RESEARCH ON SOIL FERTILITY IN SUGARCANE PRODUCTION

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Summary

Field trials were conducted in 2020 to evaluate cane and sugar yield responses to phosphorus (P) and sulfur (S). 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 continued at two locations at the Sugar Research Station in St. Gabriel, LA. 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 (Micronized Sulfur Technology) fertilizers from Sulvaris (ammonium sulfate MST or AS-MST[17-0-0-16 S]; monoammonium phosphate MST or MAP-MST[9-43-0-16 S]; muriate of potash MST or MOP-MST[0-0-50-15 S]; and liquid MST[5-0-0-38 S]), ammonium sulfate (AMS – 21-0-0-24 S), and ammonium thiosulfate (NH_4 thiosulfate – 12-0-0-26 S) applied at 25 lbs S/ac (Site 1) and 40 lbs S/ac (Sites 2 and 3). Yield, quality components, and nutrient content of leaf, shredded stalk, and soil samples were determined. There was a significant response to P application at Site 1 wherein an average of 3.9 ton/ac stalk yield and 1172 lbs/ac sugar yield was recorded. There was a notable increase in soil P and leaf P content recorded 30 days after treatment application suggesting that the increases in yield can be attributed to improvement on P nutrition. While there were indications of positive response to P application at Site 2, most were not statistically significant. This could be partly due to higher initial soil P level. The performance of different ratios of MAP and EXPCRG was virtually the same suggesting that EXPCRG whether pure or in combination with MAP can be a good source of P to sugarcane. The S trials showed that while the effects were not all statistically significant, the application of S regardless of sources generally improved cane and sugar yield. At Site 2 where sugar yield increase was significant, MOP-MST (+1711 lbs/ac) and Liquid-MST (+1,342 lbs/ac) were as effective as the NH_4 thiosulfate (+1,137 lbs/ac), a common S source in sugarcane production in Louisiana. This was further supported by the positive impact of MST-fertilization on S content of soil, leaf, and stalk along with the stalk S removal rate. All these support that MOP-MST and Liquid-MST are potential S sources for sugarcane.

Objective

This research was designed to evaluate different P and S fertilizer sources. 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

<u>Effect of Different Ratios of MAP and EXPCRG® Application</u>

The application of MAP and EXPCRG, regardless of ratios resulted in significant increase in cane stalk and sugar yield at Site 1 with an average increase of 3.9 ton/ac stalk yield and 1172 lbs/ac sugar yield (Table 1). The quality component was not significantly affected by MAP and EXPCRG fertilization thus the improvement in sugar yield was mainly attributed to increase in

cane tonnage production. At Site 2, sugarcane treated with different ratios of MAP and EXPCRG produced numerically higher cane stalk and sugar yield compared to untreated sugarcane. Quality components were not significantly affected by the treatments.

The analysis on soil samples collected one month after treatment application indicated that the application of different ratios of MAP and EXPCRG significantly increased soil P levels by almost 2x as the control at Site 1 (Table 1). Similar effect was observed at Site 2 but the increase in soil P level was not significant. The soil Mg levels at both sites were increased with increasing proportion of EXPCRG in the mixture (*p*-values: 0.1276 and 0.1064). The improvement on soil P level brought about by the application of different ratios of MAP and EXPCRG was carried until harvest at both sites. The soil P was maintained to levels close at or above the critical P level for Louisiana soils (35 mg/kg).

Leaf P content at 30 days after P application was increased with MAP and EXPCRG application but was statistically significant only at Site 1 ($p<0.001$; Table 2). There was no evident response of leaf Mg on the different ratios of MAP and EXPCRG. At harvest, there was no significant treatment effect on leaf Mg and P observed for both sites. However, the stalk P and Mg content at Site 1 was improved with MAP and EXPCRG application. The impact of the treatment was more pronounced on the stalk Mg and P removal rate. The amount of P removed by stalk was improved by 5.2 lbs P/acre with MAP and EXPCRG application regardless of ratio. At Site 2, stalk Mg removal rate was significantly higher with EXPCRG application, the highest was noted with 100% EXPCRG rate. The nutrient removal rate by stalk was influenced more by the improvement on cane tonnage due to P application. Thus, even if it appeared that the application of different ratios of MAP and EXPCRG had no evident impact on stalk nutrient content, the results on ANOVA indicated several cases of significant effect on stalk nutrient removal rate.

<u>Sugarcane Response to Different Sulfur Sources</u>

The results on the analysis of variance (ANOVA) and mean yield and quality components for all three sites are reported in Table 3. Significant effect of the treatments was observed only on sugar yield at Site 2, and TRS and sucrose content at Site 3. However, the control plots for the three sites recorded the lowest cane yield averaging only at 46.8 tons/ac compared to S-treated plots at 49.8 tons/ac. There was no single S source that consistently performed the best or better than the rest of the S sources. Cane yield response to S sources at Site 1 had the highest level of confidence (*p*-value = 0.126). Here, the Liquid-MST application increased cane yield by 7.1 ton/ac. Sugar yield improvement at Site 2 was significant (*p*-value = 0.084) with MOP-MST recording the highest at +1711 lbs/ac followed by Liquid-MST (+1,342 lbs/ac) and NH_4-thiosulfate (+1,137 lbs/ac). The sugar yield increases due to the application of Liquid-MST (Site 1), and MOP-MST, MOP + AMS and NH_4-thiosulfate (Site 3) were the highest at these respective sites but with a lower level of confidence ($p>0.10$).

The soil test results at harvest showed the significant impact of S application on soil S. Plots treated with MAP-MST and MOP + AMS had a higher soil S level compared to other S-treated plots for Site 1 whereas for Site 2, these were the plots treated with MAP-MST, MOP-MST, and MOP + AMS (Table 4). The initial levels of soil S at Sites 1 and 2 were low, approaching the critical soil S level of 10 ppm. On the other hand, the soil S at Site 3 was below the critical

level. It is imperative that the annual application of S should be considered as an integral part of fertilization program in crops like sugarcane. The application of MAP-MST (43% P analysis) resulted in elevated level of soil P at harvest for the three sites. This was not the case for MOP-MST (50% K) nor MOP (60% K) + AMS application, i.e., no soil K improvement was detected at harvest. Sugarcane's demand for K (3 lbs K per ton of cane) is higher than P (1 lb P per ton of cane), thus even after the cropping season, most of the P from the applied MAP-MST remained in the soil whereas the K in the soil was virtually the same across the treatments (including the control). This suggests that available K (exchange site and in soil solution) in the soil from K fertilization was taken up by cane. While there was a significant change in soil pH due to treatment application at Site 1, there was no subsequent effect on soil Cu and Zn (micronutrient content) nor on the concentration of base cation Mg and Ca observed.

The S content of leaf collected three weeks after treatment application responded positively to S application regardless of source at Site 1 and Site 2 (Table 5). These positive responses (of leaf S) were observed at harvest and in stalk samples. There were significant differences observed on leaf P content at Site 1 and 2, but only at midseason sampling and that the effect appeared not in association with the S treatment. Among the sources, the MOP + AMS application often resulted in the production of leaf with the highest S content across sampling times and sites. Similarly, stalk S content was recorded the highest on sugarcane treated with MOP + AMS.

The amount of S removed by stalks was significantly increased with S application regardless of source (Figure 1). Among S sources, MOP + AMS recorded the highest increase in stalk S uptake at Site 1 and Site 2 at 23.5 lbs/ac and 16.84 lbs/ac, respectively. However, at Site 1 these values were statistically similar with 19.7 lbs/ac of AS-MST and 17.7 lbs/ac of Liquid-MST. At Site 3, there were no significant differences among the sources but both MOP-MST and AS-MST recorded the highest increase (numerically) in stalk S uptake at about 22 lbs/ac. The average amount of S removed for every ton of stalk produced across sites was 0.6 lb.

