The Effects of Silicon (Si) and Fiber Composition from Canola and Wheat Residue on Soil Crusting

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Introduction

Arid and semi-arid agronomic regions that have adopted conservation management practices, such as reduced tillage, may be prone to soil crusting. Surface crusting is predominantly caused by the combination of raindrop impact and excessive Si in the soil (Wakindiki and Ben-Hur, 2002). It can reduce water infiltration, enhance runoff & erosion, and interfere with seed germination. Structural components (e.g. hemicellulose, cellulose, lignin, and silicon (Si)) vary between crop types. Grasses such as wheat tend to have higher levels of Si and lower amounts of lignin compared to oilseeds (Stubbs et al., 2009). When such residue is left on the soil surface these components, specifically Si, may contribute to soil crusting. Therefore, it may be beneficial to consider crops with lower amounts of Si when planning crop rotations in areas where soil crusting can be a concern.

Goal

To determine if introducing canola into a crop rotation could reduce the occurrence or severity of soil crusting in comparison to wheat dominated systems.

Objectives

1) To determine the role and allocation of fiber and Si in both wheat and canola grown with varying nitrogen (N) rates.
2) Evaluate how Si may effect soil crusting.

Methods

Crop residue:

- Wheat *(Triticum aestivum) and* canola *(Brassica napus)* were grown in a greenhouse with a 50:50 mixture of Palouse silt loam and Sunshine Mix #2. Four N fertilizer rates were applied at 6, 60, 180, and 420 mg N/kg soil. Crops were given specific amounts of water through out the experiment and water use was recorded. Upon harvest, residues (straw + leaves) were analyzed for:
  - yield (g)
  - hemicellulose, cellulose, and lignin using a modified version of the VanSoest et al. (1991) procedure with the ANKOM automated system
  - plant Si using modified methods from Van der Vorm (1987)
- Statistical analysis was done using linear regression in SAS 9.4. The F statistic for the overall model was evaluated using a p-value of <0.05. Each crop was assessed separately.

Rotational Comparison (28 days):

- A Ritzville silt loam collected from two different fields was used. The first field was previously cropped in wheat while the second field was previously cropped in canola. Four rates of silica solution (SiO_2) was added to both soils: 0 g/kg soil (control), 0.04 g/kg soil (low), 0.4 g/kg soil (medium), and 4.0 g/kg soil (high). Soil samples were analyzed for:
  - surface resistance (Humboldt pocket penetrometer)
  - crust thickness using a caliper
  - amorphous Si (Si_{am}) (Van der Vorm, 1987)
- Data was analyzed using the PROC GLM procedure in SAS at a 95% confidence interval utilizing Tukey's method of comparison. The two factors considered were rotation history and SiO_2 treatment.

Image 1. Greenhouse seedlings

Image 2. Plant samples in the muffle furnace preparing for Si analysis

Image 3. Soil Incubation with additions of SiO_2

Image 4. Soil samples prepared for analyses

Figure 1. Wheat residue hemicellulose (g), cellulose (g), lignin (g), and Si (mg) per N fertilizer rate.

