Soil Amendment with Green Manures and Seed Meals Improve Soil Health and Enhance Soil Microbial Activity in Potato and Douglas-fir

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Introduction

Soil fumigation is a common tool to manage soil-borne pathogens in cropping systems. Due to safety and environmental concerns, fumigation chemicals are increasingly restricted. Green manures (GM) and brassica-based soil amendments have been used traditionally around the world for management of soil fertility and quality, and more recently have gained interest for management of soil-borne pathogens. We evaluated the effects of various GM and *Brassica* seed meal amendments on beneficial and pathogenic soil organisms along with soil enzyme activity, water holding capacity, and nitrogen mineralization in two different cropping systems. We hypothesized that one or more green manure or brassica seed meals would affect the soil density of *Fusarium* and *Trichoderma* in Douglas-fir seedling and enhance soil health indicators in potato and Douglas-fir compared to untreated or fumigated soils.

Objectives

- To evaluate the effects of brassica soil amendments on soil density of *Fusarium* and *Trichoderma* in Douglas-fir rhizosphere, and growth of Douglas-fir seedlings.
- To assess dehydrogenase enzyme activities, nitrogen mineralization, and water holding capacity in soil under potato and Douglas-fir with a range of GM and brassica-based amendments.
- To assess the ability of potato to re-uptake nitrogen applied to a prior GM.

Materials and Methods

- The Douglas-fir study was conducted in western WA nurseries and consisted of 5 treatments:
  - *B. carinata* seedmeal (BcSM, 4484 kg ha^{-1})
  - B. *juncea* green manure (BjGM, 11.2 kg seeds ha^{-1})
  - B. *juncea* seedmeal (BjSM, 4484 kg ha^{-1})
  - untreated control
  - methyl bromide/chloropicrin fumigation (MBC-fum)
  - The soil type in study site was Cagey loamy sand. Treatments were incorporated September 21, 2011, seedlings transplanted May 30, 2012, and harvested January 7, 2013.
- Selected soil-borne microorganisms (*Fusarium* and *Trichoderma*) were assessed in conifer study via soil dilution plating.
- The potato study was located at Othello and Pullman, WA and consisted of 9 treatments:
  - metam sodium fumigation (MS-fum)
  - untreated control (Control)
  - barley (*H. vulgare*) green manure (BGM)
  - *Brassica juncea* green manure (BjGM)
  - *B. napus* green manure (BnGM)
  - BGM incorporated thrice (BGM x3)
  - BjGM incorporated thrice (BjGM x3)
  - BnGM incorporated thrice (BnGM x3)
  - Soil from a long time mustard green manure practitioner and potato producer (DG)
  - The soil type in study site was Shano silt loam.
- Soil dehydrogenase enzyme activity (Tabatabai, 1994) and N mineralization (Waring and Bremner, 1964), were analyzed in both studies.
- In addition, water holding capacity (Jarrell et al., 1999) in potato and tree morphology in conifer were also analyzed.
- In potato ^{15}N –enhanced fertilizer was used on GM crop to quantify recovery of GM-applied N fertilizer by the following potato crop.

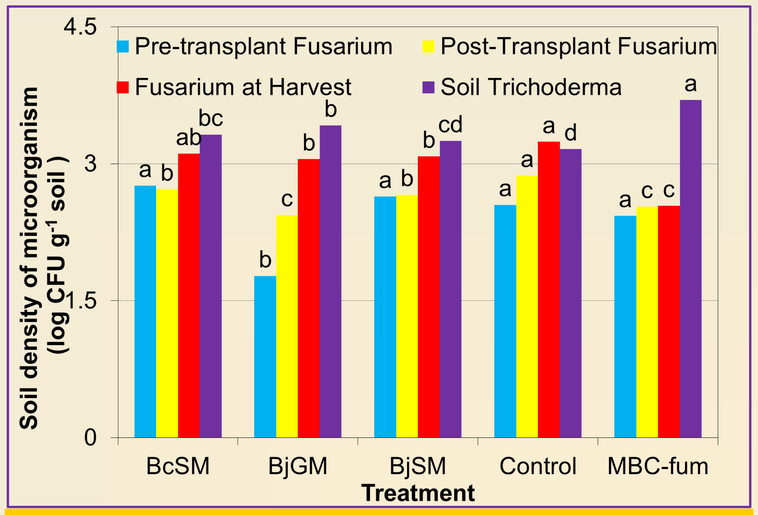

Fig. 1. Soil density of potentially pathogenic *Fusarium* spp. and beneficial *Trichoderma* spp. as affected by soil treatments in conifer study. Different letters indicate difference at P < 0.05 within each microorganism x time.

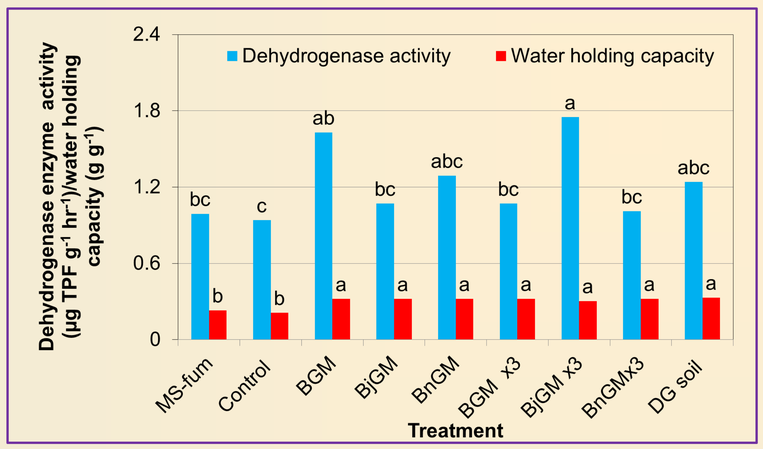

Fig. 2. Effect of various green manures on soil dehydrogenase activity, and water holding capacity in potato study. Different letters indicate difference at P < 0.05 within each measured parameter.

