Project: Evaluation of Aquazone Systems LLC Ozone Generator treated irrigation water on turfgrass performance an soil quality

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Objective: The objective of this project is to evaluate performance of the Aquazone Systems, LLC Ozone Generator in stimulating root growth and improving soil quality.

Summary: The Aquazone Systems, LLC Ozone Generator (AZO) treated area had improved turfgrass quality as evidenced by significantly higher chlorophyll index readings. The AZO treatment did not increase rooting depth. Although sodium levels in the AZO treated area was significantly lower than the non-treated control (CON) area, both the AZO and CON areas reported significantly higher sodium compared to the initial conditions at the start of the trial. Due to inconsistent irrigation distribution, the results are inconclusive, but suggest that ozone treatment might improve turfgrass quality.

Experimental design: Irrigation heads were adjusted to throw approximately 40 feet to provide two areas on the practice green that receive irrigation from two irrigation heads treated with Aquazone Systems Ozone Generator and a separate area where two irrigation heads deliver water that has not been treated (see Fig 1). One pre-test standard fungicide application was applied to the green prior to initiation of the trial. Fertilizers and other regularly scheduled treatments without the use of pesticides will be applied as usual to both AZO treated and CON areas during the test period. Flow meters were installed to monitor total volume applied daily. Approximately 100 gal of water was applied through the irrigation heads delivering water to the AZO area and CON non-treated areas. Unfortunately, the method of irrigation was variable due to manual intervention. A catch can irrigation audit for each sample location revealed that the AZO treated area received about 0.095 inches of water per irrigation cycle compared to 0.149 inches for the CON area. Approximately 57% more water was delivered to the CON area compared to the AZO treatment on a daily basis due to manual intervention. This over-irrigation of the non-treated (CON) area confounded the results and data analysis.

Measurements:

1) Root length: Three separate 8-core (1 inch diameter, 6 inches deep) samples will be collected from the AZSO side of the green and labeled AZSO-1, AZSO-2, and AZSO-3. Corresponding samples from the non-treated control side of the green will be labeled CON-1, CON-2 and CON-3.

    a) Maximum root length for each core will be measured and recorded during the sampling process by carefully removing he core from the sample probe lifting the core by the thatch layer and measuring the longest root.

    b) After the maximum root length has been determined, the entire core (verdure, thatch, mat and soil) and soil will be placed into the appropriate bag as noted above. The cores will be homogenized and shipped to Brookside laboratories for analysis of soil chemistry and organic matter content.

2) Turf quality: The average of four individual CM1000 chlorophyll meter readings will be collected at each of the three sample locations in the treated and non-treated area.

3) Soil chemistry: factors will be evaluated for each composite.

4) Organic matter content: Organic matter content will be evaluated by ash at 360 F (humus) and 440 (humus and leaves and roots).

Results and Discussion

The lack of uniform irrigation between the treated (AZO) area and the non-treated (CON) area, resulted in more complex statistical analysis being needed to determine which factor was most likely to have influenced the improved turf quality observed in the AZO treated area. The results are not conclusive due to the irrigation uniformity problem, but the results suggest that the ozone treatment was more likely to have improved turf quality than the reduced volume of water used to irrigate the AZO test area.

Table 1 provides the results of regression analysis using the CM1000 turf quality measurements as the dependent variable and all of the other measurements (including inches of irrigation per day) as the independent variables. This type of anlaysis paints a broad picture of what factors might be interacting to produce improved turfgrass quality. Ozone treatment, higher plant density as evidenced by OM440-OM360 values and increased percentage potassium provided positive correlations with turf quality. This type of analysis is not conclusive, but it suggests that the ozone treatment, not irrigation may have played a role in turfgrass quality improvement.

Table 2 reports standard analysis of variance to detect significant differences between treated AZO and non-treated CON test areas. Based upon analysis of variance, the AZO treated area provided significantly improved quality compared to the CON area. Several other parameters indicated significant differences that might be expected to result from over-irrigation of the CON area. Those include increased sulfur, sodium and salinity (electrical conductivity).

