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Influence of Biochar, Rock Phosphate, and Urea Nitrogen Fertilizer on Growth and Yield of Cucumber (*Cucumis sativus*) Grown in Standoff, Southern Alberta Greenhouse

Adebusoye O. Onanuga[1], Roy Weasel Fat[1] & Roy M. Weasel Fat[1]

[1] Red Crow Community College, Standoff, Alberta, Canada

Correspondence: Adebusoye O. Onanuga, Indigenous Agriculture Program, Red Crow Community College, Standoff, P.O. Box 1258, Cardston, AB T0K0 0KO, Canada. Tel: 587-999-4250; 403-393-2258. E-mail: adebusoyeo@redcrowcollege.com

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Abstract

Two trials were performed in greenhouse Standoff, Southern Alberta to investigate urea, rock phosphate, and biochar soil amendment on cucumber crops. The objective of the study was to confirm the effectiveness of rock phosphate and biochar with urea on greenhouse cucumber production. Two experiments were conducted in the Summer of 2020 and 2021 cropping seasons. The treatments applied in 2020 were the varying application of rock phosphate at 0 for control, 50 kg P ha^{-1} and 100 kg P ha^{-1} for phosphorus, and urea at 60 kg N ha^{-1} and 90 kg N ha^{-1} for nitrogen with their combinations N60 + P50, N90 + P100. In the 2021 cropping season, treatments applied were varying levels of Biochar (C) applied at a rate of 25 kg ha^{-1} (LC), 50 kg ha^{-1} (MC), and 100 kg ha^{-1} HC for Low, Medium, and High level, respectively, Urea (N) was applied at 30 kg N ha^{-1} and 60 kg N ha^{-1} (Low N and High N level, respectively) while rock phosphate (P) was applied at 25 kg P ha^{-1} and 50 kg P ha^{-1} (Low P and High P level, respectively) with their combinations. The seven treatments for each cropping season were replicated three times resulting in twenty-one experimental pots. The agronomical parameters data collected were subjected to one-way univariate analysis of variance using Duncan's Multiple Range Test at 5% to separate the treatment means. The results of the experiment showed that High P and Low N treated pots influenced the growth of cucumber crop at 122 days after sowing (DAS) while High N, Low N, and Low N + Low P jointly favored the highest number of cucumbers on the vines than other treated pots at 82 DAS during the 2020 cropping season. However, all the treatments supported cucumber vine length except control and High P at 96 DAS while Low P + MC, High P, and High N+ P produced more fruits than control, High N and Low N + P + HC treatments at 96 DAS during the 2021 cropping season. It was observed that the addition of biochar in the 2021 cropping season influenced the growth and yield of cucumber when compared performance of cucumber crops in two growing seasons. This experiment advocates the use of biochar soil amendment in cucumber production.

Keywords: cucumber, rock phosphate, biochar, urea, nutrients residual

1. Introduction

Cucumber is a fruit vegetable that provides sustainable living for many people in the world. Cucumber is a tropical fruit vegetable crop that grows in warm and cool ecological areas. Cucumber performs well in an environment of well-drained soil with adequate soil nutrients. It requires a temperature of 16 to 30 ^oC with a humidity of 60% (De luca et al., 2006; Osaji et al., 2017). The estimated total world production of cucumber in 2018 was 75,219,440 metric tons. Canada could be able to produce 55,934 tons resulting in 0.074% of the world's production (FAOSTAT, 2020). However, there is a great need to increase the production of cucumber. Nutrient management is an important factor to consider in the production of cucumber.

Biochar is an organic soil amendment in form of charcoal (Bracmort, 2010; Ndor et al., 2015). Biochar is made by pyrolysis or burning organic or waste agricultural materials such as wood chips, leaf litter, dead plant materials at a high temperature of 450-500 ^oC with or without oxygen (Bracmort, 2010; Chan et al., 2007; Sohi et al., 2009). It is black, highly porous, lightweight, and fine-grained with a large surface area. Biochar is efficient in converting into stable Carbon and keeps carbon in the soil in form of carbon sequestration (Sohi &

Shackley, 2009). Biochar improves soil quality. Njoku and Mbah (2012) reported that biochar improved soil properties (soil quality) and increased maize grain yield. Another benefit of biochar is contributing to food security by increasing yields and water retention during drought. Furthermore, biochar mitigates climate change, it enriched the soil and reduced the need for chemical fertilizer. It improves soil fertility thereby stimulating plant growth and yield. Osaji et al. (2017), and Akca and Namli (2015) confirmed that biochar improved soil fertility and the growth and yield of cucumbers.