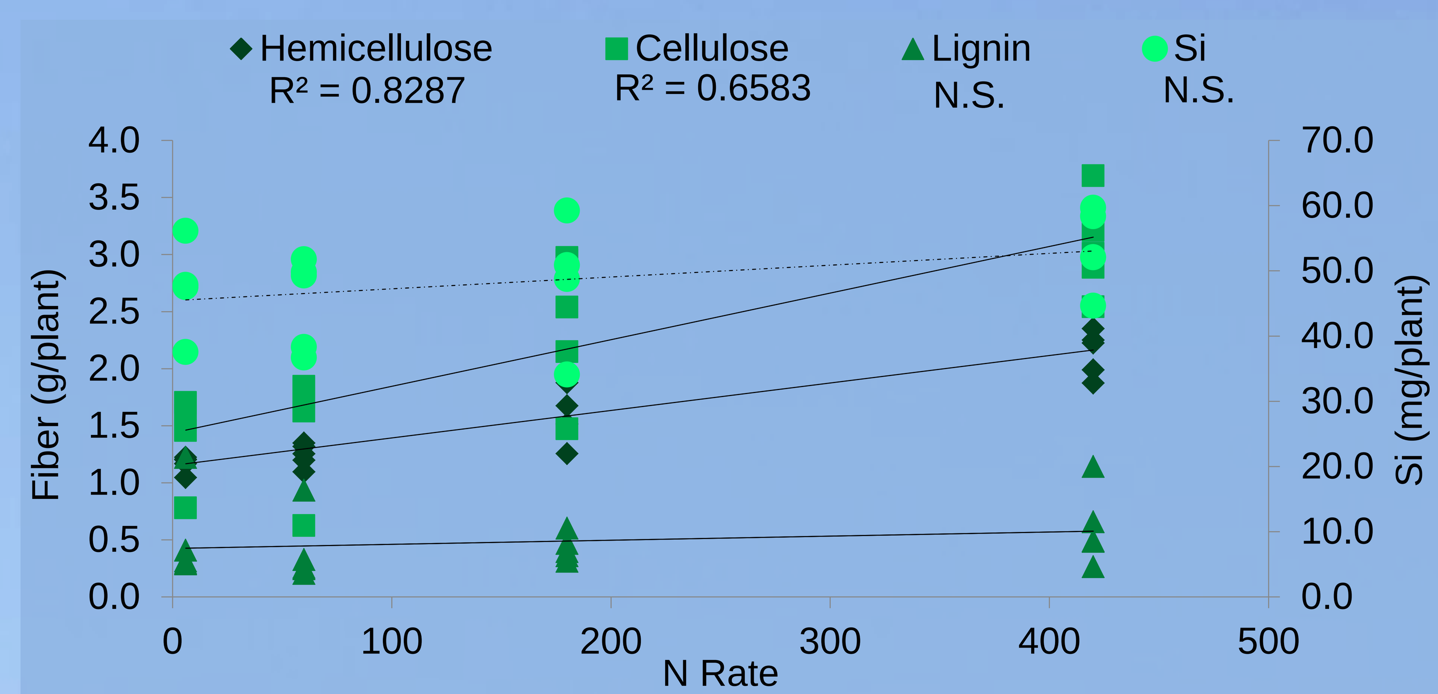


Figure 2. Canola residue hemicellulose (g), cellulose (g), lignin (g), and Si (mg) per N fertilizer rate.

