RESEARCH ON SOIL FERTILITY IN SUGARCANE PRODUCTION

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Summary

Field trials were conducted in 2019 to evaluate cane and sugar yield responses to (1) phosphorus (P), sulfur (S), and silicon (Si) fertilization, and (2) biostimulant application. A study on the impact of different ratios of monoammonium phosphate (MAP, 11-52-0) and EXPCRG® (5-28-0-10% Mg, Mosaic Co.) on sugarcane yield and quality components was established at two locations at the Sugar Research Station in St. Gabriel. The treatments consisted of different ratios of MAP and EXPCRG with a target rate of 50 lbs P/ac: 0:0 (control), 100:0, 0:100, 75:25, 50:50 and 25:75. For the S study, the treatment structure consisted of a control, different MST®-based fertilizers from Sulvaris (Phosphate MST WS, Potash MST, Liquid MST) and ammonium thiosulfate (NH_4 thiosulfate) applied at 25 lbs S/ac (Site 1 in St. Gabriel) and 40 lbs S/ac (Sites 2 and 3 in St. Gabriel, and Site 4 in Napoleonville). The Si study was established at two locations with the following treatments: control, wollastonite at 2 ton/ac, and foliar application of Zumsil-AgroSil solution. The treatment structure of the biostimulant study consisted of 3-split and one-time application of Symbiotic AGx solution and a control, with and without winter cover crops. Yield, quality components, and nutrient content of leaf, shredded stalk, and soil samples were determined. There was a significant sugar yield response to P application at Site 1 with 100:0 MAP:EXPCRG- treated plot having the highest yield at 11,511 lbs/ac, which was about 25% or 2,500 lbs/ac higher than the control. This was followed by the plot treated with 25:75 MAP:EXPCRG. The EXPCRG-treated plots were able to maintain a higher level of soil P for a longer period than MAP-treated plots. In reference to the control, sugar yield was increased by 19.5%, 14%, and 10% with Liquid MST, Phosphate MST, and Potash MST application, respectively. These increases were comparable to the 14.7% increase in sugar yield due to NH_4 thiosulfate application. All of these suggest that these MST-based fertilizers are potential S sources for sugarcane production in Louisiana. Wollastonite application was effective in increasing soluble soil Si but significant increase in cane and sugar yield was observed only at the location where the 1st ratoon crop was planted. The 3-split application of AGx increased cane and sugar yield by 4.4 ton/ac (13%) and 772 lbs/ac (12%), respectively (p<0.1). Changes in soil chemical parameters in response to the treatments were due to cover cropping rather than AGx application. Nevertheless, the few responses that can be attributed to AGx application such as increased in soil pH, P, K, Mg, and S can partly explain the positive impact (of AGx application) on sugarcane productivity.

Objective

This research was designed to evaluate different P, S, and Si fertilizer sources, and the potential of biostimulant application in sugarcane production. This annual progress report is presented to provide the latest available data on certain nutrient management practices and not as final recommendation for growers to use.

Results

Effect of Different Ratios of MAP and EXPCRG® Application

The results on the analysis of variance (ANOVA), and average of yield and quality components for the two sites in St. Gabriel are presented in Table 1. Plots applied with P regardless of MAP:EXPCRG ratios obtained numerically higher cane yield compared with the control plots. The cane yield for the treated plots ranged from 51.7 – 56.7 ton/ac for Site 1 and 33.6 – 35.0 ton/ac for Site 2 while the control plots obtained 50.3 ton/ac and 32 ton/ac for Site 1 and Site 2, respectively. On the other hand, mean sugar yield across the treatments was significantly different for Site 1 (p-value = 0.062) wherein the application of 100% MAP showed the highest value at 11,511 lbs/ac. For Site 2, there was no significant treatment effect observed on sugar yield (p-value = 0.546). A significant effect of the treatments ($p<0.1$) was observed on theoretical recoverable sugar (TRS) and sucrose but only at Site 1. Cane applied with 100% MAP and MAP:EXPCRG at 25:75 ratio obtained the highest TRS and sucrose values at >200 lbs/ton and ~15%, respectively. The TRS, Brix, and sucrose at Site 2 had no response to the treatments.

Soil P was significantly increased in P-treated plots at 30 days after treatment application (DAT) and at harvest but only for Site 1 (Table 1). Soil P levels at Site 2 tended to increase with MAP and EXPCRG application. While the initial soil P at both sites was below the 35 mg/kg critical P level for Louisiana soils, the lack of sugarcane response at Site 2 may be partly due to its higher initial soil P level at 26.8 mg/kg compared to the 16.2 mg/kg measured at Site 1. Based on soil P response, the performance of EXPCRG as a P fertilizer is comparable to MAP. In fact, the EXPCRG-treated plots were able to maintain a higher level of soil P for a longer period than MAP-treated plots.

There was no significant treatment effect observed on P and Mg content of leaf at midseason and at harvest (Table 2). Similarly, stalk P and Mg concentration was not affected by MAP:EXPCRG ratio. However, there were differences in the amount of P and Mg removed per ton of cane at Site 1 with 100:0 MAP:EXPCRG-treated cane recording the highest level ($p<0.1$). Similar result was obtained at Site 2 except that only the amount of Mg removed by stalk was detected significant at p-value = 0.021.

Sugarcane Response to Different Sulfur Sources

Table 3 summarizes the results on the ANOVA on cane yield and quality components. There was a significant treatment effect observed on cane yield at Site 3 and 4, and on sugar yield on Sites 2-4 ($p<0.1$). The performance of MST-based fertilizers varied across the sites. Liquid MST-treated sugarcane recorded the lowest level of cane at Site 3 whereas this treatment along with Phosphate MST and NH_4 thiosulfate obtained the highest cane yield at Site 4. Based on sugar yield response, the performance of Liquid MST, Potash MST, and Phosphate MST was comparable to NH_4 thiosulfate which is a common source of S in Louisiana sugarcane production systems. In reference to the control, sugar yield was increased by: 16% (909 lbs/ac) and 23% (1761 lb/ac) with the application of Liquid MST at Site 2 and Site 4, respectively; 16% (913 lbs/ac), 8% (867 lbs/ac), and 20% (1563 lbs/ac) with NH_4 thiosulfate application at Site 2, Site 3, and Site 4, respectively; 16% (908 lb/ac) and 12% (896 lbs/ac) with Phosphate MST application at Site 2 and Site 4, respectively; and 12% (1260 lbs/ac) and 8% (594 lbs/ac) with the application of Potash MST at Site 3 and Site 4, respectively. The improvement in sugar yield was largely attributed to improved cane tonnage. There were significant differences observed on quality components at Site 2 and Site 4. The application of S particularly the Liquid MST was beneficial in improving TRS and % sucrose at Site 4 but other than this, S fertilization appeared to have no positive impact on cane quality components.

There were indications that the application of MST-based fertilizers was effective in improving S nutrition of sugarcane. Similar to NH_4 thiosulfate, the application of MST-based fertilizers resulted in improvement in soil S (Table 4). It is notable that the soil treated with Liquid MST had the highest S across sites at 30 DAT. The application of Phosphate MST improved both soil P and S at Site 4 but its impact at the other sites was not consistent nor significant. Similarly, the impact of Potash MST application on both soil K and S was observed only at Site 4. There was a large reduction in soil S levels from 30 DAT to harvest mainly due to cane removal and possibly losses via leaching process. Sulfur fertilization regardless of sources improved leaf S content in 3 out of 4 sites at both midseason and harvest samplings ($p<0.1$; Table 5). Among the MST-fertilizers, Liquid and Phosphate were particularly more effective. Phosphate MST application also improved leaf P content at Sites 1, 2, and 4 30 DAT whereas Potash MST application resulted in significant leaf K content increase at Site 1 and 4 ($p<0.1$). Improvement on stalk S content and removal rate was also observed in S-treated cane wherein many cases MST-based fertilizers were comparable with or even exceeded the performance of NH_4 thiosulfate (Table 6).

The recorded yield increases from MST-based fertilizers application were comparable to the 14.7% increase in sugar yield from NH_4 thiosulfate application. The evident increases in yield, and soil and plant S content associated with the application of MST-based fertilizers were indicative of the potential of these products as S fertilizers for sugarcane production in Louisiana. It is important to consider soil S level as a decision tool for S fertilization program to increase the probability of receiving benefits (yield and income) from any investment made on S fertilizer. Further refinement of S fertilizer recommendation can be made base on crop age, cane yield potential, and soil type.

Evaluation of Silicon Sources

There was a significant increase in cane and sugar yield due to wollastonite application at Site 1 (Table 7). The increase in soil Si ($p<0.05$) that was accompanied by an increase in Si content in leaf and stalk demonstrates the positive impact of Si fertilization in cane productivity. This was further supported by the lack of response of soil pH (Table 7), Mehlich-3 extractable nutrients, and cane nutrient uptake (data not shown). Zumsil-AgroSil treated cane showed improvement in both yield and plant Si uptake but the increases were not large enough to separate it from the control nor the wollastonite treatment. Essentially, the effect of wollastonite and Zumsil-AgroSil on cane productivity was similar. At Site 2, soil Si content was increased by wollastonite application. However, no significant yield response was observed.

