Final Report

Investigation of the Effect of Experimental Milorganite Formulations on Turfgrass Color, Quality and Growth

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1. Scope and Objective

The overall objective of this research was to compare the agronomic and environmental impacts of various experimental Milorganite formulations compared to Milorganite Classic. To accomplish this objective, a field study, a greenhouse study, and various laboratory characterizations were performed. The field study tracked agronomic responses of the Kentucky bluegrass to the various formulations during two growing seasons, while the greenhouse study evaluated the leaching potential of the products. Various characterizations of the fertilizers and soil were performed to evaluate the chemical differences among the fertilizers.

2. Methods and Materials

<u>Field Study</u>

This research project was conducted at the University of Wisconsin – Madison. The field study site was located at the University's O.J. Noer Turfgrass Research and Education Facility in Verona, WI. The research was carried out on a Kentucky bluegrass lawn grown on a Batavia silt loam soil. The grass was mowed weekly or as needed at a cutting height of 2.5 inches, and irrigation was applied weekly to replace 80% of reference evapotranspiration (ET) as estimated by an on-site weather station. In July, 2013, regular irrigation was withheld to attempt to identify difference among the treatments in response to drought stress.

The study evaluated ten treatments listed in Table 1 which include six (6) different treatments of Milorganite in various compositions of iron and nitrogen (A-F), two (2) treatments with Milorganite and Crystal Green® (G-H), a control treatment with no fertilizer and a treatment with Scotts® Turf Builder® commercial fertilizer. Crystal Green® is a commercial, slow-release, high-purity, phosphorus fertilizer (N-P-K-Mg: 5-28-0-10) approved in many states including Wisconsin, that is generated by a process developed by Ostara Nutrient Recovery Technologies, Inc. of Vancouver, BC. Ostara's patented nutrient recovery process takes the ammonia- and phosphorus-rich liquid stream from dewatered anaerobic digestion biosolids that typically recycles to the head of a plant, and creates the Crystal Green commercial product. This process and product strongly compliment the enhanced biological phosphorus removal (EBPR) process currently being investigated by the MMSD-VWM team, by removing a significant recycled source of phosphorus and ammonia-nitrogen from the wastewater treatment process.

The experiment was a randomized complete block design with four replications of each of the ten treatments, totaling forty individual plots. The individual plots measured four feet by four feet (16 sq. ft.). Pictures of the experimental plots are available in the Appendix. Fertilizers were applied at a rate of 1 pound of nitrogen (N) per 1000 square feet using hand shakers. The treatments listed in Table 1 were applied on August 10, 2012, September 24, 2012, May 15, 2013, July 3, 2013, and September 13, 2013.

Turfgrass color index was evaluated weekly using a reflectance meter (CM1000, Spectrum Technologies), which measures the amount of green light reflected from the turf (picture of the device is in the Appendix). Visual turfgrass quality ratings were taken on a weekly basis using a 1 to 9 scale, where a rating of 9 indicates the highest possible turf quality and a 6 is the minimally acceptable quality for a lawn, and 1 represents completely dead turf. One of the main components of visual quality rating is the color of the grass. Other factors include density of the grass and how uniform it appears. Because color is a main factor involved in judging quality, the color index (measured by the handheld unit) and visual quality (based on human judgment) tend to track together, and treatments with high color index tend to have a high visual quality ranking.

Clippings were collected every second week, dried at 60°C for at least 48 hours, and then weighed to estimate clipping yield. The clippings have been saved and will be analyzed collectively for N, P and Fe content shortly. When the results are available, this report will be updated.

<u>Greenhouse Leaching Evaluation and Chemical Characterizations</u>

To evaluate the leaching potential from the fertilizer formulations, perennial ryegrass was grown in a greenhouse setting in columns filled with sand. The columns were 4 inch diameter PVC pipes cut to 12 inches with a drain cap placed on the bottom. The sand was packed by hand into the columns in three inch increments to achieve uniform bulk density. The fertilizer was incorporated into the sand at a rate of 30 g P per m^2 (roughly 3 kg of fertilizer per m^3 of soil), a rate chosen based on similar work by Snyder and Cisar (2008). The columns were seeded on July 23, 2013 and subjected to leaching by applying 1.5 pore volumes (calculated after measuring soil bulk density) of deionized water on August 6, August 19, September 2, September 16, September 30, 2013. The leachate was collected and analyzed using inductively coupled plasma atomic emission spectrometry (ICP-AES) for phosphorus. The percent of applied phosphorus recovered in leachate was calculated.

