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S. I. BIOCHAR

How can potatoes be smartly cultivated with biochar as a soil nutrient amendment technique in Atlantic Canada?

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Abstract

The question if biochar is a suitable soil nutrient amendment for potato cultivation in the Atlantic Canada is yet to be answered. The objective of this study was to answer this question. Three replicates of twelve lysimeters, each 8000 cm^2, were packed with an Atlantic Canada representative soil to cultivate potatoes with four treatments of soil amendments (T_1 = control [no added nutrients], T_2 = B [biochar], T_3 = F [synthetic fertilizer @ recommended NPK], and T_4 = B + F [biochar + recommended NPK]) under a completely randomized block design with factorial arrangements. Chemical analyses of soils were conducted for physical, hydrological, and chemical (including concentration of macro- and micro-nutrients) prior to and after the completion experiments to evaluate soil fertility and its resulting effects on crop yield. The biochar amendment improved soil micro- and macro-nutrients. Soil organic matter, pH, and cation exchange capacity (ECE) significantly increased by application of biochar. The maximum potato yield of 30,467.4 kg h^{-1} was achieved by the combined application of biochar and synthetic fertilizer as this combination resulted in the maximum net benefit ($4433.98 ha^{-1}) in comparison with control treatment that had net loss of $– 2621.49 ha^{-1}. It is therefore concluded that biochar amendment of soils resembling to that of the Atlantic Canada representative soil used in this study, with a mix of recommended NPK for, can formulate a smart precision farming nutrient management technique for this region subject to the field trials and replicate experimental treatments for more than three times.

Keywords Economic analysis · Natural resource management · Precision agriculture · Soil micro- and macro-nutrients · Soil fertility

Introduction

Canada produces high quality potatoes (*Solanum tuberosum* L.), which is one of the most consumed vegetable worldwide. It is an export commodity of the Province of Prince Edward Island, Canada. The potato industry in Atlantic Provinces of Canada is highly profitable as Canada has been among the global leaders in potato production, with two of its Atlantic Canadian provinces, Prince Edward Island and New Brunswick, contributing 24.5 and 13.6% to the country's potato industry, respectively (Farooque et al. 2019). The province of Prince Edward Island grows potatoes on over 33,000 ha and exports 131,047 tons for tens of million Canadian dollars annually. The neighboring Atlantic Province of New Brunswick generates about 1.3 billion Canadian dollars every year. For optimum yield of potatoes, the crop management practices implemented within potato fields need evaluation to design precision agricultural practices. Soil amendments are among the most important management practices for achieving optimum yield of a crop.

High quality disease-free seed, moist and warm seedbed, insect-pest management, neutral soil pH, and fertile soil ensure high yield of quality potatoes. The Prince Edward Island Analytical Laboratories (www.gov.pe.ca/agriculture/labservices) recommends incorporating 1–3 tons ha^{-1} of

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This article is part of the Topical Collection on *Implications of Biochar Application to Soil Environment under Arid Conditions*

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limestone to improve soil pH from 5.5 to 6.5 for achieving optimum yield of high quality potato varieties grown in Prince Edward Island including general round Potatoes, Potatoes-BURBANK, and Potatoes-PROSPECT. Application of 130–185 kg ha^{-1} of nitrogen (N), 135–200 kg ha^{-1} of phosphate (P from P_2O_5), and 135–200 kg ha^{-1} of potash (K from K_2O) is also recommended for ensuring the required soil fertility.

Over the past decade, researchers have explored how biochar addition to soil can enhance soil fertility (Chan et al. 2007; Blackwell et al. 2010; Akhter et al. 2015; Ahmed and Schoenau 2015). The amendment of biochar carbon-rich product in agricultural fields have proven multiple benefits including improvement of soil fertility (Woolf et al. 2010), soil water retention (Morris et al. 2016), enhancement in seed germination (Eizenberg et al. 2017), higher crop productivity (Liu et al. 2013), and reduced soil environmental pollution (Abel et al. 2013). Application of biochar as a soil amendment has also been tested in combination with, and in comparison to, the application of synergistic fertilizer by various researchers (Van Zwieten et al. 2010; Jeffery et al. 2011). Asai et al. (2009) and Saarnio et al. (2013) have reported that application of biochar with inorganic fertilizer can lead to enhanced plant growth.

