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Effects of Rock Phosphate, Triple Super Phosphate and Biochar on Strawberry Monoculture, Strawberry-Cucumber and Strawberry-Tomato Intercrops in Two Southern-Alberta Greenhouse Soils

Adebusoye Onanuga

Niitsitapi Agriculture and Environmental Science Programs, Red Crow Community College, Standoff, Alberta, Canada
Email: adebusoye.onanuga@mikaisto.com

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Abstract

Intercropping increases food production and reduces the risk of crop failure. However, using combination of rock phosphate and biochar in greenhouse intercrop is limitedly adopted by the growers. Two years trials were conducted in the greenhouse. In 2022 trial, varying levels of rock phosphate and biochar soil amendment were applied to the two soil types in southern Alberta grown with two varieties of strawberry in each of the soil types. In 2023 trial, the same treatments were applied with higher rates than that of 2022 trial, grown with strawberry-cucumber intercropped in standoff soil while strawberry was intercropped with tomato crop in St Mary soil. The 2022 results showed that high rock phosphate fertilizer application at a rate of 250 Kg ha^{-1} supported strawberry biomass production while low rock phosphate at a rate of 100 Kg ha^{-1} supported fruit production. In 2023 trial, the application of low rock phosphate and high rock phosphate at a rate of 120 and 500 Kg ha^{-1}, respectively with medium application of biochar at a rate of 1 ton ha^{-1} positively influenced the number of fruit and biomass production. There was an interspecific competition between strawberry and tomato intercropped in the same pot. Tomato crops performed better than strawberry in the intercrop, combination of tomato and strawberry is not suited for intercropping. This study reveals the potential of rock phosphate over triple super phosphate in greenhouse fruit crop production, as well as to adopt good cropping system in greenhouse crop production.

Keywords

Rock Phosphate, Biochar, Triple Super Phosphate, Strawberry, Cucumber,

Tomato, Intercrop

1. Introduction

Sustainable cropping system and soil nutrients management would support food security in our community. The cultivation of fruits and vegetables in the greenhouse with judicious use of soil nutrients techniques can sustain an increase in greenhouse horticultural crop production. Cropping systems and nutrient management are the main techniques to alleviate world hunger to secure food for the increase in world population [1]. According to Food and Agriculture organization of the united nations defined food security as when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [2]. Food can be made more accessible by cultivating different crops at a time, as well as managing soil fertility [3]. Intercropping two or more crops is a good cropping system for sufficient crop production, as well as maintaining soil fertility [3] [4], [5]-[7]. Intercropping prevents the risk of total crop failure [3] [8] [9]. However, yield advantage and nutrient acquisition are established in crops, whereby competition is set up between one crop to another crop in the intercrop [2] [5] [10]. Rock phosphate is a natural input mined from igneous or sedimentary rock as P fertilizer that influenced high availability of P in the soil [11]. Rock Phosphate is released slowly and readily available for plant use and nutrient use efficiency unlike chemical P fertilizer that appears fixed in the soil, not available for the plant uptake [12] [13]. Biochar is the pyrolysis of wood and other waste materials from plants and animals at a high temperature of more than 400 degrees Celsius with or without oxygen. The wood ash from combustion is a good source of organic soil amendment. Biochar holds nutrients, moisture, and beneficial microbes in the soil for plant growth, development, and yield [14]-[19]. Biochar along with rock phosphate increases soil fertility and plant nutrition. Application of biochar with rock phosphate increases soil fertility, whereby biochar supported the release of P to the soil for nutrient uptake by the crops [20] [21]. Researchers have confirmed the effectiveness of biochar for P uptake by crops [19] [20]-[22]. These agricultural inputs are cheaper and readily available to the producers. However, to date, the using rock phosphate and biochar as nutrients to support horticultural crop growth and yield in the greenhouse are limited in southern Alberta among the indigenous and nonindigenous greenhouse fruits and vegetable producers. Furthermore, the practice of intercropping fruit crops to increase horticultural crops in the greenhouse in southern Alberta is limited. The main objective of this research was to investigate the yield of strawberry, strawberry-cucumber, strawberry-cherry tomato intercropped treated to phosphorus sources and biochar soil amendment grown on two soils in the greenhouse. We hypothesized that the application of rock phosphate fertilizer and biochar soil amendment to the soils influenced more yield of fruit crops in the intercrop than application of triple super phosphate fertilizer.