Water extractable P was determined by shaking a mixture of 1 part biosolids to 200 parts water for one hour on an orbital shaker. The solution was then filtered and analyzed for P using ICP-AES. The percent water soluble P was calculated by dividing the water soluble P by the total P in the biosolids for a measurement of percent water extractable P (Sharpley and Moyer, 2000). Similarly, oxalate-extractable P, Fe, and Al was determined by shaking 0.5 g of biosolids with 30 ML of 0.175 M ammonium oxalate and 0.1 M oxalic acid in a light-free environment (Loeppert and Inskeep, 1997). Oxalate extractable P, Fe, and Al were used to calculate the phosphorus saturation index (PSI), which has been used extensively as an environmental indicator of potential for phosphorus loss from soil or fertilizer to the environment.

Table 1 – Description of fertilizer treatments utilized in the study.

Treatment	Iron (%)	Nitrogen (%)	Milo:Ostara Ratio	Bucket ID (date, N/Fe content)
Sample A	4.02	6.00	N/A	6/19, 5.9N/4.2Fe
Sample B	5.16	6.05	N/A	7/6, 6.03N/5.12Fe
Sample C[1]	3.14	6.37	N/A	7/13, 6.18N/3.26Fe
Sample D	5.15	5.75	N/A	Milo Classic
Sample E	5.82	5.98	N/A	7/7, 5.78N/6.22Fe
Sample F[1]	2.37	6.07	N/A	7/19, 5.25N/2.64Fe
Sample G[1]	1.97	5.97	90:10	7/19+Crystal Green®
Sample H[1]	1.66	5.97	80:20	7/19+Crystal Green®
No fertilizer	N/A	N/A	N/A	N/A
Scotts® Turf Builder®	2.27	32.54[2]	N/A	N/A

Notes: (1) Milorganite comes in large and small granule sizes (Milo Classic and Greens Grade), and contains 5-6% organic nitrogen and at least 4% iron content; therefore, Samples C, F, G and H would be considered "off-spec" Milorganite due to lower iron content.
(2) Scotts® Turf Builder® consists of chemically-formulated nitrogen.
N/A: Not Applicable

3. Field Study Results

Average color index, visual turfgrass quality and clipping weights from August 2012 to July 2013 are gathered in the Table 2. The letters shown after the numerical averages are used to indicate statistical differences (Fisher's Least Significant Difference). Averages with similar letters are considered to be statistically similar, meaning that one is not necessarily better or worse than the other, even though the numbers may be different.

Table 2 - Average color index, visual quality, and clipping weights from August 2012-July 2013. Results followed by different letters within each column are statistically different according to Fisher's Least Significant Difference (alpha=0.05).

Treatment	Color Index*	Visual Quality	Clipping weight
	1-999 (greenest)	1-9 (best)	grams/m^2
Sample A	397 B	6.81 BC	12.86 BC
Sample B	406 B	6.80 BCD	12.29 BC
Sample C	396 B	6.71 CDE	12.57 BC
Sample D (Classic)	397 B	6.62 E	14.14 ABC
Sample E	400 B	6.74 BCDE	12.40 BC
Sample F	394 B	6.71 CDE	11.73 C
Sample G	406 B	6.66 DE	13.14 BC
Sample H	412 AB	6.86 B	15.48 AB
No fertilizer	323 C	5.45 F	5.01 D
Scotts® Turf Builder®	434 A	7.11 A	17.57 A

* Missing measurements from final two rating dates because of equipment failure.