Rock phosphate fertilizer is an organic phosphate fertilizer that provides phosphorus fertilizer to plants in the form of monophosphate or diphosphate. Rock phosphate is natural organic P fertilizer mined from rocks (Chien & Friesen, 1992). This fertilizer could be used directly to supply P nutrient for plant uptake (Chien & Friesen, 1992). It has been known that it provides other nutrients to plants such as calcium, and magnesium (Chien & Van Kauwenbergh, 1992). Rock phosphate could release P to acidic soils within the pH of 5.5 to 6.7 (Black, 1968; FAO, 1984; Jensen, 2010). It could also lower alkaline soil pH for easy nutrient uptake (Black, 1968; FAO, 1984; Zapata, 2003). Rock phosphate has a high residual effect in the soil by releasing P into the soil for subsequent cropping season (PerroStt & Wise, 2000; Onanuga et al., 2021).

Application of Nitrogenous fertilizer to soil inform of urea has been tested to influence P uptake. Nevertheless, there is a synergistic reaction between N and P uptake that benefits crop growth and yield (Chien & Friesen, 1992). However, the use of rock phosphate and biochar is still alien in Canada for crop production. Moreover, different biochar has been tested in different ecological zones, but there were no or scanty results on the use of biochar in Standoff, Southern Alberta. Therefore, the objective of this research effort was to evaluate the effect of biochar and rock phosphate on the growth and yield of cucumber crops planted in southern Alberta soil grown in a greenhouse.

2. Materials and Methods

2.1 Site Description

The experiment was conducted in Red Crow Community College Greenhouse. Red Crow Community College is in Standoff, Alberta. Standoff is a first nations Kainai Blood Tribe (KBT) reserve community. It is located on latitude 49^o North and longitude 113^o West. Its location is on Hwy 2, 43 km Southwest of Lethbridge. The annual average temperature and rainfall are -1 to 12 ^oC and 515 mm, respectively. Standoff soil is a Brown Chernozemic soil that is found in the Southern part of Alberta. The greenhouse temperature and relative humidity were recorded from April to September. The minimum greenhouse temperature was 14 ^oC while the maximum was 32 ^oC and the relative humidity minimum was 35% while the maximum was 65%

2.2 Physico-chemical Properties of the Soils

Soil samples at 0-15 cm were taken for physico-chemical analysis (Table 1). Nitrate-Nitrogen was extracted in the soil using 0.01M calcium chloride and N was detected by the colorimeter. The phosphorus was extracted using modified Kelowna, read by auto flow colorimeter while potassium was extracted from the soil using 1N neutral ammonium acetate. Micronutrients were extracted from the soil using DTPA and measured by atomic absorption.

Table 1 shows the Physico-chemical analysis of the soils used in this experiment. The major essential nutrients Nitrogen (N) was deficient in both soils and Phosphorus (P) was low in 2020 soil while optimum in 2021 soil. Potassium was excess in both soils. It was observed that the quantity of phosphorus and potassium in the 2021 cropping season was more than that of the 2020 cropping season. Moreover, secondary nutrients such as Calcium (Ca) and Magnesium (Mg) were optimum whereas Sulphur (S) was deficient in the soils. Micronutrients such as Zinc (Zn), Boron (B), Copper (Cu), and Sodium (Na) were low in the soils while soil Iron (Fe) and Manganese (Mn) were excess. The pH of the soils was 7.6 and 7.8 for 2020 and 2021, respectively (1:1 soil: water). Soil texture was done using Sodium Hexametaphosphate, measured by hydrometer. The soil texture was silty clay and loam silty clay for 2020 and 2021 soil, respectively.

