Calcium Silicate Slag Application Influences Nutrient Availability in Soil and Uptake By Wheat

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INTRODUCTION

- Silicon (Si) has proved to be a beneficial nutrient to many crops including wheat, providing abiotic and biotic stress resistance. The form that is available to plants is mono- silicic acid (H_4SiO_4).
- Calcium silicate slag is a by-product from the steel industry and is commonly used as a source of Si fertilizer.
- The US is the largest exporter of wheat in the world and ranks the third highest in planted acreage and gross farm receipts among US field crops.
- Influence of varying rates of Si and N on yield improvement and nutrient uptake in wheat is not fully understood.

OBJECTIVE

To investigate the influence of varying rates of Si and N on yield and essential nutrient uptake in wheat.

MATERIALS AND METHODS

- **Experimental Sites**:
  1. St. Joseph, LA (**NERS 2013**) on a Commerce silt loam soil (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts).
  2. St. Joseph, LA (**NERS 2014**) on a Sharkey-Tunica-Newellton complex (Very-fine, smectitic, thermic Chromic Epiaquerts) and Commerce silt loam soil types.
  3. Benhur, LA (**BH 2014**) on a Cancienne silt loam soil (Fine-silty, mixed, superactive, nonacid, hyperthermic Fluvaquentic epiaquepts).
- **Treatment Structure**: N rates: 101 and 145 kg ha^{-1}; $CaSiO_3$ (17% Si) rates: 1, 2, 4.5, and 9 Mt ha^{-1}. Check plots: lime (90% $CaCO_3$ Equivalent) at 4.5 Mt ha^{-1}; no lime.
- **Experimental Design:** Randomized Complete Block Design, Four replications.
- **Establishment**: Seeds of wheat variety Terral TV8525 were drilled at a rate of 100 kg seeds ha^{-1}. Nitrogen treatment was applied as top-dressed urea (46%N) (Fig 1B).
- **Sample and Field Data Collection**: Biomass clippings at Feekes 5 and 10.5 growth stages; whole plant sub-samples at harvest (Fig. 1D); plot yield using a combine harvester (Fig. 1E); mid-season and post-harvest (Fig. 1F) soil samples.
- **Analyses:** _Soil samples_ - 0.5 M acetic acid extractable Si following Molybdenum Blue Colorimetry (MBC) and Mehlich-3 extractable nutrients by Inductively Coupled Plasma Mass Spectrometry (ICP). _Plant tissue samples_ - elemental composition using HNO_3-H_2O_2 wet digestion followed by ICP, total N content by dry combustion and Si content by Oven- Induced Digestion procedure followed by MBC.
- **Statistical Analysis**: Analysis of variance using PROC Mixed in SAS. Mean separation procedure and contrast analysis followed when treatment effect was significant.

Figures 1A-F. Application of $CaSiO_3$ slag and lime prior to planting (A); Top dressing of urea (B); Disease monitoring and rating (C); Whole plant sampling for yield component determination (D); Plot harvesting with combine harvester (E); and post-harvest soil sampling (F).

Table 1. Analysis of Variance on effect of Si ($CaSiO_3$) and N (Urea) on soil pH and concentration (mg kg^{-1}) of nutrients at harvest

	[1]pH	[2]Si	[3]NO_3	[3]Ca	[3]Mg	[3]S	[3]Fe	[3]Mn	[3]Zn
Effects					**NERS 2013**				
N	NS	NS	*	NS	NS	NS	NS	NS	NS
Si	***	***	***	***	***	**	NS	NS	*
N * Si	NS	NS	NS	NS	NS	NS	NS	NS	NS
					NERS 2014				
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Si	**	***	*	**	NS	NS	NS	NS	**
N * Si	NS	NS	NS	NS	NS	NS	NS	NS	NS
					BH 2014				
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Si	**	***	**	***	***	***	NS	**	***
N * Si	NS	NS	NS	NS	NS	NS	NS	NS	NS

P < 0.001=***, P<0.01=**, P< 0.05=*, NS= Non Significant

[1]Soil pH, [2]0.5 M acetic acid extractable Si, and [3]Selected Mehlich-3 extractable nutrients soil samples at different N and CaSiO3 slag rates in all three site years were used. Other nutrients did not show significant changes.

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Table 2. Analysis of Variance on effect of Si ($CaSiO_3$) and N (urea) on uptake (mg kg^{-1}) of nutrients by wheat straw at harvest

	[1]Si	[2]N	[3]P	[3]Ca	[3]Mn	[3]S	[3]Fe	[3]Mo	[3]Zn
Effects					**NERS 2013**				
N	**	NS	NS	NS	NS	NS	NS	NS	NS
Si	NS	NS	NS	NS	****	**	NS	NS	NS
N * Si	NS	NS	NS	NS	NS	NS	NS	NS	NS
					NERS 2014				
N	NS	NS	NS	**	NS	**	NS	NS	NS
Si	NS	NS	NS	NS	**	NS	NS	*	NS
N * Si	NS	***	***	**	NS	**	*	NS	NS
					BH 2014				
N	NS	***	NS	**	NS	NS	NS	NS	NS
Si	NS	NS	NS	NS	***	NS	*	**	NS
N * Si	NS	NS	NS	NS	NS	NS	NS	NS	NS

P < 0.001=****, P</=0.01=***, P</ = 0.05=**, P</= 0.1= *

NS= Non Significant [1] Si measured by oven induced digestion, [2]N=Total N using dry combustion method. [3]Selected nutrients analyzed using nitric acid digestion of post-harvest straw samples at different N and $CaSiO_3$ slag rates in all three site years were used. Other nutrients did not show significant changes.

RESULTS

The results showed that application of $CaSiO_3$ slag increased the content of extractable Ca, Mg, S, Zn, NO_3^- and Si in soil (P<0.05). The application of $CaSiO_3$ slag also increased soil pH across site-years (P<0.01).

Straw Si and Mn content and uptake had a consistent negative relationship for all three site-years (P<0.05). Increasing $CaSiO_3$ slag rates significantly increased Fe, Mo, P and S uptake in straw (P<0.05).

This study brought into light some of the possible interactions between Si and other nutrients. Higher uptake of Mo concurrent with high rates of Si could be a reason for grain yield increases observed for BH 2014 at the highest Si rate of 9 Mt ha^{-1} for both N rates (P<0.1).

CONCLUSIONS

The increased availability of nutrients in the soil and their uptake could play a role in improved yields thus, $CaSiO_3$ slag as a liming material in place of common agricultural lime may be a good alternative for sustaining wheat productivity.

REFERENCES

White, B. 2015 "EVALUATING THE EFFECTS OF SILICON AND NITROGEN FERTILIZATION ON WHEAT PRODUCTION“. **Thesis. submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College. Web**