Laboratory assays for sodic soil reclamation

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Introduction

- The field sites is an 810 ha private farm in Guayama municipality (PR south coast)
- 175 field plots in an area of 304 ha sampled to a depth of 15 to 20 cm
- Soils analyzed for general soil fertility parameters; saturated paste (EC, SAR, pH)
- Soils are primarily Haplustepts, Haplusterts, and Calciusterts, mostly non-calcareous of high fertility
- Crops: inbred maize, hybrid maize, soybean
- Inbred maize very sensitive to high salinity and sodium
- The estimated area affected by saline-sodic conditions beyond accepted thresholds[1] is 37 ha (about 12% of the area) and by sodic soil conditions about 28 ha (about 9% of the area).
- Other areas may not have saline or sodic soil classification, but the salt and sodium levels may be high enough to affect crops; thus the estimated area where some form of reclamation is needed is 142 ha or 75 plots.

Soil dispersion and salt or sodium accumulation

Soil dispersion and liquefication caused by high soil sodium

Uneven plant growth of inbred lines in V 94-95, Jan 2015

Plants affected by salts or sodium

1 - Saline, sodic and saline-sodic soil is defined as that having a saturated paste extract electrical conductivity (EC) >4 dS/m and ESP <15%, <4 dS/m and ESP >15%, and >4 dS/m and ESP >15%, resepectively.

Objectives

- Provide practical recommendations (gypsum sources and rates) for reclamation of excess soil Na
- Provide long-term strategies to improve soil quality
- In this poster we report on laboratory assays that evaluated gypsum sources and rates on leachate water chemical composition

Materials and Methods

- Soil sampled from field V-95-96; August 2014 (Table 1)
- Soil series is Paso Seco (Fine, mixed, superactive, isohyperthermic Entic Udic Haplusterts)
- Soil (bulk density of 1.1 g/cm^3) packed in 60 mL syringe microcosms
- Mechanical extractor (Figure 1) (Jaynes and Bigham, 1986), simulated the leaching process
- Measurements: Leachate volume, pH, EC, Ca, Mg, Na concentrations
- Consecutive 2.54 cm leachings, each equivalent to 46 mL (2 pore-volumes)
- Soil was equilibrated to -30 kPa after each leaching
- Experiment – 1 Gypsum source (pHusion®) with two levels (750 and 4,500 mg/kg soil (dry wt.)
- Experiment – 2
  - **Gypsum sources (Table 2)**: Agricultural grade gypsum, pHusion® gypsum, Reagent grade gypsum
  - **Gypsum levels**: 750, 1,500, 3,000, 6,000, 12,000 mg/kg soil
- Soil mixed with 25% silica sand to facilitate drainage (unammended soil did not drain)

Figure 1. Mechanical extractor with soil microcosms

Results and discussion

Table 1. General soil fertility characteristics of the soils (Field V-95) used in the experiments[1].

pH	SOM	NO_3-N	Olsen P	Ca	K	Mg	Na	CEC
	g/kg	---mg/kg---		------------cmol$_c$(-)/kg			------------------	
8.2 [2]	4.5	51	110	21.6	1.56	5.68	6.41	35.3
8.2 [3]	2.9	56	27.6	18.1	1.05	5.23	10.81	35.2

1 - pH measured on 1:1 soil:water; soil organic matter (SOM) by loss on ignition, exchangeable cations (Ca, Mg, K, Na) by NH4OAc extraction, cation exchange capacity (CEC) by sum of cations ; analysis by Harris laboratories (http://agsource.crinet.com/page298/Agronomy).
2 – Soil used in Experiment – 1
3 – Soil used in Experiment - 2

Table 2. Chemical characteristics of gypsum sources (analysis by A&L Great Lakes Laboratories)

Gypsum source	Free water	Ca	S	CCE	pH	Purity (gypsum)
	------------------------------			%--	------------------------	
pHusion®	1.3	21.0	17.7	3.5	5.99	88.0
Agricultural grade	5.1	24.2	14	19	7.81	74.5
Reagent grade	nd					

1 – Free water by ASTM C471; Ca by ASTM C471.11.3; S by AOAC 980.02; CCE (calcium carbonate equivalent) by AOAC 955.01; pH by A&L SOP 7.01; purity by ASTM C471.
2 – nd, no data

Experiment – 1 (Table 3, pHusion gypsum)

