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Compost and poultry manure as preplant soil amendments for red raspberry: Comparative effects on root lesion nematodes, soil quality and risk of nitrate leaching

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ABSTRACT

Raspberry fields in the Pacific Northwest, USA and British Columbia, Canada are often prepared for replanting by fumigating with broad-spectrum biocides to control root-lesion nematodes, *Pratylenchus penetrans*. Nematode-suppressive organic amendments have been advocated as reduced risk alternatives to fumigation but may pose other risks to the environment. This study compared alternative pre-plant soil management practices with respect to their effects on plant-parasitic nematode populations, soil quality parameters and risk of nitrate leaching. In fall of 2009 and 2010, a mature raspberry field was mowed down and plowed, and replicate plots were randomly allocated to each of six treatments: (1) a non-amended control, (2) fumigation with Basamid®, (3) fall seeded barley cover crop, (4) recommended rate (20 m^3 ha^{-1}) and (5) historical "biofumigant" high rate (250 m^3 ha^{-1}) of spring incorporated poultry manure, and (6) spring incorporated compost (250 m^3 ha^{-1}). Raspberry cv Saanich was planted approximately one month after incorporation of amendments. Composite soil samples were taken from each plot at multiple times during two subsequent growing seasons and analyzed for nematode populations and soil chemical and physical properties. Primocane biomass was assessed at the end of each of the first two growing seasons as an index of crop vigor. The high poultry manure and compost treatments suppressed root-lesion nematode populations nearly as well as fumigation over two growing seasons. These treatments also improved soil bulk densities and aggregation relative to control, cover crop and fumigation treatments, while compost addition beneficially increased soil pH, CEC and Ca concentrations more than manure. Primocane production in the manure and compost treatments was greater than in the control and cover crop treatments, but less than in the fumigated treatment. Substantial nitrate accumulation in soil amended with the high rate of manure indicated that application of sufficient manure to suppress parasitic nematodes would pose a significant risk of nitrate leaching. In contrast, soil nitrate accumulation was not significantly increased in the compost amended plots. Overall, compost application reduced nematode populations, improved crop growth and did not increase the risk of nitrate leaching in the short term and may be a viable alternative to fumigation.

1. Introduction

Root-lesion nematodes, particularly the species *Pratylenchus penetrans*, are economically important pests of perennial fruit crops. They are particularly damaging to young berry and tree-fruit crops replanted into soil previously used to grow similar crops, and they are often important components of broader replant disease complexes afflicting most perennial fruit crops (Mazzola and Manici, 2012; Trudgill, 1984; Zasada et al., 2015). The productivity of raspberry fields in the Pacific Northwest, USA and coastal British Columbia (BC), Canada often begins to decline after about four to seven years of production due to the buildup of root-lesion nematode populations and *Phytophthora rubi,* which causes raspberry root rot on poorly drained sites (Rudolph and DeVetter, 2015). This decline in productivity necessitates crop removal and soil treatment prior to replanting.

Preplant treatment of soil with broad-spectrum fumigants is the primary means of controlling root-lesion nematodes and improving replant success of perennial fruit crops worldwide. However, soil fumigants pose multiple risks to the environment

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(Sande et al., 2011) and are being subjected to increasing scrutiny by regulatory agencies in the US and Canada. Recent changes to buffer zone requirements for fumigation in North America are making it increasingly difficult and expensive for many growers to fumigate (http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_fact-fiche/soil-fumigant-fumigation-sol/index-eng.php). Consequently, there is a rapidly growing need to identify alternative soil treatments that will suppress parasitic nematode populations and improve early growth of perennial fruit crops without presenting the adverse environmental risks associated with fumigation.

Various types of manures and composts have been used as soil amendments to suppress fungal diseases and plant-parasitic nematodes (Litterick and Wood, 2009; Noble and Coventry, 2005), although some studies indicate that compost and manure amendments can also lead to increased populations of parasitic nematodes (Thoden et al., 2011). In BC, many growers have traditionally amended their fields with readily available poultry manure prior to replanting, either in addition to fumigating or instead of fumigating, under the belief that it helps to suppress parasitic nematode populations. Such use of organic amendments for nematode and replant disease management may, however, present problems for nutrient management and environmental contamination. For example, the past use of poultry manure on raspberry fields in BC has been associated with nitrate contamination of the vulnerable transboundary Abbotsford-Sumas Aquifer which underlies the primary raspberry production area in BC and Washington State (Zebarth et al., 2015). Composts made from manures have lower total nitrogen contents, and less readily available forms of nitrogen, than raw manures and consequently may not present the same risk of nitrate leaching. However, composts have not been seriously considered for use as preplant amendments in this production system due to perceived greater costs, and also due to a lack of knowledge of their effectiveness and potential environmental impacts relative to those of raw manure amendments and fumigation.