Acknowledgement
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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, 2020

MAP:EXPCRG	**Cane yield (ton/ac)**	**Sugar yield (lbs/ac)**	**TRS (lbs/ton)**	**Brix (%)**	**Sucrose (%)**	**Soil P, (mg/kg)**		**Soil Mg, (mg/kg)**	
						30 DAT	**Harvest**	**30 DAT**	**Harvest**
Site 1 (L01-299 1st Ratoon, Silt loam)									
0:0	47.3 b	9940 b	210	19.18	15.36	20.9 b	20.8 b	189	174
100:0	51.7 a	11039 a	213	19.04	15.45	44.9 a	36.8 a	199	196
0:100	50.4 a	11690 a	213	18.82	15.35	42.7 a	38.9 a	228	211
75:25	51.7 a	11144 a	216	19.23	15.61	41.8 a	34.4 a	195	191
50:50	51.1 a	10740 a	210	19.05	15.31	38.7 a	38.4 a	252	204
25:75	51.0 a	10945 a	214	18.85	15.45	43.7 a	33.9 a	201	182
***p*-value**	**0.0037**	**0.0955**	**0.9833**	**0.5633**	**0.9858**	**0.0051**	**0.009**	**0.1276**	**0.1161**
Site 2 (L01-299 1st Ratoon, Silty clay loam)									
0:0	42.2	9439	224	19.16	15.97	47.3	25.5 b	363	373
100:0	42.7	9505	222	19.08	15.88	48.4	36.6 a	361	402
0:100	44.1	9863	224	19.13	15.98	55.7	37.7 a	390	381
75:25	44.5	9709	218	18.92	15.66	52.6	36.7 a	367	372
50:50	43.1	9740	226	19.18	16.08	53.2	36.3 a	387	372
25:75	44.4	9918	224	19.16	15.97	63.5	34.9 a	399	391
***p*-value**	**0.4822**	**0.4936**	**0.5982**	**0.8146**	**0.644**	**0.4321**	**0.0394**	**0.1064**	**0.8679**

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

Values with the same letter within column for each site are not significantly different at $p<0.10$.

Table 2. Chemical properties of soil treated with different ratios of MAP:EXPCRG at two locations at the Sugar Research Station, St. Gabriel, LA, 2020

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 1st Ratoon, Silt loam)								
0:0	0.191	0.192 c	0.130	0.139	0.071 c	0.078 c	20.5 c	22.5 b
100:0	0.204	0.242 a	0.128	0.134	0.087 a	0.094 a	27.3 a	29.4 a
0:100	0.208	0.224 b	0.128	0.139	0.081 ab	0.090 ab	24.2 b	27.0 a
75:25	0.211	0.243 a	0.128	0.135	0.077 bc	0.082 bc	24.3 b	25.8 ab
50:50	0.206	0.233 ab	0.130	0.136	0.080 ab	0.088 abc	24.8 ab	27.1 a
25:75	0.201	0.223 b	0.133	0.132	0.084 ab	0.095 a	25.9 ab	29.1 a
***p*-value**	**0.3224**	**<0.001**	**0.9628**	**0.8653**	**0.0242**	**0.0900**	**0.0063**	**0.0443**
Site 2 (L01-299 1st Ratoon, Silty clay loam)								
0:0	0.230	0.297	0.128	0.176	0.065	0.109	16.6 b	27.7
100:0	0.237	0.304	0.134	0.182	0.069	0.107	17.8 ab	27.7
0:100	0.247	0.314	0.137	0.185	0.071	0.107	19.0 a	28.8
75:25	0.239	0.320	0.131	0.184	0.070	0.115	18.8 a	30.7
50:50	0.251	0.315	0.132	0.178	0.071	0.114	18.6 a	29.2
25:75	0.230	0.296	0.132	0.175	0.068	0.106	18.2 a	28.5
***p*-value**	**0.3684**	**0.3625**	**0.5115**	**0.5735**	**0.3815**	**0.6285**	**0.0885**	**0.6650**

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

DAT – days after treatment application

Values with the same letter within column for each site are not significantly different at $p<0.10$.

Table 3. Cane tonnage, sugar yield, and quality component of sugarcane treated with different sulfur sources, St. Gabriel, LA, 2020

Treatment	Cane Yield ton/ac	Sugar Yield lbs/ac	Brix %	TRS %	Sucrose %
Site 1, L01-299 3rd Ratoon					
Control	45.5	10135	19.0	222	15.9
AS-MST	45.0	9512	18.4	211	15.2
MAP-MST	47.1	10448	19.1	221	15.8
MOP-MST	47.9	10584	18.8	221	15.7
MOP + AMS	50.3	11091	18.9	221	15.8
Liquid MST	52.6	11359	18.8	216	15.5
NH_4 Thiosulfate	47.4	10275	18.8	217	15.6
***p*-value**	**0.126**	**0.264**	**0.407**	**0.614**	**0.562**
Site 2, L01-299 3rd Ratoon					
Control	42.2	9221 d	18.8	219	15.6
AS-MST	44.0	9439 cd	18.6	215	15.4
MAP-MST	44.1	9716 bcd	18.9	220	15.7
MOP-MST	47.7	10932 a	19.1	229	16.2
MOP + AMS	45.1	9213 d	18.2	206	14.9
Liquid MST	47.2	10563 ab	18.8	224	15.9
NH_4 Thiosulfate	47.4	10358 abc	18.7	218	15.6
***p*-value**	**0.573**	**0.084**	**0.485**	**0.363**	**0.385**
Site 3, L01-299 1st Ratoon					
Control	52.6	10440	18.6	198 d	14.6 c
AS-MST	52.8	11913	19.2	224 a	16.0 a
MAP-MST	53.0	11005	18.6	208 bcd	15.1 bc
MOP-MST	56.3	12294	19.2	218 abc	15.7 ab
MOP + AMS	54.9	12240	18.8	222 ab	15.8 a
Liquid MST	55.1	11174	19.4	203 cd	15.1 bc
NH_4 Thiosulfate	57.6	12295	19.3	214 abc	15.5 ab
***p*-value**	**0.369**	**0.534**	**0.128**	**0.048**	**0.020**

TRS – theoretical recoverable sugar; AS – ammonium sulfate; MST – micronized sulfur technology; MAP – monoammonium phosphate; MOP – muriate of potash; AMS – ammonium sulfateValues with the same letter within column for each site are not significantly different at $p<0.10$.

Table 4. Mehlich-3 extractable nutrients, and pH of soil post-harvest treated with different sulfur sources, St. Gabriel, LA, 2020

Treatment	pH	Nutrient Content Based on Mehlich-3 Procedure, mg/kg						
		P	K	S	Mg	Ca	Cu	Zn
Site 1, L01-299 3rd Ratoon								
Control	5.87 a	35.2 b	169	12.4 cd	1806	372	2.71	2.93
AS-MST	5.59 bc	41.9 b	165	12.8 bcd	1749	373	2.57	2.90
MAP-MST	5.56 bc	59.8 a	163	16.1 a	1776	377	2.37	3.14
MOP-MST	5.64 ab	33.7 b	168	13.0 bcd	1747	358	2.64	2.82
MOP + AMS	5.38 c	36.9 b	158	15.4 ab	1982	357	2.58	2.98
Liquid MST	5.57 bc	36.2 b	162	12.5 cd	1659	342	2.45	2.82
NH4 Thiosulfate	5.74 ab	36.6 b	153	10.3 d	1640	343	2.62	2.85
***p*-value**	**0.070**	**<0.001**	**0.817**	**0.040**	**0.285**	**0.361**	**0.737**	**0.220**
Site 2, L01-299 3rd Ratoon								
Control	6.11	38.5 b	145	8.5 c	1717	344	3.32	3.47
AS-MST	5.78	39.7 b	154	10.1 bc	1758	363	3.14	3.11
MAP-MST	6.15	77.2 a	143	11.1 ab	1850	367	3.15	3.20
MOP-MST	5.86	38.0 b	162	12.2 ab	1979	374	3.40	3.19
MOP + AMS	5.84	35.0 b	151	12.3 a	1781	363	3.19	3.16
Liquid MST	5.64	36.5 b	150	10.1 bc	1730	348	2.97	3.07
NH4 Thiosulfate	5.54	36.5 b	120	8.7 c	1384	286	2.85	2.63
***p*-value**	**0.204**	**0.026**	**0.247**	**0.047**	**0.393**	**0.199**	**0.479**	**0.315**
Site 3, L01-299 1st Ratoon								
Control	5.68	23.8	69	2.7	693	148	1.55	1.20
AS-MST	5.50	39.4	67	5.0	790	150	1.68	1.49
MAP-MST	4.91	42.9	68	5.0	683	134	1.42	1.32
MOP-MST	4.82	33.6	92	6.3	721	155	1.78	1.62
MOP + AMS	5.20	24.4	64	3.4	618	128	1.34	1.10
Liquid MST	4.75	38.9	70	5.1	597	129	1.37	1.42
NH4 Thiosulfate	5.14	34.2	79	4.8	762	161	1.82	1.52
p-value	**0.545**	**0.226**	**0.437**	**0.256**	**0.490**	**0.715**	**0.174**	**0.472**

TRS – theoretical recoverable sugar; AS – ammonium sulfate; MST – micronized sulfur technology; MAP – monoammonium phosphate; MOP – muriate of potash; AMS – ammonium sulfate

Values with the same letter within column for each site are not significantly different at $p<0.10$.