- Leachate volume and cations increased with gypsum level
- Leachate volume recovered at the highest gypsum level was 82% of the maximum (114 mL)
- Exchangeable Na to reduce ESP to 5% was 4.74 cmol$_c$(-)/kg, thus the highest gypsum level was effective in removing Na to desired levels (yellow cell)
- Ca and Mg removed was <5% of that added plus exchangeable
- Leachate SAR was still high because the percent reduction of Na in leachate was near 72% while Ca and Mg was near 92%

Experiment – 2 (Table 3, reagent gypsum)

- The soil in experiment – 2 had higher exchangeable Na than in Experiment 1
- At least 6,000 mg gypsum/kg was needed to maximize leaching
- There was trend for increasing leachate volume in the order of Agricultural Gypsum < pHusion < Reagent Grade Gypsum (data not shown)
- Solution cations (Ca, Mg, Na) increased with increasing gypsum amendment
- A reduction of 9.04 cmol$_c$ Na/kg was needed to reach ESP of 5%; amending with 6,000 and 12,000 mg gypsum/kg reached solution Na of 7.82 and 8.68 cmol$_c$ Na/kg, respectively after five leachings. An estimated ESP of 6.1% was reached
- The highest gypsum level was effective in removing Na to desired levels
- An acceptable leachate SAR was achieved at 6,000 mg gypsum/kg mg/kgstill high because the percent reduction of Na in leachate was near 72% while Ca and Mg was near 92%

Table 3. Cumulative leached volume, exchangeable cations recovered in solution, % recovery of cations and final SAR of leachate (cations measured by UGA Laboratory, http://aesl.ces.uga.edu/)

Gypsum source	Gypsum level	Leached volume[1]	Exchangeable[2] Ca	Exchangeable[2] Mg	Exchangeable[2] Na	Recovery[3] Ca	Recovery[3] Mg	Recovery[3] Na	SAR
	mg/kg dry soil	mL	---------cmolc(+)/kg-------			-----------------%--------------			
Experiment-1									
pHusion	750	33.6a	0.22a	0.18ns	2.48a	0.95a	3.5ns	38.8a	18.4ns
	4,500	93.3 b	0.51 b	0.28	4.71 b	1.93 b	5.0	73.3 b	24.7
Experiment-2									
Reagent	750	117.0abc	0.42a	0.34a	3.95a	2.23a	6.53a	36.53a	10.04 bc
	1,500	112.3 ab	0.74 ab	0.61 b	5.84 b	3.75 b	11.55 b	54.05 b	18.04 d
	3,000	115.4abc	0.91 b	0.66 b	7.00 bc	4.25 b	12.7 b	64.7 bc	13.6 c
	6,000	137.1 cd	1.4 c	0.89 c	7.82 cd	5.78 c	17.05 c	72.33 cd	8.51 b
	12,000	138.9 d	4.22 d	1.8 d	8.68 d	13.88 d	34.33 d	80.3 d	2.44 a

1 - Leached volume is the sum of three extractions in Experiment-1 and five extractions in Experiment-2.
2 - Exchangeable cations was calculated as LV*C/dry soil mass; where LV is the leached volume, and C is the cation (Ca, Mg, or Na) concentration of the leached volume, summed across the three extractions in Experiment-1 and five extractions in Experiment-2.
3 - % recovery was calculated as $C/C_{exchangeable}$*100; where C is the cation (Mg, Na) concentration in the leached volume and $C_{exchangeable}$ is NH4OAc extractable cations. For Ca the amount of Ca added as the gypsum source was included in the calculation.