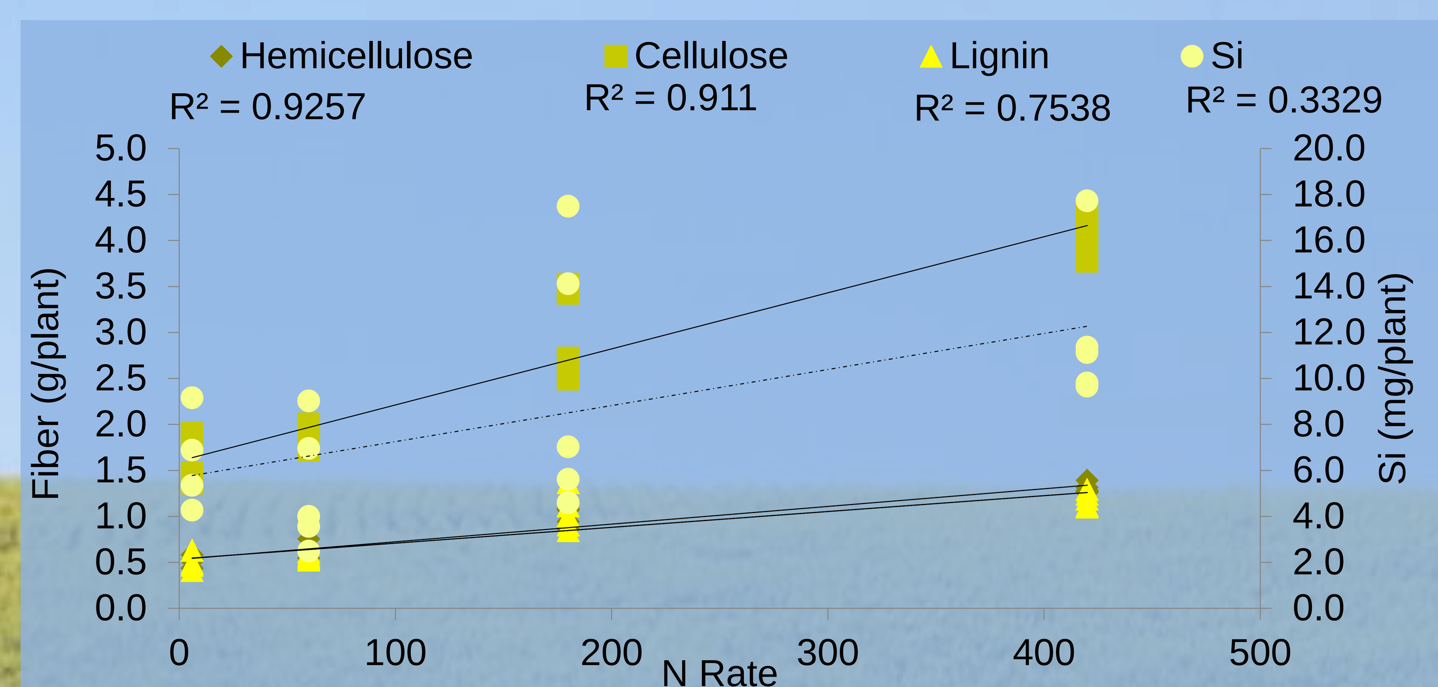


Figure 3. Residue yield per N rate

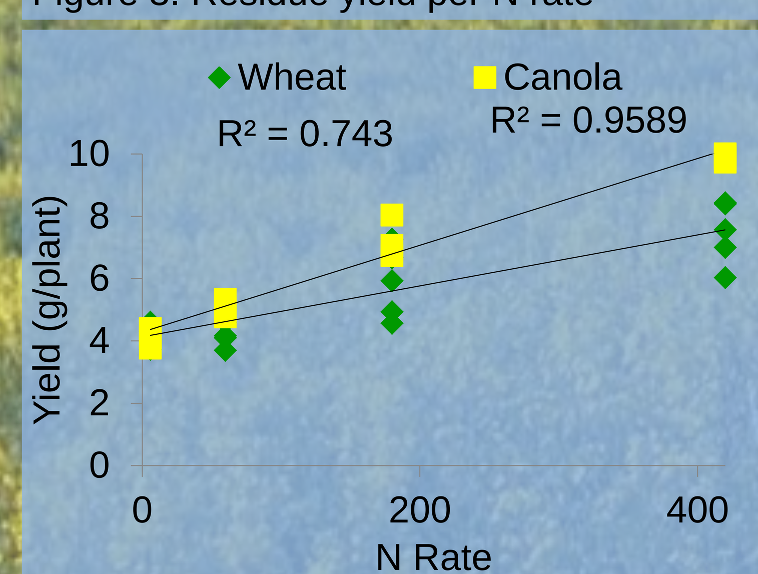


Figure 4. Si accumulation vs water use

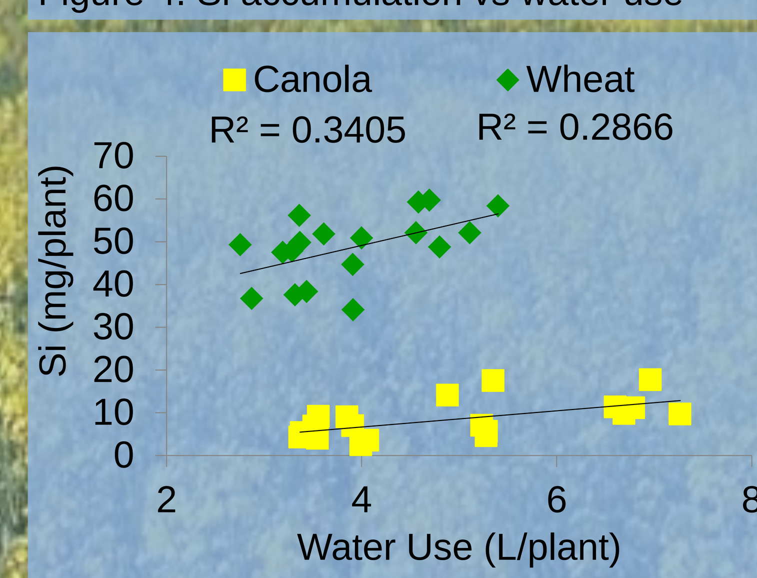