Effect of Biostimulant Application on Sugarcane Productivity

Yield and quality components of L01-299 2^{nd} ratoon cane in response to AGx foliar application with and without cover crops are reported in Table 8. There was no interaction effect of AGx application and cover crops observed on yield and quality component. The AGx foliar application significantly increased cane tonnage by 13% (4.4 tons/ac) when applied in splits. Sugar yield was increased by 12% (>700 lbs/ac) with AGx application regardless of the number of application, i.e. 3-split and one-time. AGx application had no effect on quality components but the one-time application of AGx tended to be higher than the control and the 3-split AGx treatment. The presence of cover crops significantly reduced both cane tonnage and sugar yield but improved the cane quality components.

There were significant main and interaction effects observed on post-foliar soil chemical properties (Table 9). The general trend indicates that the soil pH, base cations (K, Ca and Mg) and Cu were higher in plots treated with AGx than the control with one-time application being consistently higher (p<0.1) than the control. It is notable that soil P and S levels were significantly reduced with one-time application of AGx. With the exception of Zn, there were differences in soil nutrient content between with and without cover crops treatments. The interaction effect indicated that the impact of one-time AGx application on base cations and Cu levels were higher in the presence of cover crops. Most of these effects, if not all, were observed or carried over to post-harvested soil samples (Table 10).

The AGx treatment had no significant effect on stalk nutrient composition and removal rate (Tables 11 and 12). On the other hand, cover cropping significantly reduced stalk Ca, Mg, and S concentration and uptake while stalk P and Zn contents and uptake were increased. The significant interaction effect indicated that with one-time AGx application, the presence of cover crops resulted in reduction in stalk Mg and Mn content and uptake; however, P uptake by stalk was increased.

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Table 1. Sugarcane yield, quality components, and soil Mg and P levels in response to different ratios of MAP:EXPCRG at two locations at the Sugar Research Station, St. Gabriel, LA, 2019

MAP:EXPCRG	**Cane yield**	**Sugar yield**	**Brix**	**TRS**	**Sucrose**	**Soil P, mg/kg**		**Soil Mg, mg/kg**	
	ton/ac	**lbs/ac**	**%**	**lbs/ton**	**%**	**30 DAT**	**Harvest**	**30 DAT**	**Harvest**
Site 1 (L01-299 Plant Cane, Silt loam)									
0:0	50.3	9,596 B	190 B	17.98	14.52 AB	16.25 B	10.33 C	223	228
100:0	55.0	11,511 A	208 A	18.04	14.92 A	36.33 A	20.28 B	242	247
0:100	53.0	10,107 B	190 B	17.82	14.00 B	30.24 A	32.64 A	274	253
75:25	56.7	10,284 B	182 B	17.80	13.13 C	34.61 A	16.75 BC	251	238
50:50	51.7	9,707 B	188 B	17.63	13.88 BC	39.44 A	23.70 B	253	250
25:75	52.3	10,606 AB	202 A	17.96	14.63 AB	33.93 A	21.42 B	237	230
***p*-value**	**0.207**	**0.062**	**0.003**	**0.586**	**0.016**	**0.030**	**0.002**	**0.118**	**0.389**
Site 2 (L01-299 Plant Cane, Silty clay loam)									
0:0	32.0	5,504	172	17.55	13.10	26.77	30.70	377	368
100:0	34.7	5,824	168	17.50	12.36	36.38	39.92	381	360
0:100	33.6	5,951	177	17.66	13.33	37.99	44.27	381	372
75:25	34.4	5,884	172	17.47	12.43	32.61	38.17	390	361
50:50	35.0	6,132	175	17.35	13.18	32.50	40.20	368	363
25:75	34.0	5,855	172	17.50	13.10	35.44	40.00	390	373
***p*-value**	**0.182**	**0.546**	**0.874**	**0.652**	**0.186**	**0.273**	**0.414**	**0.831**	**0.952**

TRS – theoretical recoverable sugar
MAP:EXPCRG – ratios of monoammonium phosphate and EXPCRG applied. The P rate is 50 lbs/acre.
DAT – days after treatment application

Table 2. Chemical properties of soil treated with different ratios of MAP:EXPCRG at two locations at the Sugar Research Station, St. Gabriel, LA, 2019

MAP:EXPCRG	% in Leaf 30 DAT		% in Leaf at Harvest		% in Stalk at Harvest		Removal Rate by Stalk, lbs/ton	
	Mg	**P**	**Mg**	**P**	**Mg**	**P**	**Mg**	**P**
Site 1 (L01-299 Plant Cane, Silt loam)								
0:0	0.175	0.187	0.121	0.086	0.027	0.037	0.150 BC	0.525 C
100:0	0.175	0.212	0.124	0.092	0.034	0.043	0.220 A	0.752 A
0:100	0.177	0.205	0.116	0.105	0.026	0.041	0.158 BC	0.686 AB
75:25	0.183	0.205	0.120	0.093	0.028	0.039	0.145 BC	0.579 BC
50:50	0.168	0.195	0.117	0.089	0.030	0.039	0.181 AB	0.707 AB
25:75	0.167	0.193	0.122	0.097	0.024	0.038	0.119 C	0.500 C
***p*-value**	**0.781**	**0.279**	**0.673**	**0.517**	**0.208**	**0.831**	**0.095**	**0.072**
Site 2 (L01-299 Plant Cane, Silty clay loam)								
0:0	0.157	0.228	0.135	0.097	0.067	0.078	0.338 B	1.283
100:0	0.150	0.223	0.132	0.102	0.069	0.083	0.425 A	1.481
0:100	0.154	0.216	0.136	0.109	0.067	0.079	0.370 B	1.306
75:25	0.156	0.225	0.131	0.113	0.067	0.076	0.366 B	1.213
50:50	0.154	0.223	0.130	0.112	0.066	0.083	0.350 B	1.423
25:75	0.151	0.218	0.127	0.105	0.066	0.085	0.355 B	1.444
***p*-value**	**0.942**	**0.588**	**0.911**	**0.697**	**0.965**	**0.514**	**0.021**	**0.158**

MAP:EXPCRG – ratios of monoammonium phosphate and EXPCRG applied. The P rate is 50 lbs/acre.

DAT – days after treatment application

Table 3. Cane tonnage, sugar yield, and quality component of sugarcane treated with different sulfur sources, St. Gabriel (Sites 1-3) and Napoleonville (Site 4), LA, 2019.

Treatment	Cane Yield ton/ac	Sugar Yield lbs/ac	Brix %	TRS %	Sucrose %
Site 1, L01-299 2nd Ratoon					
Control	41.6	6943	16.6	167	12.6
Potash MST	42.0	7553	17.2	180	11.3
Liquid MST	41.5	6876	16.6	166	12.5
Phosphate MST	47.1	8006	16.8	171	12.8
NH_4 Thiosulfate	43.0	7468	17.0	173	13.0
***p*-value**	**0.460**	**0.280**	**0.906**	**0.559**	**0.868**
Site 2, L01-299 2nd Ratoon					
Control	34.2	5821 B	16.3 A	167 A	12.5 A
Potash MST	35.8	5703 B	15.6 B	157 B	11.6 B
Liquid MST	38.3	6730 A	16.6 A	173 A	12.9 A
Phosphate MST	38.5	6729 A	16.6 A	171 A	12.8 A
NH_4 Thiosulfate	38.6	6734 A	16.2 A	172 A	12.4 A
***p*-value**	**0.510**	**0.058**	**0.012**	**<0.001**	**0.009**
Site 3, L01-299 Plant Cane					
Control	52.3 BC	10353 B	17.8	201	14.4
Potash MST	59.5 A	11613 A	17.5	197	14.2
Liquid MST	47.9 C	9290 C	17.8	196	14.2
Phosphate MST	50.8 C	10224 B	18.3	203	14.7
NH_4 Thiosulfate	56.9 A	11220 A	17.7	199	13.6
***p*-value**	**0.023**	**0.002**	**0.283**	**0.895**	**0.685**
Site 4, L01-299 1st Ratoon					
Control	36.8 B	7677 D	17.9	212 CD	14.8 BC
Liquid MST	41.4 A	9438 A	18.4	230 A	15.8 A
NH_4 Thiosulfate	42.5 A	9241 A	17.9	220 BC	14.8 BC
Phosphate MST	41.5 A	8573 BC	17.8	209 D	14.6 BC
Potash MST	40.4 AB	8271 C	17.6	208 D	14.3 C
p-value	**0.004**	**<0.001**	**0.671**	**0.001**	**0.021**

TRS – theoretical recoverable sugar

Table 4. Mehlich-3 extractable P, K, and S, and pH of soil treated with different sulfur sources, St. Gabriel (Sites 1-3) and Napoleonville (Site 4), LA, 2019.