Biochar amendment is one of the best solutions for soil management as its incorporation in soil improves soil's physical properties and aids in mitigating soil water deficit conditions. Biochar improves soil water holding capacity due to high surface area and negatively charged surfaces (Laird 2008; Haefele et al. 2011; Batool et al. 2015). Biochar application results in carbon sequestration potential and improved soil porosity (Lehmann 2007; Bonanomi et al. 2017) that catalyzes the strengthening of seeds in soil as the soil physical and hydrologic properties are interrelated, such as soil resistance with soil bulk density, saturated hydraulic conductivity with soil porosity, and soil saturated hydraulic conductivity with soil organic carbon (Awal et al. 2019). Similarly, biochar applications have positive effects on the most important physiological processes of plants such as increase in the rate and capacity of photosynthesis (Xu et al. 2015); it retains and improves uptake of plant nutrients including nitrogen (N), potassium (K), phosphorous (P), calcium (Ca), and magnesium (Mg) that are dominantly linked with growth responding arrangements and regulation of osmotic potential within internal plant physiology (Uchida 2000; Walter and Rao 2015). Moreover, amendment of biochar minimizes soil hardening and soil bulk density and increases soil pH by 0.5–1.0 unit when applied in field at the rate of 30 Mg ha^{-1} (Shackley et al. 2012). The release of nutrient content from biochar is slow and frequent when it is amended with soil and is thus ideal for recovery of degraded soils (Cushion et al. 2010). Hale (2013) indicated enhancement in nutrient and water use efficiencies and soil fertility under biochar organic amendments.

The biochar amendment has a variety of productive impacts including improved quality of potatoes rendering certain economic facilities to farmers along with promoting food safety by employing organic fertilizers, i.e., organic farming eventually leading to establishment of sustainable cropping system (Dou et al. 2012). Previous studies on the use of biochar as an organic soil amendment for the improvement of yield of various crops including maize, sorghum, soybean rice, wheat, and tomato have reported mixed results (Blackwell et al. 2010; Jeffery et al. 2011; Jones et al. 2012; Hammond et al. 2013; Ahmed and Schoenau 2015).

Extensive literature research did not reveal an in-depth study to show the interactive effects of biochar application for sustainable potato cultivation. The reported study here was conducted to fill this knowledge gap by evaluating the incorporation of biochar as a soil amendment in various combinations and as an alternative source of soil nutrients for potatoes in order to design nutrient management practices for economically viable and environmentally safe potato cultivation techniques in Atlantic Canada.

Materials and methods

Study area and experimental soil

The experiment was conducted at the open rooftop of the School of Sustainable Design Engineering at the University of Prince Edward Island Canada (latitude 46.2575° N and longitude − 63.1375° W). The soil used in this lysimeter experiment was clay with calcareous characteristics, making the soil very fertile. The soil texture had 23% sand, 36% silt, and 41% clay with 1.84% organic matter. Three soil samples used in this experiment were collected from potato fields to make composite samples that were analyzed prior to filling the lysimeters. Prior to filling in lysimeters, the soil was broken into < 10 mm by hand, air-dried, and cleaned by removing visible plant residues. Post-experiment soil samples were collected from the root zone depth of potatoes at harvesting point using an auger. The soil samples were secured in cold room prior to analyses.