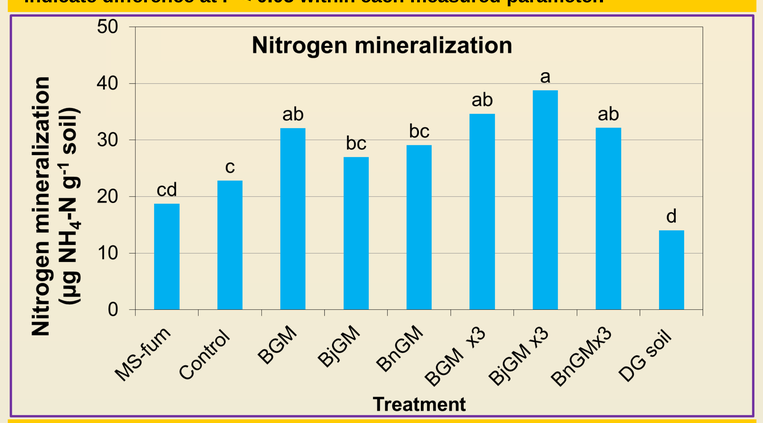

Fig. 3. Effect of green manure treatments on nitrogen mineralization in potato soils. Different letters indicate difference at P < 0.05.

Trt	Height	Stem Diameter	DH	N-min
	cm	mm	µg TPF g^{-1} hr^{-1}	µg g^{-1}
BcSM	41.02bc	7.85b	0.67a	5.87a
BjGM	44.53ab	8.32ab	0.735a	6.82a
BjSM	40.99bc	7.63b	0.617a	5.82a
Control	39.77c	7.64b	0.463b	5.73a
MBC-fum	46.38a	8.63a	0.31c	3.63b

Table. 1. Conifer height and stem diameter, soil dehydrogenase enzyme activiy (DH), and nitrogen mineralization (N-min) as affected by soil treatments. Different letters indicate difference at P < 0.05 within each measured parameter.

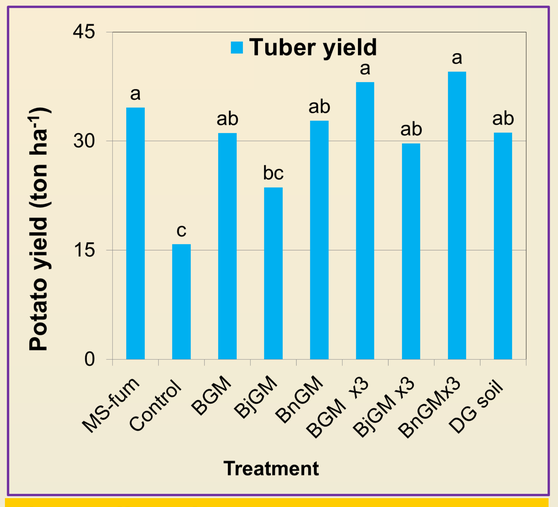

Fig. 4. Effect of green manure treatments on potato yield.
Different letters indicate difference at P < 0.05.

Conclusions & Discussion

- In the Douglas-fir study, BjGM suppressed density of soil-borne *Fusarium* spp., while its effects on tree growth and soil health parameters were encouraging. The BjGM also encouraged the population of potentially beneficial organism, *Trichoderma* spp.
- In the potato study, the green manure treatments consistently provided positive impact on soil health parameters and potato yield compared to control.
- Numerous biotic and abiotic factors contribute to the pathogen suppressiveness of soil amendment treatments (Bonanomi et al., 2007). The relative suppressiveness observed in BjGM-amended soils in this study may be related to chemical, biological, and/or physical changes in the soil.
- Beneficial effects on soil health may, in turn, affect plant response to pathogens, effectively increasing the pathogen densities required to cause significant plant damage.
- The cost of green manuring is less than the direct expenses due to significant re-uptake of GM-applied N by the following potato crop.
- GM should be considered as a component of crop management strategies for improving soil health and cropping system productivity.

Results

Conifer study

- At pre-transplant, the soil density of *Fusarium* was significantly lower in BjGM compared to other treatments. Two months after transplanting, *Fusarium* density was similar in BjGM and MBC-fum, but significantly lower compared to other treatments. At harvest, all brassica treatments had significantly lower *Fusarium* compared to control, but significantly greater than MBC-fum (Fig. 1).
- The *Trichoderma* density was significantly greater in BcSM and BjGM compared to control but significantly lower than MBC-fum (Fig. 1).
- Tree height and caliper was significantly greater in MBC-fum and BjGM compared to control (Table 1).
- Soil dehydrogenase enzyme activity was significantly greater in brassica treatments compared to MBC and control and nitrogen mineralization was significantly greater in brassica treatments compared to MBC-fum (Table 1).

Potato study

- Soil dehydrogenase activity was significantly greater in BGM and BjGMx3 compared to MS-fum and control. Similarly, water holding capacity was significantly greater in green manure treatments compared to MS-fum and control (Fig. 2). Nitrogen mineralization was significantly greater in BGM, BGMx3, BjGMx3, and BnGMx3 compared to control and MS-fum (Fig. 3).
- Potato tuber yield was significantly greater in BGMx3, BnGMx3, BjGMx3, DG soil, and MS-fum compared to control (Fig. 4).
- The average ^{15}N re-uptake from green manure to potato crop was **64 ±20 %** (95% confidence interval).

Acknowledgements

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