Effect of Silicon Fertilization on Growth, Yield, and Disease Development in Wheat Plant

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INTRODUCTION

- Wheat (*Triticum aestivum*) is one of the most important crops worldwide with the global production exceeding that of all other crops. The United States is a major wheat-producing country and wheat ranks third among U.S. field crops in both planted acreage and gross farm receipts, behind corn and soybeans.
- Leaf rust diseases caused by *Puccinia triticina* are among the most widespread and economically important diseases of wheat and perhaps the worst and most prevalent disease affecting wheat throughout the state of Louisiana.
- Silicon (Si) is an abundant element in the lithosphere and is implicated in the tolerance to abiotic as well as biotic stresses across multiple angiosperm taxa.
- In general, Si supplementation benefits crops by increasing yield and enhancing resistance to pathogens and pests.

OBJECTIVE

- Investigate the efficacy of silicon fertilizers on reducing wheat leaf rust disease

MATERIALS AND METHODS

- **Research Site:** LSU AgCenter Research Stations, Ben Hur and Winnsboro, Louisiana.
- **Experimental Design**: 2 x 7 factorial treatment structure was superimposed on 9 m x three 1.8 m bed plots using split plot in randomized completely block design with four replications.
- **Treatments Structure**:
  - Wheat variety: Terral 8525
  - Silicon fertilizer rates: Wollastonite (23% Si) and calcium silicate ($CaSiO_3$, 12% Si) slag at 280 kg ha^{-1}
  - Foliar Silicon (Armurox®) rates: 1000, 2000, and 4000 ml ha^{-1}
  - Nitrogen fertilizer rates: 100, 145 kg ha-^{1} as urea (45%)
- Parameters Measured:
  - Biomass yield, at Feekes growth stage 9, grain yield, yield components, rust rating (Fig. 2), and distribution of silica bodies on leaf surface using SEM-EDX (scanning electron microscopy with energy dispersive X-ray spectroscopy).
  - Analyses:

    Soil samples - 0.5 M acetic acid extractable Si following Molybdenum Blue Colorimetry (MBC) and Mehlich-3 extractable nutrients by Inductively Coupled Plasma 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 and Duncan test (0.5 level of confidence) using SPSS.

Figures 1 A-F. Application of wollastonite and slag prior to planting (A) , nitrogen treatment application (B), foliar silicon application (C), experimental site at Ben Hur farm, and whole plant sampling for yield component determination (E) and hand harvesting (F).

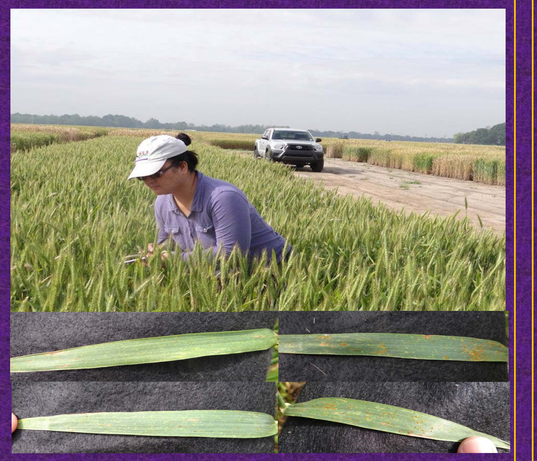

Figure 2. Leaf rust infection rating in wheat applied with different silicon sources under two level of nitrogen supply.

RESULTS AND HIGHLIGHTS

Table 1. Results of analysis of variance for agronomic and disease parameters.

Location	SV	Tiller	Panicle	Yield			Silicon content			Silicon Uptake			Lodging	Rust 1	Rust 2	Scab
				Biomass	Straw	Grain	Biomass	Straw	Grain	Biomass	Straw	Grain				
Ben Hur	N	NS	NS	NS	<0.010	NS	NS	NS	NS	<.05	NS	NS	<0.001	<0.001	<0.05	-
	Si	NS	NS	NS	NS	NS	<.001	<.001	<0.001	<.001	<0.001	NS	<0.01	NS	NS	-
	N x Si	NS	NS	NS	NS	NS	<0.05	NS	NS	NS	NS	NS	<0.01	NS	NS	-
Winnsboro	N	NS	NS	NS	<0.10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Si	NS	NS	NS	NS	NS	<0.001	<0.001	<0.05	<0.001	<.001	<.05	<0.05	<0.10	NS	NS
	N x Si	NS	<0.10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