Table 5. Leaf and stalk P, K, and S concentration of sugarcane treated with different S sources, St. Gabriel, LA, 2020

Treatment	**% in Leaf at 21 DAT**			**% in Leaf at Harvest**			**% in Stalk**		
	P	**K**	**S**	**P**	**K**	**S**	**P**	**K**	**S**
Site 1, L01-299 3rd Ratoon									
Control	0.309 b	1.419	0.176 f	0.176	1.249	0.141 d	0.128 a	0.568	0.064 d
AS-MST	0.300 bc	1.459	0.287 ab	0.173	1.195	0.179 ab	0.129 a	0.700	0.141 a
MAP-MST	0.356 a	1.450	0.258 de	0.192	1.301	0.165 c	0.121 a	0.484	0.104 c
MOP-MST	0.284 c	1.494	0.264 cde	0.172	1.307	0.159 c	0.117 a	0.599	0.108 bc
MOP + AMS	0.278 c	1.314	0.304 a	0.160	1.182	0.184 a	0.094 b	0.498	0.136 a
Liquid MST	0.285 c	1.477	0.246 e	0.177	1.330	0.169 bc	0.117 a	0.592	0.115 bc
NH_4 Thiosulfate	0.288 bc	1.364	0.274 bcd	0.173	1.268	0.168 bc	0.115 a	0.571	0.108 bc
***p*-value**	**<0.001**	**0.339**	**<0.001**	**0.180**	**0.370**	**<0.001**	**0.040**	**0.260**	**<0.001**
Site 2, L01-299 3rd Ratoon									
Control	0.314 ab	1.169	0.189 e	0.162	1.215	0.132 d	0.116 ab	0.504	0.066 c
AS-MST	0.294 bc	1.347	0.285 ab	0.134	1.217	0.148 bc	0.102 c	0.511	0.096 b
MAP-MST	0.310 abc	1.162	0.245 cd	0.154	1.174	0.140 cd	0.122 a	0.531	0.092 b
MOP-MST	0.281 c	1.192	0.235 d	0.176	1.335	0.147 bc	0.106 bc	0.455	0.088 b
MOP + AMS	0.290 bc	1.437	0.302 a	0.158	1.192	0.169 a	0.097 c	0.534	0.128 a
Liquid MST	0.283 c	1.253	0.239 d	0.168	1.201	0.153 b	0.097 c	0.424	0.085 b
NH_4 Thiosulfate	0.251 d	1.134	0.220 d	0.155	1.164	0.155 b	0.099 c	0.458	0.093 b
***p*-value**	**0.006**	**0.623**	**<0.001**	**0.146**	**0.383**	**0.002**	**0.032**	**0.248**	**0.002**
Site 3, L01-299 1st Ratoon									
Control	0.183	1.028	0.126	0.139	1.141	0.108 c	0.088	0.510	0.031 b
AS-MST	0.171	0.897	0.147	0.154	1.231	0.141 ab	0.084	0.409	0.094 a
MAP-MST	0.150	0.571	0.102	0.139	1.152	0.148 a	0.083	0.443	0.080 a
MOP-MST	0.200	1.088	0.174	0.139	1.146	0.144 a	0.105	0.530	0.093 a
MOP + AMS	0.195	1.086	0.184	0.151	1.168	0.138 ab	0.079	0.518	0.086 a
Liquid MST	0.193	1.074	0.168	0.146	1.172	0.142 ab	0.084	0.426	0.089 a
NH_4 Thiosulfate	0.197	1.025	0.176	0.142	1.174	0.139 ab	0.083	0.489	0.088 a
p-value	**0.985**	**0.556**	**0.772**	**0.193**	**0.993**	**0.085**	**0.531**	**0.365**	**0.020**

DAT – days after treatment application; TRS – theoretical recoverable sugar; AS – ammonium sulfate; MST – micronized sulfur technology; MAP – monoammonium phosphate; MOP – muriate of potash; AMS – ammonium sulfate

Values with the same letter within column for each site are not significantly different at $p<0.10$.

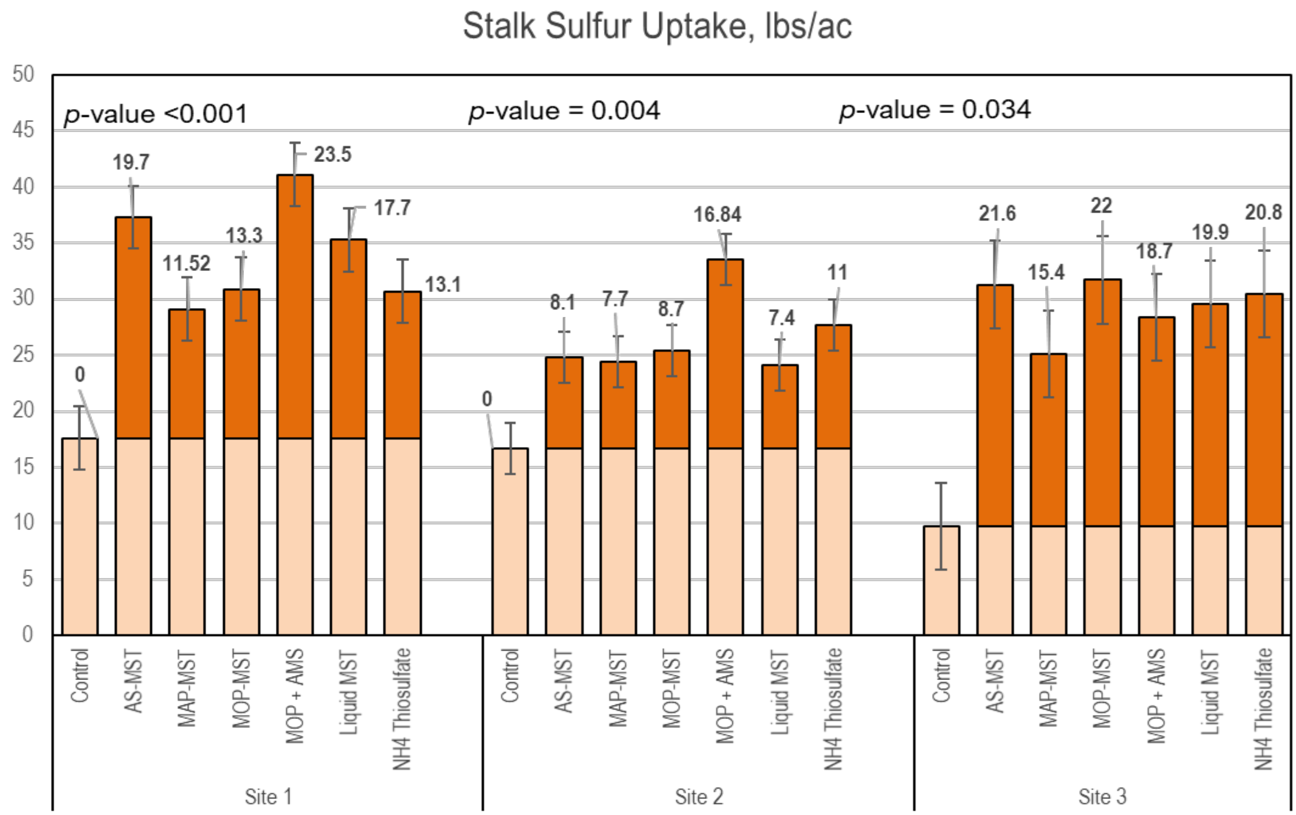

Figure 1. Stalk sulfur uptake in response to different sources of S at three locations in St. Gabriel, LA, 2020. Values on top of the orange-colored bars represent the increase in stalk S uptake in lbs/ac due to application of different S sources.