2. Materials and Methods

2.1. Greenhouse Environmental Description

The experiment was conducted in Red Crow Community College Greenhouse. Red Crow Community College is in Standoff, Alberta, Canada. Standoff is a first nations Kainai Blood Tribe (KBT) reserve community. It is located on latitude 49˚ North and longitude 113˚ West. Its location is on Hwy 2, 43 km Southwest of Lethbridge. Standoff and St Mary's soils are Brown Chernozemic soil 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˚C while maximum was 32˚C and relative humidity minimum was 35%, while the maximum was 65%. The greenhouse sprinkler irrigation system ran three times daily at 6 a.m., 12 noon and 6 p.m.

2.2. Physico-Chemical Properties of the Two Experimental Soils and Rock Phosphate

Soil samples at 0 - 15 cm were taken for physico-chemical analysis (**Table 1**). Nitrate-Nitrogen was extracted in the soil using 0.01 M calcium chloride, and a colourimeter detected N. The phosphorus was extracted using modified Kelowna, read by auto flow colourimeter, while potassium was extracted from the soil using 1 N neutral ammonium acetate. Micronutrients were extracted from the soil using diethylenetriaminepentaacetic acid (DTPA) and measured by atomic absorption spectrophotometry (AAS). The greenhouse experiment was performed on two (2) soil types or locations to evaluate the suitability of the soils to support growth and yield of the test crops in this experiment. Soil1 location (Standoff soil) was taken to greenhouse, as well as soil 2 location (St. Mary's soils). The composite samples were taken for each soil for physico-chemical and biological properties before planting. **Table 1** shows the physico-chemical analysis of the soils used in this experiment. The major essential nutrients: nitrogen (N) in soil 1 (Standoff soil) was higher than soil 2 (St Mary's soil), and phosphorus (P) and potassium (K) in soil 2 was higher than soil 1. Moreover, secondary nutrients and micronutrients levels vary in both soils (**Table 1**). The soil pH was 7.5 and 7.1 in soil 1 and 2 locations, respectively (1:1 soil: water). Soil texture was done using Sodium Hexametaphosphate, measured by hydrometer. The soil texture was silty clay loam in soil 1 and loam in the soil 2. **Table 1** also shows the physico-chemical properties of the rock phosphate, the extraction methods, measurement and determination of the nutrients content was done according to standard laboratory procedure similar to the nutrient determination used in pre soil chemical analysis. The nutrients content of P (623.2 $Kgha^{-1}$), K (7257.5 $Kgha^{-1}$), S (280.0 $Kgha^{-1}$), Ca (2781 $mgkg^{-1}$), Mg (380 $mgkg^{-1}$), micronutrients, organic matter (7.1%) and pH (6.2) in the rock phosphate fertilizer could able to support gradual release of the nutrients to soil for plant use.

Table 1. Physico-chemical properties of the experimental soils.

Soil Properties	Standoff soil	St Mary soil	RP
Available NO_3 N (Kg ha^{-1})	14.60	7.90	-
Available P_2O_5 P (Kg ha^{-1})	32.50	170.4	623.2
Available K_2O K (Kg ha^{-1})	1174.70	4684.0	7257.5
S (Kg ha^{-1})	7.9	30.3	280.0
Ca (mgkg^{-1})	4968.0	4792.0	2781.0
Mg (mgkg^{-1})	760.0	930.0	380.0
Zn (mgkg^{-1})	0.5	11.5	66.0
B (mgkg^{-1})	0.7	3.2	1.5
Cu (mgkg^{-1})	1.9	1.2	6.4
Fe (mgkg^{-1})	21.1	50.5	45.6
Mn (mgkg^{-1})	14.5	88.9	32.8
Na (mgkg^{-1})	40.9	21.1	842.3
OM (%)	3.9	17.2	7.1
Soil pH	7.5	7.1	6.2
Soil Texture	Silty Clay Loam	Loam	Pellet

RP—Rock phosphate.

2.3. Biochar Properties

Table 2. Chemical Properties of the Biochar.

