 a	0.740 a
June 19	0.694 b	0.707 b	0.742 a	0.715 NS	0.706	0.721
June 26	0.686 b	0.699 b	0.722 a	0.698 b	0.690 b	0.719 a
July 11	0.726 c	0.744 b	0.762 a	0.740 NS	0.742	0.749
July 17	0.716 c	0.754 b	0.771 a	0.739 b	0.743 b	0.759 a
July 24	0.714 c	0.727 b	0.741 a	0.725 NS	0.725	0.733
July 31	0.733 NS	0.743	0.739	0.735 NS	0.740	0.740
Aug 7	0.720 NS	0.721	0.729	0.720 NS	0.723	0.727
Aug 14	0.747 NS	0.748	0.746	0.750 NS	0.744	0.747
Aug 21	0.704 A³	0.697 AB	0.689 B	0.686 B	0.700 A	0.705 A
Sept 1 ⁴	missing					
Sept 4	0.714 NS	0.718	0.714	0.708 NS	0.714	0.723
Sept 11	0.717 A	0.698 AB	0.673 B	0.707 NS	0.692	0.689
Sept 18	0.692 a	0.683 a	0.638 b	0.657 NS	0.673	0.682
Sept 24	0.713 a	0.710 a	0.683 b	0.691 b	0.716 a	0.699 ab
Oct 4	0.742 a	0.746 a	0.718 b	0.730 b	0.751 a	0.727 b
Oct 11	0.728 NS	0.744	0.718	0.715 B	0.742 A	0.733 AB

¹For each evaluation 3 readings were taken with a TCM 500 color meter (Spectrum Technologies Inc.) on each plot. Each source within a program had a total of 9 readings (3/plot X 3 replications).

NS = not significant

²values followed by the same lowercase letter within the same role of a single data set are not significantly different ($P > 0.01$).

³values followed by the same capital letter within the same row of a single data set are not significantly different ($P > 0.05$).

seed cleaning apparatus previously described. The mean particle weights separated from clippings are shown in Figure 8. Generally, particles collected in clippings 48 hours after application showed no significant difference or were of no practical difference. It should be noted that the utility of this second day of clipping collection is of marginal value. The measurement of particles collected from plots receiving 0.75lb/1000 ft.² of Country Club fertilizer confirm the visual analysis by being significantly heavier than other fertilizer sources on 3 of the 4 dates of application. The low and middle rates of each fertilizer source were generally similar, however. This may indicate that at normal greens application rates a small amount of fertilizer particles are collected during mowing from most fertilizer sources.

The results of an analysis of dried collected clippings weights is presented in figure 9. As expected the 0.75lb/1000 ft.² rate of each fertilizer source had the heaviest clipping weights. On 5 of the 6 collection dates with significant error mean squares, the 0.5lb/1000 ft.² rate of Country Club + seaplant source was similar to the heavier rate. In general, all rates of Country Club + seaplant fertilizer provided heavier clippings than similar rates from the other two

