Scientia Horticulturae 188 (2015) 6–14

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Soil quality response to cover crops and amendments in a vineyard in Nova Scotia, Canada

Aime J. Messiga[a], Mehdi Sharifi[a,*], Andrew Hammermeister[b], Kyle Gallant[b], Keith Fuller[c], Martin Tango[d]

[a] Canada Research Chair in Sustainable Agriculture, Environmental and Resource Studies Program, Trent University, Peterborough, ON, Canada K9J 7B8
[b] Department of Plant and Animal Sciences, Faculty of Agriculture, Dalhousie University, Truro, NS, Canada B2N 5E3
[c] Atlantic Food and Horticulture Research Centre, Agriculture and Agri-Food Canada, Kentville, NS, Canada B4N 1J5
[d] School of Engineering, Acadia University, Wolfville, NS, Canada B4P 2R6

ARTICLE INFO

Article history:
Received 12 December 2014
Received in revised form 26 February 2015
Accepted 27 February 2015
Available online 28 March 2015

Keywords:
Cover crops
Municipal solid food waste
Mussel shell
Organic C
Wine grape
Wood ash

ABSTRACT

The effects of cover crop mixtures combined with organic and industrial wastes on selected soil properties were assessed in a vineyard in Eastern Canada. The experimental treatments were randomly arranged in a nested design with three replicates. Four alleyway cover crop mixtures [control with no cover crop (CONT), oats + pea + hairy vetch (OPV), oats underseeded with red clover (ORCl), and timothy + alsike + red clover (TM)] were applied to main plots. Five fertility treatments [fertilizer without N (NDEF), full synthetic fertilizer (FERT), wood ash (WA), municipal solid food waste (MSFW), and mussel sediment (MS)] were assigned to sub-plots. Changes in selected soil quality (0–15 cm) were assessed at the beginning of the growing season (May 9, 2011 and April 28, 2012), at bloom in early-July (July 06, 2011 and 2012), and at harvest in late-October (October 31, 2011 and October 20, 2012). At bloom, soil mineral N was 23.56 kg ha^{-1} for OPV and 20.68 kg ha^{-1} for ORCl, but only 16.38 kg ha^{-1} for CONT and 12.53 kg ha^{-1} for TM. At harvest, soil mineral N was 21.95 kg ha^{-1} for ORCl, but only 15.43 kg ha^{-1} for OPV and TM and 9.10 kg ha^{-1} for CONT. Soil mineral N was mainly in the form of NO_3^-–N until bloom, but at harvest majority of soil mineral N was consisted of NH_4^+–N. After one year of experiment, the three organic and industrial amendments maintained greater soil pH (7.34 for MSFW and 7.35 for WA) and Mehlich-3 extractable P (399 kg P_{M3} ha^{-1} for MSFW and 333 kg P_{M3} ha^{-1} for WA) compared with FERT (pH 7.17; 306 kg P_{M3} ha^{-1}) and NDEF (pH 7.12; 288 kg P_{M3} ha^{-1}) treatments. After two years of experiment, the combination of cover crop × amendment improved soil organic-C by 8.8% and 10.6% and -N by 8.1% and 9.8% compared with amendment alone and cover crop × FERT treatment, respectively. Potentially mineralizable N estimated by UV-absorbance of $NaHCO_3$ extraction was greater under ORCl (0.79 abs) compared with the other cover crops (0.69 abs). The microbial biomass C was 205 kg ha^{-1} under MSFW and 212 kg ha^{-1} under WA, but only 168 kg ha^{-1} under NDEF, 125 kg ha^{-1} under FERT. The combination of cover crops and organic or industrial wastes provide comparable soil mineral N supply and available P with fertilized treatments while improving soil physical and biological properties and overall soil quality in this vineyard production system.

1. Introduction

In Canada, Nova Scotia is the third most developed wine grape growing region after British Columbia and Ontario (Winery Association of Nova Scotia, 2009). Vineyard acreage is projected to increase by 40% by 2020 in Nova Scotia (Kittilsen, 2008). One major constraint, however, is that vineyards of the region are mainly located in areas with steep slope characterized by light textured soils, low soil organic matter (SOM) content, low soil fertility status, low water holding capacity and often, due to high gravel content and shallow depth, a high risk of nutrient leaching. Management strategies aimed at improving the quality and fertility status of the soils under vineyards are therefore needed.