<u>Color Index</u>

Averaged over all measurement dates in 2012 and 2013, the Scotts® Turf Builder® treatment had statistically greater color index than all other treatments, except for sample H, which contained 20% Ostara (as shown in Table 2 with the "A" suffixes). This finding was not surprising because Turf Builder contains approximately 70% water soluble or "quick release" nitrogen, compared to approximately 15% water soluble nitrogen in the Milorganite treatments. In Table 2, Sample H has a color index of 412 with an "AB" after it, which means that it was statistically similar to all treatments with an A or a B, although it is numerically greater than all treatments with a B, and numerically lower than the Scotts treatment. The non-fertilized control treatment had statistically lower color index than all other treatments, as indicated by the unique lettered suffix (C). Although the various Milorganite formulations (A-H) have different numerical values, they all are statistically similar to each other, indicating that under the conditions of the study, the various Milorganite formulations did not significantly affect the color response of the grass. Complete results of color index for each of the individual rating dates are shown in Tables 3A-C.

Table 3A - Turfgrass color index (1-999; 999=greenest) for individual rating dates during late summer and fall 2012. Fisher's Least Significant Difference at alpha 0.05 was 48.0. Differences larger than 48.0 color units are statistically significant.

Treatment	18-Aug	23-Aug	31-Aug	7-Sep	14-Sep	21-Sep	28-Sep	5-Oct	12-Oct	19-Oct	25-Oct	1-Nov	16-Nov
Sample A	417	384	434	408	378	406	364	355	386	388	472	280	276
Sample B	392	350	407	393	384	394	370	341	377	370	439	284	282
Sample C	393	364	401	386	364	382	355	339	368	375	475	297	274
Sample D	388	381	409	390	367	393	357	332	356	369	407	267	270
Sample E	427	385	428	405	383	406	362	341	372	373	418	282	271
Sample F	418	403	442	408	390	414	363	352	384	392	477	275	291
Sample G	384	357	414	390	380	394	357	336	386	387	519	255	293
Sample H	377	369	405	396	371	392	359	351	373	395	510	288	323
Control	380	347	371	350	342	343	321	294	321	296	334	198	214
Scotts	428	430	458	419	385	390	372	410	490	493	539	324	343

Table 3B - Turfgrass color index (1-999; 999=greenest) for individual rating dates during 2013. Fisher's Least Significant Difference at alpha 0.05 was 48.0. Differences larger than 48.0 color units are statistically significant.

Treatment	8-May	21-May	30-May	6-Jun	13-Jun	18-Jun	27-Jun	3-Jul	10-Jul
Sample A	420	433	389	549	390	348	408	317	368
Sample B	419	452	415	574	384	347	422	344	388
Sample C	427	443	410	555	379	330	385	320	370
Sample D	409	445	415	555	377	334	416	341	395
Sample E	422	457	395	544	380	349	401	303	383
Sample F	443	412	394	544	356	330	385	333	380
Sample G	448	470	434	580	363	323	411	320	385
Sample H	480	463	413	581	375	337	416	340	393
Control	302	361	349	436	343	286	292	267	260
Scotts	498	498	411	623	382	339	387	307	454

Table 3C - Turfgrass color index (1-999; 999=greenest) for individual rating dates during 2013. Fisher's Least Significant Difference at alpha 0.05 was 48.0. Differences larger than 48.0 color units are statistically significant.

Treatment	July 17	July 24	July 31	Aug 7	Aug 14	Aug 21	Aug 28	Sept 5	Sept 12	Sept 19	Sept 26
Sample A	337	410	357	391	414	383	414	425	403	549	455
Sample B	371	443	363	414	465	414	434	477	442	590	445
Sample C	332	412	351	413	438	404	434	453	432	561	460
Sample D	355	422	358	405	445	421	433	442	431	566	452
Sample E	352	430	367	394	430	394	428	460	434	575	445
Sample F	338	392	354	373	393	350	405	420	414	550	436
Sample G	336	444	376	422	458	405	428	449	422	569	499
Sample H	367	456	375	452	456	431	436	441	433	582	473
Control	209	295	280	312	332	323	325	379	348	453	400
Scotts	418	479	391	393	441	400	422	453	421	621	490

Visual Quality

As expected, turfgrass visual quality results mirrored those of color index, although more statistical differences were detected. Averaged over the study period, Scotts® Turf Builder® had statistically greater quality than all other treatments, while the non-fertilized control had the lowest visual quality, significantly lower than all other treatments (Table 2). Among the Milorganite formulations, Samples A, B, E, and H had the greatest average visual quality and were statistically similar to each other. Sample H had significantly greater visual quality than Samples C, D, F, and G. Interestingly, Sample D (Milorganite Classic) had the lowest average visual quality of all the Milorganite samples, but was statistically similar to Samples C, E, F, and G. These results suggest, under the conditions of this study, that the modifications to the formulation that were evaluated would not be expected to have a negative impact on visual turfgrass quality. Complete results of visual quality for each of the individual rating dates are shown in Tables 4A-4B.

