Effect of Mustard Biofumigation on Potato Yield and Soil *Verticillium* Populations in Grower Fields

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Abstract

Biofumigation, a soil management practice using mustard plants to suppress soilborne pathogens, has been evaluated in grower fields to assess its impact on *Verticillium* populations and potato performance. This study was conducted in Biofumigation Field A (BFA), Biofumigation Field B (BFB) and Biofumigation Field C (BFC) using two mustard varieties: AAC Brown-18 and Rojo Caliente. The experimental design compared biofumigated treatments against non-biofumigated controls (wheat rotation or early mustard removal). Potato yield, tuber defects, and specific gravity were measured across treatments. Results indicated no significant differences in total yield across treatments but showed a reduction in tuber defects in biofumigated plots in BFA. These findings suggest that mustard biofumigation may contribute to improved tuber quality while maintaining yield levels, supporting its potential as a sustainable soil health strategy for potato production.

Introduction

Potato early dying (PED) disease is a major problem for potato farmers in North America, causing a loss of 30-50% in severely affected fields ((Davis et al. 2001). The main cause of PED is a fungus called *Verticillium* spp., and the disease becomes even worse when root-lesion nematodes (*Pratylenchus* spp.) are also present (Powelson & Rowe, 1993). In the past, *Verticillium alboatrum* was the main species responsible for PED in Eastern Canada, but now *Verticillium dahliae* is more common (Borza et al. 2018). PED is very difficult to control because the pathogens can survive in the soil for a long time and can infect many different plants (Bélair et al. 2007). The best way to control PED and other soil diseases has been chemical fumigation, using products like chloropicrin or metam sodium. Some potato growers in Canada have recently started using fumigation to reduce PED and improve yields (Taylor et al. 2005). However, chemical fumigants can be harmful to the environment, human health, and soil health, and they are also expensive. Because of these concerns, researchers are looking for alternative ways to manage PED (Sande et al. 2011).

One promising method is biofumigation, which uses plants from the mustard family to release natural chemicals that kill harmful organisms in the soil (Larkin et al., 2011). Biofumigation is a natural way to protect soil from harmful pests, diseases, and weeds. It works by using special chemicals that plants release when they break down (Szczygłowska et al. 2011). To make biofumigation effective, plants should be cut into small pieces and mixed into the soil as soon as possible (Gimsing and Kirkegaard, 2006). The success of biofumigation depends on factors such as the amount of mustard plants used, how quickly they are mixed into the soil, and environmental conditions (Kruger et al. 2013). Mustard plants (*Brassica* spp.) have been shown to help reduce PED and other soil diseases in potatoes (Ngala et al., 2015). Some mustard varieties, like Caliente mustard (*Brassica juncea* and *Sinapis alba* blend), were specifically developed for biofumigation and have been effective in reducing *Verticillium* wilt (Larkin & Halloran, 2014). However, their seeds are more expensive than regular mustard varieties. Another variety, Centennial Brown mustard, *B. juncea* (L.) Czern, has a higher level of protective chemicals (glucosinolates) than the common brown mustard and is a more affordable option than Caliente mustard (Rakow et al., 2009). Some plants, especially those in the mustard family (Brassicaceae), contain special compounds called glucosinolates (GS). These compounds stay inactive inside plant cells until the plant is damaged (cut or chewed) (Peng et al. 2019). When this happens, an enzyme called Myrosinase reacts with GS, breaking them down into new substances. One of these substances, called isothiocyanates (ITCs), is very powerful in stopping pests and diseases because it attacks their proteins, making it hard for them to survive (Yang et al. 2011). Research shows that mustard plants like Indian mustard, brown mustard, turnip, and radish release strong-smelling sulfur compounds when shredded. These compounds help stop harmful soil diseases that affect potatoes, such as *Rhizoctonia solani*, *Pythium ultimum*, and *Sclerotinia sclerotiorum*. In experiments, just 1 gram of Indian mustard placed in a dish with potato diseases could stop 80–100% of the disease growth (Baysal-Gurel et al. 2020). Another study found that black mustard (*Brassica nigra*) mixed into the soil reduced a major potato disease by 75% within one month, and the effect lasted for six months (Yulianti et al. 2007).

Mustard plants have the highest amount of GS when they are flowering (Malik et al. 2010). Future research could explore ways to improve Myrosinase activity by integrating it to produce more ITCs, as well as finding new, stronger forms of this enzyme (Ji et al. 2024). The objective of this study was to evaluate the effect of biofumigation on the population density of *Verticillium* spp., and potato tuber yield in Manitoba.