Vineyard floor management strategies including cover crops have the potential to improve soil quality and fertility (Baumgartner et al., 2008). Cover crops are typically planted after minor soil preparation in the alleys between grapevines. They

* Corresponding author. Tel.: +1 705 748 1011x7954; fax: +1 705 748 1569.
E-mail addresses: mehdisharifi@trentu.ca, mehdisharifi@trentagriculture.ca (M. Sharifi).

http://dx.doi.org/10.1016/j.scienta.2015.02.041
0304-4238/

contribute to carbon (C) and nitrogen (N) inputs to soil, thus reducing soil erosion and the need for synthetic fertilizers without affecting wine grape yield and quality. In a five-year experiment under vineyard in California, soils with cover crops showed greater capacity for N mineralization and greater microbial biomass N content (Steenwerth and Belina, 2008a). In the same experiment, greater values of microbial biomass carbon (MBC) and dissolved organic C were also observed under cover crop soils compared with cultivated soils (Steenwerth and Belina, 2008b). In a three-year vineyard experiment in Portugal, water use was higher in plots sown with combination of grasses and legumes cover crops compared with plots where soil was tilled between vine rows (Monteiro and Lopes, 2007).

The addition of various bio-wastes and nutrient-rich industrial by-products to agricultural soil has been proposed as a way to improve the chemical, physical as well as biological properties of soils (Canadian Council of Ministers of the Environment, 2005). Some of the materials studied as soil conditioners and potential sources of plant nutrients are municipal solid food waste (MSFW) compost (Weber et al., 2014) and wood ash (WA) (Voundi Nkana et al., 2002; Sharifi et al., 2013). The addition of MSFW in a four-year lowbush blueberry (*Vaccinium angustifolium* Ait.) field provided equivalent amounts of plant essential nutrients compared with inorganic fertilizer (Warman et al., 2009). Wood ash can be used to increase soil pH and supply soil nutrients due to carbonates, oxides and hydroxides of Ca, K, and Mg (Perkiömäki and Fritze, 2002). Studies have also shown that WA additions to soil reduce the solubility of Al, Mn, Zn, Fe, and Cu (Perkiömäki and Fritze, 2002). In an eight-month incubation experiment, Sharifi et al. (2013) demonstrated that WA from three Atlantic sources can be considered as an effective liming agent and source of K in agricultural production systems. Little is known on the potential effects of mussel sediments (MS) in agriculture. To the best of our knowledge, it has seldom been tested as a soil conditioner or source of nutrients in agriculture. These potentially valuable bio-wastes and nutrient-rich industrial by-products are relatively easy to incorporate into soils, (i.e. wine grape production systems) and may represent an environmentally, safe and economical alternative to other methods of disposal in Nova Scotia and elsewhere (Cabral et al., 2008).

Few studies have explored the interaction effects of legume cover crops (Monteiro and Lopes, 2007) and bio-wastes and nutrient-rich industrial by-products (Weber et al., 2014) on soil quality in vineyard. We hypothesized that the combination of leguminous cover crops and bio-wastes and nutrient-rich industrial by-products can improve soil quality and nutrient cycling while producing yields comparable to those achieved with synthetic fertilizer. The objective of this study was to assess the effects of management practices consisting of legume cover crops and bio-wastes and nutrient-rich industrial by-products applied to vineyard on chemical, physical, and biological soil properties corresponding to overall soil quality.

2. Materials and methods

2.1. Site description

The study was conducted at Petite Riviere Vineyard, established in 1999 on a Bridgewater loam-drumlin phase soil [Cryorthods under the U.S. Soil Taxonomy (Soil Survey Staff, 2010)] located at St. Mary's in the LaHave River Valley area of Lunenburg County (44°22′N, 64°31′W). The soil is gravelly sandy clay loam developed on slate-derived till overlying a granite batholith (Webb and Marshall, 1999). It is moderately well-drained, shallow, and stony. Bulk density of the topsoil (0–15 cm) was measured in late-spring 2011 and 2012 using a procedure adapted to stony conditions at the vineyard (USDA, 2004). Bulk density was on average 1.22 g cm^{-3}. Lunenburg County is characterized by an undulating to rolling drumlinized till plain that slopes in a south-easterly direction toward the Atlantic Ocean. Elevations range from a high of about 270 m inland. During the growing season (May to October), the 30-year average daily temperature varies between 9.3 °C in October and 19.5 °C in July. The local climate is humid continental with an annual rainfall of 1323 mm, 641 mm of which falls during the growing season.