Soil properties	Biochar	
	2022	2023
Total nitrogen N (Kg ha^{-1})	150	670
Total phosphorus P (Kg ha^{-1})	650	1.0
Total potassium K (Kg ha^{-1})	2700	4.0
Total Carbon (%)	86.8	81.8
Zn (mg kg^{-1})	32.6	44.8
Co (mg kg^{1})	0.73	0.74
Cu (mg kg^{1})	5.29	10.2
Ni (mg kg^{1})	2.98	3.67
Mo (mg kg^{1})	0.33	0.69
Hg (mg kg^{1})	<0.005	<0.04
Pb (mg kg^{1})	2.06	0.96
U (mg kg^{1})	0.11	0.061
Moisture (%)	11	30 - 55
Ash (%)	2.73	2.96
Bulk Density (kg m^{-3})	213	216.4
Conductivity (1:9)	0.64	10.60 (1:2)
pH	9.39	10.1
Texture	Coarse	Soft

Two types of biochars were used for these trials (Table 2). The 2022 Biochar was composed of 100% wood, pyrolyzed 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. The Total N, Total P, and K were 150, 650, and 2700 Kg ha^{-1}, respectively. The Total Carbon was 86.8% by combustion method. The 2023 biochar used was processed in the same method as 2022 biochar, but with different properties, Total N, Total P, and K were 670, 1.0, and 4.0 Kg ha^{-1}, respectively. The biochar pH, moisture and total dry ash were 10.1, 30% - 35% and 2.96%, respectively (Table 2). The 2022 biochar was manufactured by a company in Calgary, Alberta, Canada while 2023 biochar used was manufactured by a company in Vancouver, British Columbia, Canada.

2.4. Greenhouse Cropping System Experiment

2.4.1. 2022 Greenhouse Monoculture Cropping System Experiment

Thirty-nine greenhouse pots were filled with 3 kg soil for each of the soil location (Standoff and St Mary). The soils were treated to the low level of rock phosphate at a rate of 100 kg ha^{-1}, high rock phosphate at a rate of 250 kg ha^{-1}, and application of superphosphate (RP) at a rate of 60 Kg ha^{-1} (reference P fertilizer), low level of biochar was applied at a rate of 50 Kg ha^{-1}, medium level of biochar was applied at a rate of 100 Kg ha^{-1}, high level of biochar application was applied at a rate of 250 Kg ha^{-1} and control received no rock phosphate and biochar applications. Rock phosphate is a commercially produced fertilizer free from Uranium produced by Nutrien Inc Canada. The basal application of nitrogen in form of urea was applied in splint application at 140 kg ha^{-1} (140 Kg ha^{-1} each application) to the entire experimental pots. The first and second fertilizer applications were done on June 22, 2022, and July 19, 2022, respectively (Table 3). The two strawberry seedlings varieties were planted as a test crop for the greenhouse experiment. Kent strawberry variety was planted on soil 1 location (Standoff) while Albion ever bearing strawberry variety was planted on soil 2 location (St Mary's soil).

2.4.2. 2023 Greenhouse Intercropping System Experiment

In 2023 trial, the 3 kg potted soils received low level of rock phosphate application at a rate of 120 Kg P ha^{-1}, high rock phosphate at a rate of 500 kg P ha^{-1}, Reference triple superphosphate applied at a rate of 120 Kg P ha^{-1}, low level of biochar applied at a rate of 500 Kg ha^{-1}, medium level of biochar was applied at a rate of 1000 Kg ha^{-1}, and high level of biochar was applied at a rate of 5000 Kg ha^{-1} The basal application of nitrogen in form of urea was applied across the pots at a rate of 280 kg N ha^{-1} Kent Strawberry and cucumber were transplanted on May 29, 2023 into the Standoff soil (Soil 1). Tomato seeds were planted in the nursery on May 8, 2023, and transplanted on May 29, 2023, to St Mary's soil (Soil 2). Kent strawberry variety was planted to the two soils while cucumber variety was intercropped with strawberry in the standoff soil and tomato was intercropped with strawberry in St Mary Soil (soil 2).

The agronomical parameters collected were the number of fruits measured by counting, and the biomass weight measured by the electrical sensitive scale (Sartorius Lab. Instruments, GMBH & Co, Germany-ENTRIS 2202-1SUS). These parameters were taken fortnightly. The experimental pots were replicated three times treated with Low P, High P, Reference SP, Low biochar, Medium biochar, High biochar, and their combinations by joint application of Low P + Low biochar, Low P + Medium biochar, Low P + High biochar, High P + Low biochar, High P + Medium biochar, High P + High biochar and control no fertilizer application applied to one soil location resulting into 13 × 3 × 1 = 39 pots for each soil in the greenhouse experiment (Table 3).

Table 3. Experimental Design.