Table 4A - Turfgrass Visual Quality (1-9, 9=best, 6=minimally acceptable) for individual dates during late summer and fall 2012. Fisher's Least Significant Difference at alpha 0.05 was 0.75. Differences equal to or larger than 0.75 quality units are statistically significant.

Treatment	18-Aug	23-Aug	31-Aug	7-Sep	14-Sep	21-Sep	28-Sep	5-Oct	12-Oct	19-Oct	25-Oct	1-Nov	16-Nov
Sample A	7.0	7.0	6.8	6.8	6.8	6.5	6.3	6.8	6.0	6.0	6.0	5.8	6.3
Sample B	6.8	6.5	6.5	6.5	7.5	6.8	5.8	6.5	5.5	6.0	6.0	5.8	6.3
Sample C	6.8	6.5	6.3	6.3	7.0	6.3	6.3	6.5	5.8	5.8	6.0	6.0	6.0
Sample D	6.8	6.3	6.5	6.3	7.0	6.3	5.5	6.5	5.8	5.8	5.5	5.5	5.8
Sample E	7.0	6.5	6.8	6.8	7.3	6.8	5.8	6.8	5.8	5.8	5.5	6.0	5.8
Sample F	6.8	7.0	6.8	6.8	7.3	7.3	6.3	6.8	6.0	6.0	6.0	5.8	6.0
Sample G	6.8	6.0	6.5	6.0	6.3	6.8	5.8	6.8	6.0	5.8	5.8	5.5	6.0
Sample H	6.8	6.8	7.0	6.0	7.3	6.8	5.8	6.5	6.0	5.8	6.3	5.3	6.8
Control	6.5	6.5	6.8	6.0	6.5	6.0	5.8	6.0	5.5	5.0	5.0	5.5	4.3
Scotts	7.5	7.3	6.8	6.5	6.8	6.8	6.3	7.3	6.8	6.8	6.8	6.0	7.0

Table 4B - Turfgrass Visual Quality (1-9, 9=best, 6=minimally acceptable) for individual dates during 2013. Fisher's Least Significant Difference at alpha 0.05 was 0.75. Differences equal to or larger than 0.75 quality units are statistically significant.

Treatment	8-May	21-May	30-May	6-Jun	13-Jun	18-Jun	27-Jun
Sample A	6.5	6.8	7.8	7.0	7.5	7.0	7.0
Sample B	6.0	6.8	7.0	7.0	7.3	7.0	7.0
Sample C	6.0	6.8	7.3	6.8	7.8	6.8	7.0
Sample D	6.3	6.5	7.0	6.8	7.0	7.0	6.8
Sample E	6.3	6.8	7.3	6.5	7.0	7.0	6.8
Sample F	6.5	6.5	7.3	6.8	6.8	7.0	7.3
Sample G	6.8	7.0	7.3	6.8	7.0	6.5	6.8
Sample H	6.8	7.5	7.3	7.0	7.5	7.0	7.0
Control	5.0	5.0	6.0	4.8	6.8	5.3	5.3
Scotts® Turf Builder®	6.8	8.0	7.8	7.3	7.5	6.8	7.5

Table 4C - Turfgrass Visual Quality (1-9, 9=best, 6=minimally acceptable) for individual dates during 2013. Fisher's Least Significant Difference at alpha 0.05 was 0.75. Differences equal to or larger than 0.75 quality units are statistically significant.