Organic matter was determined by using dichromate oxidation method (Walkley and Black 1943). Soil electrical conductivity (EC) and pH were determined in a 1:5 soil/water extract. Plant available N was determined by the method defined by Hesse (1971). Available P was determined using the method as described by Olsen et al. (1954), and K was determined by the method described by Junsomboon and Jakmunee (2011). Soil bulk density was determined by core method, using the process of the Spanish Ministry of Agriculture (APA 1986). The phosphorous/aluminum (ratio) was determined using the standard Mehlich extraction method. The lime index was determined using Shoemake-McLean-

Pratt (SMP) buffer method. All the chemical analysis was performed at a commercial laboratory of Prince Edward Island Analytical Laboratories—Department of Agriculture and Fisheries—except soil N. Hydro-chemical characteristics of the soil are given in Table 1.

Manufacturing of biochar

Biochar is produced from a variety of raw material and on a range of pyrolysis temperature. Figueredo et al. (2017) characterized biochars made from sugarcane bagasse, eucalyptus bark, and sewage sludge on 350–500 °C pyrolysis temperature and evaluated the release of nutrients and contaminants. They reported that the raw material and the pyrolysis temperature impact quantity and quantity of its nutrients of biochar including carbon content. Biochar used in this experiment was prepared from soft wood pallets. During processing of biochar production, the temperature of the biochar pyrolysis unit was between 450 and 550 °C in a perpendicular oven manufactured by Sanli Bioenergy Co. Ltd. (Pan et al. 2011). Cast iron tube of 6 mm internal diameter was used as reactor wall. The Paragon Sentry Xpress 4.0 furnace was used for the reactor placement. The raw materials of biochar were first heated at 105 °C for 30 min to remove the moisture, while the temperature of the plant was set to 450 °C and 550 °C. The gas produced from biochar preparation was condensed in the plant and collected as a liquid bio-oil for the safety of environmental pollution (Fig. 1). The biochar was milled to pass through a 1-mm filter prior to its use as a soil amendment. Table 1 lists chemical characteristics of the biochar used in this experiment.

Treatments and experimental design

The 2-m-long, 0.4-m-wide, and 0.4-m-deep lysimeters (Fig. 2) used in this experiment were arranged in a completely randomized design with factorial arrangement. There were four treatments of soil amendments including (i) T_1 = control having no amendments, (ii) T_2 = B having biochar incorporated in soil @744 g lysimeter^{-1}, (iii) T_3 = F with synthetic fertilizer applied twice @71 g lysimeter^{-1}, and (iv) T_4 = 50% biochar (372 g laysmeter^{-1} + 50% NPK (35.5 g lysimeter^{-1} applied). The treatments were replicated three times during summer of the year 2017. Full dose of biochar (744 g) was applied at the seedbed preparation stage of T_2 lysimeter^{-1}. Half doses of synthetic fertilizer (35.5 g for T_3 and 17.75 g for T_4) were applied during seedbed preparation stage and the remaining half fertilizer (35.5 g for T_3 and 17.75 g for T_4) after 30 days of sowing in T_3 and T_4 treatment lysimeters, respectively.

Crop management

A potato cultivar Russet Burbank was planted on June 10, 2017. Five potatoes were sown at 15 cm depth and 40 cm distance from one another in each bed. The soil was folded over the sown seeds, creating a crest and was patted down. The lysimeters were irrigated according to their irrigation water requirements. The need for supplemental irrigation was continuously evaluated from the metrological daily data (min and max temperatures, rainfall, snowfall, heat degree days) collected at the nearby weather station (Fig. 3). Insect and disease in plants were controlled by using local standard pesticide. All cultural practices were maintained similarly for all treatments. Mature potatoes were gently harvested after 16 weeks of their sowing. Marketable potato (> 130 g) and non-marketable (≤ 130 g) potato were separated during the harvesting on October 18, 2017.