SV – sources of variation, N – nitrogen, Si – silicon treatment, Rust 1 and 2 – rust rating conducted in mid-April with one week interval

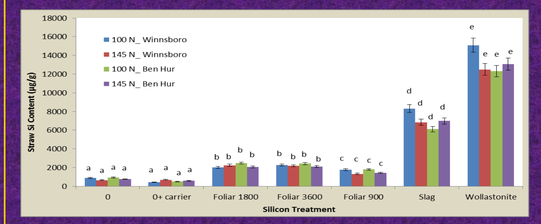

Figure 3. Straw silicon content of wheat treated with different sources of silicon under two levels of N supply.

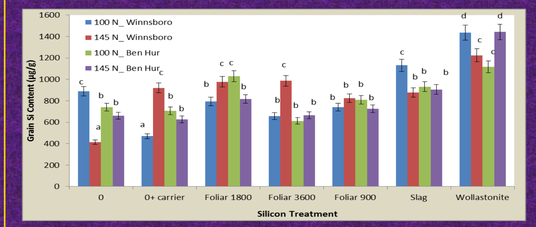

Figure 4. Grain silicon content of wheat treated with different sources of silicon under two levels of N supply.

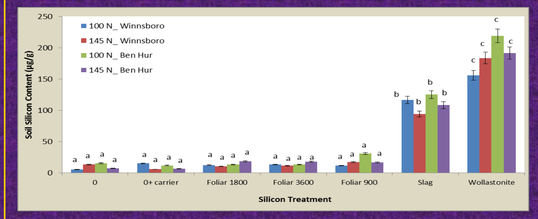

Figure 5. Soil silicon content of wheat treated with different sources of silicon under two levels of N supply.

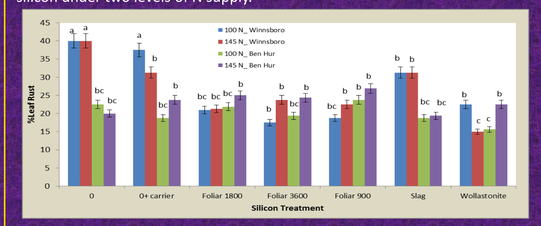

Figure 6. Rust percentage of wheat treated with different sources of silicon under two level of N supply.

- For both sites, Si treatment showed consistent and significant effect on Si content and uptake of biomass, straw, and grain (P<0.05, Table 1). Only straw yield was affected by nitrogen and it was only in one site.
- Generally, an increasing trend in Si content of straw and grain was observed with wollastonite and slag application (Figures 3 and 4). Silicon content of grain was very low and the differences among treatments were very small. The resulting increase in yield due to the wollastonite application was more evident when combined with 145 kg N ha^{-1} N application rate.
- The results of soil analysis clearly showed that wollastonite and slag application resulted in a significant increase in soil Si level (Figure 5). The application of wollastonite tended to significantly decrease leaf rust disease development of plots supplied with wollastonite. Leaf rust was also reduced from 40 to 20% in plots received foliar Si application (Figure 6) .

Fig 7. Leaf rust infection rating in wheat applied with different silicon sources.

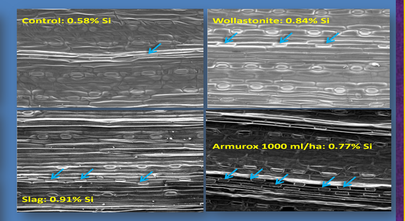

Figure 7. Distribution of silica bodies on upper leaf surface area analyzed using SEM-EDAX analysis.

- The distribution of silica bodies at the lower and upper surface of wheat leaves was only affected at Winnsboro site whereas there was a significant interaction effect recorded at Ben Hur (data not shown). Higher Si content was observed on leaf surface of wheat treated with wollastonite, slag, and Armurox (1000 ml ha^{-1} rate).
- The value of Si role was not fully realized on wheat productivity, i.e. grain yield due to substantial interference of excessive rainfall before harvesting which led to deterioration of grain and occurrence of scab disease.
- There were indications of Si and N positive correlation effect on wheat growth and reduction in leaf rust disease development. Repeated trials of this study will be conducted to further support these initial findings.

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