NITROGEN MANAGEMENT RESEARCH IN LOUISIANA SUGARCANE PRODUCTION SYSTEMS

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Summary

Field trials were conducted at the LSU AgCenter Sugar Research Station in St. Gabriel, LA to address the objectives of this project. The performance of different coated urea (45% N) products and urea-ammonium nitrate (UAN – 32% N) solution applied at 0, 40, 80 and 120 lbs N/ac was evaluated. In addition, the performance of urea, knife-in UAN, calcium nitrate ($CaNO_3$), ammonium sulfate (NH_4 sulfate), and knife-in UAN + foliar N (UAN+foliar) applied at 80 lbs N/ac was evaluated on L01-299 cultivar planted on a Commerce silty clay loam soil. The performance of sensor-based N recommendation + N-rich strip technology (Sensor+N-Rich) and combinations of best management practices (BMPs) was compared to a Farmer's standard N practice using a replicated strip trial on Commerce silty clay loam soil. Images of sugarcane canopies were taken from multiple N trials using DJI Phantom 4 equipped with MicaSense RedEdge-M™ sensor during the day of N fertilization. Using a series of models, NDVI generated from aerial images was converted to GreenSeeker NDVI (Converted NDVI) and then used for predicting cane stalk and sugar yield. 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. Based on stalk and sugar yield N response curve, the optimal N rates were between 80 to 120 lbs N/ac using coated urea and UAN as sources. The results also demonstrate the potential of coated urea, urea, and NH_4 sulfate as N sources for sugarcane production. At 80 lbs N/ac rate, NH_4 sulfate application increased cane yield by 7.2 tons/ac and sugar yield by 1,847 lbs/ac; these were 22 and 23% higher than the untreated (check) cane, respectively and the highest (yield increase) compared to other N sources. The N recommendation by Sensor+N-Rich and BMPs was lower by 23 and 57 lbs N/ac, respectively than the Farmer's standard N practice but did not result in yield reduction. This suggests that implementation of robust, on-a-need basis N decision tool can save up N fertilizer that subsequently can improve N use efficiency in sugarcane production. Converted NDVI from aerial images of sugarcane canopies can be used for predicting cane stalk and sugar yield of ratoon crops but not for plant cane. Refinement of these models should focus on addressing the saturation issues associated with canopy closure early in the season for plant cane crop.

Objectives

This project was designed to: (1) validate the current N recommendation for sugarcane production in Louisiana, (2) evaluate the potential of different N sources for sugarcane production, (3) evaluate the performance of sensor-based N and N-rich strip technology as a N decision tool, and (4) establish the approach for using aerial images for predicting sugarcane yield and N requirement.

Performance Evaluation of Coated Urea and UAN

Nitrogen rate had a greater impact than source on most measured variables for both sites (Tables 1 and 2). Both TRS and Brix did not respond to the treatments however, there were significant N rate and source interaction effect on cane and stalk yield for both sites, and stalk N content and removal rate for Site 2 only. Stalk N removal rate increased with increasing N rate but did not differ across N sources. On average, cane stalk yield was increased by 10 tons/ac while sugar yield was increased by ~2,000 lbs/ac for Site 1. Increases for Site 2 were ~11 tons/ac for stalk yield and ~2,200 lbs/ac for sugar yield. The regression analysis demonstrated that a higher N rate (120 lbs N/ac) was required for Coated Urea 1 to maximize cane stalk yield compared to the 80 lbs N/ac requirement using Coated Urea 2 and UAN as N sources for Site 1 (Figure 1). The optimal N rate using Coated Urea 1, Coated Urea 2 and UAN at Site 2 was 120 lbs/ac whereas cane stalk yield plateaued at 80 lbs N/ac using Coated Urea 3 as source. Similar result was observed using sugar yield as response variable (Figure 2). Coated Urea 2 and UAN had the same optimal N rate (120 lbs/ac) while Coated Urea 1 and Coated Urea 3 required an application rate of only 80 lbs N/ac to maximize sugar yield. However, across these sources UAN attained the highest maximum yield at 10,454 lbs/ac (Table 1).

Increasing N rate increased soil NO_3 and NH_4 levels, with greater increases coming from Coated Urea 1 and Coated Urea 2 two and four weeks after application (Figure 3). These observations were carried to eight weeks after N application and at harvest but with diminishing effect. On the other hand, the soil NO_3 and NH_4 levels at 6-12-inch depth tended to increase with sampling time indicating vertical movement of soil N had taken place. Similar patterns of soil NO_3 and NH_4 levels with sampling time, N source, and N rate were recorded at Site 2 (Figure 4). The UAN-treated soil had lower level of NO_3 and NH_4 across sampling time than soil treated with coated urea. This suggests that in less than two weeks, majority of NO_3 and NH_4 (if not all) in UAN were released to the soil solution while some were already absorbed by cane roots. Most of the soil NO_3 and NH_4 levels measure from 2 weeks and after were more likely from the urea component (50%) of the UAN solution. For Site 2, such pattern on soil NO_3 and NH_4 levels existed between Coated Urea 1 and UAN, and only at 2 weeks after N application whereas Coated Urea 2- and Coated Urea 3-treated soils were able to catch up on NO_3 and NH_4 levels four week after N application. As expected, soil NO_3 and NH_4 levels reduced with sampling time with harvest having the lowest level remained in the soil due to removal of cane and some losses possibly to leaching (as shown by the increasing level of soil NO_3 and NH_4 at 6-12 inch with time) and runoff.

<u>Effect of Nitrogen Source on Sugarcane Yield</u>

This study was continued on a new site (Commerce silty clay loam) in 2020 using L01-299 cultivar. Among the N sources, the highest yield increase was obtained from sugarcane treated with NH_4 sulfate; increases were +7.2 tons/ac (22%) for cane yield and +1,847 lbs/ac (23%) for sugar yield in reference to the check (Figure 5). Between N sources, both NH_4 sulfate and urea showed better performance than UAN and UAN+foliar. Sugarcane treated with $CaNO_3$ obtained stalk and sugar yield that was virtually the same as those from urea, UAN, and UAN+foliar treatments. Overall, the results suggest the potential of urea and NH_4 sulfate as N sources for sugarcane production.

<u>Evaluation of Nitrogen Recommendation Approach</u>

A replicated, strip (plot size: 5 rows x 400 ft long) trial was conducted to evaluate the impact of different best management practices on sugarcane productivity. Among the treatments

included the farmer's standard N practice (Farmer's Standard), sensor-based N recommendation in combination with N-rich strip technology (Sensor+N-Rich), and the best management practices (BMPs) which constituted the Sensor+N-Rich, sweeping off residue and cover cropping. Figure 6 shows the stalk and sugar yield for these treatments along with the N rate applied. While mean yields among these treatments were statistically the same, the Sensor+N-Rich and BMPs N rate recommendations were lower by 23 and 57 lbs N/ac, respectively than the Farmer's standard. This outcome demonstrates that implementation of robust, on-a-need basis N decision tool can save up N fertilizer that can subsequently improve N use efficiency in sugarcane production.

Aerial Images for Predicting Yield in Sugarcane Production

The validation work conducted in 2020 is outlined in Figure 7. The aerial images taken by MicaSense RedEdge-M™ sensor attached to DJI Phantom 4 were collected (from sugarcane canopies) in May. The aerial images were processed and converted to NDVI readings. The current model to convert NDVI derived from aerial images (UAV-NDVI) to GreenSeeker NDVI (Converted NDVI) has been established. These Converted NDVI readings were used to validate the GreenSeeker-based models for predicting stalk and sugar yield. At harvest, stalk and sugar yield was determined from the plots where the aerial images were taken early in the season. The relationship between predicted yield and measured yield was determined. The slope of the regression line measures the accuracy of the models whereas the coefficient of determination (R^2) measures the precision (repeatability) of the models. Table 3 summarizes the outcome of the validation done for 5 sites (with varying soil type and crop age). The precision of cane stalk yield prediction model was higher than the sugar yield prediction model. Overall, both models predicted only half of the actual yield, i.e., 0.43x for cane stalk and 0.54x for sugar yield. All these are for ratoon crops. For plant cane, the predictions made by both models were notably poor. Refinement of these models should address the saturation issues associated with canopy closure early in the season for plant cane crop.