Treatment	**30 DAT**				**Harvest**			
	pH	**P, mg/kg**	**K, mg/kg**	**S, mg/kg**	**pH**	**P, mg/kg**	**K, mg/kg**	**S, mg/kg**
Site 1, L01-299 2nd Ratoon								
Control	5.7 ABC	36.0	139	13.3 D	5.4 BC	31.1 B	145	11.5 C
Potash MST	5.6 BCD	31.9	144	14.5 CD	5.6 ABC	31.6 B	149	12.9 AB
Liquid MST	5.4 D	36.0	128	25.2 A	5.4 C	33.5 B	142	12.7 AB
Phosphate MST	5.5 CD	37.1	129	13.7 CD	5.3 C	47.0 A	152	13.4 AB
NH_4 Thiosulfate	5.4 D	38.0	133	19.8 B	5.3 C	34.2 B	139	12.4 BC
***p*-value**	**0.024**	**0.669**	**0.69**	<0.001	**0.054**	**<0.001**	**0.53**	**0.042**
Site 2, L01-299 2nd Ratoon								
Control	5.9	33.6	136	13.0 C	5.7	33.7	143 AB	11.2 D
Potash MST	6.0	30.9	142	14.6 BC	5.7	24.2	137 BC	12.4 BCD
Liquid MST	5.6	33.1	141	19.5 A	5.4	37.9	148 A	14.0 A
Phosphate MST	5.8	39.3	141	14.0 BC	5.8	31.8	132 C	11.4 CD
NH_4 Thiosulfate	5.6	34.5	143	18.3 A	5.5	32.0	141 ABC	13.5 AB
***p*-value**	**0.405**	**0.416**	**0.687**	**<0.001**	**0.529**	**0.442**	**0.076**	**0.019**
Site 3, L01-299 Plant Cane								
Control	6.0	16.5	100 A	11.7 CD	6.5	10.8	82	7.45
Potash MST	5.7	21.7	98 A	17.9 AB	5.9	10.9	80	10.89
Liquid MST	5.5	17.1	85 AB	17.7 AB	6.1	10.3	81	8.49
Phosphate MST	6.0	21.7	70 B	11.6 D	6.5	16.0	67	8.01
NH_4 Thiosulfate	5.5	19.9	93 A	21.7 A	6.0	11.7	76	8.50
***p*-value**	**0.887**	**0.496**	**0.093**	**0.016**	**0.865**	**0.589**	**0.637**	**0.162**
Site 4, L01-299 1st Ratoon								
Control	5.7	20.2 B	68 B	16.3 B	5.9 B	14.9 B	70 C	6.77
Liquid MST	6.6	14.1 B	112 A	36.4 A	7.0 A	9.0 B	95 AB	8.16
NH_4 Thiosulfate	6.7	16.8 B	119 A	25.4 AB	7.1 A	9.4 B	77 C	7.65
Phosphate MST	6.5	46.1 A	112 A	39.5 A	6.7 A	31.4 A	70 C	9.39
Potash MST	6.5	16.3 B	133 A	26.5 AB	7.0 A	9.7 B	101 A	28.19
p-value	**0.159**	**<0.001**	**0.005**	**0.184**	**0.049**	**0.009**	**0.016**	**0.44**

DAT – days after treatment application

Table 5. Leaf P, K, and S concentration 30 days after treatment application and at harvest, St. Gabriel (Sites 1-3) and Napoleonville (Site 4), LA, 2019

Treatment	% in Leaf at 30 DAT			% in Leaf at Harvest		
	P	**K**	**S**	**P**	**K**	**S**
Site 1, L01-299 2nd Ratoon						
Control	0.272 C	0.991 B	0.158 E	0.181	1.265	0.144 C
Potash MST	0.274 BC	1.102 A	0.189 D	0.180	1.303	0.166 AB
Liquid MST	0.283 ABC	1.003 B	0.194 CD	0.172	1.340	0.172 A
Phosphate MST	0.294 A	0.960 B	0.201 BCD	0.180	1.393	0.175 A
NH_4 Thiosulfate	0.274 BC	0.959 B	0.213 AB	0.175	1.310	0.161 B
***p*-value**	**0.014**	**0.066**	**<0.001**	**0.885**	**0.685**	**<0.001**
Site 2, L01-299 2nd Ratoon						
Control	0.273 AB	1.006	0.156 D	0.169	1.207	0.138 C
Potash MST	0.266 B	1.018	0.191 C	0.161	1.180	0.157 AB
Liquid MST	0.274 AB	1.077	0.219 A	0.176	1.229	0.169 A
Phosphate MST	0.282 A	0.994	0.196 C	0.166	1.178	0.154 B
NH_4 Thiosulfate	0.246 C	0.952	0.206 B	0.169	1.221	0.164 AB
***p*-value**	**0.008**	**0.336**	**<0.001**	**0.379**	**0.915**	**0.029**
Site 3, L01-299 Plant Cane						
Control	0.192	1.210	0.171	0.138 C	0.138 C	0.087
Potash MST	0.205	1.154	0.177	0.157 AB	0.157 AB	0.097
Liquid MST	0.197	1.211	0.188	0.169 A	0.169 A	0.103
Phosphate MST	0.207	1.163	0.179	0.154 B	0.154 B	0.101
NH_4 Thiosulfate	0.195	1.211	0.190	0.164 AB	0.164 AB	0.086
***p*-value**	**0.618**	**0.986**	**0.181**	**0.029**	**0.029**	**0.238**
Site 4, L01-299 1st Ratoon						
Control	0.183 B	0.730 B	0.208 C	0.095 B	0.562 D	0.151 C
Liquid MST	0.154 C	0.922 A	0.235 AB	0.091 B	0.603 CD	0.170 BC
NH_4 Thiosulfate	0.171 BC	0.904 A	0.232 AB	0.093 B	0.684 C	0.184 AB
Phosphate MST	0.212 A	0.947 A	0.235 AB	0.109 A	0.805 A	0.194 A
Potash MST	0.168 BC	0.947 A	0.225 BC	0.093 B	0.796 B	0.187 AB
p-value	**0.002**	**0.021**	**0.0785**	**0.062**	**<0.001**	**0.024**

DAT – days after treatment application

Table 6. Stalk P, K, and S concentration and removal rate as affected by different sulfur sources, St. Gabriel (Sites 1-3) and Napoleonville (Site 4), LA, 2019

Treatment	% in Stalk at Harvest			Removal Rate by Stalk, lbs/ton		
	P	**K**	**S**	**P**	**K**	**S**
Site 1, L01-299 2nd Ratoon						
Control	0.137 A	0.653	0.069 C	0.722 AB	3.43 AB	0.362 C
Potash MST	0.146 A	0.680	0.106 B	0.791 A	3.67 AB	0.571 B
Liquid MST	0.133 AB	0.720	0.124 A	0.707 B	3.82 A	0.660 A
Phosphate MST	0.120 BC	0.566	0.097 B	0.630 BC	2.98 BC	0.511 B
NH_4 Thiosulfate	0.122 BC	0.570	0.104 B	0.660 BC	3.07 B	0.560 B
***p*-value**	**0.008**	**0.146**	**<0.001**	**0.008**	**0.044**	**<0.001**
Site 2, L01-299 2nd Ratoon						
Control	0.133	0.601 C	0.067 D	0.697	3.15BC	0.352 C
Potash MST	0.143	0.753 A	0.109 AB	0.727	3.82 A	0.551 AB
Liquid MST	0.130	0.570 C	0.115 A	0.688	3.02 BC	0.608 A
Phosphate MST	0.134	0.608 C	0.095 C	0.719	3.25 B	0.507 B
NH_4 Thiosulfate	0.125	0.593 C	0.102 ABC	0.654	3.11 BC	0.536 B
***p*-value**	**0.668**	**0.006**	**<0.001**	**0.849**	**0.029**	**<0.001**
Site 3, L01-299 Plant Cane						
Control	0.059	0.444	0.020 BC	0.328	2.49 AB	0.110 B
Potash MST	0.065	0.486	0.030 ABC	0.356	2.66 AB	0.162 AB
Liquid MST	0.053	0.433	0.033 A	0.299	2.43 AB	0.183 A
Phosphate MST	0.060	0.380	0.021 C	0.344	2.18 B	0.119 B
NH_4 Thiosulfate	0.069	0.508	0.038 A	0.387	2.83 A	0.211 A
***p*-value**	**0.361**	**0.472**	**0.048**	**0.415**	**0.577**	**0.050**
Site 4, L01-299 1st Ratoon						
Control	0.085	0.276 B	0.082 B	0.476	1.55 B	0.460 B
Liquid MST	0.077	0.394 A	0.123 A	0.438	2.25 A	0.703 A
NH_4 Thiosulfate	0.083	0.392 A	0.135 A	0.465	2.19 A	0.752 A
Phosphate MST	0.113	0.399 A	0.150 A	0.640	2.26 A	0.851 A
Potash MST	0.063	0.425 A	0.125 A	0.349	2.36 A	0.694 A
p-value	**0.287**	**0.063**	**0.061**	**0.252**	**0.059**	**0.042**

Table 7. Yield, quality components, and Si content of L01-299 treated with foliar- and soil-applied sources of silicon, Sugar Research Station, LA, 2019

