The Impact Of Biochar And Compost As A Soil Amendment On The Growth, Yield, And Chemical Composition Of Maize (Zea Mays): A Study On Two Different Land Uses

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ABSTRACT

Soil health is the production base, and management allows manufacturers to work with the land. Healthy soil provides a clean environment and nutritious crop. The performance of the crop on alkaline-saline soil is incomplete due to poor nutrient management. Biochar and compost initiated distinctive biomass to improve soil health. Equally; limited studies were conducted on the co-application of biochar and compost produced from the same field of alkaline. Therefore; a pot experiment of two different soils i.e. banana cultivated fields (BCF) and Coastal fallow land (CFL) was conducted to estimate the effect of co-application of biochar and compost on the soil properties, growth, and yield attributes of Maize. Completely Randomized Design (CRD) with a total of 24 pots, filled with 15kg of soil, with four different treatments including control (Co), 1% Compost (C), 1% Biochar (B), and 1% Biochar + Compost (B+C), within three times replicate. Generally; study findings showed that 1%B+C has a significant ($p<0.05$) effect on the growth and yield followed by 1%C, 1%B, and Co. In the comparison of the alone 1%B and 1%C, 1%C performs better and more significantly ($p<0.05$) different compared to 1%biochar and control. Similarly; the availability of NPK, SOM%, and CEC of both BCF and CFL increased within co-application of 1% B+C, compared to 1%C, and 1%B. While; the increased order of the co-application was recorded as 1%B+C >1%B > 1%C and Co. Consequently, co-application of 1%B+C with fertilizer could be a suitable management approach to increased crop yield and improve soil health of the alkaline calcareous soil.

Keywords: Biochar, Compost, growth, yield, and Maize.

INTRODUCTION

Co-application of Biochar and compost can potentially increase agricultural production by restoring degraded soils. As an organic amendment, biochar is advantageous to boost the soil's nutrients and enhance plant nutrient delivery (Jeffery et al., 2016; Choudhary et al., 2021). Reducing water runoff, biochar has demonstrated the ability to reduce runoff losses of nitrogen and phosphorus. Though; the addition of biochar enhances both soil health and crop productivity (Tomczyk et al., 2020). Low organic matter content, the availability of minerals, particularly micronutrients, and biological activity are the main obstacles that alkaline soils (Karimi et al., 2020; Liu et al., 2017). Some studies have documented the effect of biochar on soils' availability of macronutrients. Normally, the applications of biochar and compost for different purposes such as increased soil fertility, carbon sequestration, and climate change mitigation (Mclennon et al., 2020; Yu et al., 2019). Compost is prepared through humification and the microbiological process from agricultural waste foodstuffs such as garden grasses, tree leaves, vegetable trash, crop straws, and animal manures. Compost alters soil and then facilitates aerobic plant growth Ayilara et al. (2020). Composting soil improves crop development and yield by increasing soil porosity, nutrient and moisture ratio, and soil fertility condition. Biochar and compost enhance the quality of the soil. A refractory carbon, biochar has a direct impact on the soil's nitrogen cycle and lowers N effluxes. Nitrogen fixation, mineralization, and immobilization could be improved with applications of biochar (Liu et al., 2016). Application of biochar could increase crop output by 5-51% while lowering soil nitrous oxide (N_2O) emissions by 28-60%. Borchar et al. (2019).

Gupta et al. (2016) found a research study on compost made from the usages kitchen and cow dung has potentially increased the quantity of organic matter in the soil, while; also enhancing the availability of nitrogen, phosphorous, and potassium. Through; enhancing soil structure, compost reduces soil erosion, surface runoff, and crust formation, improving soil hydraulic properties, water retention, and soil porosity Mai et al. (2014). Usually, compost and biochar content mixture of soil minerals with less dense organic material results in positive effects. Moreover; fine-textured soils, are immediately visible after compost application (Izilan, 2022). The primary industry driving economic growth in developing nations is agriculture. Chemical fertilizers are becoming essential for agriculture, while; they are now quite expensive and occasionally unavailable in time. Integrated methods for enhancing soil fertility and crop yield have gained popularity in recent years (Das et al., 2020). Additionally, the use of organic (Biochar and Compost) and inorganic (NPK) fertilizers in combination has been investigated Islam et al. (2017). Heat stress and salinity are the major issues in the arid and semi-arid regions of Pakistan, and losses directly affect the production of the crop Ahmed et al. (2024). Climate change and poor land management pose a changeable threat, resulting in desertification and decreased output. Certain consequences of land loss are more radical in terms of manifestation. To boost soil productivity and sustainability, several methods and approaches have been used, with the application of compost and biochar being the most successful. The rate of decomposition of organic materials in the soil is high and considerably resistant**;** biochar and compost can last for a longer period in the soil. Conclusively, this present study helped improve the SOM, SOC, NPK nutrient availability, soil EC, and CEC. Due to high temperatures and low rainfall, the soil of Uthal, Balochistan, is deficient in organic matter. The improvement in organic matter will result in better soil health conditions. Better soil health will lead to better maize production, which is the main crop of Uthal, Balochistan.