The objective of our research was to compare preplant amendments of a compost, poultry manure, and a fall/winter cover crop green manure (barley), to fumigation (positive control) and untreated soil (negative control) through two growing seasons after replanting with respect to: (1) raspberry primocane production as an indicator of crop growth; (2) population densities of *P. penetrans*; (3) soil aggregation, bulk density, water-holding capacity and chemical properties as indices of soil quality; and (4) dynamics of nitrate in the soil profile.

2. Materials and methods

2.1. Field experiment

The study site was a portion of a *P. penetrans*-infested 7 year-old raspberry field at the Agriculture and Agri-Food Canada, Clearbrook research substation (Lat. 49°0.702′N, Long. 122°20.097′W) near Abbotsford, British Columbia, which is located over the Abbotsford-Sumas Aquifer. Soil at the site was a well-drained Abbotsford sandy loam which is characterized by 20–50 cm of medium-textured eolian deposits over sandy and gravelly glacial outwash and classified in the Canadian soil classification system as Orthic Humo-Ferric Podzol (Luttmerding, 1981). As a well-drained site, there was no history of Phytophthora root rot at the site and PCR analyses for *P. rubi* conducted as part of an associated study were negative, however, the site was not assessed for the presence of any other putative fungal root pathogens.

Two experiments were conducted. For Experiment 1, the site was prepared for replanting in August, 2009. The old raspberry plants were flail-mowed and the soil was deep-ripped and plowed. The area was then divided into 24 plots, 7 m × 3 m in size (12 plots centered on each of two rows). Four plots were allocated to each of the following six treatments in a randomized complete block design: (1) Control; (2) Fumigation; (3) Cover crop; (4) Low manure; (5) High manure; and (6) Compost. Experiment 2 was established in the fall of 2010 in an adjacent field. Experiment 2 was conducted in a similar manner as Experiment 1 except that an additional treatment, Fumigation + Compost (fall fumigation followed by spring compost amendment), was included and each treatment was replicated five times for a total of 35 plots.

The Control received no amendment or cover crop before replanting. The Fumigation treatment had the granular fumigant Basamid (Mitsui & Co., Toronto, ON; active ingredient dazomet) applied at the label rate of 50 g m^{-2} and incorporated using rototiller in mid-September. The Cover crop treatment was a fall cover crop of an outcrossing "common" variety of barley (*Hordeum vulgare*) planted in mid-September. The planting of such cover crops is a common and recommended practice in the region to reduce nitrate leaching although barley is also known to be a good host for *P. penetrans* (Kimpinski et al., 1989). The Low manure treatment was spring incorporation of broiler litter at 16 (Experiment 1) or 23 m^3 ha^{-1} (Experiment 2) and the High manure treatment was spring incorporation of broiler litter at 250 m^3 ha^{-1}. The manure was obtained from a commercial broiler farm in the area and was applied by hand and incorporated by rototiller in late March of 2010 and 2011 for Experiment 1 and Experiment 2, respectively. The Low manure application rate was chosen to reflect current recommended application rates (BCMA, 2012) whereas the High manure was chosen to reflect high historical application rates. The Low manure application was chosen to provide approximately 100 kg ha^{-1} plant available N during the first growing season, assuming that approximately 33% of total N in the manure would be plant available in the year of application (Dean et al., 2000; Gale et al., 2006). The Compost treatment was spring incorporation of compost at the same volumetric rate (250 m^3 ha^{-1}) and at the same time as for the High manure treatment. The compost was produced using the turned windrow approach at the AAFC Pacific Agri-Food Research Centre in Agassiz, British Columbia, with primary feedstocks of layer manure, greenhouse waste (discarded plants with potting media) and yard waste. The windrows were turned at least weekly for at least six weeks and then cured for approximately six weeks before use. The Fumigation + Compost treatment of Experiment 2 included the same fumigation as the Fumigation treatment in combination with the same compost application as the Compost treatment to test for a potential additive effect of these two practices.

Properties of the compost and manure used in the experiments are presented in Table 1. When applied on a common volumetric basis (250 m^3 ha^{-1}), total inputs of carbon and nitrogen differed between the High manure and Compost treatments. Averaged over

Table 1
Properties of broiler manures and composts used in the experiments. Measurements are on a dry weight basis.

	Broiler manure		Compost	
	2010	2011	2010	2011
Bulk density (kg dry m^{-3})	250	210	355	355
Organic matter (g kg^{-1})	860	890	350	570
C/N ratio	9.4	12	12.3	12
Total nitrogen (g N kg^{-1})	51.3	41.4	18.6	18.5
NH_4-N (g N kg^{-1})	6.18	13.29	0.15	0.12
Phosphorus (g P kg^{-1})	13.8	25.0	17.8	18.8
Potassium (g K kg^{-1})	15.3	18.2	24.0	22.8
Conductivity (mS cm^{-1})	3.48	8.18	4.10	10.46
Application rate[a] (Mg dry ha^{-1})	62.5	52.5	88.8	88.8

[a] For volumetric application of 250 m^3 ha^{-1}.