Treatment	Cane yield	Sugar yield	Brix	TRS	Sucrose	Leaf Si	Stalk Si	Soil Si	Soil pH
	tons/ac	lbs/ac	%	lbs/ton	%	%	%	mg/kg	
Site 1, 1st Ratoon, Silt loam									
Control	27.4 B	4848 B	17.3	179	13.4	2.39	0.600	49.1 C	6.33
Wollastonite	32.3 A	6160 A	17.8	190	14.0	2.42	0.701	69.0 A	6.13
Zumsil-AgroSil	30.4 AB	5570 AB	17.6	183	13.6	2.66	0.664	52.8 B	6.13
***p*-value**	**0.067**	**0.030**	**0.21**	**0.394**	**0.35**	**0.306**	**0.242**	**0.035**	**0.575**
Site 2, Plant Cane, Silt loam									
Control	47.6	9464	18.1	200	14.6	3.32	0.722	45.6 C	5.90
Wollastonite	47.9	9874	18.3	206	14.9	3.01	0.620	63.9 A	6.36
Zumsil-AgroSil	47.8	9520	18.1	200	14.5	2.83	0.669	47.7 B	6.09
***p*-value**	**0.982**	**0.572**	**0.298**	**0.549**	**0.48**	**0.313**	**0.508**	**0.015**	**0.317**

TRS – theoretical recoverable sugar

Table 8. Yield and quality components of 2nd ratoon L01-299 treated with Symbiotic AGx solution, St. Gabriel, 2019

AGx	Cover Crops	Cane yield	Sugar yield	Brix	TRS	Sucrose
		tons/ac	lbs/ac	%	lbs/ton	%
Control		33.6 B	6349 B	17.7	196	14.3
3 split AGx		38.0 A	7121 A	17.8	193	14.2
1 time AGx		36.2 AB	7119 A	17.9	202	14.6
	No	40.5 A	7601 A	17.6 B	193 B	14.1 B
	Yes	31.4 B	6125 B	18.0 A	201 A	14.6 A
Analysis of variance						
AGx		**0.072**	**0.098**	**0.626**	**0.340**	**0.383**
Cover Crops		**<0.001**	**<0.001**	**0.032**	**0.074**	**0.061**
AGx x Cover Crops		**0.684**	**0.563**	**0.962**	**0.817**	**0.878**

Table 9. Nutrient content and pH of soils 30 days after the 3-split and one-time AGx treatment application was done, with and without cover crops, St. Gabriel, LA, 2019

AGx	Cover Crops	pH	P	K	Ca	Mg	S	Cu	Zn
			mg/kg						
Control		5.49 B	37 B	180 B	1876 C	344 B	16.8 A	3.18 B	3.24 AB
3 split AGx		5.63 B	45 A	193 AB	2011 B	344 B	17.6 A	3.26 B	3.52 A
1 time AGx		6.10 A	28 C	213 A	2273 A	415 A	14.3 B	3.64 A	3.01 B
	No	5.58 B	40 A	161 B	1755 B	322 B	17.8 A	3.08 B	3.38
	Yes	5.90 A	33 B	230 A	2352 A	412 A	14.7 B	3.64 A	3.14
Control	No	-	-	220 CD	1790 CD	308 C	-	3.07 C	-
	Yes	-	-	251 B	1962 C	379 B	-	3.30 B	-
3 split AGx	No	-	-	238 BC	1851 C	330 BC	-	3.18 BC	-
	Yes	-	-	259 B	2171 B	357 BC	-	3.35 B	-
1 time AGx	No	-	-	192 D	1624 D	330 BC	-	3.00 C	-
	Yes	-	-	347 A	2922 A	501 A	-	4.29 A	-
Analysis of variance									
AGx		**0.002**	**0.011**	**0.041**	**0.001**	**0.056**	**0.062**	**0.001**	**0.090**
Cover Crops		**0.012**	**0.076**	**<0.001**	**<0.001**	**0.002**	**0.010**	**<0.001**	**0.170**
AGx x Cover Crops		**0.575**	**0.289**	**<0.001**	**<0.001**	**0.086**	**0.903**	**<0.001**	**0.198**

Table 10. Nutrient content and pH of AGx-treated soils collected after harvest with and without cover crops, St. Gabriel, LA, 2019

AGx	**Cover Crops**	**pH**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Zn**
						mg/kg			
Control		5.84 AB	44 A	250	2962	560 B	10.8 A	4.26 B	3.64
3 split AGx		5.73 B	49 A	251	2947	570 B	10.9 A	4.25 B	3.87
1 time AGx		6.11 A	33 B	270	3220	624 A	10.0 B	4.58 A	3.46
	No	5.73 B	43	206 B	2512 B	498 B	10.7	3.77 B	3.52 B
	Yes	6.06 A	40	309 A	3574 A	670 A	10.3	4.95 A	3.80 A
Control	No	-	-	212 C	2575 DE	500 CD	-	3.85 C	-
	Yes	-	-	287 B	3349 B	620 B	-	4.68 B	-
3 split AGx	No	-	-	223 C	2741 CD	527 C	-	4.02 C	-
	Yes	-	-	280 B	3153 BC	612 B	-	4.49 B	-
1 time AGx	No	-	-	182 D	2220 E	469 D	-	3.45 D	-
	Yes	-	-	359 A	4219 A	778 A	-	5.70 A	-
Analysis of variance									
AGx		**0.088**	**0.018**	**0.121**	**0.317**	**0.036**	**0.050**	**0.034**	**0.126**
Cover Crops		**0.020**	**0.448**	**<0.001**	**<0.001**	**<0.001**	**0.179**	**<0.001**	**0.078**
AGx x Cover Crops		**0.504**	**0.869**	**<0.001**	**0.002**	**<0.001**	**0.850**	**<0.001**	**0.494**

Table 11. Nutrient composition of stalk of cane treated with 3-split and one-time application of AGx solution, St. Gabriel, LA, 2019

AGx	Cover Crops	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
		%					mg/kg			
Control		0.122	0.518	0.006	0.059	0.066	51	15.4	17.1	1.79
3 split AGx		0.119	0.514	0.006	0.063	0.064	65	17.4	16.4	1.92
1 time AGx		0.113	0.514	0.008	0.058	0.051	67	14.2	16.5	1.93
	No	0.107 B	0.491	0.091 A	0.066 A	0.070 A	61	16.3	15.2 B	1.89
	Yes	0.129 A	0.540	0.074 B	0.054 B	0.050 B	61	15.0	18.1 A	1.86
Control	No	-	-	-	0.063 B	-	-	16.7 AB	-	-
	Yes	-	-	-	0.054 C	-	-	14.1 BC	-	-
3 split AGx	No	-	-	-	0.064 B	-	-	15.8 ABC	-	-
	Yes	-	-	-	0.062 BC	-	-	19.1 A	-	-
1 time AGx	No	-	-	-	0.072 A	-	-	16.5 AB	-	-
	Yes	-	-	-	0.045 D	-	-	11.8 C	-	-
Analysis of variance										
AGx		**0.643**	**0.997**	**0.964**	**0.334**	**0.319**	**0.492**	**0.145**	**0.843**	**0.325**
Cover Crops		**0.010**	**0.256**	**0.049**	**<0.001**	**0.026**	**1.000**	**0.316**	**0.023**	**0.745**
AGx x Cover Crops		**0.467**	**0.644**	**0.121**	**0.005**	**0.476**	**0.174**	**0.056**	**0.235**	**0.154**

Table 12. Nutrient removed by stalk of cane treated with 3-split and one-time application of AGx solution, St. Gabriel, LA, 2019

AGx	Cover Crops	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
							lbs/ac			
Control		29.0	123	20.0	14.0	15.7	1.22	0.366	0.407	0.042
3 split AGx		28.3	122	19.5	15.0	15.1	1.54	0.415	0.390	0.046
1 time AGx		26.9	122	19.5	13.9	12.1	1.59	0.338	0.392	0.046
	No	25.5 B	117	21.6 A	15.8 A	16.6 A	1.45	0.388	0.361 B	0.045
	Yes	30.6 A	129	17.7 B	12.8 B	12.0 B	1.45	0.357	0.432 A	0.044
Control	No	28.0 ABC	-	-	15.0 B	-	-	0.398 AB	-	-
	Yes	30.0 AB	-	-	13.0 C	-	-	0.335 BC	-	-
3 split AGx	No	25.3 BC	-	-	15.3 B	-	-	0.376 ABC	-	-
	Yes	31.2 A	-	-	14.6 BC	-	-	0.454 A	-	-
1 time AGx	No	23.1 C	-	-	17.1 A	-	-	0.392 AB	-	-
	Yes	30.7 AB	-	-	10.7 D	-	-	0.282 C	-	-
Analysis of variance										
AGx		**0.650**	**0.997**	**0.967**	**0.295**	**0.319**	**0.492**	**0.147**	**0.844**	**0.316**
Cover Crops		**0.010**	**0.256**	**0.051**	**<0.001**	**0.027**	**0.999**	**0.319**	**0.023**	**0.733**
AGx x Cover Crops		**0.453**	**0.643**	**0.121**	**0.005**	**0.481**	**0.174**	**0.057**	**0.237**	**0.131**

NITROGEN MANAGEMENT RESEARCH IN LOUISIANA SUGARCANE PRODUCTION SYSTEMS

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In Cooperation with the Sugar Research Station