Table 1. Physic-chemical properties of greenhouse soil

Properties	2020 Soil	2021 Soil
N (kg/ha)	49.32	47.10
P (kg/ha)	32.20	100.90
K (kg/ha)	1473.92	2149.80
S (kg/ha)	31.4	16.80
Ca (ppm)	4835.33	4549.00
Mg (ppm)	590.00	550.00
Zn (ppm)	1.50	1.10
B (ppm)	0.60	0.50
Cu (ppm)	1.60	1.20
Fe (ppm)	27.50	17.50
Mn (ppm)	13.30	9.10
Na (ppm)	51.40	19.70
OM (%)	4.60	4.30
pH	7.6	7.80
EC	0.60	0.50
Saturated Bases (%)		
Ca	76.40	78.90
K	5.90	5.10
Mg	17.00	15.70
Na	0.80	0.30
ECEC	28.60	28.80
K/Mg	0.35	0.33
Sand %	19.9	15.20
Silt %	42.1	42.00
Clay %	38.0	42.80
Textural class	Silty clay loam	Silty clay

2.3 Biochar Properties

Biochar was 100% wood burnt at 500 °C for 30 minutes. Biochar pH was 9.4, Carbon at or above was 80%, moisture and total ash (dry basis) were 11% and 3%, respectively. Nitrate N, available P, and K were 12.9, 32.2, and 1570 mg/kg, respectively. Total Carbon was 86.8% by combustion method.

2.4 Experimental Design

The patio snacker Cu381B was the cucumber variety planted. Patio snacker is very compact and bushy which produced big, tasty fruits. The patio snacker cucumber seeds were planted in the nursery on July 1, 2020, and seedlings were transplanted into 2.8 kg of soil on July 20, 2020. The automatic sprinkler irrigation was set up to irrigate the seeding up to the time of harvest. The water was sprinkled on cucumber crops in the morning, afternoon, and evening at 6 a.m., 12 noon, and 6 p.m respectively. Fertilizer was banded around the crops on July 20, 2020. The nitrogen fertilizer inform of urea was applied in two levels of 60 kg N ha^{-1} for Low N and 90 kg N ha^{-1} for High N, while Phosphorus inform of rock phosphate, was applied in two levels, 50 kg P ha^{-1} for Low P and 100 kg P ha^{-1} for High P with their combinations. The treatments were N60, N90, P50, P100, N60 + P50, N90 + P100, and control with no application of fertilizer. These treatments were replicated three times resulting in twenty-one experimental pots.

The experiment was repeated in 2021 with the same materials and methods except for the addition of biochar to the soil. Biochar (C) was applied at a rate of 25 kg ha^{-1} for Low C, 50 kg ha^{-1} for MC, and 100 kg ha^{-1} for HC (Low, Medium, and High, respectively), urea (N) was applied at 30 kg N ha^{-1} and 60 kg N ha^{-1} (Low and High, respectively) while rock phosphate (P) was applied at 25 kg P ha^{-1} and 50 kg P ha^{-1} (Low and High, respectively). The treatment combinations were control, Low N + Low C, High N, Low P + MC, High P, Low N + Low P + HC, and High N + High P. Biochar was added to low N and low P fertilizer applications to investigate judicious use of urea and rock phosphate fertilizer. Cucumber seedlings were transplanted on May 11, 2021, into twenty-one (21) pots each pot contained 2.8 kg of soil. The soil samples were taken in each of the treatments to analyze residual NPK levels in the soil after harvest. The NPK nutrients in the soil were determined through the method explained above. The agronomic parameters taken were plant height, number of leaves, number of cucumbers on the vines, number of cucumbers at harvest, and weight of cucumber.

2.5 Statistical Analysis

The agronomic parameters measured in each year were analyzed statistically in a complete randomized design one-way univariate analysis of variance, and separation of treatment means at 0.05% was done using Duncan's Multiple Range Test (DMRT). Pearson correlation statistical analysis was used to compare the number of fruits produced in the 2020 and 2021 cropping seasons.

3. Results

3.1 Experiment 1: 2020 Cropping Season

3.1.1 Effect of Rock Phosphate and Urea on Cucumber Vine Length

Table 2 shows the effect of rock phosphate and urea on cucumber vine length and the number of leaves. The High N and Low N + Low P treatments significantly gave the tallest vines than other treatments, although Low N, Low P, and High N + High P significantly produced the same height as High N and Low N + Low P treatments while control gave the least vine at 41 days after sowing (DAS). The Low N + Low P treatment gave the tallest vine height than other treatments although High N, High P, and High N + High P treatments significantly gave the same vine height as Low N + Low P treated pot whereas control gave the shortest vine height than other treatments at 82 DAS. The High P treatment gave the taller vines length than other treatments at 122 DAS.