Table 3 provides results of regression analysis using each parameter as the dependent variable with ozone treatment coded as a 1 and non-treated coded as 0 for the independent variable. Five factors were found to be significantly correlated with ozone treatment; turf quality was increased by ozone treatment, Bray-2 phosphorus ppm decreased with ozone treatment, sodium ppm decreased with ozone treatment, calcium percentage increased with ozone treatment and sodium percentage decreased with ozone treatment. Unfortunately, the higher irrigation volumes applied to the non-treated area might explain the lower sodium and higher calcium percentage observed in the ozone treated area. Phosphorus was initially higher in the non-treated plots so the impact of ozone on Bray-2 phosphorus is questionable.

Table 4 provides results of an additional regression analysis looking at irrigation volume as the independent variable and all of the various measurements as the dependent variable. Three factors were found to be significantly correlated with irrigation volume; turf quality was reduced by increasing irrigation volume, Bray-2 phosphorus ppm increased with increasing irrigation volume and chloride ppm increased with increasing irrigation volume. The lack of significant correlations with other factors suggests that irrigation volume alone may not be responsible for the relatively lower levels of sodium and sulfur observed in the AZO treated area. Unfortunately, there is no way to be confident that the results observed were due to the AZO treatment when 57% more water was applied to the CON plots.

Table 1. Turfgrass quality stepwise multiple regression vs. all variables. Turfgrass quality was assessed using the CM1000 chlorophyll meter. Only three factors were positively correlated with turfgrass quality when evaluated using forward stepwise multiple regression ($p<0.05$ to enter or remove factors) with chlorophyll meter index as the independent variable. This analysis attempts to detect interactions between all variables and their impact on turf quality.

Parameter	**Slope**	**p**
Ozone treatment (1 = ozone, 0 = control)	**14.3**	**0.001**
OM 440 – OM 360 (leaves, stems, shoots, roots)	**41.7**	**0.005**
Potassium percentage	**42.5**	**0.025**

Table 2. Chlorophyll (turf quality), root length and soil quality factor analysis of variance.
Values in the same row followed by the same letter are not significantly different (Fisher's LSD $p<0.05$). Yellow shading highlights significant differences observed before the trial began. Green shading highlights significant differences observed at the end of the trial.

Parameter	Control Initial	Ozone Initial	Control Final	Ozone Final
CM1000 (chlorophyll index)	208 c	209 c	312 b	350 a
Root length (mm)	52 a	46 ab	33 ab	32 b
Organic matter (360 F ash)	4.0 a	3.9 a	2.5 b	2.7 b
Organic matter (440 F ash)	4.7 a	4.5 a	3.1 b	3.3 b
OM 440 – 360	0.64 a	0.69 a	0.55 a	0.51 a
pH	7.2 a	7.3 a	7.0 b	6.9 b
Organic Matter (OM%)	2.5 a	2.5 a	2.9 a	2.3 a
Sulfur (SO4-S ppm)	26 c	21 c	87 a	62 b
Phosphorous (P Bray-2 ppm)	196 a	121 c	214 a	147 b
Calcium (Ca ppm)	1072 b	896 c	1210 a	1285 a
Magnesium (Mg ppm)	156 b	138 b	206 a	190 a
Potassium (K ppm)	56 ab	50 b	66 a	58 ab
Sodium (Na ppm)	39 c	38 c	161 a	125 b
Calcium percentage	74 a	73 a	67 c	70 b
Magnesium percentage	18 a	18 a	19 a	17 a
Potassium percentage	2.0 a	2.1 a	1.9 ab	1.6 b
Sodium percentage	2.4 c	2.7 c	7.7 a	5.9 b
Electrical Conductivity (EC dS/m)	0.81 b	0.86 b	1.3 a	0.20 c
Chloride (Cl ppm)	19 b	22 b	128 a	89 a
Boron (B ppm)	0.70 b	0.59 b	0.89 a	0.78 ab
Iron (Fe ppm)	107 b	95 b	137 a	139 a
Manganese (Mn ppm)	29 b	28 b	40 a	39 a
Copper (Cu ppm)	3.4 a	3.7 a	3.8 a	4.3 a
Zinc (Zn ppm)	17 a	15 a	15 a	15 a
Ammonium nitrogen (NH4 ppm)	2.1 a	2.2 a	1.7 a	2.1 a
Nitrate nitrogen (NO3 ppm)	1.8 b	1.2 b	9.9 a	4.3 ab
Total nitrogen (TOTN ppm)	3.9 a	3.3 a	11.6 a	6.4 a

Table 3. Ozone treatment regression analysis.
Slope values associated with a probability (p) of less than 0.050 are considered significant. Ozone treatment was scored as 1 and non-treated as 0.