Leon Millot was the grape variety in this study. The dormant pruning was made in March of each year and prunings were left on the ground in the vine rows. At the beginning of the growing season, the vine rows without a permanent cover crop were tilled to prepare the seedbed. Leon Millot grapes reach veraison in late August to early September. A heavy summer pruning takes place to allow the grapes to have direct sunlight and build sugar and turn dark red. The harvest occurs in mid-October. Pest and disease management was carried out consistent with local recommendations (Craig, 2013). Ignite® (glufosinate ammonium) herbicide was applied three times during the growing season in all treatments to keep a 0.50 m weed free zone under the vines to minimize competition for nutrients and water.

2.2. Experimental design

Experimental design was a nested design with four cover crops randomly assigned to main plots and five fertility treatments randomly assigned to sub-plots. Experimental treatments were replicated in three blocks, with individual experimental plots measuring 5 m × 2 m and consisted of three measurable vines and two guard vines. Vine rows were 1.8 m apart with in row spacing being at 1.0 m intervals. The four cover crop treatments were: (i) control with no cover crop (CONT), (ii) mixture of oats (*Avena sativa* L.) + pea (*Pisum sativum* L.) + hairy vetch (OPV), (iii) oats underseeded with red clover (ORCl), and (iv) mixture of 70% timothy (*Phleum pratense*) + 15% alsike (*Trifolium hybridum*) + 15% red clover (commercially called triple mix; TM). The five fertility treatments were (1) synthetic fertilizer minus N (NDEF), (2) synthetic fertilizer with N (FERT), (3) WA, (4) MSFW, and (5) MS. The FERT application rate was based on soil test and provincial recommendations (Nova Scotia Department of Agriculture and Fisheries, 2004). The NDEF consisted of 83 kg K ha^{-1} as KCl + 40 kg S ha^{-1} as $MgSO_4$ ($7H_2O$) and elemental S (90%) + 24 kg Mg ha^{-1} as $MgSO_4{\cdot}7H_2O$ + 2.4 kg B ha^{-1} as elemental B (15%). The FERT treatment consisted of the same composition as NDEF + 40 kg N ha^{-1} as NH_4NO_3. The WA originated from Brooklyn Power Ash and was applied at 6.3 Mg ha^{-1} on a dry weight basis. Using this application rate the estimated total supply of K was 83 kg ha^{-1}, with the assumption that 80% of the total WA potassium was available in the first year (Sharifi et al., 2013). Nitrogen as NH_4NO_3 (34% N) and sulfur as $MgSO_4$ ($7H_2O$) (90% S) were applied at rate 40 kg ha^{-1} in the WA treatment. The MSFW was applied at 13.4 Mg ha^{-1} on a dry weight basis based on the assumption that 15% of the total N is available in the application year (Sharifi et al., 2014). Nitrogen was applied at rate 30 kg ha^{-1} and K was applied as KCl (62% K) at rate 83 kg ha^{-1} to balance the nutrients in the MSFW. The MS was applied at rate 42,000 L ha^{-1} (105.3 Mg ha^{-1} on a dry weight basis) to supply 99 kg total N ha^{-1} based on the assumption that 40% of total N in the MS is available in the application year. Potassium was applied at rate 83 kg ha^{-1} due to low level of K in this amendment.

The soil was tilled down to 10 cm depth with a rototiller. Amendments were manually applied in a 1.3 m wide band between vine rows and lightly incorporated into the soil in the spring of 2011 during seedbed preparation. In 2012 the amendments were top dressed on the soil with permanent cover crops and incorporated for treatments with annual cover crops. The seeding rates for the