Table 2. Effect of rock phosphate and urea fertilizer on cucumber height and number of leaves over time grown in greenhouse

Treatments	Days After Sowing (DAS)			Days After Sowing (DAS)		
	Cucumber Height (cm)			Number of Leaves		
	41	82	122	41	82	122
Control	23.00c	51.00c	50.80b	4.33d	6.67c	6.33b
Low N	103.30ab	149.33bc	115.00b	15.7bc	20.00abc	23.33a
High N	132.70a	259.67ab	154.81b	19.33b	28.00ab	16.00ab
Low P	93.10ab	141.67bc	132.10b	30.7a	17.67abc	12.00ab
High P	85.70b	175.00abc	526.67a	21.7b	8.33abc	8.33b
Low N + Low P	130.40a	353.33a	152.41b	15.7bc	29.67a	13.00ab
High N + High P	106.70ab	266.67ab	91.43b	9.7cd	15.33bc	4.33b
S.E.	18.95	79.52	69.92	4.18	5.71	4.91

3.1.2 Influence of Rock Phosphate and Urea on Cucumber Number of Leaves

The Low P treatment significantly produced the highest number of leaves than other treated pots while control and High N + High P treatments produced the least number of leaves at 41 DAS. The Low N + Low P treatment produced the highest number of leaves than all the treated pots but was not significantly different from Low N, High N, Low P, and High P treatments whereas control gave the least number of leaves at 82 DAS. Low N treated pot produced a greater number of leaves than control, High P and High N + High P treatments at 122 DAS.

3.1.3 Effect of Rock Phosphate and Urea on the Number and Weight of Cucumber

Table 3 shows that High N, Low N, and Low N + Low P treatments jointly produced the highest number of cucumbers on the vines than other treated pots at 82 DAS, whereas no significant effort was made by the treatments to support cucumbers at harvest. However, at 122 DAS, cucumber weight was significantly influenced by High P and Low P treatments. These two treatments (High P and Low P) treatments gave more weight than other treatments including control.

Table 3. Influence of rock phosphate and urea fertilizer on number of cucumbers on the vines, number of cucumbers at harvest and weight at harvest over time grown in the greenhouse

Treatments	Days After Sowing (DAS)						
	Number of cucumber			No of cucumber at harvest		Weight of cucumber (g)	
	41	82	122	82	122	82	122
Control	0.33	0.00b	0.67	0.00	0.00	0.00	0.00b
Low N	0.33	1.33ab	1.00	0.33	0.33	14.33	16.28b
High N	0.33	2.67a	1.00	0.67	0.00	120.8	0.00b
Low P	0.67	0.67b	1.67	0.00	0.67	0.00	55.76ab
High P	0.00	0.00b	1.00	0.00	0.67	0.00	121.59a
Low N + Low P	0.00	1.00ab	1.67	0.00	0.00	0.00	0.00b
High N + High P	0.00	0.33b	0.67	0.33	0.00	86.67	0.00b
S.E.	0.47	0.78	0.99	0.31	0.31	56.99	37.13

3.1.4 Effect of Rock Phosphate and Urea on Cucumber Length and Diameter

Table 4 reveals the effect of rock phosphate and urea on the length and diameter of cucumber. The High P, Low P, and Low N treatments gave a longer length of cucumber than other treated pots at 122 DAS. The treatments applied could not be able to support cucumber diameter.

Table 4. Effect of rock phosphate and urea fertilizer on cucumber length and diameter over time planted in the greenhouse

Treatments	Days After Sowing (DAS)			
	Length (cm)		Diameter (cm)	
	82	122	82	122
Control	0.00	0.00b	0.00	0.00
Low N	2.67	0.23ab	3.83	0.40
High N	1.2	0.00b	0.93	0.00
Low P	0.00	0.83ab	0.00	0.70
High P	0.00	1.00a	0.00	0.90
Low N + Low P	0.00	0.00b	0.00	0.00
High N + High P	6.33	0.00b	5.33	0.00
S.E.	3.69	0.38	3.52	0.38

3.2 Experiment 2: 2021 Cropping Season

3.2.1 Influence of Rock Phosphate, Biochar, and Urea on Cucumber Vine Length

Table 6 reveals that Low N + LC and High N + P treatments had the highest cucumber vine length while the control had the least at 21 days after sowing (DAS). It was observed that all the treatments had a longer vine length than the Low N + P + HC treatment while the control had the least at 40 DAS. The treatments applied supported vine length of cucumber, Low N + LC, and High P treatments significantly produced the highest vine length than other treated pots while control gave least vine length at 67 DAS. The same trends were observed at 82 DAS. All the treatments supported cucumber vine length except control and High P treatment at 96 DAS.