Summary

Field trials were conducted at the LSU AgCenter Sugar Research Station in St. Gabriel and on a producer's field in Napoleonville, LA to evaluate the effect of different nitrogen (N) sources on sugarcane productivity. The performance of coated urea (45% N) and UAN (urea-ammonium nitrate) applied at 0, 40, 80 and 120 lbs N/ac was evaluated. At four locations at the Sugar Research Station, the following N sources applied at 80 lbs/ac were also evaluated : urea, knife-in UAN, calcium nitrate – $CaNO_3$, ammonium sulfate – NH_4SO_4, and knife-in UAN + foliar N. The demonstration trial in Napoleonville evaluated only three N sources, i.e. knife-in UAN, $CaNO_3$, and NH_4SO_4, all applied at rates to supply 80 lbs N/ac. A check or control (0 N) was included in the treatment structure. Images of sugarcane canopies were taken using DJI Phantom 4 equipped with MicaSense RedEdge-M™ sensor between April and May. On the same day the aerial images were taken, normalized difference vegetation index (NDVI) readings were collected using a GreenSeeker® handheld sensor. The relationship between these two sets of NDVI readings was evaluated. Cane tonnage, quality components, and sugar yield were determined at harvest. Soil samples were taken as well from some trials for soil NH_4 and NO_3 monitoring. Sugarcane was very responsive to N application; across the sites the highest increase in cane tonnage and sugar yield was 11.9 ton/ac (44%) and 2,168 lbs/ac (41%), respectively (p<0.01). However, there was no significant difference in cane and sugar yield between the coated urea- and UAN-treated cane. In addition, the different N sources that were evaluated at four locations in St. Gabriel had no impact on cane and sugar yield. On the other hand, the UAN-treated cane in Napoleonville obtained the highest cane and sugar yield at 42.5 ton/ac and 9,337 lbs/ac, respectively among the sources tested. The NDVI derived from aerial images can capture cane canopy information similar to what can be acquired from ground-based sensor, but a separate algorithm should be used for estimating sugarcane yield potential.

Objectives

This project intends to evaluate the performance of different N sources in improving sugarcane productivity. In addition, this project also aims to evaluate the potential use of unmanned aircraft system (UAV) equipped with a digital camera in predicting sugarcane yield and N requirement.

Performance Evaluation of Coated Urea and UAN

Based on the analysis of variance (ANOVA) performed on agronomic variables, there were no differences among Coated Urea 1 (30-day release), Coated Urea 2 (45-day release) and UAN

(Table 1). While there was significant N rate effect detected on cane yield, sugar yield, stalk N content, and N removal rate ($p<0.01$), the differences mainly came between the check (0) vs. all N rates. This means that the impact of 40, 80, and 120 lbs/ac on these parameters was essentially the same across N sources. The interaction effect of source x rate on cane and sugar yield has p-values of 0.12 and 0.11, respectively. For this reason, yield response curves were generated for each N source (Figure 1). The graphs indicated that the maximum cane yield (37 tons/ac) and sugar yield (6353 lbs/ac) were achieved at an application rate of 80 lbs/ac using Coated Urea 1. For Coated Urea 2 and UAN, cane tonnage and sugar yield were maximized at 40 lbs/ac.

The NH_4 and NO_3 concentration in the soil at 0-6 inches depth peaked four (4) weeks after N application (Figure 2). The pattern of soil NH_4 and NO_3 content was very similar between Coated Urea 1 and UAN. At this sampling date, the amount of N/ac measured was equivalent to 50 lbs NH_4-N and 22 lbs NO_3-N (72 lbs/ac total) for Coated Urea 1, and 45 lbs NH_4-N and 13 lbs NO_3-N (58 lbs N total) for UAN. On the other hand, the NH_4 and NO_3 content in soil treated with Coated Urea 2 declined steadily with time. In fact, the highest values were obtained two weeks after N application which was equivalent to 46 lbs NH_4-N and 19 lbs NO_3-N (65 lbs/ac total). The graphs also showed that majority of N from these N sources was released 16 weeks after application, such that the soil NH_4 and NO_3 content of the check was the same as those treated with the Coated Urea and UAN. At the 6-12 inches depth, both trend (with time) and concentrations of NH_4 and NO_3 in the soil were very similar across the N sources and the check.

Effect of Nitrogen Source on Sugarcane Yield

There was an evident cane (Figure 3) and sugar (Figure 5) yield response to applied N across sites ($p<0.05$). On the other hand, the TRS values tended to be higher in the check than the N-treated cane (Figure 4). On average across 4 locations, the highest yield increase due to applied N was obtained from sugarcane treated with NH_4 sulfate with 11.6 ton/ac (40%) cane yield and 1,607 lbs/ac (30%) sugar yield higher than the check (Figures 3a and 5a; $p<0.05$). However, there was no difference observed between N sources. The results obtained from the demonstration trial in Napoleonville showed that the UAN-fertilized plot had 17.6 ton/ac (71%) and 3,658 lbs/ac (64%) higher cane and sugar yield, respectively, than the check (Figures 3b and 5b). Based on cane and sugar yield, UAN as a N source performed better than $CaNO_3$ and NH_4 sulfate. The large improvement in cane tonnage due to UAN application offset the TRS reduction (Figure 4b) which subsequently resulted in the highest sugar yield.

Potential Use of Aerial Images in Sugarcane Production

GreenSeeker® NDVI readings and aerial images taken by MicaSense RedEdge-M™ sensor attached to DJI Phantom 4 were concurrently collected (from sugarcane canopies) in April and May. The aerial images were processed and converted to NDVI readings. Data was pooled across sites prior to regression analysis. The GreenSeeker- and UAV- NDVI readings were highly correlated with coefficient of determination (r^2) values of 0.78 (Figure 6).). These UAV-NDVI readings were used to validate the GreenSeeker-based algorithm for predicting cane yield. The relationship between UAV-NDVI predicted cane yield and measured cane yield was weak with r^2 value of 0.16 (Figure 7) suggesting that a separate algorithm should be specifically established for predicting sugarcane yield using UAV-NDVI. The initial findings showed that UAV-NDVI had a moderately strong positive relationship with cane tonnage ($r^2 = 0.41$; Figure 8). The NDVI from aerial images can capture cane canopy information similar to what can be acquired from ground-based sensor. However, translating the UAV-NDVI into values useful for estimating sugarcane yield and response to applied N requires separate algorithms.

Acknowledgements

The authors wish to express appreciation for the financial support provided by the American Sugar Cane League and Pursell Agri-Tech.

Table 1. Mean yield, quality components, stalk N concentration and removal rates of L01-299 2nd ratoon crop treated with different sources and rates of N, St. Gabriel, LA, 2019.

Source	N Rate lbs/ac	Cane ton/ac	Sugar lbs/ac	Brix %	TRS lbs/ton	Sucrose %	Stalk N %	N Removal Rate	
								lbs/ac	lbs/ton
Coated Urea 1		33	5626	15.9	163	12.2	0.348	61	1.78
Coated Urea 2		33	5484	15.7	160	12.0	0.337	58	1.71
UAN		32	5452	16.0	165	12.3	0.323	54	1.65
***p*-value**		**0.234**	**0.661**	**0.471**	**0.579**	**0.547**	**0.344**	**0.213**	**0.378**
SED		**0.610**	**143**	**0.214**	**4.75**	**0.280**	**0.017**	**3.60**	**0.082**
	0	28	4669	15.8	162	12.1	0.296	43	1.50
	40	34	4735	16.0	164	12.3	0.338	59	1.73
	80	35	5771	15.8	160	12.0	0.372	57	1.89
	120	35	5908	15.9	164	12.2	0.339	61	1.72
***p*-value**		**<0.001**	**<0.001**	**0.886**	**0.881**	**0.885**	**0.006**	**<0.001**	**0.006**
SED		**0.705**	**165**	**0.228**	**5.09**	**0.300**	**0.019**	**3.90**	**0.090**
Coated Urea 1	0	29	4757	15.9	160	12.1	0.295	44	1.49
	40	33	5521	16.0	164	12.3	0.330	56	1.69
	80	37	6353	15.9	167	12.4	0.412	79	2.12
	120	35	5874	15.8	162	12.1	0.356	64	1.80
Coated Urea 2	0	28	4904	15.9	170	12.5	0.302	44	1.54
	40	33	5558	15.8	161	12.1	0.337	58	1.71
	80	35	5656	15.7	154	11.7	0.367	67	1.86
	120	36	5818	15.4	156	11.7	0.344	63	1.71
UAN	0	27	4346	15.6	157	11.8	0.293	41	1.46
	40	35	6126	16.1	167	12.4	0.347	64	1.79
	80	32	5304	15.8	161	12.0	0.336	55	1.69
	120	34	6032	16.3	174	12.8	0.317	57	1.65
***p*-value**		**0.117**	**0.112**	**0.525**	**0.269**	**0.323**	**0.592**	**0.167**	**0.548**
SED		**1.221**	**286**	**0.321**	**7.27**	**0.427**	**0.027**	**5.85**	**0.137**

TRS – Theoretical recoverable sugar
UAN – urea ammonium nitrate solution (32% N)