Statistical analysis

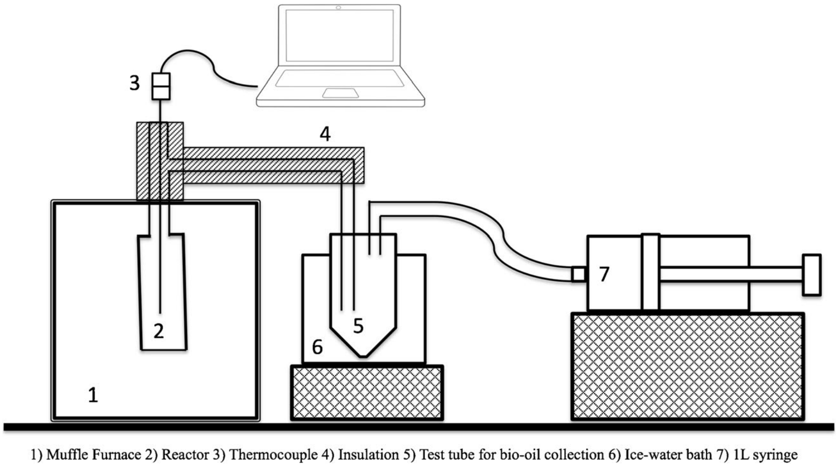
The treatment effects on the studied variables were analyzed by constructing analysis of variance (ANOVA) using SAS (SAS Institute 2004). When *F*-values were significant, the least significant difference test was used for comparing means of treatments. The difference in treatment means were considered significant at $p < 0.05$. Correlations among the studied variables were drawn by using Sigma Plot. The economic analysis of the crop expenses and output was performed on the basis of cost that varied in different treatments and by

Table 1 Physico-chemical characteristics of biochar and soil used in the experiments

Biochar	Values	Soil	Values
pH	9.4	pH	5.5 ± 1.20
Organic matter (%)	14.1	Organic matter (%)	1.84 ± 0.14
Total nitrogen (g kg^{-1})	9.1	Total soil nitrogen (g kg^{-1})	0.08 ± 0.11
Total phosphorous (g kg^{-1})	4.3	Total soil phosphorous (g kg^{-1})	7.5 ± 0.90
Total potassium (g kg^{-1})	36.5	Total soil potassium (g kg^{-1})	15.0 ± 10.25
C/N	12.5	Electrical conductivity (dS m^{-1})	2.67 ± 0.11
		Field capacity (cm^3 cm^{-3})	0.43 ± 0.03

Values are the mean of three replicates ($n = 3$) with ± 1 as the standard error of mean

Fig. 1 Mechanism of condensing gas and collecting bio-oil liquid produced during biochar preparation as a part of environmental safety from pollution



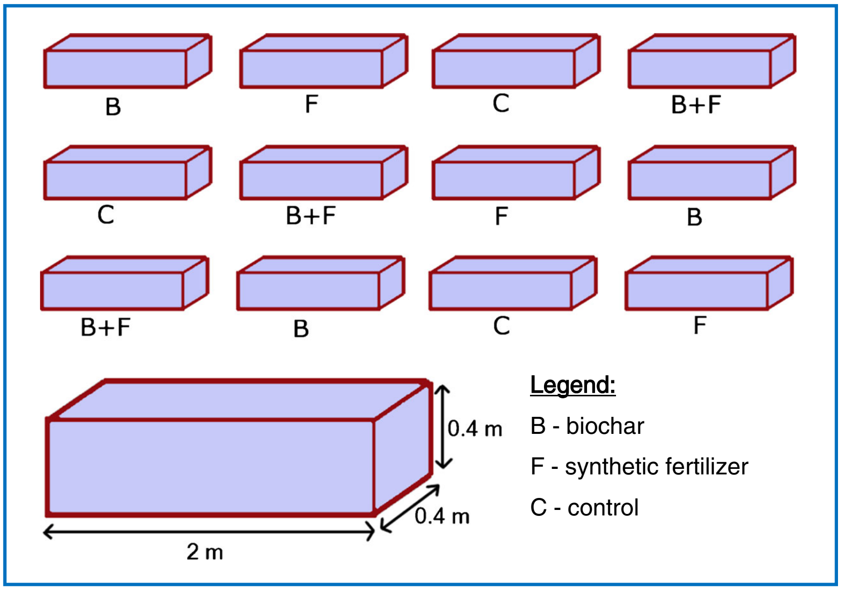
adding fixed cost by following the procedure devised by Byerlee (1988).

