Silicon and Nitrogen Fertilization Influences Wheat Biomass and Grain Yield

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INTRODUCTION

- Silicon (Si) has proved to be a beneficial nutrient to many crops including wheat, providing and increase in disease and pest resistance as well as structural integrity. Calcium silicate slag is a by-product from the steel industry and is commonly used as a source of Si fertilizer.
- Nitrogen (N), the most important and limiting nutrient to plants, can have large impacts on yield particularly when deficient or applied in excess. Excess N can cause a decrease in yield due to lodging.
- 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.
- Little research has been done to show the interactions and effects of both these two important nutrients in wheat production.

OBJECTIVES

- Evaluate the interactive effect of Si and N on wheat biomass and grain yield.
- Establish Si application rate to maximize wheat grain yield.

MATERIALS AND METHODS

- **Experimental Site**: St. Joseph, LA on a Commerce silt loam soil (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts).
- **Treatment Structure**: Two N rates (101 and 145 kg ha^{-1}) and four calcium silicate slag ($CaSiO_3$, 17% Si) rates of 1, 2, 4.5, and 9 Mt ha^{-1}. Two check plots were included with lime ($CaCO_3$, 90% Calcium Carbonate Equivalent) at 4.5 Mt ha^{-1} and without lime.
- **Experimental Design**: Randomized Complete Block Design (RCBD) with four replications.
- **Establishment**: Prior to planting, $CaSiO_3$ and lime treatments were applied (and incorporated) to 1.8-m x 5.2-m plots (Fig. 1A). Seeds of wheat variety Terral TV8525 were drilled at a rate of 100 kg seeds ha^{-1}. Nitrogen treatment was applied as topdressed urea (46%N).
- **Sample and Field Data Collection**: Biomass clippings at Feekes 5 (Fig. 1B) and 10.5 growth stages; whole plant sub-samples at harvest (Fig. 1E); plot yield using a combine harvester (Fig. 1F); mid-season and post-harvest (Fig. 1G) 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-G. Application of $CaSiO_3$ slag and lime prior to planting (A); Biomass clipping collection at Feekes 5 growth stage (B); Disease monitoring (C) and rating (D); Whole plant sampling for yield component determination (E); Plot harvesting with combine harvester (F); and post-harvest soil sampling (G).

Table 1. Changes in Mehlich-3 extractable nutrients, 0.5 M acetic acid extractable Si, and pH of post-harvest soil samples at different N and $CaSiO_3$ slag rates, 2013, St. Joseph.

N Kg ha^{-1}	CaSiO3 Mt ha^{-1}	Soil pH	Extractable Nutrients, mg kg^{-1}							
			Si	P	K	Mg	Ca	S	Zn	Fe
101	0	5.38	62	31	288	498	1970	8.6	2.9	336
	1	5.41	65	33	304	521	2082	9.4	2.6	355
	2	5.63	83	31	280	522	2126	9.4	2.6	334
	4.5	6.04	118	35	314	573	2475	11.1	2.2	331
	9	6.18	138	37	285	557	2449	12.9	2.3	345
145	0	5.12	58	35	297	485	1989	9.5	2.7	379
	1	5.25	64	39	300	499	2075	10.3	2.5	375
	2	5.66	94	35	299	547	2244	10.1	2.4	351
	4.5	5.97	118	38	312	542	2346	10.6	2.2	350
	9	6.34	164	36	302	597	2647	12.3	2.0	315
Check		5.13	68	38	313	499	2005	9.5	2.7	376
Check-lime		6.09	92	34	300	521	2361	9.7	2.7	316

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RESULTS

Table 2. Trend of biomass production and silicon content of wheat at different growth stages as affected by varying rates of N and $CaSiO_3$ slag.

N Kg ha^{-1}	$CaSiO_3$ Mt ha^{-1}	Feekes 5		Feekes 10.5		Harvest		
		Mt ha^{-1}	%Si	Mt ha^{-1}	%Si	Mt ha$^{-1}_{straw}$	$\%Si_{straw}$	$\%Si_{grain}$
101	0	2.96	0.81	7.99	1.95	8.9	2.68	0.06
	1	3.24	0.91	10.61	2.01	9.3	2.67	0.06
	2	4.13	0.92	10.66	2.08	10.5	2.83	0.07
	4.5	3.14	0.79	8.71	3.14	10.0	2.84	0.10
	9	4.10	0.86	11.24	2.20	9.7	2.88	0.07
145	0	3.23	0.72	10.34	1.83	8.6	2.52	0.08
	1	3.18	0.78	10.61	2.01	9.2	2.64	0.06
	2	3.35	0.84	8.94	2.00	9.9	2.78	0.07
	4.5	3.38	0.73	10.80	1.92	8.8	2.66	0.07
	9	3.30	0.74	9.35	1.97	10.5	2.61	0.05