Table 6. Effect of urea, rock phosphate and biochar on Cucumber plant height over time grown in greenhouse

Treatment	2021 Cropping Season				
	Cucumber Plant Height (cm)				
	Days After Sowing (DAS)				
	21	40	67	82	96
Control	12.10d	26.30c	48.70c	51.30c	38.00c
Low N + LC	83.00a	161.00a	192.50b	198.30b	208.00ab
High N	67.20b	196.30a	198.70ab	254.30a	243.30ab
Low P + MC	57.40b	157.30a	243.30a	256.70a	259.30a
High P	38.90c	154.30a	181.70b	189.70b	187.00c
Low N + P + HC	58.40b	98.30b	198.70ab	212.00ab	218.30ab
High N+ P	79.2a	187.00a	226.70ab	253.30a	251.00a
S.E.	9.07	21.07	23.30	22.50	26.40

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.2.2 Effect of Rock Phosphate, Biochar, and Urea on the Number of Leaves

Table 7 shows that Low N + LC treatment produced the highest number of leaves than the High N treatment and other treatments while control produced the least number of leaves at 21 DAS. The Low N + LC and High N treatments jointly produced more leaves than other treatments whereas control produced the least number of leaves at 40 DAS. The High N+ P, High P, and Low N + LC treatments produced more leaves than other treatments including control at 67 DAS. The High N, High P, and High N+ P treatments outclassed other treatments while control produced the least number of leaves at 82 DAS. All the treatments favored leaves production except Low N + LC, High N treatments, and control at 96 DAS.

Table 7. Effect of urea, rock phosphate, and biochar on the Number of leaves over time grown in the greenhouse

Treatment	2021 Cropping Season				
	Cucumber Number of Leaves				
	Days After Sowing (DAS)				
	21	40	67	82	96
Control	4.30d	6.70c	13.70b	14.70d	5.70b
Low N + LC	16.00a	22.70a	26.30ab	26.30c	13.30ab
High N	12.30b	21.70a	24.70b	40.70a	12.30ab
Low P + MC	9.00c	15.00b	26.00b	29.00bc	14.00a
High P	8.00c	15.00b	32.00a	30.00ab	14.30a
Low N + P + HC	7.30c	13.70b	20.30b	25.30c	14.70a
High N+ P	8.70c	13.00b	31.70a	38.30ab	16.70a
S.E.	1.20	1.90	5.70	4.90	3.50

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.2.3 Effect of Rock Phosphate, Biochar, and Urea on the Number of Flowers and Fruits

Table 8 shows that Low N + LC treatment produced the highest number of flowers than the High N treatment and other treatments while control and High P treatments jointly produced the least number of flowers at 40 DAS. All the treatments produced more flowers than the control at 67 DAS. The same trends were observed at 82 DAS. All treatments were significantly the same on 96 DAS. The Low N + LC treatment produced more fruits than other treatments including control whereas control and Low N + P + HC treatments were the same at

40 DAS. All the treatments had the same number of fruits except control, High P, and Low N + P + HC treatments at 67 DAS. However, at 82 DAS, all the treatments had the same number of fruits. The Low P + MC, High P, and High N+ P treatments produced more fruits than the control, High N and Low N + P + HC treatments, whereas Low N + LC treatment and control were significantly the same at 96 DAS.

Table 8. Influence of urea, rock phosphate and biochar on Cucumber number of flowers and number of fruits over time grown in the greenhouse

Treatment	2021 Cropping Season							
	Cucumber Number of Flowers				Number of Fruits			
	Days After Sowing (DAS)				Days After Sowing (DAS)			
	40	67	82	96	40	67	82	96
Control	3.00d	4.70b	3.30b	0.00a	0.33b	0.00b	3.00a	0.00c
Low N + LC	30.70a	32.70a	21.30a	3.30a	3.30a	4.00a	9.70a	0.67bc
High N	16.70b	29.70a	19.30ab	3.30a	0.67b	3.30a	2.70a	0.00c
Low P + MC	7.00c	24.00ab	18.70ab	2.30a	0.33b	4.00a	4.30a	2.00a
High P	1.00d	19.00ab	15.00ab	5.70a	0.00b	2.70ab	1.70a	1.33ab
Low N + P + HC	9.30c	22.30ab	22.30a	4.00a	2.00ab	2.30ab	4.30a	0.33c
High N+ P	9.00c	26.70ab	23.30a	5.30a	0.67b	5.30a	5.70a	1.33ab
S.E.	1.90	9.90	7.20	2.40	1.14	1.30	3.70	0.36