Results and discussion

Biochar used in this experiment had low concentration of carbon as judged from its organic matter content given in Table 1. This may be because of the type of raw material used to produce biochar as the raw material and pyrolysis temperature used to produce biochar influence the quantity and dynamics of nutrients from biochar (Figueredo et al. 2017). Since there is a mixed reported influence of raw material and pyrolysis temperature on the amount of released nutrients including biochar carbon, there have been contradictory reports about these phenomena. Lu et al. (2013) reported that biochar carbon from sewage sludge in their experiment ranged from 15.2 to 33.2%; on the contrary, Figueredo et al. (2017) found that sewage sludge in their experiment released 24.4% at 350 °C and 21.0% at 500 °C. In the study of Figueredo et al. (2017), the pyrolysis temperature had mixed results, for example, biochar carbon produced from burning of sewage sludge and eucalyptus bark increased with increase in pyrolysis temperature, and the opposite was true for biochar carbon produced from sugarcane bagasse, i.e., biochar carbon produced from burning of sugarcane bagasse decreased with increase in pyrolysis temperature.

There was enough soil moisture available for plants to grow from precipitation (rain- and snowfall) that did not generate demand for supplemental irrigation to the plants during the typical weather (min and max temperatures and heat degree days) of the Prince Edward Island (Fig. 3). The results of the study revealed that the amendment of biochar significantly improved soil fertility by improving the both micro and macro soil nutrients (Table 2). Application of biochar highly significantly ($p < 0.001$) enhanced boron in the soil, and this increase was quadratic in nature. Maximum concentration of boron (0.81 mg kg^{-1}) was observed in the soil T_2 lysimeter

Fig. 2 Treatment wise experimental layout of the study



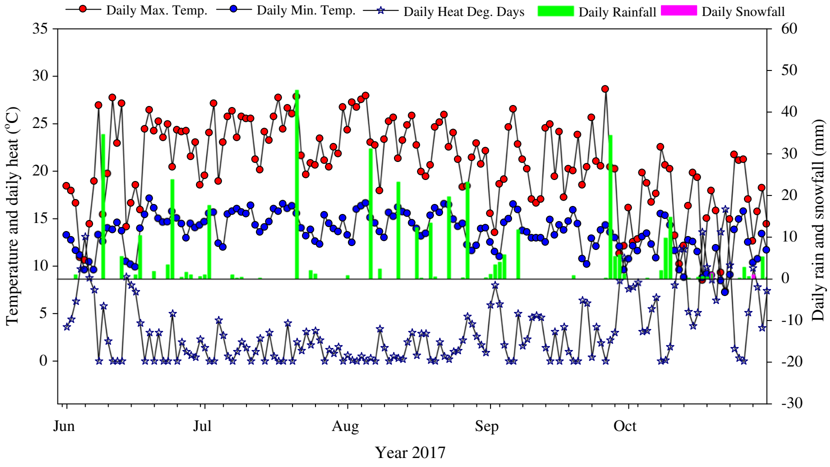


Fig. 3 Daily meteorological data recorded at the experimental site during 2017

that had biochar incorporated in its soil. The soil of treatment T_4 had maximum concentration of zinc (1.21 mg kg^{-1}) as a result of combined use of biochar and synthetic fertilizer. However, it was not significantly higher than that of T_2 soil that had the only biochar application. The application of biochar significantly improved iron concentration in soil to a maximum concentration of 154 mg kg^{-1}. Similarly, the application of biochar significantly increased copper concentration (2.45 mg kg^{-1}) in the soil.