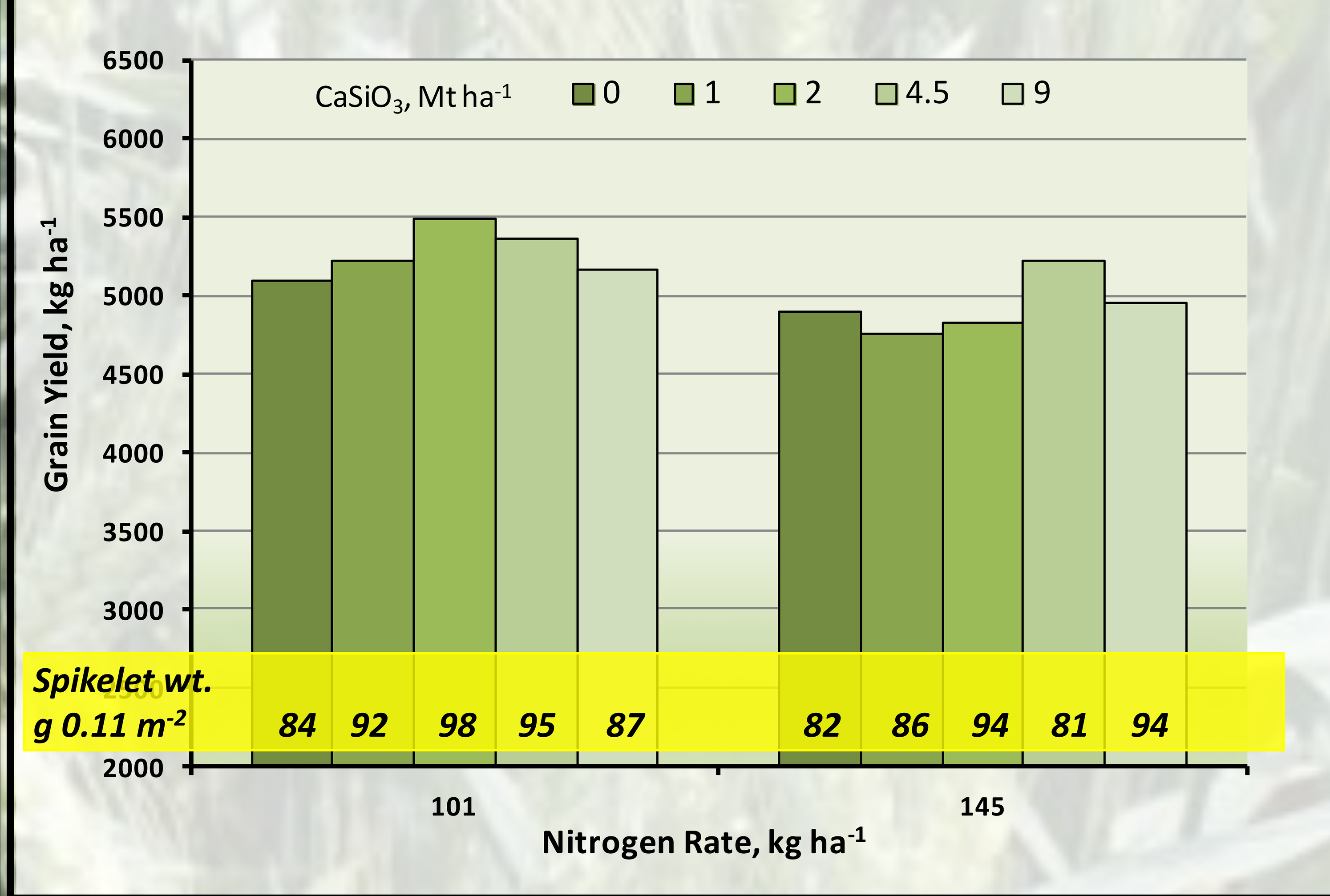

Figure 2. Grain yield and spikelet weight of wheat at varying rates of N and $CaSiO_3$.

- Extractable Si, Ca, Mg and S increased with increasing CaSiO3 rate (Tabl3 1). On average, the application of 4.5 Mt ha^{-1} of $CaSiO_3$ slag raised the 0.5 M acetic acid extractable Si by 48 mg kg^{-1}. There was a slight steady decline in extractable Zn most likely due to an increase in soil pH.
- Generally, an increasing trend in biomass and straw production was observed with increasing $CaSiO_3$ application rate up to 2 Mt ha^{-1}. Similarly, Si content of biomass and straw increased with $CaSiO_3$ rates (2 or 4.5 Mt ha^{-1}). Silicon content of grain was very low and the differences among treatments were very small (Table 2).
- However, the amount and N content of biomass clippings were different between the two N treatments (data not shown). These differences were translated to higher grain yield in plots which received 101 kg N ha^{-1} than plots applied with 145 kg N ha^{-1} (P<0.10). The addition of $CaSiO_3$ slag at a rate of 4.5 Mt ha^{-1} tended to increase grain yield of plots supplied with 145 kg N ha^{-1} while in plots applied with 101 kg N ha^{-1}, the highest grain yield was obtained at 2 Mt $CaSiO_3$ slag ha^{-1} application rate (Fig. 2).
- The resulting increase in yield due to $CaSiO_3$ slag application was more evident when combined with optimal N application rate. There were indications of Si and N interaction effect on wheat growth and development. Repeated trials of this study will be conducted to further support these initial findings.