Treatment	2022 Timing/Splint Application	2023 Single Application	2022 Rate, kg/ha †	2023 Rate, kg/ha †
Low-rate P	June, at Planting/July	May at planting	100	120
High-rate P,	June, at Planting/July	May at planting	250	500
Reference Triple Super Phosphate,	June, at Planting/July	May at planting	60	120
Low Biochar	June, at Planting/July	May at planting	50	500
Medium Biochar	June, at Planting/July	May at planting	100	1000
High Biochar	June, at Planting/July	May at planting	250	5000
Low P + Low biochar	June, at Planting/July	May at planting	100 + 50	120 + 500
Low P + medium biochar	June, at Planting/July	May at planting	100+ 100	120 + 1000
Low P + High biochar	June, at Planting/July	May at planting	100 + 250	120 + 5000
High P + Low biochar	June, at Planting/July	May at planting	250 + 50	500 + 500
High P + medium biochar	June, at Planting/July	May at planting	250 + 100	500 + 1000
High P + High biochar	May, at Planting	May at planting	250 + 250	500 + 5000

† for urea, the rate refers to kg N ha^{-1}, but for biochar the rate refers to kg dry matter ha^{-1}.

2.5. Characteristics of Two Varieties of Strawberry, Cherry Tomato, and Cucumber

Kent variety is a fast-growing early bearing strawberry. This is a June bearing (Short Day) strawberry, that grows well on the prairies and produces high yields of bright red fruit that bursts with flavor. Great for eating fresh or trying them in your next batch of jam or baking. Albion Ever-bearing seedling is a late bearing strawberry. It is a day-neutral plant. It produces the first crop in spring and another one in late summer or fall. The red berries are large, luscious, and very sweet with excellent flavor. Sweet million cherry tomato variety is commonly grown in southern Alberta. It is easy to grow, and it is adapted to different climatic conditions. It grows vigorously and it needs support for climbing. It is indeterminate and matures 60 - 65 days. Patio snacker cucumber produced little compact with regular size cucumber. It grows vigorously with the trellis. It is a parthenocarpy variety and matures 50 - 55 days.

The rationale behind intercropping strawberry with cherry tomato and cucumber was to increase food production, having more crops in the intercrop would able to secure food for the growing population, as well as testing the capacity of ecological soils to support intercrop.

2.6. Statistical Analysis

The agronomical parameters measured were subjected to one way analysis of variance (ANOVA) using IBM SPSS version 27 software. The one-way analysis of variance was used for this experiment design because one fixed factor (fertilizer treatments) was used to measure effect of the fertilizer treatments on yield parameters. The experimental units were arranged in a completely randomized design in the greenhouse. The Duncan Multiple Range Test was used for separation of treatment means at 5%.

3. Results and Discussion

3.1. 2022 Greenhouse Strawberry Experiment

3.1.1. Effect of Rock Phosphate, Triple Super Phosphate, and Biochar on Albion Strawberry Variety Number of Fruits Grown on St. Mary Soil (Soil 2)

Table 4. Kent strawberry variety biomass and fruits production affected by rock phosphate, triple super phosphate, and biochar in Standoff Soil (Soil 1).

Treatments	*Biomass		Number of fruits (Soil 1)		
			Days After Transplanting		
	Fresh Weight (g)	Dry Weight (g)	94	100	110
Control	27.2^{cd}	19.4^{bcd}	0.0^{b}	0.0^{b}	0.0^{b}
Low P	58.5^{abcd}	25.2^{abcd}	3.0^{a}	3.0a	4.3a
High P	108.1^{a}	39.2^{a}	0.0^{b}	0.0^{b}	0.0^{b}
TSP	85.3^{ab}	32.1^{abc}	0.0^{b}	0.0^{b}	0.0^{b}
Low B	38.8^{bcd}	15.3^{cd}	0.3^{b}	0.3^{b}	0.7^{b}
Medium B	85.8^{ab}	27.3^{abc}	0.0^{b}	0.0^{b}	0.7^{b}
High B	72.8^{abc}	25.8^{abc}	0.0^{b}	0.0^{b}	0.0^{b}
Low P + LB	10.5^{d}	6.6^{d}	0.0^{b}	0.0^{b}	0.0^{b}
Low P + MB	62.4^{abcd}	26.9^{abc}	0.0^{b}	0.0^{b}	0.0^{b}
Low P + HB	43.4^{bcd}	24.1^{abcd}	0.0^{b}	0.0^{b}	0.0^{b}
High P + LB	38.6^{bcd}	21.0^{abcd}	0.0^{b}	0.0^{b}	0.0^{b}
High P + MB	103.8^{a}	38.3^{ab}	0.0^{b}	0.0^{b}	0.0^{b}
High P + HB	103.9^{a}	39.8^{a}	0.0^{b}	0.0^{b}	0.0^{b}
SE	24.30	8.10	0.99	0.61	0.91

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error; NS: Not significant @5%. TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar. *Biomass taken at 110 Days After Harvest.