Parameter	**Slope**	**R^2**	**p**
CM1000 (chlorophyll index)	37.667	0.936	0.002
Root depth (mm)	-1.375	0.035	0.722
Organic matter (360 F ash)	0.213	0.486	0.124
Organic matter (440 F ash)	0.180	0.466	0.135
OM 440 – 360	-0.033	0.029	0.747
pH	-0.100	0.220	0.349
Organic Matter (OM%)	-0.573	0.300	0.260
Sulfur (SO4-S ppm)	-25.000	0.515	0.108
Phosphorous (P Bray-2 ppm)	-67.000	0.890	0.005
Calcium (Ca ppm)	75.000	0.167	0.421
Magnesium (Mg ppm)	-16.000	0.593	0.073
Potassium (K ppm)	-8.000	0.529	0.101
Sodium (Na ppm)	-36.000	0.874	0.006
Calcium percentage	3.053	0.800	0.016
Magnesium percentage	-1.619	0.270	0.290
Potassium percentage	-0.238	0.474	0.131
Sodium percentage	-1.795	0.849	0.009
Electrical Conductivity (EC dS/m)	-0.049	0.015	0.818
Chloride (Cl ppm)	-38.493	0.350	0.216
Boron (B ppm)	-0.110	0.479	0.128
Iron (Fe ppm)	2.000	0.018	0.798
Manganese (Mn ppm)	-1.133	0.025	0.763
Copper (Cu ppm)	0.543	0.346	0.219
Zinc (Zn ppm)	-0.567	0.065	0.627
Ammonium nitrogen (NH4 ppm)	0.433	0.023	0.776
Nitrate nitrogen (NO3 ppm)	-5.567	0.268	0.293
Total nitrogen (TOTN ppm)	-5.133	0.202	0.371

Table 4. Irrigation volume (inches) regression analysis vs observations. Slope values associated with a probability (p) of less than 0.050 are considered significant.

Parameter	Slope	R^2	p
CM1000 (chlorophyll index)	-570.860	0.883	0.005
Root Length (mm)	-1.384	0.000	0.982
Organic matter (360 F ash)	-2.632	0.304	0.257
Organic matter (440 F ash)	-3.475	0.714	0.034
OM 440 – 360	-0.843	0.076	0.593
pH	0.100	0.001	0.955
Organic Matter (OM%)	5.654	0.120	0.501
Sulfur (SO4-S ppm)	388.954	0.512	0.110
Phosphorous (P Bray ppm)	906.855	0.669	0.047
Calcium (Ca ppm)	-109.842	0.001	0.942
Magnesium (Mg ppm)	135.19	0.174	0.411
Potassium (K ppm)	96.717	0.318	0.244
Sodium (Na ppm)	420.913	0.490	0.121
Calcium percentage	-33.966	0.406	0.173
Magnesium percentage	4.175	0.007	0.871
Potassium percentage	1.938	0.129	0.485
Sodium percentage	17.603	0.335	0.229
Electrical Conductivity (EC dS/m)	-1.141	0.033	0.731
Chloride (Cl ppm)	927.160	0.834	0.011
Boron (B ppm)	1.147	0.327	0.236
Iron (Fe ppm)	-92.225	0.160	0.432
Manganese (Mn ppm)	-25.546	0.038	0.711
Copper (Cu ppm)	-9.960	0.477	0.128
Zinc (Zn ppm)	3.730	0.012	0.840
Ammonium nitrogen (NH4 ppm)	6.297	0.020	0.791
Nitrate nitrogen (NO3 ppm)	51.831	0.095	0.552
Total nitrogen (TOTN ppm)	58.128	0.106	0.528

Figure 1. Location of treated areas on practice green at El Niguel CC. Turfgrass quality, root depth, soil samples and irrigation catch cans were located at each points identified in this figure. Blue dots illustrate the location of the irrigation heads and the arcs illustrate the approximate throw of the irrigation heads. A Trimble AgGPS 136 sub-meter GPS was used to navigate to the locations for sampling.