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.2.4 Effect of Rock Phosphate, Biochar, and Urea on Residual NPK Nutrients Level

Figure 1 shows residual levels of nitrogen, phosphorus, and potassium (NPK) nutrients in the soil after harvest at 96 DAS. The high residual potassium nutrient was found in the soil after harvest followed by phosphorus. Nitrogen nutrient was used in all the treatments. The High P treated pot had the highest K nutrient residual level, Low P + MC treated pot had the highest P nutrient residual level, and Low P + MC together with Low N + P + HC had the highest N nutrient residual level after harvest.

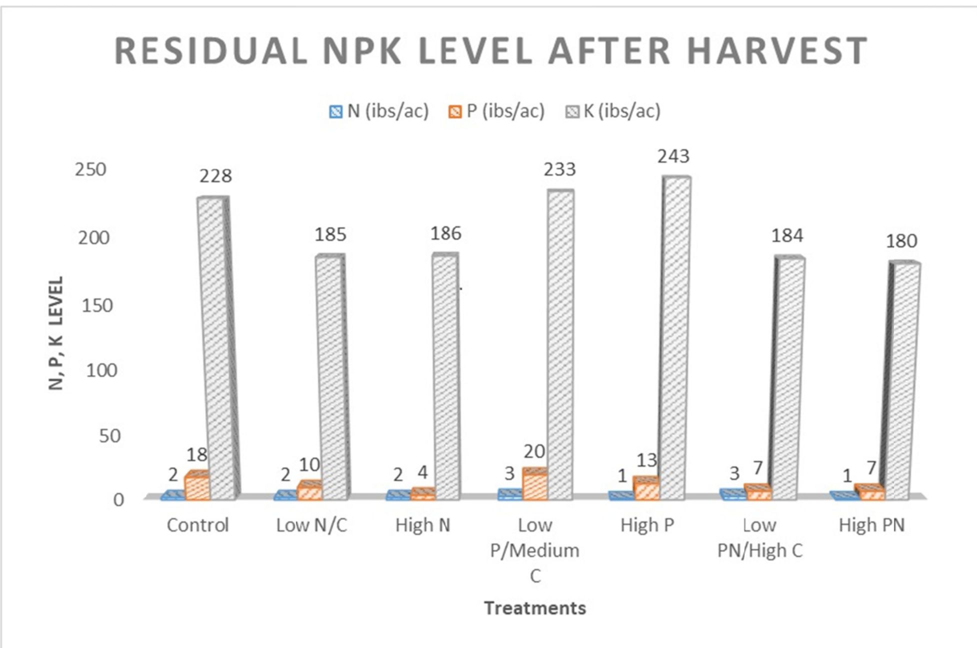

Figure 1. Residual nitrogen, phosphorus, potassium level in the soil after harvest in the 2021 cropping season

3.2.5 Relationship Between Nutrients Application on Cucumber Production in 2020 and 2021

Table 9 shows that there was no significant correlation between the number of fruits produced in the 2020 cropping season and the 2021 cropping season.

Table 9. Comparison of treatments applied in 2020 and 2021 cropping seasons on number of fruits produced

2020 and 2021 Crop Number at harvest			
Treatment	2020	Treatment	2021
Control	0.00	Control	0.00
Low N	0.33	Low N + LC	0.67
High N	0.00	High N	0.00
Low P	0.67	Low P + MC	2.00
High P	0.67	High P	1.33
Low N × Low P	0.00	Low N + P + HC	0.33
High N × Low P	0.00	High N + P	1.33
Mean	0.239	Mean	0.80
r	0.753		