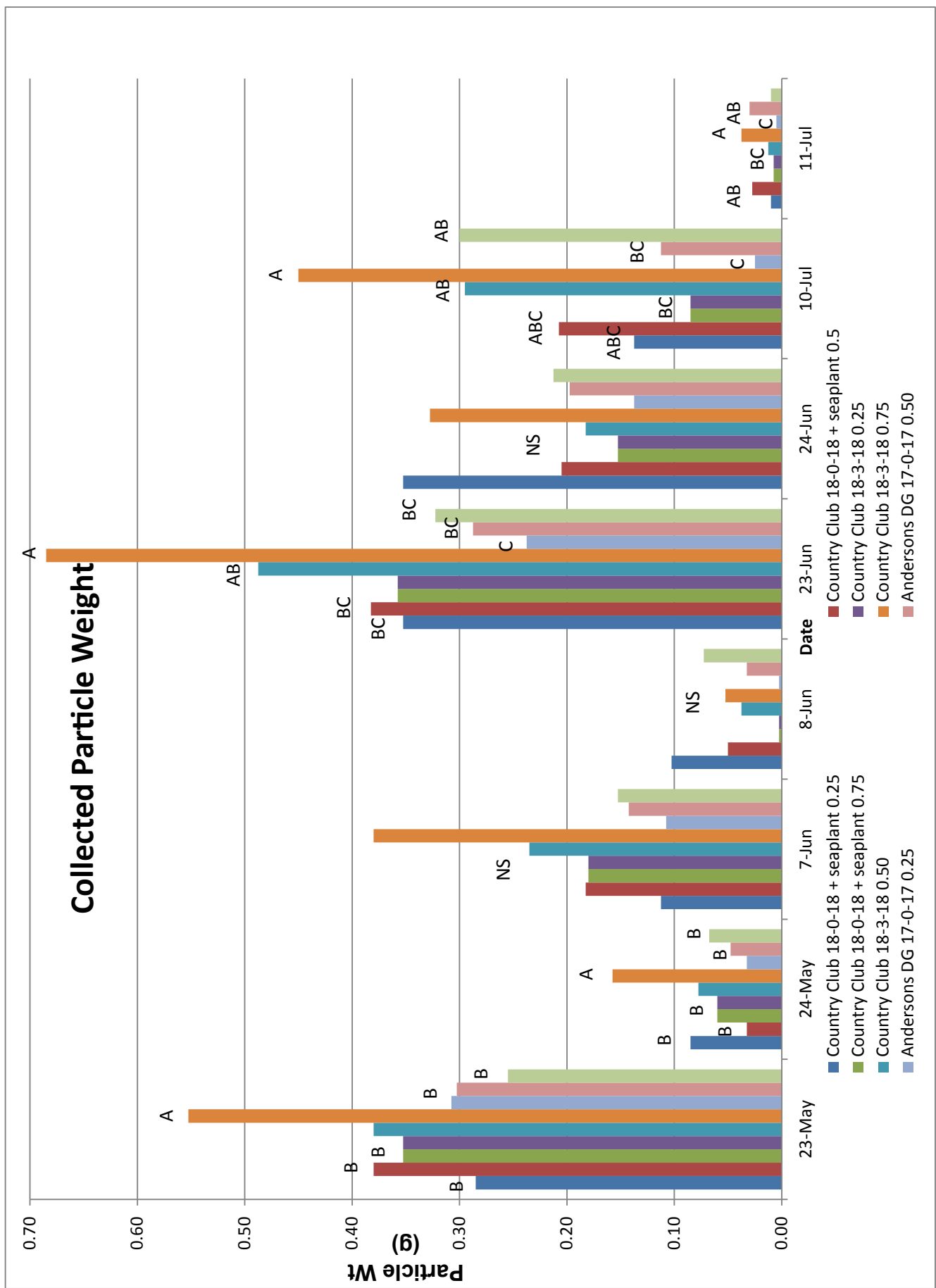


Figure 8. Mean fertilizer particles weight separated from collected turfgrass clippings following first 4 dates of treatment application.