Organic carbon within the soil was already high, i.e., 4.9% that is a good indicator of the inherent chemical fertility of this soil. The soil had optimum quantity of plant micro- and macro-nutrients depicting to a good soil fertility characteristic. The biochar amendment in the soil improved soil fertility. Biochar contains high levels of exchangeable ions, i.e., ions of K, Ca, and Mg, as well as eleven trace elements (Walter and Rao 2015). Plant growth increases by certain trace elements; however, their concentration must be lower than threshold value. Nonetheless, the determination of repercussions of each single substrate component is not doable; e.g., for determining the impact of each trace metal would require extensive experimental study (Carter et al. 2013). However, the detrimental effects of individual substrate component may be compensated by the positive effects of another component of the biochar amendment, e.g., the increase of CEC under sophisticated conditions.

Biochar amendment in the soil highly significantly ($p < 0.001$) improved soil organic matter in a quadratic trend (Table 3). The soil of treatment T_2 had the maximum soil organic matter (2.63%), which was 64% higher than that of soil of control treatment. The soil pH significantly and linearly increased by the application biochar, and the highest value of 5.7 soil pH was recorded for the soil of treatment T_2, showing 20% improvement as compared with soil pH of treatment T_1 that had a minimum value of pH (4.73).

Table 2 Effect of biochar amendment and fertilizer application on soil micronutrients

Factors	Boron (mg kg^{-1})	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})	Iron (mg kg^{-1})	Copper (mg kg^{-1})	Sodium (mg kg^{-1})	Aluminum (mg kg^{-1})
Control	0.47 ± 0.06	0.77 ± 0.15	35.33 ± 3.4	132.4 ± 7.5	1.90 ± 0.30	19.3 ± 1.2	1773 ± 62.5
B	0.81 ± 0.03	1.17 ± 0.12	42.73 ± 4.1	119.0 ± 8.2	2.45 ± 0.30	26.7 ± 3.2	1951 ± 88.3
F	0.60 ± 0.04	0.92 ± 0.07	41.43 ± 5.2	133.3 ± 10.8	2.13 ± 0.21	21.3 ± 2.1	1817 ± 54.3
B + F	0.63 ± 0.12	1.21 ± 0.17	42.53 ± 3.7	154.0 ± 15.8	2.23 ± 0.32	19.0 ± 1.0	1892 ± 32.2
LSD	0.015	1.14	7.5	35.7	0.36	4.2	120
Replication	< 0.48	< 0.21	< 0.13	< 0.75	< 0.03	< 0.17	< 0.33
Significance	< 0.0.007	< 0.01	< 0.14	< 0.22	< 0.05	< 0.01	< 0.04
CV	11.6	11.4	9.2	13.3	8.3	9.8	4.3
				Polynomial contrast			
Linear	< 0.33	< 0.11	< 0.37	< 0.56	< 0.39	< 0.93	< 0.36
Quadratic	< 0.05	< 0.40	< 0.58	< 0.46	< 0.27	< 0.05	< 0.29

CV coefficient of variance, *LSD* least significance difference, *B* biochar 744 g lysimeter^{-1}, *F* synthetic fertilizer; Recommended NPK, B + F = (50% biochar + 50% NPK)

Table 3 Effect of biochar amendment and fertilizer application on soil physico-chemical properties