Verticillium Population Data: Pending

Materials and Methods

The study was conducted in three biofumigation fields, BFA, BFB, and BFC, where mustard was planted prior to potato cultivation. The experimental treatments (Fig. 1) included:

1. *BFA*:
    - Control: No biofumigation (mustard removed early in the season).
    - Treatment: Biofumigation using AAC Brown-18 and Rojo Caliente mustard.
2. *BFB*:
    - Control: No biofumigation (mustard removed from plot area in early season)
    - Treatment: Biofumigation using Rojo Caliente Mustard
3. *BFC*:
    - Control: No biofumigation (wheat crop grown).
    - Treatment: Biofumigation using Rojo Caliente mustard.

After mustard termination, potatoes were planted, and yield, tuber quality, and specific gravity were measured. Tuber defects, including Rot %, Mechanical Damage %, Sun/Green %, Frost %, Foreign Material %, Net Necrosis %, Internal Defects %, Hollow Heart %, Trace Hollow Heart %, Wireworm %, and Scab %, were recorded.

Statistical Analysis
Statistical comparisons were performed using IBM SPSS Statistics Version 30.0.0.0 (172) to determine significant differences between treatment zones.

Results and Discussion

- **Yield:** No significant differences in total potato yield (CWT/A) were observed across treatments in either BFA (Fig. 2A) or BFC (Fig. 3A).
- **Tuber Size Distribution:** The proportion of medium and large-sized tubers (6.0-9.9 oz and >3.0 oz) was similar across treatments (Figs. 2B-D, 3B-D).
- **Tuber Defects:** Rojo Caliente mustard treatment in BFA resulted in significantly lower defect percentages compared to AAC Brown-18 and control plots (Fig. 2E). In BFC, defect levels were similar between Rojo Caliente mustard and control treatments (Fig. 3E).
- **Specific Gravity:** No significant differences were observed in specific gravity between treatments, indicating similar tuber dry matter content across all conditions (Figs. 2F, 3F).

These findings suggest that while mustard biofumigation did not significantly increase potato yield, it had a positive effect on tuber quality by reducing defects in one field. The reduction in defects observed in Rojo Caliente mustard treatments may indicate a suppressive effect on soilborne pathogens, including *Verticillium*. The absence of yield differences suggests that mustard biofumigation does not negatively impact potato production and may contribute to improved tuber quality without compromising productivity. Further long-term studies are recommended to assess cumulative effects on soil health and pathogen suppression.