4. Discussion

This current greenhouse experiment used rock phosphate and biochar soil amendments, as well as urea fertilizer to influence the growth and yield of the cucumber crop. It was noticed that low application of rock phosphate and urea gave the tallest vine length, but the growth declined at 122 Days after sowing (DAS) while high application of rock phosphate treated pots took over low treatments application in 2020 growing season whereas in 2021 growing season, use of low urea applied with low application of biochar influenced vine length at 21 DAS and 40 DAS, thereafter, low application of rock phosphate and medium application of biochar enhanced vine length growth. Mendes (2014) reported that the addition of biochar to rock phosphate caused a significant increase in the concentration of solubilized P in the medium. Furthermore, Blackwell et al. (2010) discovered that a low application at 1 t ha^{-1} of biochar increased the yield of wheat plants, whereas our result indicated that low application of biochar at 25 kg ha^{-1} (0.025 t ha^{-1}) supported the growth of cucumber. Lehmann et al. (2003); Chan et al. (2007); Asai et al. (2009); Van Zwieten et al. (2010); Schulz and Glaser (2012); Alburquerque et al. (2013) reported that biochar application to soil-grown with wheat grain influenced the availability of mineral nutrient fertilizer, the same result was obtained for cucumber crops.

Low P and Low N × P and Low N treated pots influenced leaves production throughout the experimental period in 2020. In the same trend in the 2021 cropping season, low application of urea fertilizer, lower than that of 2020 urea level application with low application of biochar sustainable increased leaves production except at 82 DAS, where High N fertilizer application increased leaves production. This means that the application of urea, low rock phosphate, and biochar increased leaves production rather than practicing the unsustainable application of huge fertilizers to the soil. Moreover, Lebrun et al. (2021) stated that the application of excessive biochar at a higher dose of more than 3% has a negative effect on the growth of Linum usitatissium growth. However, Alburquerque et al. (2014) stated that the two biochars used had the highest P concentration that enhanced Sunflower growth.

Application of low urea and low rock phosphate jointly produced a huge number of cucumber while low and high rock phosphate supported the weight and length of fruit in 2020 whereas, in the 2021 cropping season, low urea (25 kg ha^{-1}), rock phosphate (25 kg ha^{-1}) and biochar (25 kg ha^{-1}) applications consistently gave a huge number of flower production and the number of cucumbers. This signifies that sustainable cucumber production at the minimal application of fertilizer such as biochar and rock phosphate favored cucumber growth and yield instead of adding a higher application rate in the 2020 cropping season. Baronti et al. (2010) confirmed that the application of biochar at 60 tons ha^{-1} increase the yield of ryegrass in the greenhouse experiment whereas our current study revealed that the application of 25 kg ha^{-1} favored the growth and yield of cucumber.

Soil samples were taken after harvest to estimate the number of nutrients left in the soil, low P at 25 kg/ha and medium biochar at 50 kg/ha treated soils got the highest residual P although the treatments were not adequate level recommended in the soil according to Alberta agriculture, food and rural development (2005), whereas K level in the soil was the highest in the soil treated with High P (50 kg/ha). There was inherent ppotassium in the soil according to soil test results before the experiment (Table 1).

The treatments added to soils in the 2020 cropping season were compared to that of the 2021 cropping season. It was observed that biochar added to the soil in 2021 influenced cucumber growth and yield. The combination of phosphorus and nitrogen fertilizer with biochar overrides the application of rock phosphate and urea applied in the 2020 cropping season. This signifies that the application of biochar influenced nutrients (N and P) availability for effective growth and yield of cucumber. Chen et al. (2007) and Sohi et al. (2010) reported that biochar application influenced nutrient availability from mineral nutrients. Furthermore, Lehmann et al. (2003); Mizuta et al. (2004); Atkinson et al. (2010); Taghizadeh-Toosi et al. (2012) confirmed that biochar influenced ammonium and nitrate availability in the soil by preventing ammonium and nitrate losses by leaching.

5. Conclusion

Sustainable crop production using biochar and rock phosphate organic amendments, as well as urea, supported the growth and yield of cucumber. Our results showed that the application of rock phosphate, and urea with biochar at a low rate of 25 kg ha^{-1} for biochar, 30 kg ha^{-1} for urea, and 25 kg ha^{-1} for rock phosphate favored cucumber growth and yield instead of the application of high fertilizer rate of 60 and 90 kg ha^{-1} of urea and 50 and 100 kg ha^{-1} of rock phosphate without biochar application. Biochar applied with rock phosphate and urea in the 2021 growing season favored the growth and yield of cucumber. This experiment will be repeated for different crops to ascertain the potential of biochar in crop production.

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