Table 4 shows that High P treatment, as well as High P + MB, and High P + HB treatments significantly got the highest fresh weight than the other treatments while Low P + LB treatment got the least fresh weight. Similarly, High P and High P + HB treatments had the highest dry biomass than the other treatments while Low P + LB had the least dry biomass weight. The harvested number of fruits from 94 to 110 days after transplanting consistently revealed that Low P treated pots had a greater number of Kent strawberry variety fruits than the other treated pots in soil 1 (Standoff soil). This shows that rock phosphate treated pot performed better than triple super phosphate. Rock phosphate fertilizer has been known to release P slowly into the soil for the plant use to increase crop yield unlike the chemical P (triple superphosphate) that fixed in the soil and not available for the plant use [12] [23] [24]. This present study also supports using biochar soil amendment at 0.1ton ha^{-1} and 0.5ton ha^{-1} with rock phosphate applied at 100 and 250 Kg ha^{-1} positively influenced Kent strawberry variety biomass yield. The application of Biochar with rock phosphate significantly increased strawberry crop yield because biochar enhanced the soil P availability and P uptake by the crops [20] [21].

3.1.2. Effect of Rock Phosphate, Triple Super Phosphate and Biochar Soil Amendment on Albion Strawberry Variety Fresh and Dry Weight Grown on St Mary's Soil (Soil 2)

Table 5. Albion Strawberry Variety biomass production as affected by rock phosphate, triple super phosphate, and biochar in St Mary Soil.

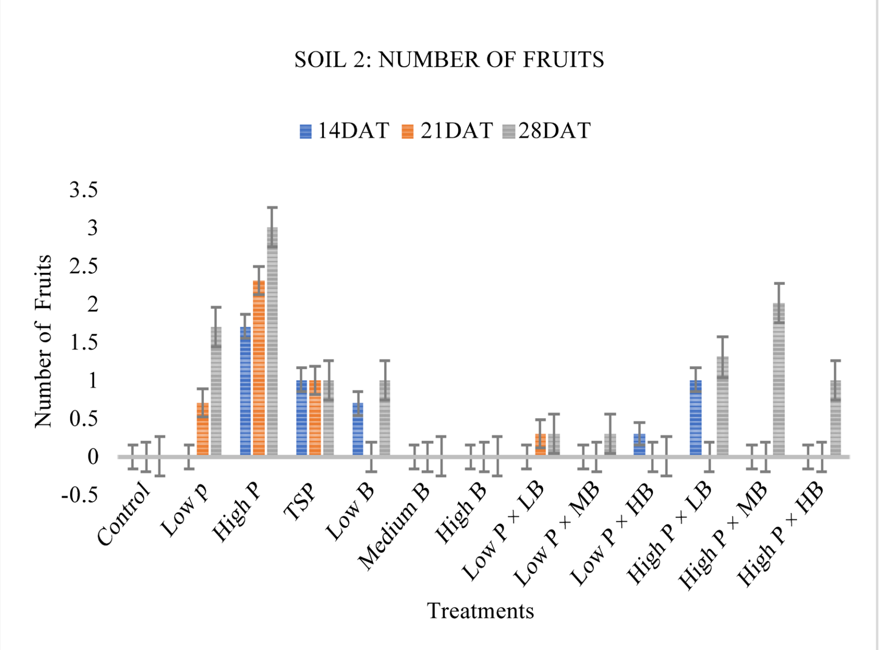
Treatments	*Biomass	
	Fresh Weight (g)	Dry Weight (g)
Control	20.6^{ab}	12.9^{ab}
Low P	49.7^{a}	24.1^{ab}
High P	37.4^{ab}	21.1^{ab}
TSP	38.3^{ab}	21.6^{ab}
Low B	39.1^{ab}	21.6^{ab}
Medium B	28.7^{ab}	19.0^{ab}
High B	14.3^{b}	7.7^{b}
Low P + LB	14.2^{b}	8.0^{b}
Low P + MB	28.6^{ab}	18.9^{ab}
Low P + HB	26.9^{ab}	14.4^{ab}
High P + LB	34.1^{ab}	16.0^{ab}
High P + MB	53.7^{a}	25.0^{a}
High P + HB	53.7^{a}	20.1^{ab}
SE	14.6	6.8

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error, TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar. *Biomass taken at 74 Days After Harvest.