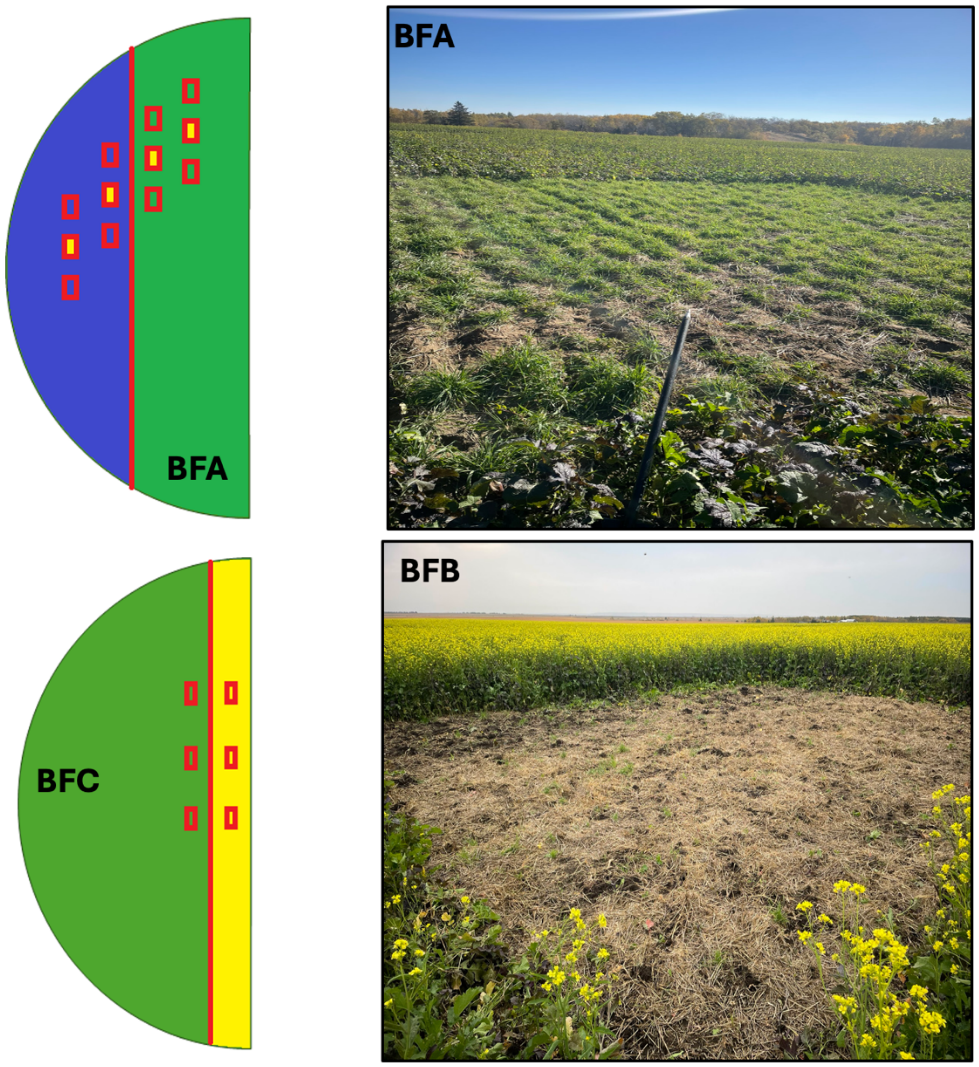

Figure 1. Biofumigation field trials (BFA and BFC) evaluating the impact of mustard rotation on soil *Verticillium*populations and subsequent potato performance. In BFA, two mustard varieties were tested: AAC Brown-18 (blue) and Rojo Caliente (green), with a non-biofumigated control where mustard was removed early in the season (yellow). In BFC, Rojo Caliente mustard (green) was compared to a non-biofumigated control where wheat was grown instead (yellow). The left side of each panel shows a schematic representation of the field layout, while the right side provides a visual representation of the control plots.

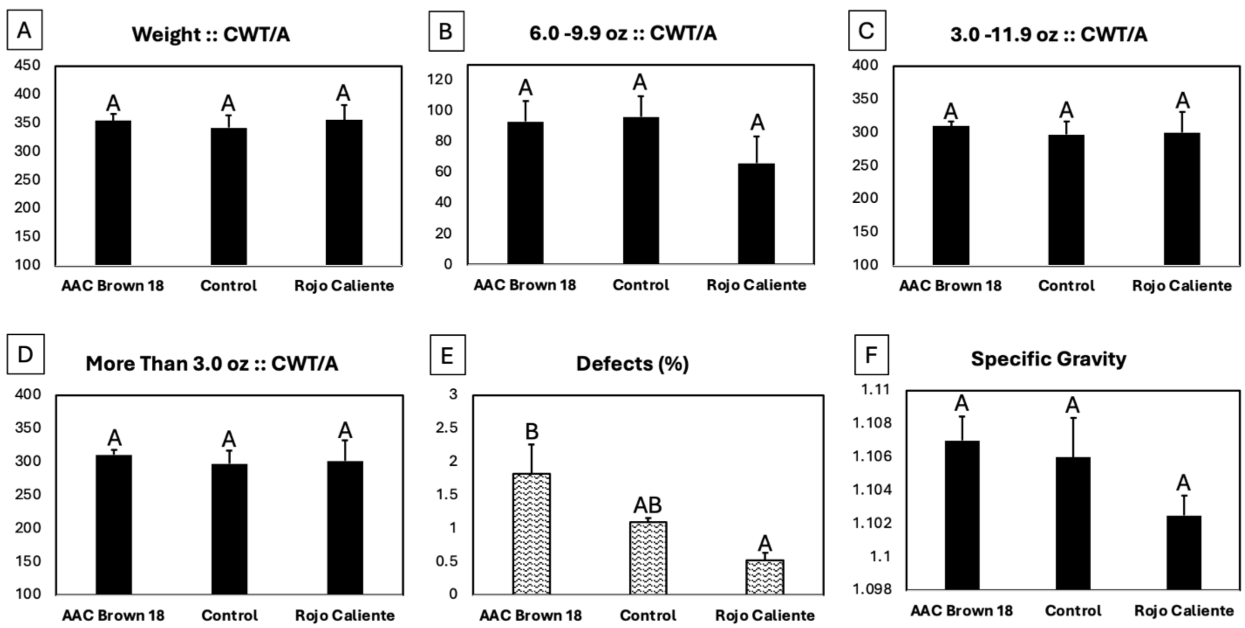

Figure 2. Effect of mustard biofumigation on potato yield, defects, and specific gravity in Biofumigation Field A (BFA). Different mustard varieties were planted in rotation before potatoes to evaluate their impact on *Verticillium* population reduction and subsequent potato performance. Panels (A-D) represent total yield (CWT/A), categorized by size classes: (A) total weight, (B) 6.0-9.9 oz, (C) 3.0-11.9 oz, and (D) more than 3.0 oz. Panel (E) Percentage of defects in harvested tubers including Rot %, Mechanical Damage %, Sun/Green %, Frost %, Foreign Material %, Net Necrosis %, Internal Defects %, Hollow Heart %, Trace Hollow Heart %, Wireworm %, and Scab %, (F) Specific gravity values. Treatments included two mustard varieties (AAC Brown 18 and Rojo Caliente) and a non-biofumigated control. Letters on the bars indicate statistically significant differences based on one-way ANOVA with a post hoc least significant difference test ($P < 0.05$). Bars sharing the same letter are not significantly different from each other.

