Effects of short to medium-term dairy manure and biochar applications on the growth, forage production and quality, soil quality and health in a continuous silage corn monocropping system in boreal climate

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Introduction

- Through the Way Forward Policy, the Newfoundland and Labrador (NL) government is engaged in an ambitious drive to double food production by 2022.
- Dairy industry is presently the most valuable agricultural commodity, contributing approximately $125 million to the provincial economy.
- Local forage production is approximately 55-60% and is not sufficient enough to cater the needs of the NL dairy industry.
- Local production has been mainly limited by short growing seasons and inherently poor-quality soils.
- Biochar (BC) is a carbon-rich product of pyrolysis of biomass under limited oxygen.
- Adding BC to the soil increases soil organic carbon (SOC), reduces soil bulk density, increases soil porosity and adsorption capacity, and improves the soil hydraulic properties.
- In silage corn systems where liquid dairy manure (DM) is applied, BC application can greatly improve the adsorptive capacity of the soil, improving nutrient retention and overall soil health due to the additional SOC.
- The soil health benefits of DM and BC application have not been fully quantified in NL.
- Most farmers are reluctant to adopt new practices due to lack of evidence of benefits.
- To address the need to increase local production of forage to eliminate reliance on imports, and to sustain growth in the dairy industry, producers need incentives and confidence for adopting practices that are more environmentally sustainable.
- We hypothesized that DM and BC will enhance silage corn yield, forage quality and soil health in the boreal climate.

Objectives

- To quantify the effects of short to medium-term application of DM and BC on forage yield and nutritional quality of silage corn.
- To evaluate the short to medium term effects of DM and BC application on soil microbial communities in a continuous silage corn cropping system.
- To monitor some soil physiochemical properties following DM and BC application to silage corn in a boreal climate.

Materials and Methods

- This field experiment was initiated at Pynn's Brook Research Station, Pasadena (49° 04′ 21.9″ N, 57° 33′ 37.4″ W), Canada in 2016.
- Experimental treatments were: 1) dairy manure with high N conc. (DM1, 0.23% N); 2) dairy manure with low N conc. (DM2, 0.079% N); 3) inorganic N fertilizer (IN); 4) DM1 + BC; 5) DM2 + BC; 6) IN + BC; 7) control (N0).
- The experiment was laid out in a randomized complete block design with four replications.
- Each plot was 4.8 m × 1.5 m.
- DM was applied before seeding @ 30,000 L ha^{-1} during 2016, 2017, 2018, 2020 and 2021. BC was applied @ 20 tons/ha in 2016.
- Silage corn (Pride A4414RR) was seeded with the SAMCO 2200 system (SAMCO Agricultural Manufacturing Ltd) using 90,900 seeds ha^{-1}.
- Soil samples from each plot were collected from 0-20 cm depth to determine soil chemical and biological properties.
- For physical properties (bulk density, water holding capacity and field capacity), samples were taken at 2 different depths (0-10cm, 10-20cm) and sieved (<2 mm) prior to subsampling or storage.

Data measurement for chlorophyll contents from the experimental plots

- Chlorophyll content were measured at the tasseling stage from six plants from each experimental plot, using SPAD 502 Plus chlorophyll meter (Spectrum Technologies, IL, USA).
- Plants from one square meter of each experimental unit were harvested manually and fresh weight was recorded.
- A sub-sample was taken and oven-dried at 60^{o}C for 3 – 7 days to determine moisture content.
- Forage yield of silage corn was calculated based at 35% dry matter content and converted to Mg ha^{-1}.
- The dry samples were ground using a Wiley mill and homogenized, a 50 g subsample was sent to Activation Laboratories Ltd (Actlabs), Ontario for nutritional quality (protein, fibre, carbohydrates, digestibility, and milk production potential) analyses.

Results

Chlorophyll Contents

- DM, IN and BC amendments had non-significant (P = 0.07) effects on chlorophyll content in silage corn.
- However, DM1 application exhibited slightly higher chlorophyll content (46.04) and lowest were recorded in control (38.32).

Forage Yield

- Experimental treatments had significant (P = 0.01) effects on forage yield of silage corn.
- DM1+BC treatment produced a higher forage yield (12.87 Mg ha^{-1}) whereas the lowest (6.37 Mg ha^{-1}) was observed in control.
- BC addition to DM1 and DM2 treatments produced 14% and 16% higher forage yield, respectively.
- Enhanced forage yield with BC amendment could be attributed to the porous structure, large surface area and functional groups of BC that adsorbed/retained more nutrients from manure application and made available to silage corn.
- BC amendments improve soil moisture contents and other physicochemical properties results in increased crop yield (Baronti et al., 2014; Duarte et al., 2019; Hass et al., 2012).
- Earlier study conducted by Ashiq et al., (2020) at the same experimental site recorded 6% and 10.5% increase in forage yield in DM1 and DM2 plots amended with BC.

Forage quality

- Experimental treatments had non-significant effects (P = 0.32; P = 0.30) on crude protein and available protein and significant (P = 0.04 and P = 0.01) effects on acid detergent fiber (ADF) and non-fibrous carbohydrates.
- BC amendment with DM1 and DM2 increased 17% and 19% ADF, 13% and 14% NDF respectively, however reduced 4% and 6% ADF and NDF in IN fertilizer amended BC treatment.
- BC amendment in DM1 and DM2 treatments decreased 12% and 16% NFC but increased 5% NFC in IN+BC treatment.
- DM1 and DM2 treatment exhibited 17.25% and 16.83% higher total digestible nutrient (TDN) compared to control. However, BC amendment in DM treatments reduced TDN by 12% but increased 1.63% in IN+BC treatment.
- DM, IN and BC application had significant (*P = 0.02; P = 0.03 and P = 0.03*) effects on net energy for lactation (NEL), net energy for maintenance (NEM) and net energy for gain (NEG) in silage corn.
- DM application produced higher NEL, NEM and NEG whereas, BC amendment in DM1 and DM2 reduced 17% and 18% NEL, 19% and 21 NEM and NEG by 30% and 32% respectively and increased 3%, 3% and 4% NEL, NEM and NEG in IN + BC treatment.
- Higher milk production was observed in DM amended plots compared to control though statistically at par with IN and IN+BC treatments.
- Overall DM1 + BC amendment produced higher forage yield, fibers, NEL, NEM and NEG. However, BC amendment didn't enhance NFC, and TDN. Further field experiments are required to validate the results.

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