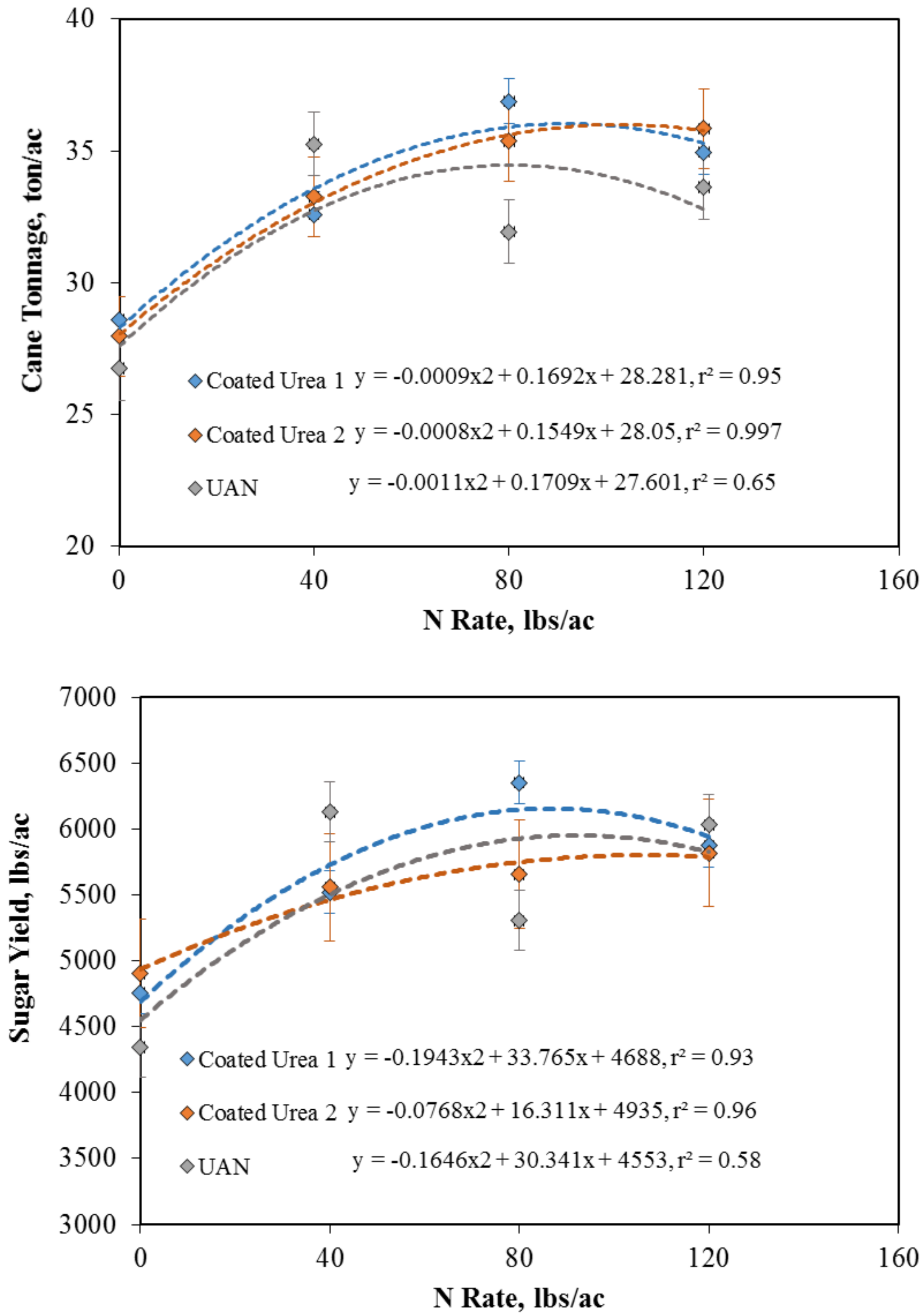


Figure 1. Cane tonnage and sugar yield response to different N sources and rates, St. Gabriel, LA, 2019.

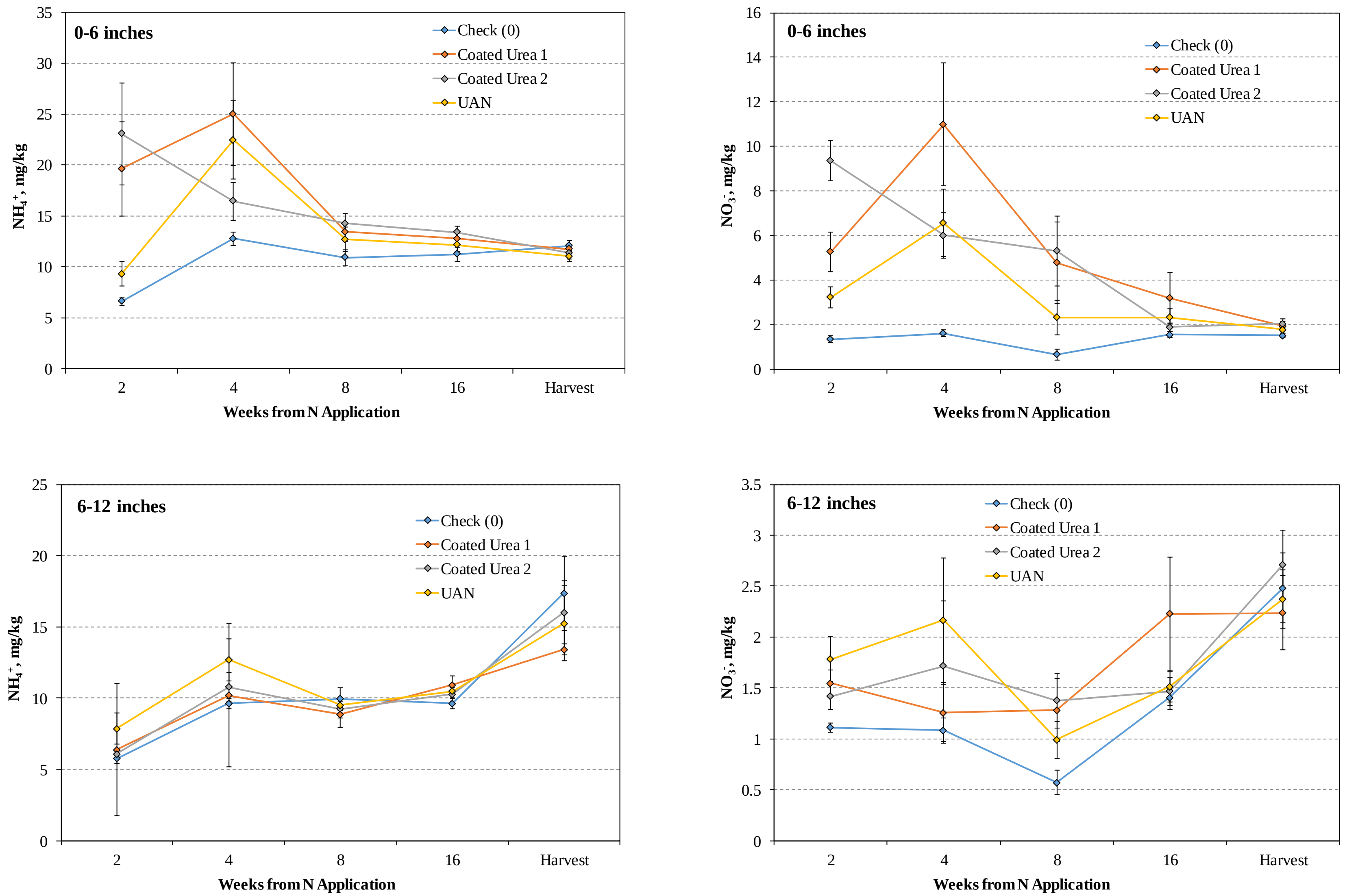
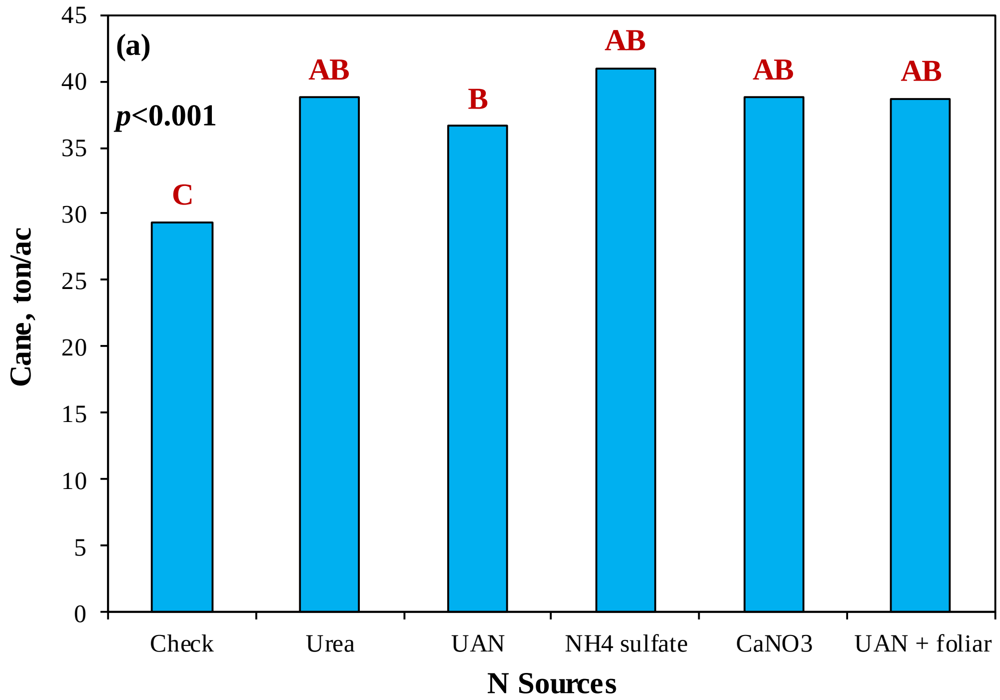