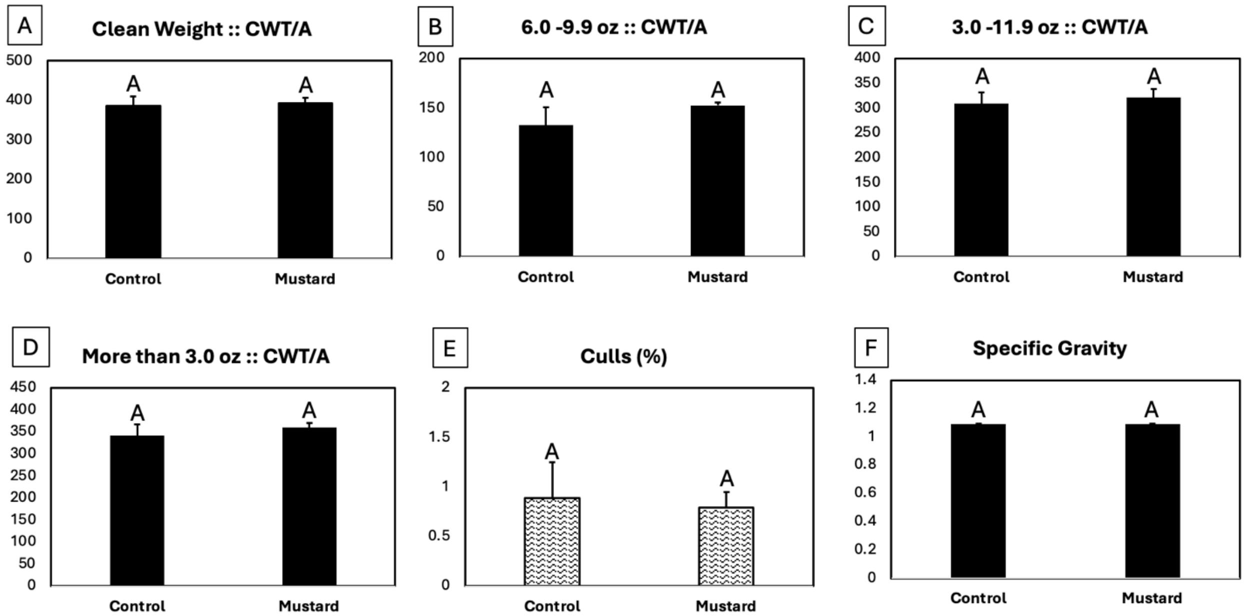

Figure 3. Effect of mustard biofumigation on potato yield, defects, and specific gravity in Biofumigation Field C (BFC). Different mustard varieties were planted in rotation before potatoes to evaluate their impact on *Verticillium* population reduction and subsequent potato performance. Panels (A-D) represent total yield (CWT/A), categorized by size classes: (A) total weight, (B) 6.0-9.9 oz, (C) 3.0-11.9 oz, and (D) more than 3.0 oz. Panel (E) Percentage of defects in harvested tubers including Rot %, Mechanical Damage %, Sun/Green %, Frost %, Foreign Material %, Net Necrosis %, Internal Defects %, Hollow Heart %, Trace Hollow Heart %, Wireworm %, and Scab %, (F) Specific gravity values. Treatments included two mustard varieties (AAC Brown 18 and Rojo Caliente) and a non-biofumigated control. Letters on the bars indicate statistically significant differences based on one-way ANOVA with a post hoc least significant difference test ($P < 0.05$). Bars sharing the same letter are not significantly different from each other.

Acknowledgements

This work was supported by the Sustainable Canadian Agricultural Partnership (SCAP; T00087). We would like to express our sincere gratitude to Susan Ainsworth, Scott Graham, and Mitch Wright for their invaluable guidance and support. We are grateful to the growers who collaborated with MHPEC to conduct the trial on their fields (BFA, BFB and BFC). We sincerely appreciate the MHPEC staff for their dedication throughout the season in executing trial operations and duties. Special thanks to Amy Unger, former Applied Research Technician at MHPEC; the Operations Team, including Garth Christison and Alan Manns; Victor Akinsunmade, former summer student at MHPEC; and Bev, a seasonal MHPEC staff member, for their hard work. We extend our special thanks to Prof. Mario Tenuta for performing the Verticillium counting analyses for this study. We also thank Ag World at the McCain Foods facility in Carberry, Manitoba, for grading the potato tubers for this trial.

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