Factors	Soil organic (%)	Soil pH	CEC (cmol kg^{-1})	Total base saturation (mg kg^{-1})	PAI (%)	Lime Index (mg kg^{-1})
Control	1.77 ± 0.15	4.73 ± 0.15	24.79 ± 3.23	34.8 ± 5.1	8.49 ± 1.2	5.57 ± 0.72
B	2.63 ± 0.16	5.67 ± 0.25	25.98 ± 2.63	46.1 ± 4.4	11.43 ± 1.5	7.00 ± 0.46
F	1.93 ± 0.14	5.13 ± 0.32	29.57 ± 1.71	36.1 ± 5.9	9.15 ± 0.52	6.60 ± 0.17
B + F	2.23 ± 0.12	5.03 ± 0.42	28.37 ± 2.31	47.6 ± 2.2	9.25 ± 0.71	6.77 ± 0.15
LSD	0.31	0.63	3.46	9.6	1.9	1.0
Replication	< 0.43	< 0.56	< 0.04	< 0.60	< 0.20	< 0.99
Significance	< 0.0001	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05
CV	7.2	6.2	6.4	11.7	9.7	7.9
				Polynomial contrast		
Linear	< 0.18	< 0.04	< 0.22	< 0.23	< 0.69	< 0.28
Quadratic	< 0.05	< 0.30	< 0.70	< 0.58	< 0.16	< 0.38

Abbreviations: as defined in the footnote of Table 2

Soils, upgraded with malleable rates of biochar, have significant alteration in average soil pH. Therefore, the patterns of soil pH with biochar enrichment were concordant with pH increase in non-amended soils in the study reported by Shackley et al. (2012). Acidic pH has the capability to check plant growth by revamping in crop nutrient dynamics; hence, the application of biochar can potentially benefit acidic soils across Canadian provinces. Moreover, biochar-amended soils were reported to have increased pH by 0.1–0.46 and CEC with an increase of 4–17% (Peng et al. 2011). Chan et al. (2007) mentioned that the soil pH dominantly increases by application of biochar originated through pyrolysis of the green waste. Studies reported in literature (Jones et al. 2012; Guerena et al. 2013; Hammond et al. 2013; Krapfl et al. 2014; Ahmed and Schoenau 2015) determined that the applied biochar augmented soil fertility content in regions where pH is not a limiting factor for crop production. Some selective studies that have indicated the productive effects of biochar emendation include Blackwell et al. (2010); Jones et al. (2012); Hammond et al. (2013); Krapfl et al. (2014); Ahmed and Schoenau (2015); and Boersma et al. (2017).

Application of biochar and synthetic fertilizer significantly ($p < 0.04$) influenced the CEC of the soil. The maximum CEC was observed in the soil of combined application of biochar and syntactic fertilizer (T_4). The total base saturation of soil was significantly ($p < 0.03$) improved by biochar amendment as compared with control treatment. The maximum total base saturation was observed in biochar-amended treatment. Biochar amendment in the soil significantly ($p < 0.05$) enhanced lime index; the maximum value of lime index (7.00 mg kg^{-1}) was recorded in soil of treatment T_2 lysimeter.

The CEC values and the exchangeable cations (Ca^{2+}, K^+, Na^+) potential in the sandy soil were lower than sandy loam soils (El-Naggar et al. 2018a), which is attributed owing to lower amount of organic and inorganic colloidal particles in latter soil (Juo and Franzluebbers 2003). The soil of the reported study was clay loam. El-Naggar et al. (2018b) reported a distinguished incline in CEC and exchangeable cations within soils that was determined with particular concern on biochar. This revealed that the biochar application augmented the cations procurable in sandy soil. Overall, soil CEC has a direct proportional relation to pH.

Application of biochar significantly enhanced soil P; the maximum concentration of P (419 mg kg^{-1}) was recorded in the soil of lysimeter incorporated with biochar alone (T_2), while the minimum concentration of P was observed in control treatment. Biochar amendment significantly enhanced soil K; however, it was statistically similar in the soil of combined application of biochar and syntactic fertilizer. The soil concentrations of Ca, Mg, and sulfur were significantly higher than that of control soil.