Collected Clipping Weights

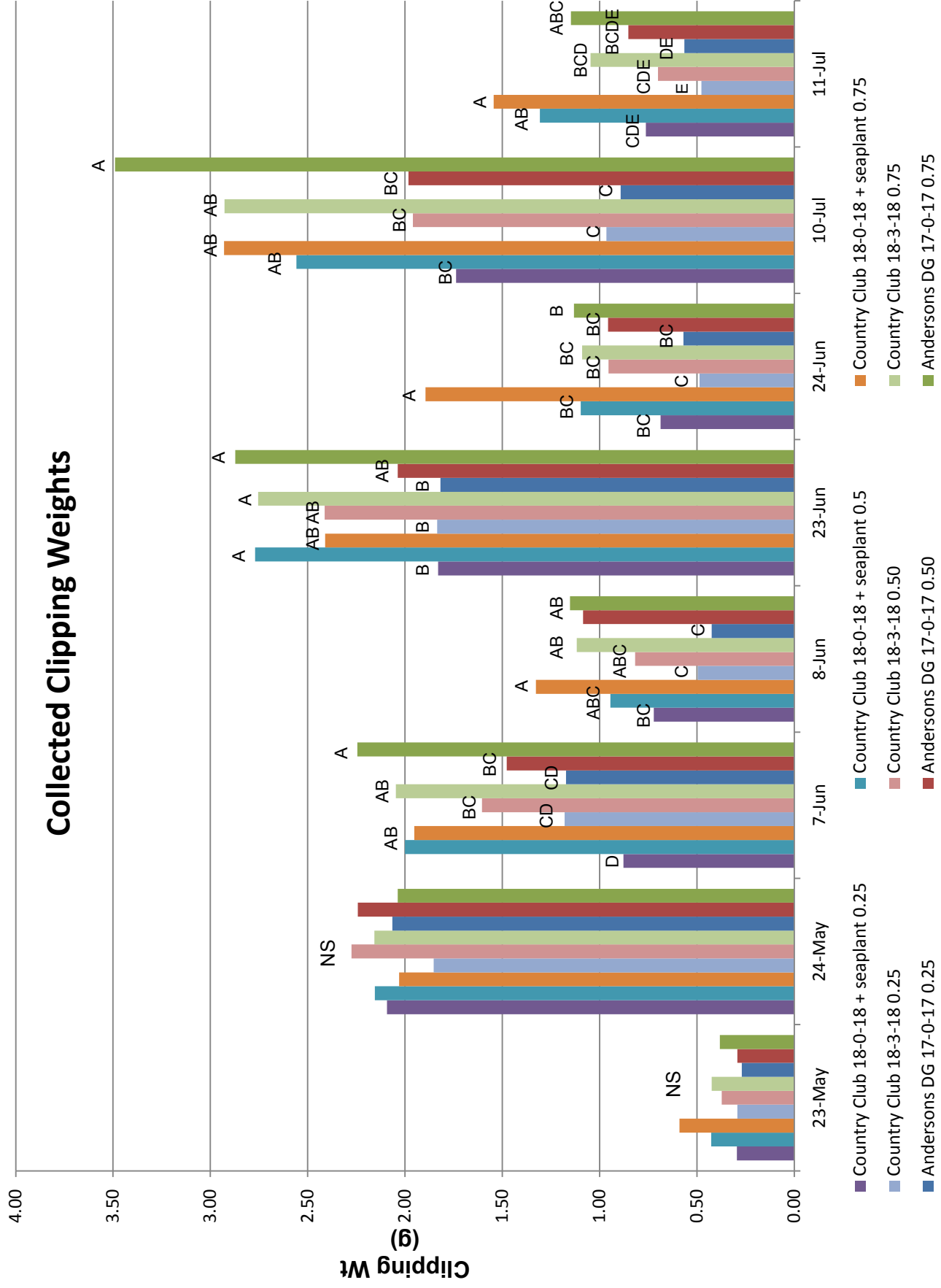


Figure 9. Mean dry clipping weights collected from plots after first 4 dates of treatment application.

fertilizer sources.

When collected clippings were analyzed as a factorial arrangement (Table 7.) dried clippings weights were consistently heavier for plots in program C for 6 of the 8 dates of collection. While the Country Club + seaplant source had significantly heavier clipping weights on July 11 this was a single date and probably not of practical value.

The subjective evaluation of particle pickup analyzed as a factorial arrangement (Table 8.) was very consistent for fertilizer source. The Country Club source was rated to have more articles in the mower basket than either of the other two sources for each date of collection with only one exception on June 8. On July 10 & 11, clippings collected from turf in program C or B were rated to have more collected particles.

After the particles were separated from dried clippings and analyzed as a factorial arrangement, particles from program B or C were significantly heavier or similar on 38% of the dates of evaluation. This was also a time in the study when the plots in these programs were receiving more nitrogen possibly holding particles higher in the canopy due to greater growth. In general, analysis of separated article weights for fertilizer sources supported subjective observations of articles in clipping baskets. The Country Club source had heavier particle weights on 25% of the collection dates. The Country Club + seaplant source was similar to the Country Club source, but heavier than the Anderson DG source on 25% of the collection dates.

Summary

All three fertilizer sources performed somewhat as expected. There was often a linear response for visual color, NDVI and the particle weight collection based on application rate. The 0.75lb/1000 ft.² rate of any source often had the highest value, but this is probably not a realistic application rate for production golf course greens. The low and medium rates are more realistic and often show similar responses. It is important to note that the Country Club + seaplant fertilizer source was very comparable to similar rates of the Andersons DG source and often outperformed the standard Country Club fertilizer source.