Figure 5. Average Si_{am} of SiO_2 treatments on soil previously cropped in wheat and canola.

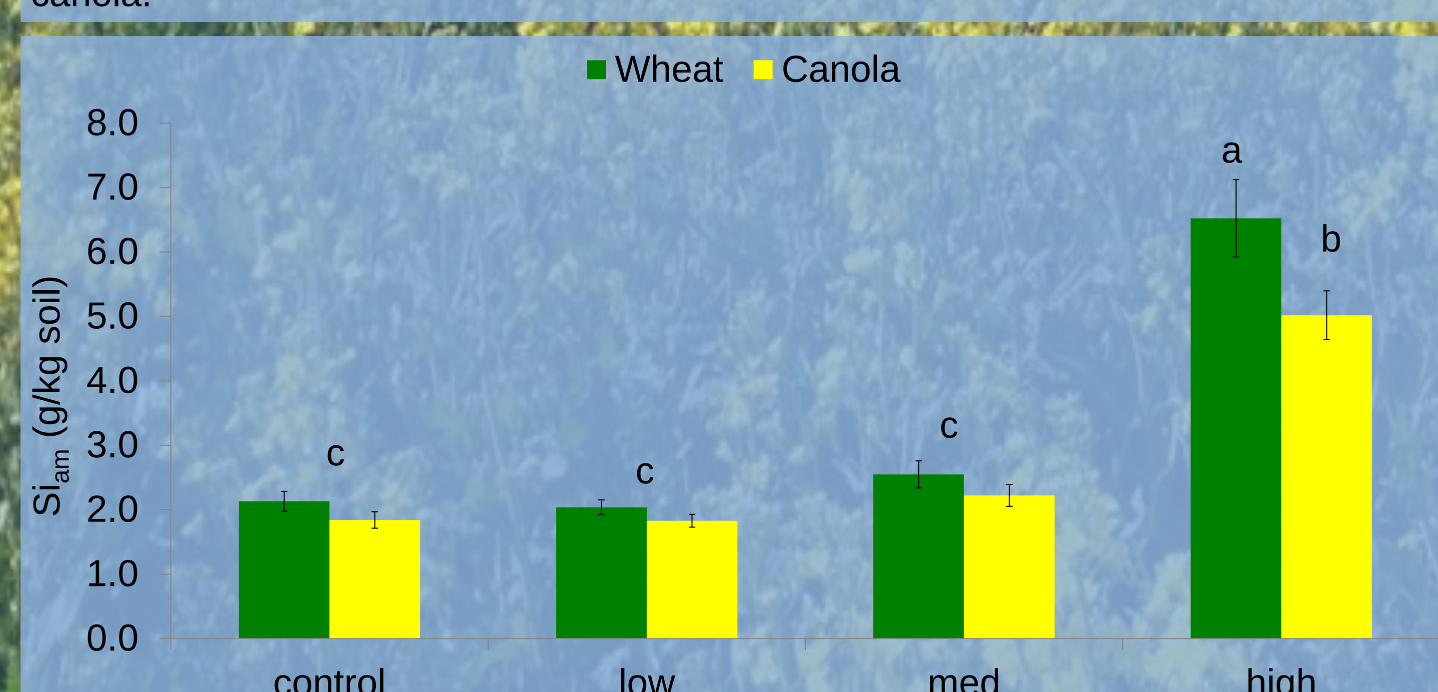


Figure 6. Average crust thickness (mm) of SiO_2 treatments on soil previously cropped in wheat and canola.