Acknowledgements

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

Table 1. Mean yield, theoretical recoverable sugar, and BRIX of cane treated with different sources and rates of N at two sites in St. Gabriel, LA, 2020

Site	Source	N Rate (lbs/ac)	Cane (ton/ac)	Sugar (lbs/ac)	TRS (lbs/ton)	Brix (%)
Site 1	UAN	0	25.6	5547	217	18.6
		40	34.0	7425	218	18.7
		80	**37.7**	**8328**	221	18.9
		120	34.6	7578	219	18.7
	Coates Urea 1	0	25.0	5434	217	18.6
		40	32.9	7257	221	18.8
		80	35.0	7634	218	18.7
		120	**36.9**	**8093**	219	18.6
	Coated Urea 2	0	25.3	5337	209	18.2
		40	35.0	7447	213	18.5
		80	**35.9**	**7556**	210	18.1
		120	34.4	7328	213	18.5
	p-value		**<0.001**	**<0.001**	**0.997**	**<0.808**
	SED		**2.2**	**527**	**4.8**	**0.223**
Site 2	UAN	0	27.6	6412	230	19.6
		40	37.1	8579	230	19.3
		80	43.1	10330	239	19.6
		120	**44.3**	**10454**	235	19.5
	Coated Urea 1	0	29.6	6993	237	19.7
		40	34.6	8300	238	19.7
		80	**41.4**	**9848**	236	19.8
		120	41.7	9658	230	19.2
	Coated Urea 2	0	30.3	7085	232	19.4
		40	37.4	8800	234	19.6
		80	41.4	9819	236	19.7
		120	**43.2**	**10097**	233	19.5
	Coated Urea 3	0	30.0	6907	229	19.3
		40	37.7	8694	229	19.4
		80	**42.2**	**9932**	234	19.6
		120	42.1	9672	230	19.4
	p-value		**<0.001**	**<0.001**	**0.904**	**0.926**
	SED		**2.1**	**520**	**4.7**	**0.236**

Site 1: Commerce silty clay loam
Site 2: Commerce silt loam
UAN – urea ammonium nitrate solution; SED – standard error of difference

Table 2. Mean stalk N content and removal rate of cane treated with different sources and rates of N at two sites in St. Gabriel, LA, 2020

Site	Source	N Rate (lbs/ac)	Stalk N Content (%)	Stalk N Removal Rate (lbs/ac)
Site 1	UAN	0	0.294	44.7
		40	0.312	62.0
		80	0.343	76.5
		120	0.401	82.6
	Coates Urea 1	0	0.310	45.6
		40	0.337	65.3
		80	0.342	69.9
		120	0.346	75.1
	Coated Urea 2	0	0.352	50.7
		40	0.353	72.1
		80	0.392	81.3
		120	0.371	74.0
	p-value		0.559	0.8166
	SED		0.028	7.02
Site 2	UAN	0	0.187	32.0
		40	0.202	47.3
		80	0.248	67.1
		120	0.306	84.0
	Coated Urea 1	0	0.178	33.2
		40	0.218	48.2
		80	0.210	55.1
		120	0.243	66.2
	Coated Urea 2	0	0.207	38.8
		40	0.232	54.3
		80	0.250	66.5
		120	0.242	65.8
	Coated Urea 3	0	0.204	37.7
		40	0.233	55.3
		80	0.217	58.4
		120	0.339	86.0
	p-value		0.0540	0.076
	SED		0.021	4.99

Site 1: Commerce silty clay loam
Site 2: Commerce silt loam
UAN – urea ammonium nitrate solution; SED – standard error of difference

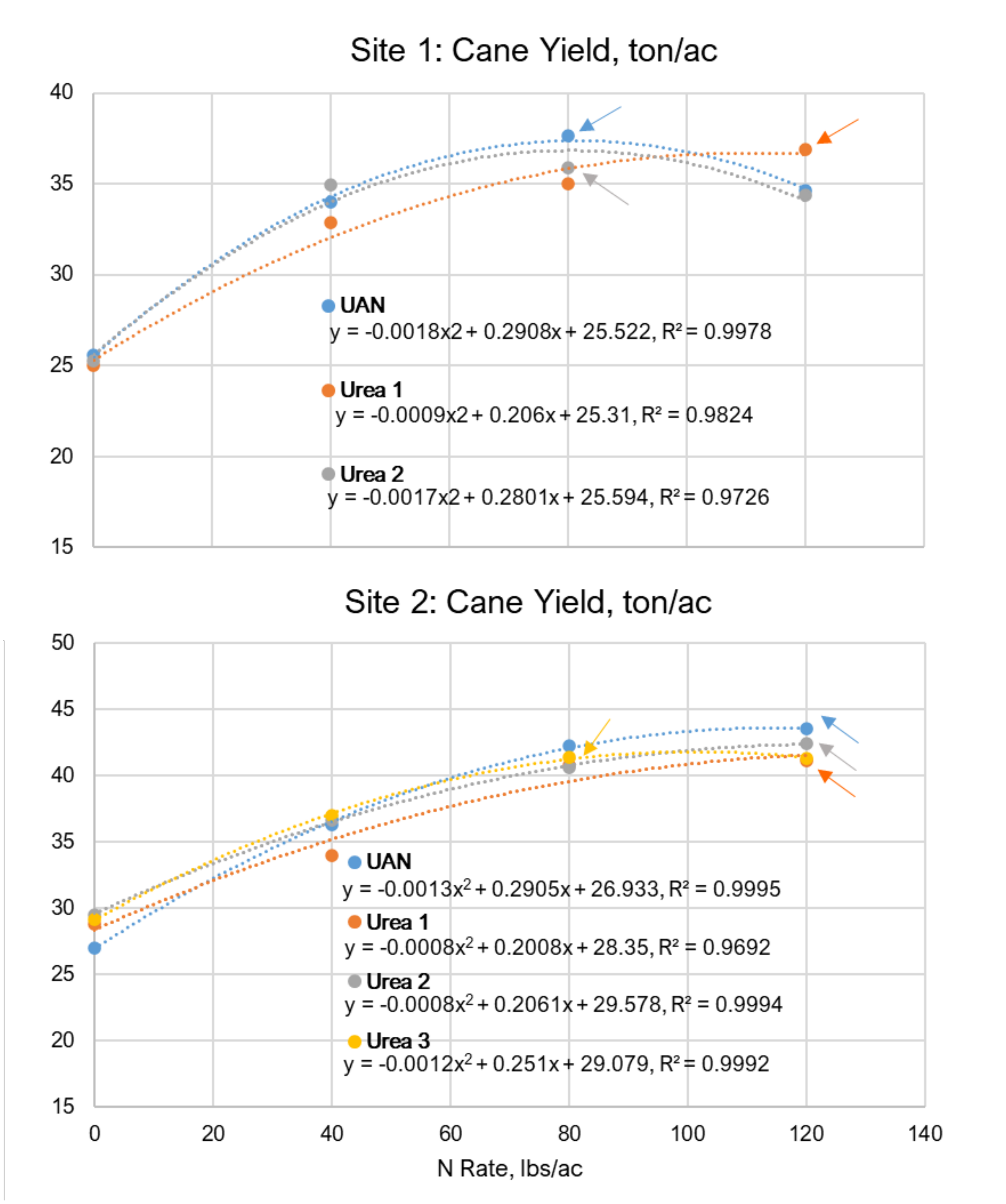


Figure 1. Cane yield response to different N sources and rates, St. Gabriel, LA, 2020. Arrows point to the maximum yield (y axis) and N rate (x-axis). Colors of the arrows correspond to the N source.