Figure 2. Ammonium and nitrate concentration at 0-6 and 6-12-inches depth of soil at 2, 4, 8, and 16 weeks after N application, and at harvest in St. Gabriel, LA, 2019



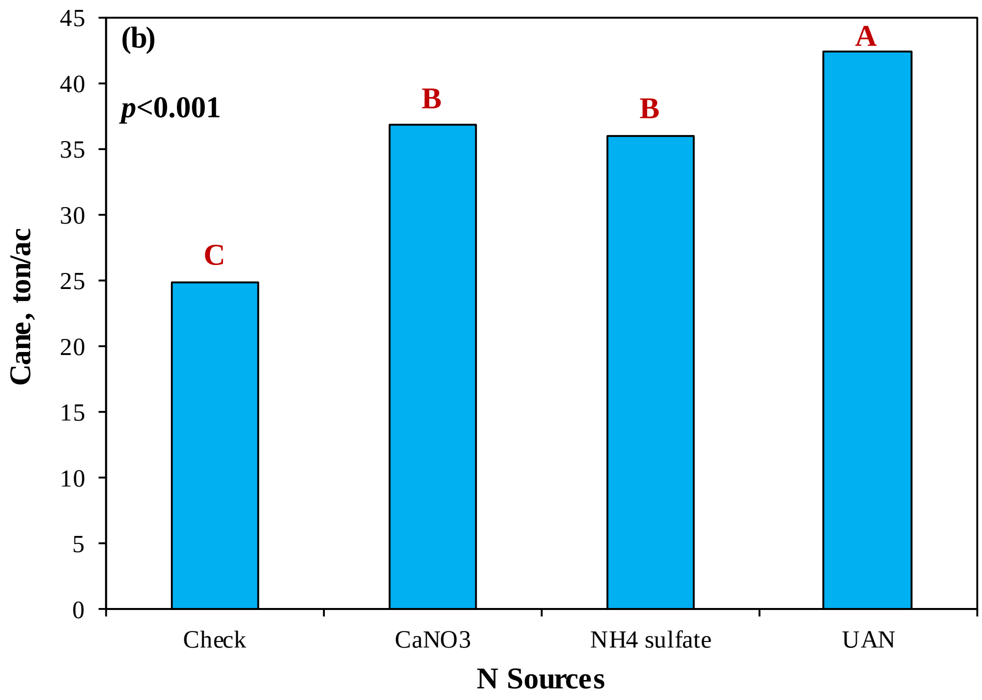


Figure 3. Cane yield response to different N sources applied at 80 lbs/ac from 4 locations at the Sugar Research Station in St. Gabriel (a) and Napoleonville (b), LA, 2019.

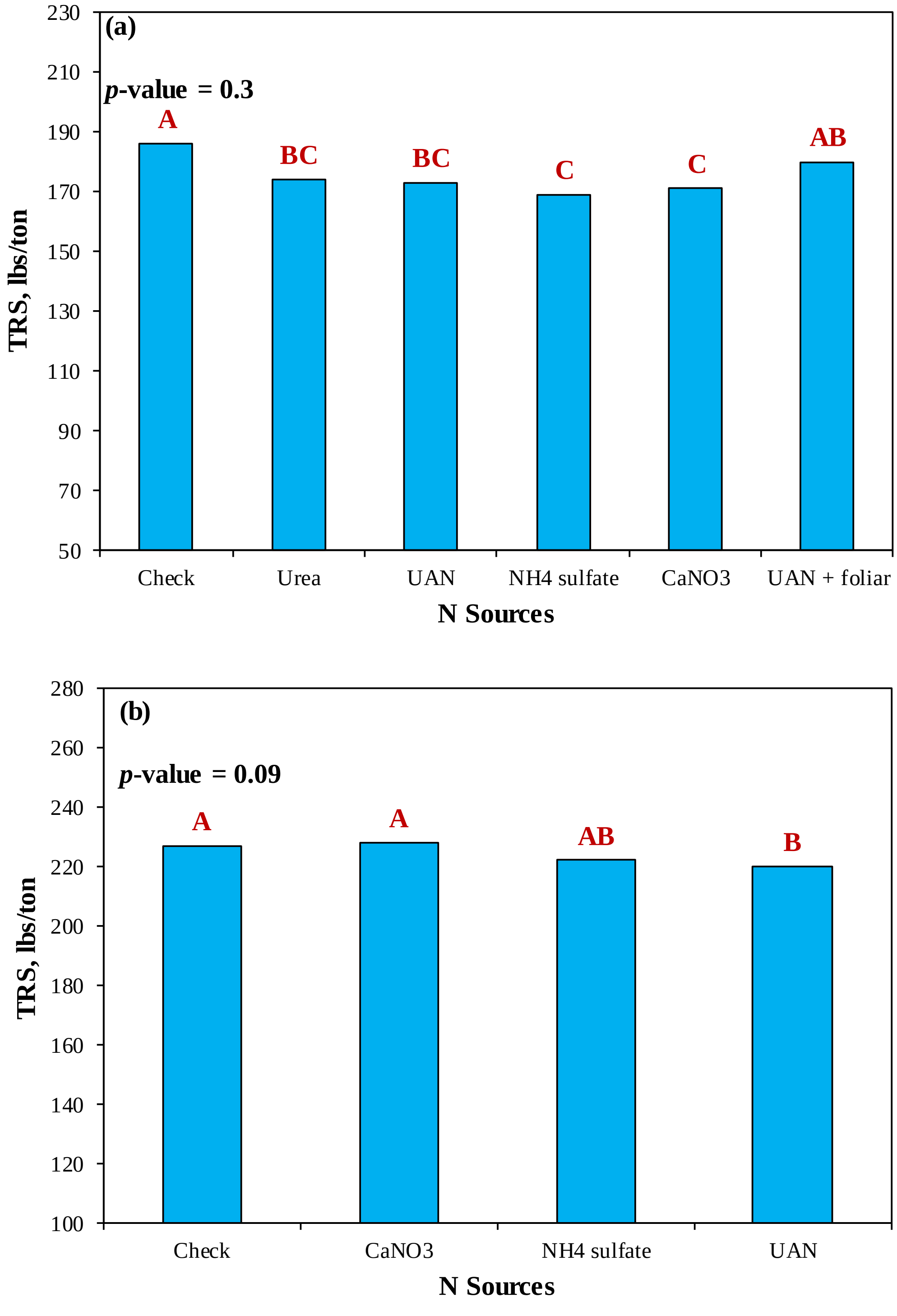


Figure 4. Theoretical recoverable sugar (TRS) response to different N sources applied at 80 lbs/ac from 4 locations at the Sugar Research Station in St. Gabriel (b) and Napoleonville (b), LA, 2019.