Treatment	July 3	July 10	July 17	July 24	July 31	Aug 7	Aug 14
Sample A	6.5	6.8	6.5	7.3	8.0	7.0	7.0
Sample B	6.8	7.0	6.3	7.0	7.8	7.0	7.8
Sample C	7.0	7.0	5.5	6.8	8.0	7.0	7.3
Sample D	6.8	6.8	6.0	6.5	8.0	7.0	7.5
Sample E	6.8	6.8	6.0	7.0	7.5	7.3	7.8
Sample F	6.8	6.8	6.0	6.5	7.8	7.0	7.0
Sample G	7.0	6.8	6.0	7.0	7.5	7.5	7.3
Sample H	6.8	7.0	6.0	7.3	7.8	7.3	7.8
Control	5.0	4.8	4.3	4.8	5.3	5.8	5.0
Scotts® Turf Builder®	6.3	7.8	7.3	7.8	7.5	7.3	7.5

Table 4D - Turfgrass Visual Quality (1-9, 9=best, 6=minimally acceptable) for individual dates during 2013. Fisher's Least Significant Difference at alpha 0.05 was 0.75. Differences equal to or larger than 0.75 quality units are statistically significant.

Treatment	Aug 21	Aug 28	Sept 5	Sept 12	Sept 19	Sept 26	Oct 2	Oct 18
Sample A	6.8	7.5	6.8	6.5	6,8	6.8	7.5	7.5
Sample B	7.8	7.8	7.3	7.5	6.8	6.3	7.3	7.3
Sample C	7.5	7.8	7.0	7.8	6.3	6.3	7.3	7.0
Sample D	7.5	7.3	7.0	7.3	7.0	6.5	7.3	7.0
Sample E	7.5	7.8	7.0	7.3	6.3	7.3	7.0	7.3
Sample F	7.3	7.0	6.8	7.0	6.5	6.5	6.8	6.8
Sample G	7.0	7.5	6.8	7.0	6.5	6.3	7.5	7.8
Sample H	7.5	7.8	7.0	7.3	6.5	7.0	7.3	7.5
Control	5.3	5.3	5.5	5.5	5.0	5.3	5.8	5.3
Scotts® Turf Builder®	7.5	7.8	7.0	6.8	6.8	7.3	7.0	7.8

Clipping Yield

When averaged over the several clipping collection events in 2012 and 2013, the Scotts® Turf Builder® treatment produced the greatest amount of clippings**,** statistically greater than all but Sample H. The non-fertilized control produced the statistically fewer clippings than all treatments. The Milorganite treatments all were statistically similar with regard to clipping yields, with the only exception that Sample H produced significantly more clippings than sample F. These results closely mirror the results of color index.

Table 5A - Turfgrass clipping yield from three collection dates in 2012. Clippings were collected from a 6 sq. ft. area from each plot. Results followed by different letters within columns are statistically different according to Fisher's Least Significant Difference (alpha=0.05).

Treatment	August 24	September 10	September 24
	-----------------------------	g dry tissue/m^2	-----------------------------
Sample A	14.68 A	7.68 AB	4.50 A
Sample B	12.55 A	8.41AB	5.59 A
Sample C	12.45 A	7.50 AB	7.14 A
Sample D	13.82 A	8.27 AB	6.80 A
Sample E	11.05 A	7.36 AB	3.72 A
Sample F	16.10 A	9.77 A	5.91 A
Sample G	13.77 A	6.95 AB	6.06 A
Sample H	9.95 A	6.55 AB	6.55 A
No fertilizer	10.36 A	5.05 B	4.49 A
Scotts® Turf Builder®	18.68 A	8.68 AB	6.07 A

Table 5B - Turfgrass clipping yield from four collection dates in 2013. Clippings were collected from a 6 sq. ft. area from each plot. Results followed by different letters within columns are statistically different according to Fisher's Least Significant Difference (alpha=0.05).