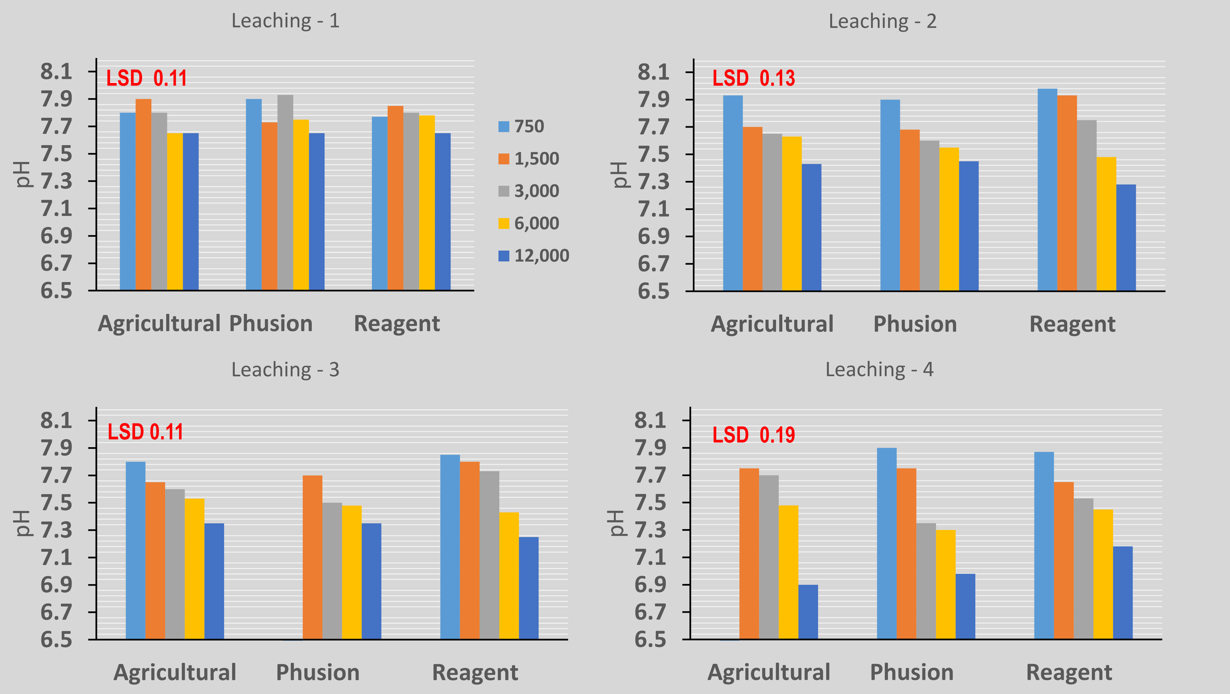

Figure 3. Leachate solution pH as influenced by gypsum sources and levels. LSD values (in red) are gypsum source * level comparisons within each leaching event.

- Leachate pH consistently decreased with increasing gypsum levels (Figure 3)
- The greatest reduction in pH as a result of gypsum levels occurred in the last leaching
- Reagent gypsum was more effective in reducing pH at the lowest amendment levels, with lower difference among gypsum sources in solution pH was observed at the highest gypsum levels.
- The leachate EC was highest in the first leaching and decreased with subsequent events (note that the reduction between the second and third leachings were dramatic) (Figure 4)
- In leachings 1 to 3, EC increased with increasing gypsum level. In leaching 4 EC decreased with gypsum levels in the range of 750 to 3,000 mg/kg, but not at the highest levels.