Table 5 shows the effect of P-sources and biochar soil amendment on albion strawberry fresh and dry weight. There was no effect of rock phosphate, triple super phosphate, and biochar soil amendment to support fresh and dry weight of strawberry in St Mary's soil. The treated pots and untreated pots were not significantly different. This may be due to inherit P fertility status of the soil as reflected in the pre soil test carried out at the beginning of the trial (Table 1).

3.1.3. Effect of Rock Phosphate, Triple Super Phosphate, and Biochar on Albion Strawberry Number of Fruits Grown on St. Mary Soil (Soil 2)

Figure 1 shows the effect of rock phosphate, triple superphosphate, and biochar on Albion strawberry number of fruits. It was recorded from 14 to 28 days after transplanting (DAT) that high rock phosphate at a rate of 250 Kg ha^{-1} consistently favoured high number of albion strawberry fruit when compared to triple super phosphate at a rate of 60 Kg ha^{-1} including other treated pots and the control experiment. The higher application level of rock phosphate than triple super phosphate also positively influenced the yield of Albion strawberry. Furthermore, rock phosphate releases phosphorus into the soil gradually due to the organic nature of the fertilizer, unlike chemical fertilizer, triple super phosphate that could be fixed and not available for plant use [23]. It was observed that albion strawberry is a short season crop due to the genetic makeup of this strawberry variety. Albion strawberry variety is ideal for regions with short growing seasons, and this variety could be planted 2 or 3 times within a year.



TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar.

Figure 1. Effect of rock phosphate, triple super phosphate, and biochar on albion strawberry variety number of fruits.

3.2. 2023 Greenhouse Experiment

3.2.1. Effect of P Sources and Biochar on Patio Snacker Cucumber Number of Fruits, Biomass Fresh and Dry Weight Intercropped with Kent Strawberry Grown on Standoff Soil

Table 6. Effect of rock phosphate, triple super phosphate and biochar number of fruits, fresh and dry weight of patio snacker cucumber variety intercropped with Kent strawberry grown on Standoff soil (soil 1).

Treatments	Number of fruits			Biomass	
	Days After Transplanting			Fresh Weight (g)	Dry Weight (g)
	7	16	27	35	35
Control	2.0^{ab}	0.0^{b}	0.0	40.6^{c}	18.3^{c}
Low P	3.7^{a}	4.0^{a}	1.0	68.7^{bc}	23.8^{bc}
High P	2.7^{a}	3.0^{a}	1.0	87.7^{bc}	27.6^{abc}
TSP	0.0^{c}	0.0^{b}	0.0	41.7^{c}	17.3^{c}
Low B	0.0^{c}	1.0^{b}	0.3	89.9^{bc}	22.7^{bc}
Medium B	0.0^{c}	0.0^{b}	0.0	65.0^{bc}	19.7^{bc}
High B	0.0^{c}	0.0^{b}	0.3	59.5^{bc}	17.0^{c}
Low P + Low B	0.0^{c}	0.0^{b}	6.7	121.5^{b}	24.8^{bc}
Low P + Medium B	0.0^{c}	0.0^{b}	0.0	89.2^{bc}	23.1^{bc}
Low P + High B	0.0^{c}	0.0^{b}	0.3	96.0^{bc}	26.6^{abc}
High P + Low B	0.0^{c}	0.0^{b}	0.0	42.9^{c}	13.7^{c}
High P + Medium B	0.0^{c}	0.0^{b}	2.0	232.6^{a}	39.7^{a}
High P + High B	0.0^{c}	0.0^{b}	1.0	190.8^{a}	33.7^{ab}
SE	0.93	0.85	2.80 (NS)	31.10	6.20

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error, NS: Not significant @5%, TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar. *Biomass taken at 74 Days After Harvest.

Table 6 shows the effect of the P-sources and biochar on patio snacker cucumber variety number of fruits, fresh and dry weight biomass after harvest. It was observed that the number of fruits produced in the control experiment and treated pots (Low P and High P) were significantly the same at 7 days after transplanting. However, the effect of the treatments was noticed at 16 days after transplanting where High and Low P treatments had a higher number of fruits than the other treatments including control. There was no significant difference between the treated pots and control experiment because the treated pots and control experiment significantly had similar number of cucumber fruits at 27 days after transplanting. Table 6 also shows the effect of treatments on fresh and dry biomass weight after harvest. The High P + Medium B and High P + High B treatments jointly had the highest fresh and dry biomass weight at 35 days after transplanting than the other treated pots, whereas control, TSP, and High P + Low B gave the least fresh and dry biomass weight. Nevertheless, the 2022 and 2023 trials had similar results. The rock phosphate has the potential over the triple super phosphate to influence crop yield with the application of biochar that holds nutrients, and moisture in the soil for plant growth, development, and yield [14]-[19].