Treatment	May 29	June 14	June 28	July 10	July 24
Sample A	3.45 BC	9.72 ABC	17.82 ABC	4.95 BC	30.22 BC
Sample B	4.50 BC	9.64 ABC	19.0 ABC	5.18 BC	19.55 CD
Sample C	3.32 BC	7.86 ABC	15.5 C	4.27 BC	31.82 BC
Sample D	3.63 BC	10.45 AB	16.18 BC	4.50 BC	32.64 BC
Sample E	2.50 CD	7.54 ABC	16.00 BC	3.54 CD	31.72 BC
Sample F	2.59 BCD	6.77 BC	15.63 C	3.50 CD	25.41 BC
Sample G	3.82 BC	9.09 ABC	20.72 ABC	4.09 BC	30.41 BC
Sample H	4.68 B	12.54 A	22.41 AB	7.05 AB	36.50 B
No fertilizer	0.55 D	4.36 C	5.82 D	0.91 D	8.86 D
Scotts® Turf Builder®	10.86 A	11.05 AB	23.45 A	9.05 A	52.5 A

Table 5C - Turfgrass clipping yield from four collection dates in 2013. Clippings were collected from a 6 sq. ft. area from each plot. Results followed by different letters within columns are statistically different according to Fisher's Least Significant Difference (alpha=0.05).

Treatment	Aug 6	Aug 23	Sept 5	Sept 20	Oct 2
Sample A	14.77 A	12.55 AB	13.00 A	24.33 BC	9.09 B
Sample B	14.36 A	16.95 A	15.95 A	29.55 ABC	10.86 AB
Sample C	12.55 A	13.72 AB	13.82 A	24.18 BC	8.82 B
Sample D	15.68 A	16.50 A	15.91 A	27.59 ABC	10.55 AB
Sample E	11.95 A	15.27 AB	14.13 A	26.59 ABC	8.55 B
Sample F	11.72 A	11.27 B	12.54 A	23.36 C	7.68 B
Sample G	12.63 A	13.77 AB	12.82 A	27.77 ABC	8.55 B
Sample H	18.05 A	17.00 A	17.27 A	30.50 AB	11.23 AB
No fertilizer	4.00 B	5.77 C	5.09 B	7.91 D	2.09 C
Scotts® Turf Builder®	11.82 A	15.77 AB	13.90 A	31.27 A	13.00 A

Nutrient Uptake

All fertilized treatments had significantly greater nitrogen uptake than the non-fertilized control treatment (Table 6). Among the fertilized treatments, Scotts Turf Builder had the greatest nitrogen uptake at 89.3 lbs/acre, but was statistically similar to Sample A (61.9 lbs/acre) and Sample H (77.6 lbs/acre). Of the Milorganite treatments, Sample F had the lowest total N uptake (56.5 lbs/acre), statistically lower than Samples A and H. Other than that exception, all Milorganite samples had statistically similar nitrogen uptake. Trends for phosphorus, potassium, and iron uptake were very similar to those of nitrogen. All Milorganite treatments had similar phosphorus and potassium uptake, with the exception of Sample F, which had significantly less phosphorus uptake than Sample H. All fertilizers had increased iron uptake relative to the non-fertilized control, except Sample F, and all fertilized treatments were statistically similar in that regard.

Table 6 - Clippings were analyzed for nutrient content. By multiplying nutrient content (i.e. % nitrogen in tissue) by the total tissue removed (from the yields reported in Table 5), the total nutrient uptake over the entire study period was calculated and is reported below for nitrogen, phosphorus, potassium, and iron. Results followed by different letters within columns are statistically different according to Fisher's Least Significant Difference (alpha=0.05).

Treatment	Nitrogen	Phosphorus	Potassium	Iron
	lbs/acre	lbs/acre	lbs/acre	oz/acre
Sample A	61.9 AB	7.7 ABC	33.6 BC	4.9 A
Sample B	66.2 BC	7.9 ABC	36.0 BC	5.5 A
Sample C	61.8 BC	7.0 BC	32.7 BC	4.8 A
Sample D	67.9 BC	8.0 ABC	37.1 ABC	4.5 A
Sample E	60.2 BC	7.2 ABC	33.1 BC	5.3 A
Sample F	56.5 C	6.4 C	30.2 C	3.4 AB
Sample G	63.4 BC	7.6 ABC	33.9 BC	4.9 A
Sample H	77.6 AB	9.2 A	42.0 AB	5.4 A
No fertilizer	21.2 D	2.6 D	11.6 D	1.4 B
Scotts® Turf Builder®	89.3 A	9.0 AB	46.9 A	4.4 A