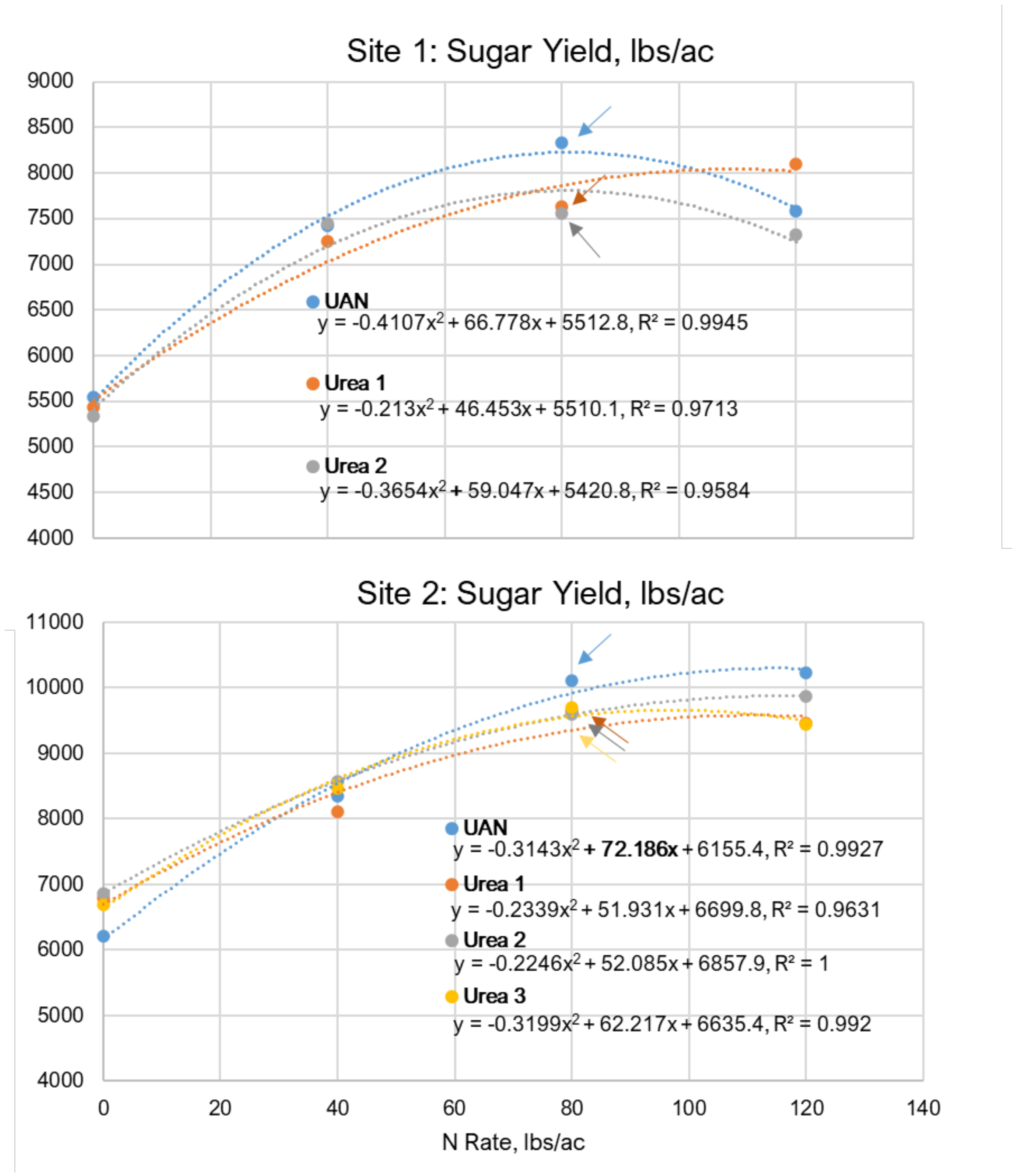


Figure 2. Sugar yield response to different N sources and rates, St. Gabriel, LA, 2020. Arrows point to the maximum yield (y axis) and N rate (x-axis). Colors of the arrows correspond to the N source.

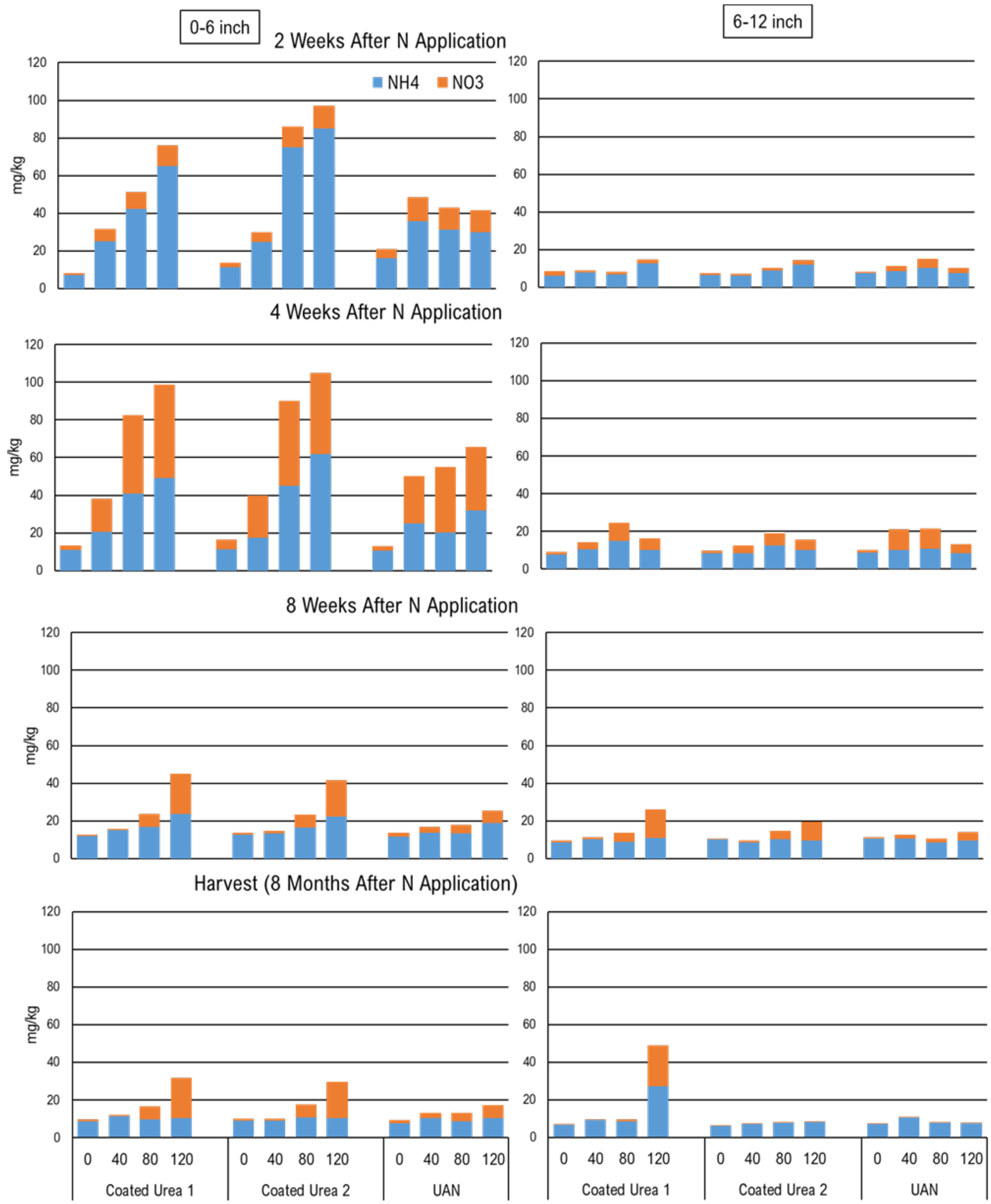


Figure 3. Soil NH_4 and NO_3 content (mg/kg) at 0-6 and 6–12-inch depth of Commerce silt loam soil (Site 1) 2, 4, and 8 weeks and 8 months after (harvest) treated with different sources of N at 0, 40, 80, and 120 lbs N/ac, Sugar Research Station, St. Gabriel, LA in 2020.