Conclusion

- No phytotoxicity was observed for turf receiving any fertilizer source at any of the applied rates.
- Turf quality responded quickly after treatment application, but remained low to moderate over the course of the study.
- The Country Club + seaplant fertilizer source appeared to recover from stress injury more than the other two fertilizer sources.

Supplemental Materials

All raw data, weather data, statistical analysis and miscellaneous photographs are supplied as separate files. Please contact me if you have any additional questions on data included in these files or this report.

Observations and Suggestions

It may, however, be useful to continue the evaluation of fertilizer performance when materials were applied during high stress situations. If the study were to be repeated it may be useful to provide different levels of stress to the turf prior to application.

Table 7. Mean dry weight of collected clippings removed from a bentgrass putting green fertilized with 3 fertilizer sources applied in 3 application programs. Each value is the mean of 9 observations.

Date	Clipping Weight					
	Program			Source		
	A	B	C	Anderson DG	Country Club	Country Club + seaplant
May 23	0.29 NS	0.36	0.47	0.32 NS	0.36	0.44
May 24	2.00 NS	2.22	2.08	2.12 NS	2.10	2.09
June 7	1.08 c	1.69 b	2.08 a	1.63 NS	1.61	1.61
June 8	0.55 b	0.95 a	1.20 a	0.89 NS	0.81	1.00
June 23	1.83 b	2.41 a	2.68 a	2.24 NS	2.33	2.34
June 24	0.58 c	1.00 b	1.37 a	0.89 NS	0.84	1.23
July 10	1.20 c	2.17 b	3.12 a	2.12 NS	1.95	2.41
July 11	0.60 c	0.95 b	1.25 a	0.86 b	0.74 b	1.21 a

NS = not significant

Values followed by the same lowercase letter within the same role of a single data set are not significantly different ($P > 0.01$).

Table 8. Means of subjective evaluation of particle pickup in mower clipping baskets and weight of particles after clippings were removed from a bentgrass putting green fertilized with 3 fertilizer sources applied in 3 application programs. Each value is the mean of 9 observations.

Date	Particle Pickup						Particle Weight					
	Program			Source			Program			Source		
	A	B	C	Anderson DG	Country Club	Country Club + seaplant	A	B	C	Anderson DG	Country Club	Country Club + seaplant
May 23	2.08 NS	2.42	2.25	1.83 b	3.00 a	1.92 b	0.32 NS	0.35	0.40	0.29 b	0.43 a	0.35 ab
May 24	1.25 NS	1.33	1.33	1.00 b	1.92 a	1.00 b	0.06 NS	0.05	0.09	0.05 B	0.10 A	0.05 B
June 7	2.17 NS	2.08	2.67	1.58 b	3.75 a	1.58 b	0.13 B	0.19 AB	0.26 A	0.13 B	0.27 A	0.18 AB
June 8	1.50 NS	1.67	1.67	1.17 b	1.92 a	1.75 a	0.04 NS	0.04	0.07	0.04 NS	0.03	0.08
June 23	2.42 NS	2.75	2.92	1.83 b	3.92 a	2.33 b	0.32 B	0.39 AB	0.47 A	0.28 b	0.51 a	0.38 b
June 24	1.25 NS	1.33	1.33	1.00 b	1.92 a	1.00 b	0.21 NS	0.20	0.29	0.18 NS	0.22	0.29
July 10	2.08 c¹	2.83 b	3.33 a	2.08 b	3.75 a	2.42 b	0.08 b	0.21 ab	0.33 a	0.15 NS	0.28	0.20
July 11	1.42 B²	1.75 AB	1.83 A	1.08 b	2.50 a	1.42 b	0.01 NS	0.02	0.03	0.02 NS	0.02	0.03

NS = not significant

¹ values followed by the same lowercase letter within the same row of a single data set are not significantly different ($P > 0.01$).

² values followed by the same capital letter within the same row of a single data set are not significantly different ($P > 0.05$).