3.2.2. The Effect of P-Sources and Biochar on Kent Strawberry Number of Fruits Intercropped with Patio Snacker Cucumber in Standoff Soil

Table 7 shows P sources and biochar soil amendment on strawberry number of fruits overtime. It was observed that the high number of fruits were produced at 16 days after transplanting when Low P + Low B treatment gave the highest number of fruits than the other treated pots while control experiment produced the least fruits. We obtained similar results at 27 days after transplanting. There was no significant difference between the control experiment and treated pots at 35 days after transplanting. Furthermore, there was 100% fruit production when rock phosphate and biochar were applied together at the rate of 0.1 ton ha^{-1} and 100 Kg ha^{-1}, respectively when compared to control experiment with no application of fertilizer. This suggests high capacity of rock phosphate and biochar to increase soil fertility by synergistic relationship of biochar with rock phosphate to favour crop yield [20] [21].

Table 7. Effect of rock phosphate, triple super phosphate, and biochar on Kent strawberry variety number of fruits intercropped with patio snacker cucumber variety in Standoff Soil.

Treatments	Strawberry number of fruits			
	Days After Transplanting			
	7	16	27	35
Control	1.3	0.0^{b}	0.0^{b}	0.0
Low P	0.7	1.0^{ab}	0.0^{b}	0.0
High P	0.7	0.7^{ab}	0.0^{b}	0.00l
TSP	1.0	0.0^{b}	0.0^{b}	0.0
Low B	0.7	0.33^{b}	0.0^{b}	0.0
Medium B	1.7	0.0^{b}	0.3^{b}	0.0
High B	1.3	0.7^{ab}	0.3^{b}	0.3
Low P + Low B	0.7	1.7^{a}	4.3^{a}	1.0
Low P + Medium B	2.0	0.7^{ab}	0.3^{b}	0.0
Low P + High B	0.3	0.0^{b}	0.0^{b}	0.0
High P + Low B	0.0	0.0^{b}	0.0^{b}	0.0
High P + Medium B	0.3	1.0^{ab}	0.7^{b}	0.0
High P + High B	0.7	0.3^{b}	0.0^{b}	0.0
SE	1.20 (NS)	0.5	0.63	0.41 (NS)

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error, NS: Not significant @5%, TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar. *Biomass taken at 74 Days After Harvest.

3.2.3. Effect of P-Sources, and Biochar Treatments on Number of Sweet Million Cherry Tomato Fruits and Biomass Yield after Transplanting Intercropped with Kent Strawberry on St Mary's Soil (Soil 2)

Table 8 shows the effect of P-sources and biochar on tomato number of fruits. It was noticed at 66 days after transplanting that Low P + Medium B treatment jointly produced the high number of fruits when compared to other treatments including control. Furthermore, a similar trend was noticed at 89 days after transplanting, whereas at 113 Dyas after transplanting High B treatment produced the highest number of tomato fruits and fresh biomass yield than the other treatments including control experiment. Moreover, it was observed that high peak fruit production occurred at 113 days after transplanting, High B treatment got the highest number of tomato fruits than the other treated pots including control with no fertilizer. High biochar at 5 tons ha^{-1} gave 100% increased number of tomato fruits when compared to control experiment with no fertilizer application. These results supported assertion made by researchers that biochar increased nutrients availability within the root zone for plant uptake to influence crop yield [19] [20]-[22]. It also has a large surface area to absorb nutrients for gradual release for plant use to increase crop growth and yield [19].

Table 8. Effect of rock phosphate, triple super phosphate, and biochar on number of sweet million cherry tomato fruits and biomass intercropped with Kent strawberry grown on St Mary Soil.