Samples Ranking

Table 6 summarizes the averaged results for the experiments from August 2012 to July 2013 with a numerical ranking (far right column) of the treatments from best to worst (1 to 10) for each performance parameter (color, quality and clipping production). This ranking provides a non-statistical sense of how the treatments are trending. This last column ("Relative Composite Rank") represents the ranking averaged over the 3 parameters. Scotts® Turf Builder® is the top treatment according to the rankings, and the non-treated control is the worst performing treatment. Among the other Milorganite treatments, the numerical ranking order from best to worst is as follows: H > A > B = G > E > D > C > F. It is important to note that these rankings may place undue emphasis on numerical values and should not be confused with actual statistical analysis shown in Tables 2, 3, 4, and 5. For example, if we compare sample H (top numerical ranking) to sample D (Milorganite Classic, ranked third from the bottom ranked), we find that H has statistically similar color, and clipping yield as Sample D, but has statistically greater visual quality. The numerical rankings suggest these two products are far apart, but the statistical summary suggests (correctly) that these products can be expected to perform similarly in two out of the three respects.

Comment on Performance of Crystal Green

Crystal Green was added to Sample F at either 10% (Sample G) or 20% (Sample H) by weight. Interestingly, Sample F performed relatively poorly across all evaluated parameters, although usually not statistically different than Milorganite Classic (Sample D). However, Sample H, which was Sample F + 20% Crystal Green, was consistently at or near the top of the relative rankings. Sample G (Sample F + 10% Crystal Green) was intermediate in performance. Therefore, there we observed a linear increase in performance of Sample F with increasing Crystal Green additions. This suggests that Crystal Green could be used to further improve Milorganite performance. However, we noticed strong segregation of the Milorganite and Crystal Green products when mixed together, likely due to the differences in particle size between the products. An ideal fertilizer blend for would have minimal segregation.

Table 6 - Composite ranking of treatments based on color, quality, and clipping production from August 2012 – July 2013. Relative composite rank is the average of the individual rankings for each parameter. Note: Numerical ranking only reflects sum of the numerical findings; however, they do not constitute a statistically significant difference.

Sample ID	Iron Content	Nitrogen Content	Color Index (1 = best; 10 = worst)		Visual Quality (1 = best; 10 = worst)		Plant Yield (1 = highest; 10 = lowest)		**Relative Composite Rank**
			Value	Rank	Value	Rank	Qty. (g)	Rank	
A	4.02	6.00	397 B	6	6.81 BC	3	12.86 BC	5	**4.7 (3)**
B	5.16	6.05	406 B	3	6.80 BCD	4	12.29 BC	8	**5.0 (t-4)**
C	3.14	6.37	396 B	8	6.71 CDE	6	12.57 BC	6	**6.7 (8)**
D	5.15	5.75	397 B	6	6.62 E	9	14.14 ABC	3	**6.0 (7)**
E	5.82	5.98	400 B	5	6.74 BCDE	5	12.40 BC	7	**5.7 (6)**
F	2.37	6.07	394 B	9	6.71 CDE	6	11.73 C	9	**8.0 (9)**
G (10% Crystal Green)	1.97	5.97	406 B	3	6.66 DE	8	13.14 BC	4	**5.0 (t-4)**
H (20% Crystal Green)	1.66	5.97	412 B	2	6.86 B	2	15.48 AB	2	**2.0 (2)**
No fertilizer	N/A	N/A	323 C	10	5.45 F	10	5.01 D	10	**10 (10)**
Scotts Turf Builder	2.27	32.54	434 A	1	7.11 A	1	17.57 A	1	**1 (1)**

4. Greenhouse and Laboratory Results

Phosphate binds readily to iron and aluminum, which leads to a decrease in water solubility of phosphorus in a material or solution containing iron (Fe) and aluminum (Al). Because the experimental formulations contain different levels of Fe (Table 7), we wanted to determine if this had any effect on the P characteristics of the fertilizers. The first three data columns in Table 7 show the phosphorus and iron levels of the various fertilizers. P_2O_5 is the form of P that is used for fertilizer labelling purposes. The total P can be calculated from P_2O_5 by multiplying by 0.437.