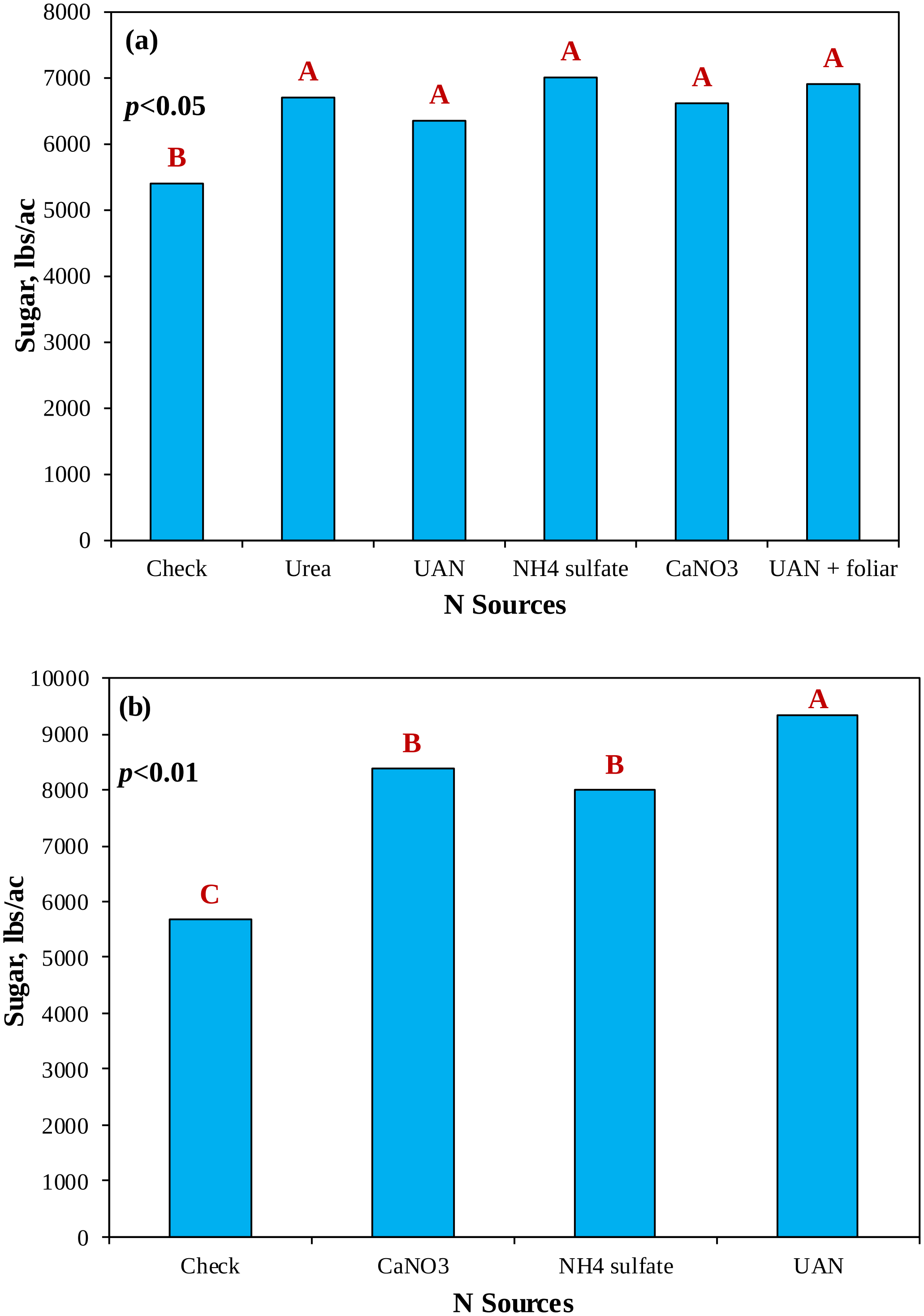


Figure 5. Sugar yield response to different N sources applied at 80 lbs/ac from 4 locations at the Sugar Research Station in St. Gabriel (b) and Napoleonville (b), LA, 2019.

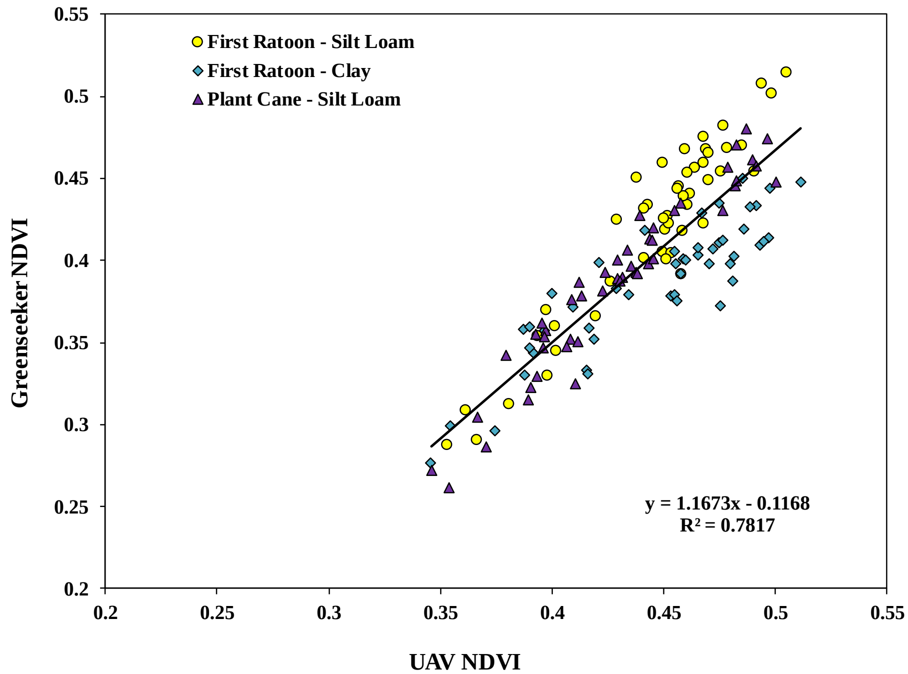


Figure 6. Relationship between aerial image-based (UAV NDVI) and GreenSeeker NDVI readings of cane canopies, Sugar Research Station in St. Gabriel, LA, 2019.

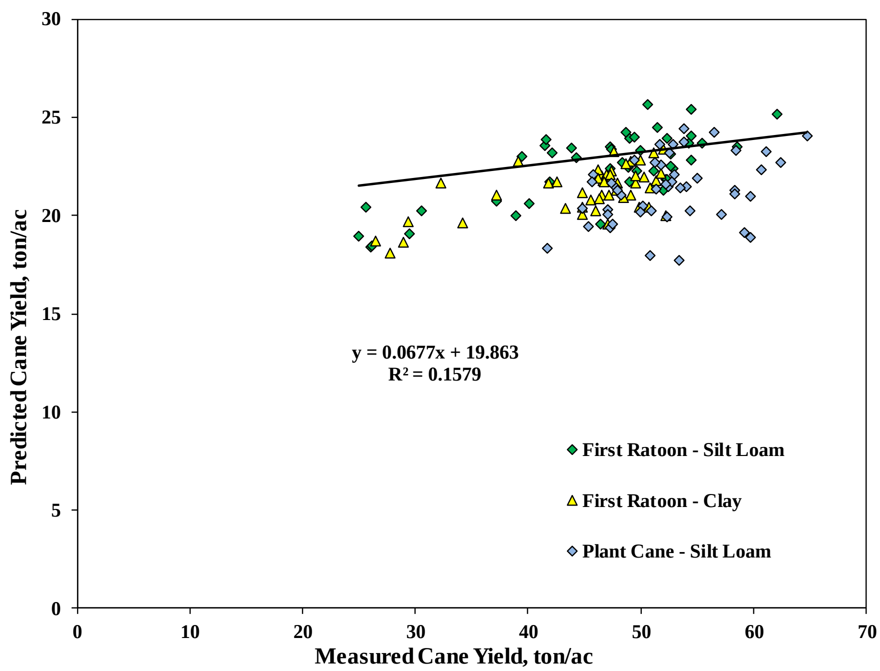


Figure 7. Relationship of predicted cane tonnage based on GreenSeeker NDVI with measured (actual) cane tonnage, Sugar Research Station in St. Gabriel, LA, 2019.

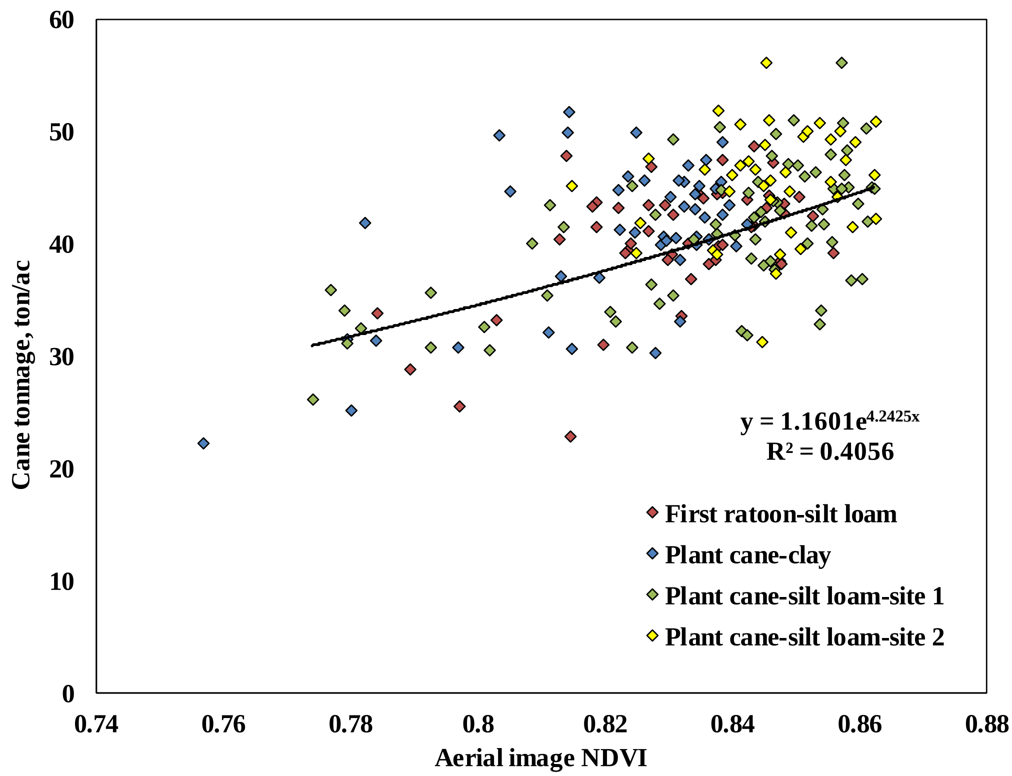


Figure 8. Relationship of aerial image based NDVI with cane tonnage, Sugar Research Station in St. Gabriel, LA, 2019.