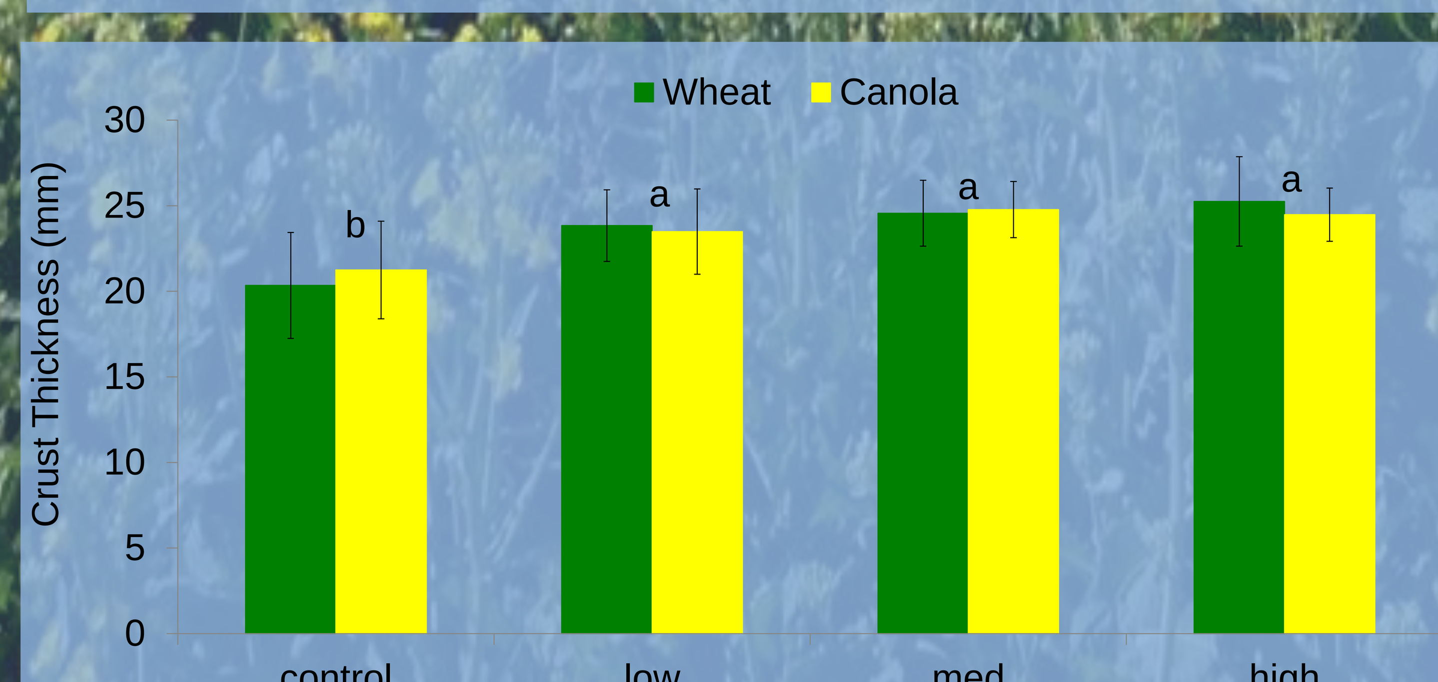