Treatments	Number of tomato fruits				*Biomass @ 113 (DAT)	
	Days After Transplanting (DAT)				Fresh weight (g)	Dry weight (g)
	66	89	103	113		
Control	0.0^{b}	0.0^{c}	0.0	0.0^{d}	23.6^{b}	2.5
Low P	3.3^{b}	3.7^{bc}	0.7	1.7^{cd}	44.0^{ab}	6.0
High P	1.0^{b}	1.3^{bc}	1.7	8.0^{abc}	64.6^{ab}	7.3
TSP	4.7^{b}	6.0^{abc}	2.0	5.0^{abcd}	62.2^{ab}	8.1
Low B	1.7^{b}	0.0^{c}	0.0	6.3^{abcd}	65.4^{ab}	5.2
Medium B	0.0^{b}	0.3^{bc}	0.0	8.7^{ab}	41.0^{ab}	2.9
High B	7.0^{ab}	6.7^{ab}	2.0	9.3^{a}	98.8^{a}	10.9
Low P + Low B	1.0^{b}	3.3^{bc}	1.3	6.3^{abcd}	39.1^{ab}	3.8
Low P + Medium B	11.3^{a}	11.0^{a}	1.0	6.7^{abcd}	78.6ab	9.6
Low P + High B	1.3^{b}	1.3^{bc}	3.0	9.0^{ab}	52.2ab	6.5
High P + Low B	3.0^{b}	2.3^{bc}	0.7	1.3^{cd}	52.0ab	8.1
High P + Medium B	3.7^{b}	3.0^{bc}	2.3	4.0^{abcd}	48.2ab	5.3
High P + High B	2.3^{b}	0.0^{c}	2.7	2.3^{bcd}	55.7ab	5.4
SE	3.10	2.70	1.40 (NS)	2.90	31.00	4.50 (NS)

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error, NS: Not significant @5%, TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar. *Biomass taken at 113 Days After Harvest.

3.2.4. Effect of P-Sources and Biochar on Kent Strawberry Number of Fruits Intercropped with Sweet Cherry Tomato Grown on St. Mary Soil Overtime

Table 9 shows P-sources and Biochar on Kent strawberry number of fruits. There was no significant difference between the untreated pots and the treated pots throughout the experimental period. It was observed that there was a competition between tomato and strawberry crops in the intercrop. The tomato acquired more nutrient for growth and development more than strawberry in the intercrop. This suggests that agronomical practicing of intercropping tomato with strawberry is at high risk of low performance when tomato is intercropped with strawberry. The competition is set up between one crop to another crop in the intercrop [8] [10] [16].

Table 9. Effect of rock phosphate, triple super phosphate, and biochar on Kent strawberry number of fruits intercropped with sweet million cherry tomato grown on St Mary Soil.

Treatments	Number of fruits				
	Days After Transplanting				
	4	10	18	28	37
Control	0.0	1.3	3.0[a]	0.0	3.3[a]
Low P	0.3	0.3	1.0[b]	0.0	0.7[b]
High P	0.7	0.7	0.0[b]	0.0	0.0[b]
TSP	0.0	0.0	0.0[b]	0.0	0.3[b]
Low B	0.0	0.0	0.0[b]	0.0	0.0[b]
Medium B	0.0	0.0	0.3[b]	0.0	0.3[b]
High B	0.0	0.0	0.7[b]	0.0	0.7[b]
Low P + Low B	0.0	1.0	0.7[b]	0.3	4.3[a]
Low P + Medium B	0.0	0.3	0.3[b]	0.3	0.3[b]
Low P + High B	0.0	0.0	0.7[b]	0.0	0.3[b]
High P + Low B	0.3	1.0	0.0[b]	0.0	0.0[b]
High P + Medium B	0.0	0.0	1.0[b]	0.0	1.0[b]
High P + High B	0.0	0.3	0.3[b]	0.0	0.0[b]
SE	0.32 (NS)	0.70 (NS)	0.64	0.20 (NS)	0.74

Note. Means with different letters are significantly different according to Duncan's Multiple Range Test (DMRT) $p < 0.05$; SE: standard error, NS: Not significant @5%, TSP—Triple Super Phosphate, P—Phosphorus, B—Biochar, LB—Low biochar, MB—Medium biochar, HB—High biochar.

4. Conclusion

The present trial confirmed the potential and effectiveness of rock phosphate over triple superphosphate in greenhouse fruit crop production. Rock phosphate positively influenced strawberry fruit production. In 2022 trial, the application of rock phosphate at 100 and 250 Kg ha^{-1} and biochar applied at 0.1 and 0.5 ton ha^{-1} favoured strawberry monocropping. In 2023 trial with higher application of nutrients to the soils than that of 2022 trial, rock phosphate and biochar applied to the soils influenced more crops performance than triple super phosphate in strawberry-cucumber and strawberry-tomato intercropped. We also noticed that there was a competition when strawberry was intercropped with tomato. This cropping system should not be encouraged because of non-complementarity in the interaction between the two crops. We conclude that the single or combined application of rock phosphate fertilizer and biochar soil amendment to the soils influenced more yield of fruit crops than application of triple super phosphate fertilizer.

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Conflicts of Interest

The corresponding author states that there is no conflict of interest.

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