Total water soluble P of the fertilizers was measured. The Crystal Green fertilizer had significantly more total water soluble P than all Milorganite formulations. The Milorganite fertilizers tended to be statistically similar, although sample F had significantly greater water soluble P than samples D and E. Sample F also contained the lowest Fe content of all Milorganite samples at 2.37%. The Phosphorus Saturation Index (PSI) is often used to estimate the P loss potential from soils, and higher the PSI, the greater potential for P losses from the soil. The PSI is calculated by dividing the oxalate extractable P extracted by the oxalate extractable Fe + Al. From Table 7, we find that the samples with the lowest Fe content tend to have a higher PSI, and the samples with the highest Fe content tend to have a lower PSI.

The results indicate, unsurprisingly, that changes to the composition of the biosolids product lead to quantifiable changes in the chemical properties of the materials. However, the more interesting question was whether or not these chemical changes would affect the grass growth or the susceptibility to nutrient leaching. In the greenhouse column evaluation, we grew perennial ryegrass on four inch diameter, twelve inch depth columns of sand. To simulate a worst case scenario, we mixed the sand with a large amount of P from the Milorganite and Crystal Green fertilizers. Then, every two weeks we subjected the columns to a leaching event by applying enough water to force drainage. We generated a total of five leaching events over the study period and analyzed the leachate for P. The results indicated that less than 0.5% of the P applied was recovered in the drainage from the Milorganite treatments, which were statistically similar to each other (Table 7). Significantly more P was recovered from the Crystal Green treatment, although still less than 10%. These results suggest that even though statistically significant chemical differences in water soluble P and PSI could be quantified in the laboratory, the differences did not translate to the greenhouse leaching experiment, which suggests that the chemical differences were too small to create an observable difference under the conditions of the study.

Table 7 - Summary of results from chemical characterization and leaching experiment

Sample ID	Total P_2O_5	Total P	Total Fe	Total Water Soluble P	Phosphorus Saturation Index	Phosphorus Leached in Greenhouse Study
	%	%	%	%	unitless	% of applied
A	4.3	1.88	4.02	0.059 BC	54.3 E	0.20 B
B	4.7	2.05	5.16	0.098 BC	61.6 C	0.11 B
C	5.1	2.23	3.14	0.084 BC	66.6 B	0.23 B
D	5.4	2.36	5.15	0.046 C	49.6 F	0.17 B
E	4.7	2.05	5.82	0.033 C	58.0 D	0.13 B
F	4.4	1.92	2.37	0.127 B	84.6 A	0.45 B
Crystal Green	28.0	12.2	0.0*	0.41 A	N/A**	9.47 A

* Estimated; Fe content not measured.

** Because Crystal Green does not have appreciable iron or aluminum content, the Phosphorus Saturation Index (which is oxalate extractable P / Fe + Al) cannot be calculated.

5. Conclusions

Based on the results of this evaluation, the following conclusions can be made:

1. Relative to Milorganite Classic (Sample D), the modifications to the Milorganite formulation (including the addition of Crystal Green) did not negatively influence the color, visual quality, clipping yield, or nutrient uptake of a Kentucky bluegrass lawn on a silt loam soil in Wisconsin.

2. Based on the clear improvement of the performance of Sample F through additions of Crystal Green (10% in Sample G and 20% in Sample H), Crystal Green has potential as a future additive to Milorganite products. However, the two products exhibit strong segregation which would need to be addressed first.

3. Significant differences in water soluble P content and phosphorus saturation index were observed, and products containing lower total iron content tended to have greater water solubility and phosphorous saturation index.

4. While differences in P solubility and saturation index were observed among the Milorganite samples, these chemical differences did not result in significant differences in phosphate leaching from a greenhouse study involving sand columns.

Appendix: Pictures from the O.J. Noer Turfgrass Research Facility in Madison, WI

Pictures below were taken during a field visit on June, 20 2013:

Pictures 1, 2 and 3: Overview of the experiments plots

Picture 4: Focus on a row (4 samples)

Picture 5: Color Index measure