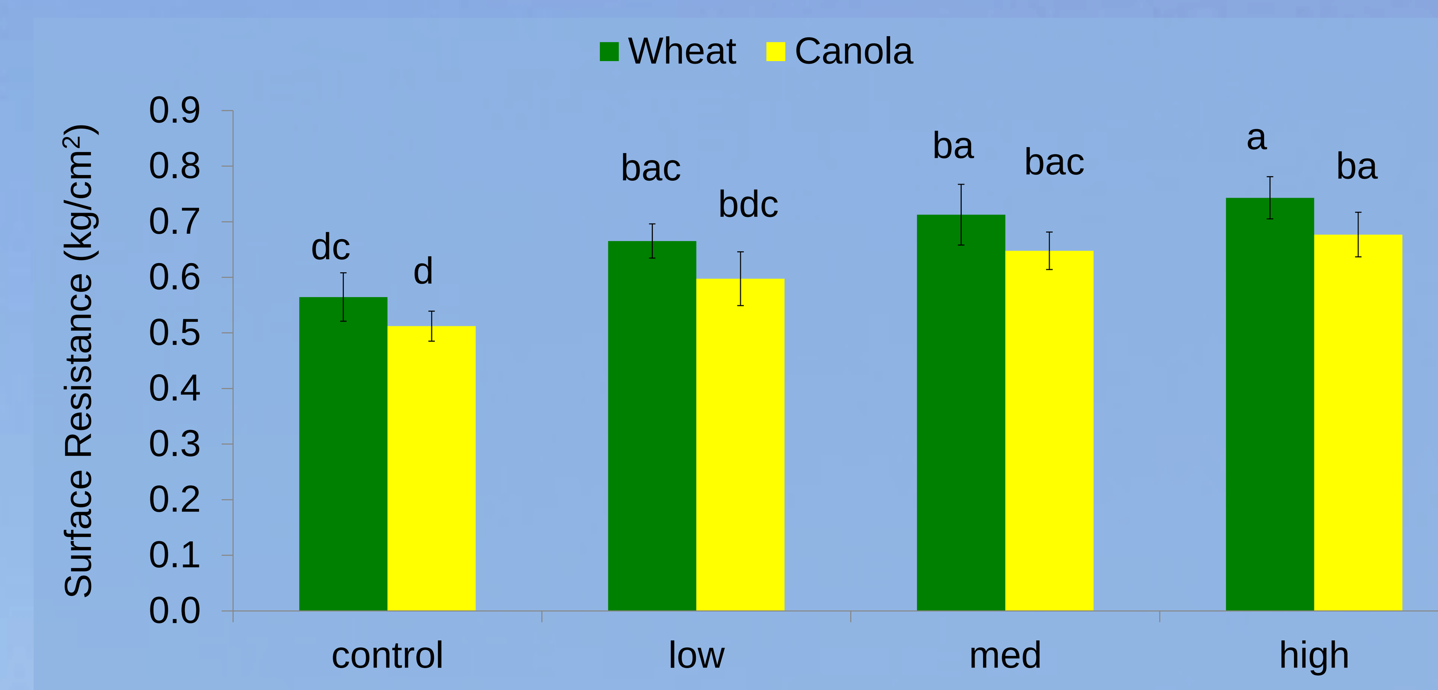