Application of biochar and synthetic fertilizer significantly influenced marketable potato yield. The maximum marketable potato yield (30,467.4 kg ha^{-1}) was achieved by combined application of biochar and synthetic fertilizer. The amendment of biochar linearly increased the potato yield and when the crop was subjected to 50% biochar and 50% synthetic fertilizer as compared with control treatment. The marketable potato yield increased by 59% (18,123.5 vs 30,467.4 kg ha^{-1}) during the study. The results showed that without fertilization, the net benefit became negative ($–2621.49 ha^{-1}).

This study revealed that biochar amendment distinctly increased potato yields. The results are in concurrence with the findings of Du et al. (1998) and, similarly, Asai et al. (2009) who described that biochar exhibits a projection in crop productivity potential by refining physico-chemical attributes. The variability in responding toward crop yielding potential depends on the chemical as well as physical characteristics of biochar, soil ambient environment, and crop strain (Yamato et al. 2006; Van Zwieten et al. 2010). Likewise, Chan et al. (2007) reported that N availability toward cropping systems can also be enhanced by biochar application. Besides this, it also aids for the improvement of N use efficiency due to higher levels of organic carbon and N deposition in soils (Pan et al. 2011).

A number of experimental evidences elaborate the effect of biochar application in improving crop yield potential and various soil parameters associated with specific studies reported in literature (Cushion et al. 2010; Ahmed and Schoenau 2015; Coomes and Miltner 2016; El-Naggar et al. 2018a). A review of the past studies on the use of biochar as soil amendment depicts that, depending upon the feedstock attributes and pyrolytic environments, the nutritional substance of biochar may face variability to distinguished extent with total N and other nutrients in varying patterns (Ernsting 2011; Hafeez et al. 2017). The present study showed that biochar application resulted in a higher P availability in comparison with synthetic fertilizer application. The sudden rise of this P content within soils might be linked with lower Ca^{2+} concentration plus higher soil pH of the amended soil. The relative low Ca^{2+} concentration in soil may decrease lower precipitation rate of P under high pH conditions as caused by biochar application in the current study and previously reported by El-Naggar et al. (2015). These results were in agreement with the findings of Chan et al. (2007) and Ma and Matsunaka (2013) who reported that when biochar was applied to the soils of their experiments, it made P availability higher to the plants of these soils than those grown on soils without biochar application. Hinsinger (2001) is of opinion that the availability of such P is negatively impacted due to pH alteration and subsequent release of P from biochar particles.

The effectiveness of any crop management is finally evaluated on the basis of its economic returns. Economic analysis was the basic consideration in selecting an experimental treatment for the highest net returns for its further recommendation to the farmers. The economic analysis of the data showed that the maximum net benefit ($4433.98 ha^{-1}) was achieved by the application of biochar and synthetic fertilizer at 50% ratio. The results showed that without fertilization, the net benefit became negative ($– 2621.49 ha^{-1}). Therefore, the farmers may apply crop nutrients in the form of synthetic fertilizer with a mix of recommended biochar amendment.

Conclusion

The question that if biochar can serve as a soil nutrient amendment and replace typical synthetic fertilizers for potatoes cultivation in Atlantic Canada is answered here. This leads us to help farmers know how potatoes can be smartly cultivated with biochar soil amendment techniques in Atlantic Canada. The study revealed that biochar amendment in the soil improved soil fertility as its application to the soil resulted in enhanced soil pH, which can positively affect the nutrient availability and the productivity of low pH soils such as those in Prince Edward Island. Biochar thus may be considered as an alternative technique for reclaiming low pH acidic soil. However, the combined applications of biochar and synthetic fertilizer were resulted the maximum marketable potato yield (30,467.4 kg ha^{-1}) with suitable net benefit ($4433.98 ha^{-1}). Therefore, the farmers may adapt the technique of combined use of biochar and syntactic fertilization to improve soil pH and potatoes' yield. However, response of soil and plant systems to biochar and synthetic fertilizer amendments requires field trials on a large scale to replicate the experimental treatments used in this study for more than three times. This will help designing precision agricultural practices for smart cultivation of potatoes in Atlantic Canada.

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