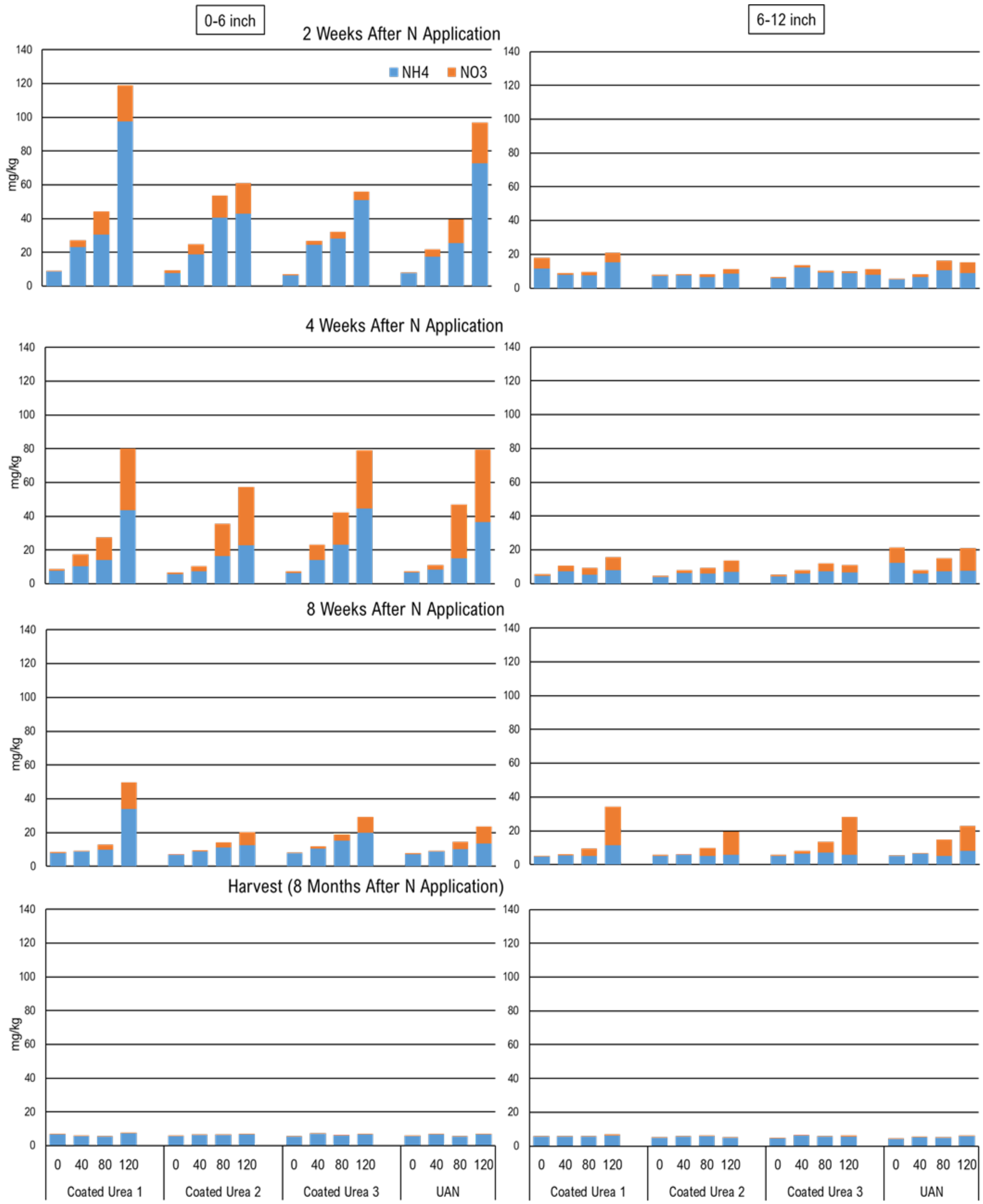


Figure 4. Soil NH_4 and NO_3 content (mg/kg) at 0-6 and 6–12-inch depth of Commerce silty clay loam soil (Site 2) 2, 4, and 8 weeks and 8 months after (harvest) treated with different sources of N at 0, 40, 80, and 120 lbs N/ac, Sugar Research Station, St. Gabriel, LA in 2020.

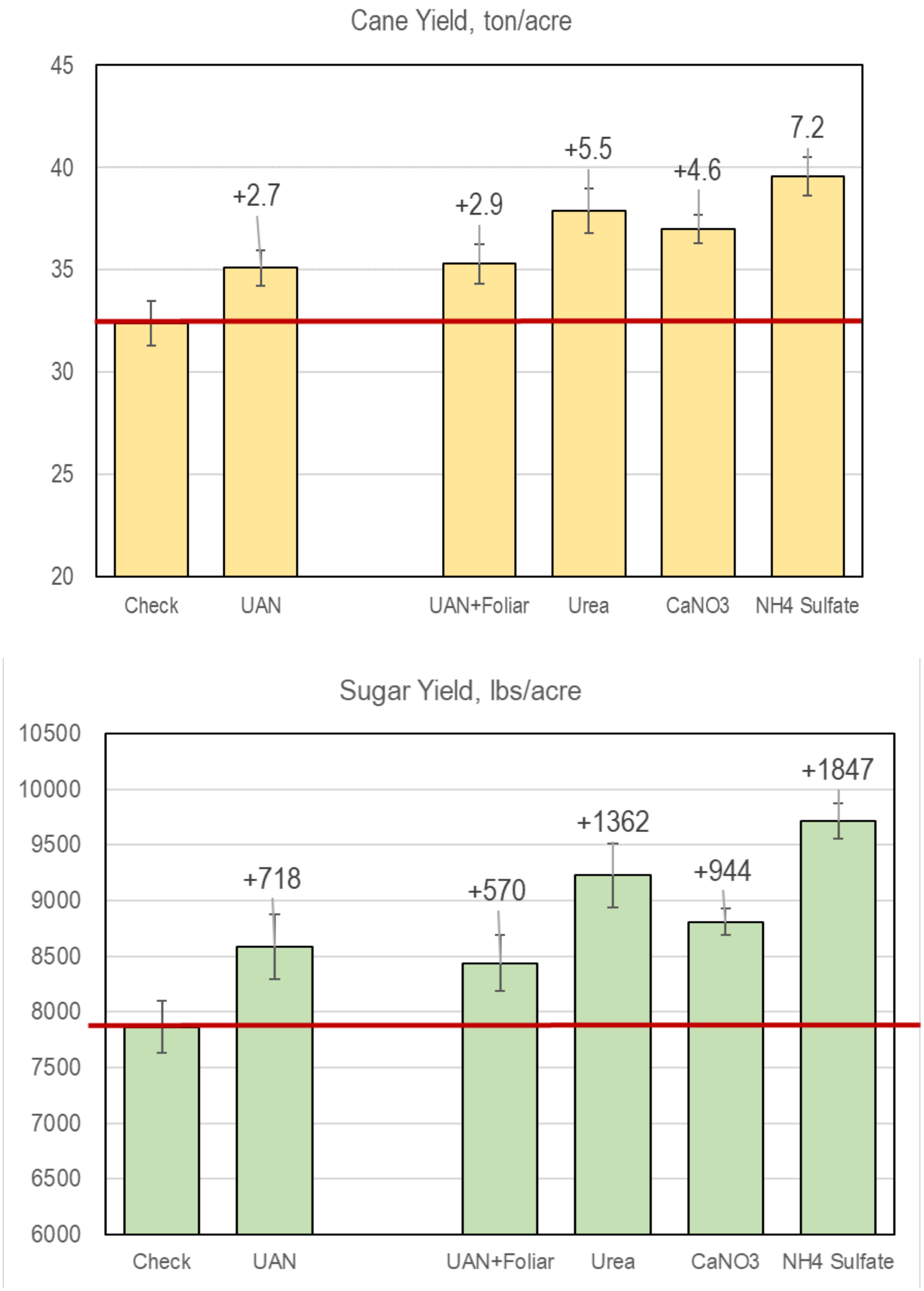
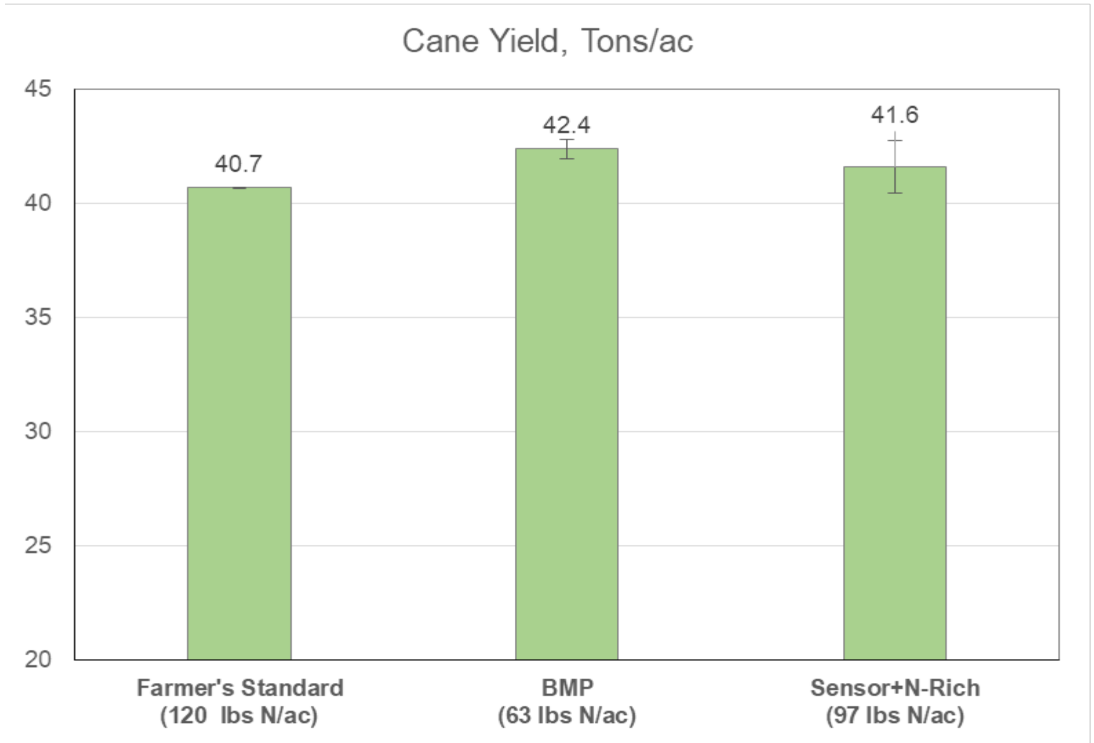


Figure 5. Stalk and sugar yield of L01-299 (plant cane) treated with different N sources at 80 lbs N/ac rate, St. Gabriel, LA, 2020. Values on top of the bars represent increase in stalk and sugar yield in ton/ac and lbs/ac, respectively due to N application.