Figure 7. Average surface resistance (kg/cm²) of SiO_2 treatments on soil previously cropped in wheat and canola.



Results

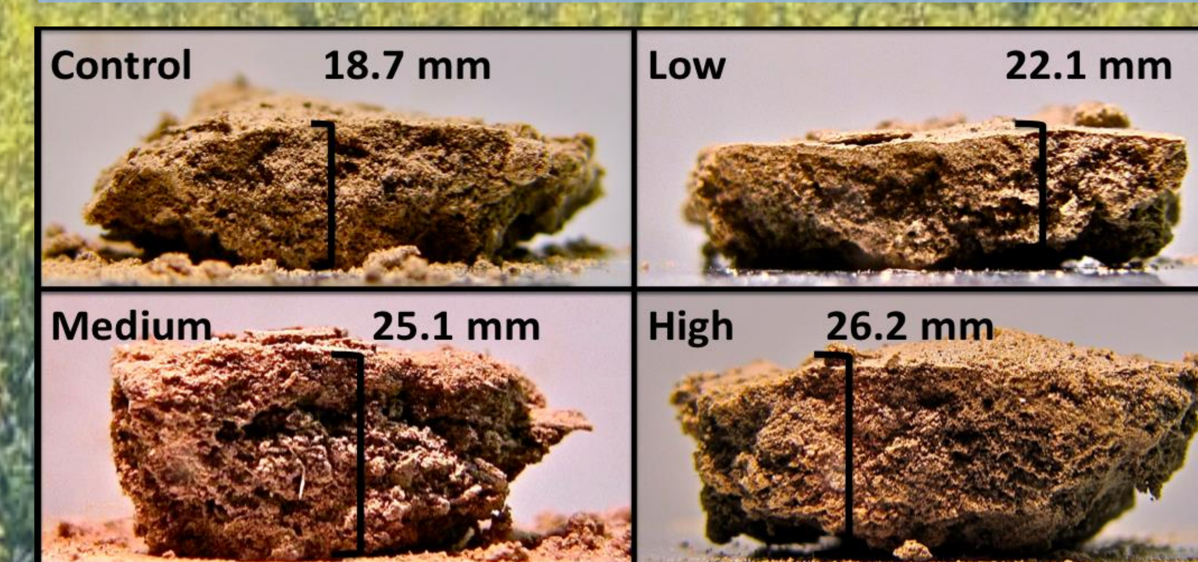
Crop residue:

- Wheat accumulated more total hemicellulose and Si than canola. Increasing N rates significantly increased wheat hemicellulose and cellulose levels (Figure 1).
- Canola accumulated more total cellulose and lignin than wheat. All fiber components and Si significantly increased with increasing N rate (Figure 2).
- Both wheat and canola yields increased with increasing N rate (Figure 3).
- Water use increased with yield and N rate for both crops. Wheat Si did not increase as much with water use as it did for canola (Figure 4).

Rotational Comparison:

- Si_{am} was higher in soil collected from the wheat field initially and throughout the experiment (Figure 5). However the only significance between soil types or treatments was found at the highest level.
- Crust thickness (Figure 6) only significantly increased between the control and SiO_2 treatments. No differences were seen between soil types.
- Surface resistance slightly increased with increasing levels of SiO_2 and was slightly higher in the wheat soil for all treatments (Figure 7).

Image 5. Example of SiO_2 effects on soil previously cropped in wheat.



Conclusions

- Wheat produces increasing amounts of total hemicellulose and cellulose with increasing yield.
- Wheat is an active accumulator of Si. A specific amount of total Si was accumulated independent of N rate or yield.
- Canola produces increasing amounts of all fiber components and Si with increasing growth.
- Canola is a passive accumulator of Si. Low Si and the results from Figure 4 suggests that canola only passively accumulates Si with water uptake.
- Si does play a role in soil crusting. Increasing amounts of SiO_2 solution increases the amount of Si in the soil, crust thickness, and surface resistance.
- The soil that has been traditionally cropped in a winter wheat fallow rotation had higher Si levels and therefore effected the crusting potential.
- Crop rotations including canola may help alleviate the negative effects caused by soil crusting.

References

Wakindiki, I.I.C., and M. Ben-Hur. 2002. Soil mineralogy and texture effects on crust micromorphology, infiltration, and erosion. Soil Sci. Soc. Am. J. 66(3):897-905.

Stubbs, T.L., A.C. Kennedy, P.E. Reisenauer, and J.W. Burns. 2009. Chemical composition of residue from cereal crops and cultivars in dryland ecosystems. Agron. J. 101:538-545.

Van der Vorm, P.D.J., 1987. Dry ashing of plant-material and dissolution of the ash in HF for the colorimetric determination of silicon. Commun. Soil Sci. Plant Anal. 18(11):1181-1189.

VanSoest, P.J., J.B. Robertson, and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-359.

Acknowledgements The authors thank the following support of this research:

- WA Oilseeds Cropping Systems Project 3016
- USDA NIFA Award #2011-68002-30191 (REACCH)
- WSU ARC project 9024