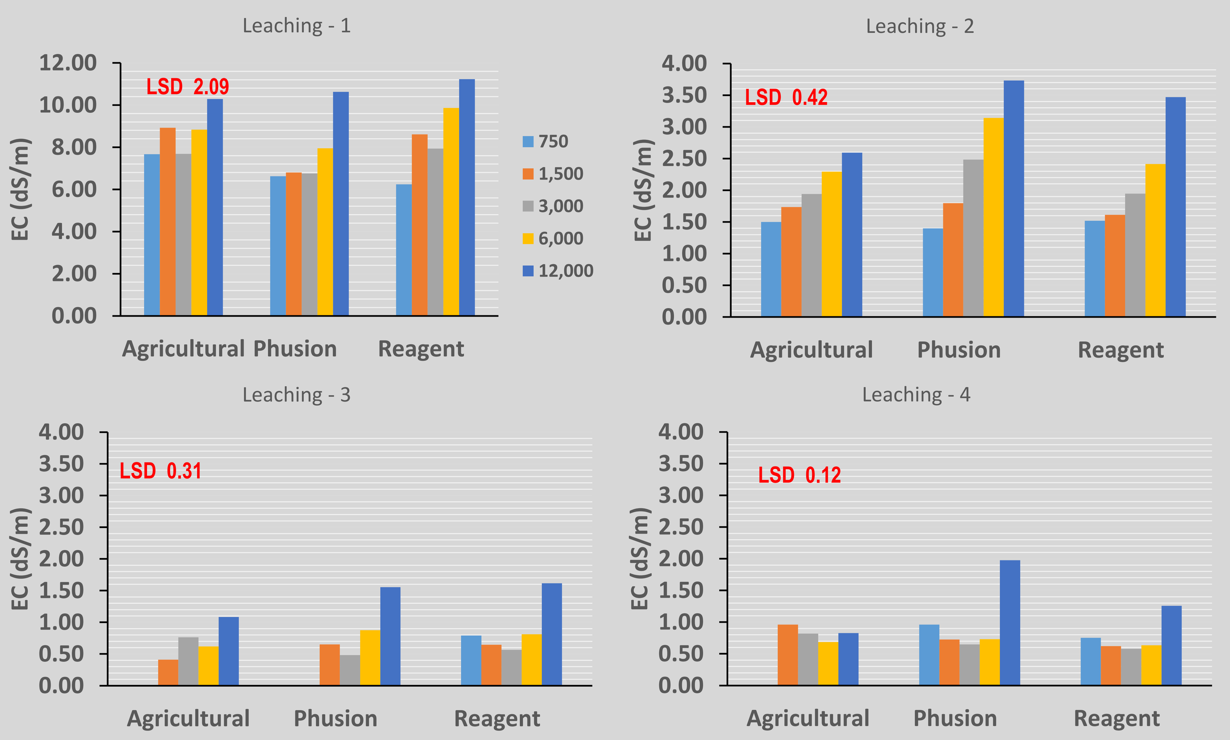

Figure 4. Leachate solution electrical conductivity (EC) as influenced by gypsum sources and levels. LSD values (in red) are gypsum source * level comparisons within each leaching event.

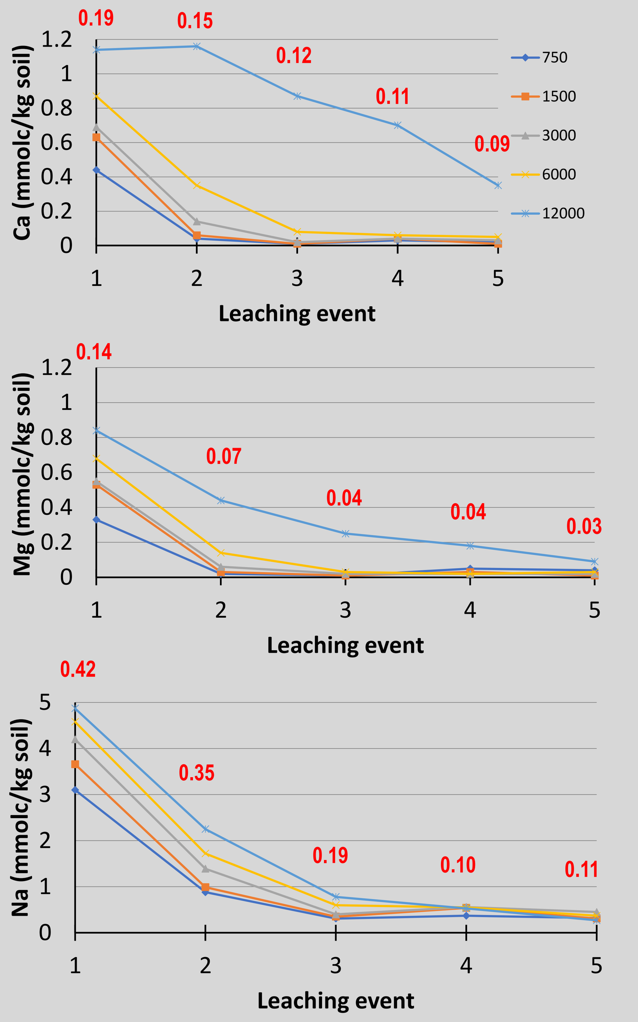

Figure 2. Leachate solution composition of Experiment – 2 (Reagent gypsum), by leaching event. LSD values are gypsum level comparisons within each leaching event.

- Soil solution cation concentrations followed gypsum amendment levels (Figure 2)
- All cations were highly correlated (r > 0.9), with lower correlation at the highest gypsum level (data not shown)
- The reduction of soil solution Na was highly associated with soil solution Ca and Mg (especially at gypsum levels of 750 to 3,000 mg/kg); this may be part of the reason why SAR levels did not decrease at the lower gypsum levels (Table 3).
- In contrast at gypsum level of 12,000 mg/kg and to a lesser extent at 6,000 mg/kg, Ca concentrations were high enough to reduce SAR to acceptable levels (see Table 3)

Conclusions

- Soil microcosms using the mechanical extractor may not simulate field conditions but is effective towards evaluating the effects of gypsum sources and rates on soil solution composition.
- The best amendment and rate was that which increased leachate volume, had lower leachate pH and EC and SAR.
- Agricultural gypsum was as effective as pHusion® and Reagent gypsum at the highest rate.
- pHusion® gypsum seemed to be most effective near the 3,000 mg/kg level of amendment.
- Gypsum at 12,000 mg/kg was the most effective soil remediation strategy reducing ESP to near 6%, yet a more practical rate may be an application level of between 6,000 and 12,000 mg/kg.
- The successful transfer of this technology to field conditions will require adequate soil infiltration rates and leachate removal from soil.

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