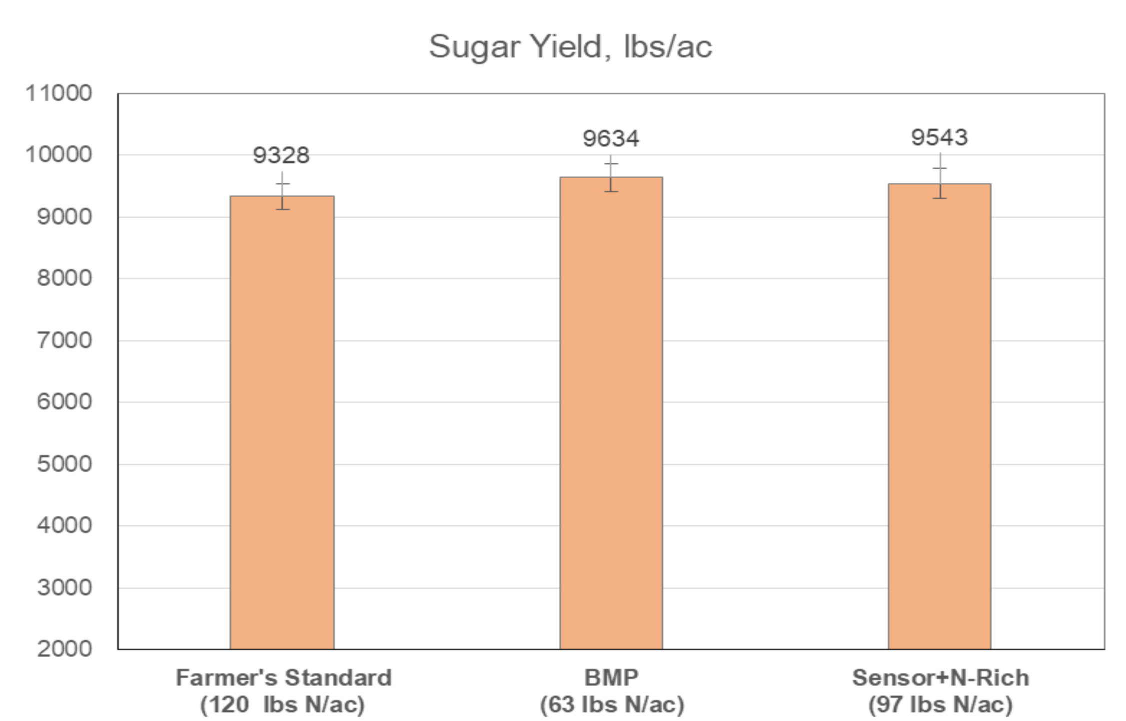


Figure 6. Cane stalk and sugar yield in response to different N recommendation/application approach, St. Gabriel, LA, 2020.

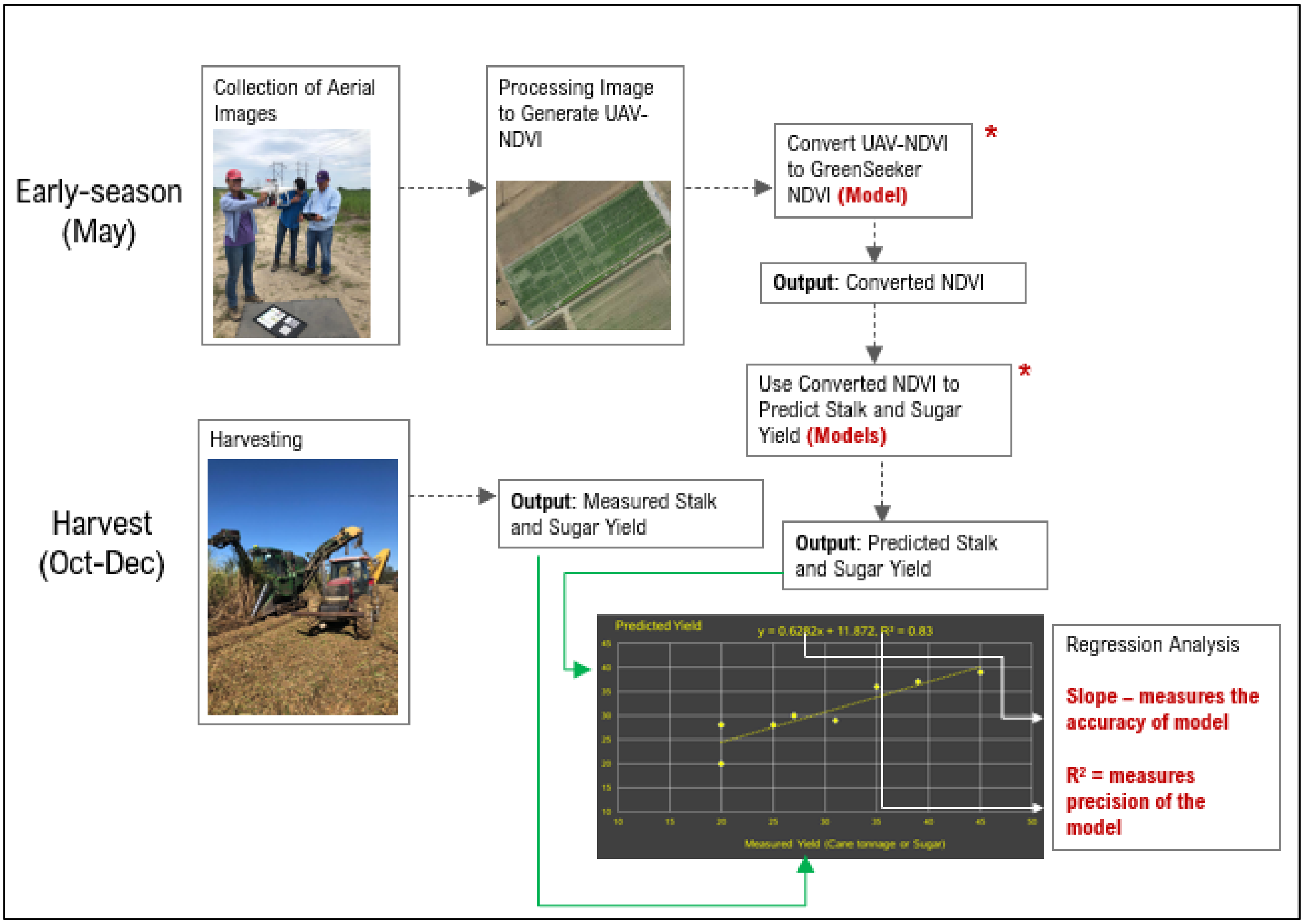


Figure 7. Validation workflow to determine if stalk and sugar yield prediction models established from GreenSeeker NDVI can be used with converted NDVI as predictor. Asterisks indicate that section of the workflow where models cannot be shown due to pending application for disclosure of proprietary.

Table 3. Results on validation work for cane with different crop age grown on different soil types, St. Gabriel, LA, 2020

Soil Type	**Crop Age**	**Cane Stalk Yield**		**Sugar Yield**	
		Slope	**R^2**	**Slope**	**R^2**
Silt loam	2nd Ratoon	0.53	0.77	0.72	0.62
Silty clay loam	2nd Ratoon	0.39	0.73	0.54	0.60
Silty clay loam	1st Ratoon	0.40	0.67	0.47	0.41
Silty clay	3rd Ratoon	0.43	0.75	0.54	0.51
Silty clay loam	Plant Cane	0.18	0.13	0.02	0.01