MATERIAL AND METHODS

Outline of the study area: The current study was conducted in the Green-net house of the Faculty of Agriculture, Lasbela University of Agriculture Water and Marine Sciences (LUAWMS) Uthal. LUAWMS is situated 25^o, 50.34” N, 66^o, 37.41” E in district Lasbela, Uthal. Lasbela is symbolic of a tropical dry, and hot climate, summer is long February-August, with windstorms commonly occurring in May and September, with a cool winter with an average temperature between 20-25^{0}C in the month of December-Mid-February with an average of limited rainfall20 cm/annum, that increase the heat stress and drought Akbar et al. (2015).

Description of experimental study: For this research study purpose, a variety of plant leaves (forest tree), fruit waste, milk tea waste, and animal manure were collected around the Uthal, and collected material was transported to the University to prepare compost under the windrow composting system. Organic waste material was air-dried for one week to minimize and remove excess moisture. Likewise; the dried material was oven dry in a hot air oven for 48 hours at 65^{0}C and ground with an electric grinder into the finer particles. The ground material was transferred to a locally fabricated composter containing a drier, crusher, and processor for the composting process, the whole process was completed in 50 days**.**

Preparation of biochar: Initially Banana waste plant material was collected surrounding the Uthal and transported to the Lab Department of Soil Science, Faculty of Agriculture, LUAWMS, for further processing. The material was grounded to air-dry in the open air environment for a few days after the plant material was transferred into a hot air oven to oven-dried at a temperature of 65 ^{0}C for 24 hours and awaiting moisture remaining <12%, likewise; oven-dried banana plant material was crushed into the particle size of <5mm and stored in airtight bags. Finally, the material was placed into a muffle furnace followed by Sanchez et al. (2016), and a maximum 400 ^{0}C temperature was adjusted for 1 hour after the cooled muffle furnace prepared biochar was collected and sieved 2mm sieve Yang et al. (2019).

Description of pot experiment: For this research study; two different types of soil i.e. Banana cultivated field (BCF), and Coastal fallow Land (CFL), BCF was selected from the surrounding University from Uthal, and CFL was selected from Winder and accounted as a coastal region Ahmed et al. (2024). Randomly from three different locations at 0-20cm of soil depth soil samples were collected and transported to the laboratory dept. of Soil Science, Faculty of Agriculture, Lasbela, University of Agriculture, Water and Marine Sciences (LUAWMS). Soil samples were air-dried in the open-air environment, and all the plant material and stones manually were separated and sieved through a 2mm sieve. Pot experiment Completely Randomized Design (CRD) with a total of 24 well-labelled pots, filled with 15kg of soil with four different treatments including control (Co), 1% Compost (C), 1% Biochar (B), and 1% Biochar + Compost within three times of replicate. Manually 6 healthy seeds of Maize (*Zea Mays L*) were sown in each pot and thinned 1 plant after 10-12 days, and three plants from each pot/replication were recorded for growth and yield parameters. Timely all the agronomic observations were maintained, and timely irrigation was applied. Additionally; application of NPK 90-60-40 $kgha^{-1}$ was also applied to estimate the effect of both Biochar and compost under different applications. Nitrogen was applied in three split doses, whereas phosphorous and potassium were applied before sowing of seed according to the local practice.

Growth and yield attribute: Before harvesting the crop, three plants/pots were selected to estimate the agronomic observations such as plant height (cm), Number of leaves/plant, Leaf area (cm^2), and Cob Weight (g) and NKP concentration in plant.

Soil sample processing and analysis: A total of 48 soil samples before the application of both treatments and after harvesting of the crop. Collected soil samples were transported to the lab for further analysis of soil physico-chemical properties. Samples were air dried in an open-air environment, manually root material was separated, and finally sieved sample through a 2mm sieve. Besides; a 1:20 soil and water extract ratio was prepared to estimate the impact of different applications of both Biochar and compost on both types of soil properties such as pH, Electrical conductivity (dSm^{-1}) through digital pH meter and Electric conductivity meter, soil organic matter followed (Walkley & Black, 1934), Available phosphorous, Olsen (1954) Available potassium Estefan et al. (2013), Total nitrogen Black (1965), Cation exchange capacity and organic carbon (Jackson, 2005; Estefan et al., 2013).

Statistical Analysis

One-way analysis of variance (ANOVA) Gomes and Gomes, 1984. The differences among treatments mean will be calculated by the Least Significant Difference (LSD) test 5% probability level was used SPSS Version 20 (IBM.2016)

RESULTS

Soil characteristics of cultivated and coastal soil: Before and after the harvesting soil samples were collected to estimate the effect of biochar 1%, compost 1%, and biochar + compost 1% on soil different soil characteristics such as pH, electrical conductivity (EC) dSm^{-1}, soil organic matter (SOM) %, soil organic carbon (SOC) %, cation exchange capacity (CEC) meq/100g, exchangeable sodium carbonate (ESC) mmol/100g, nitrogen (N) %, phosphorous (P) $mgkg^{-1}$, and potassium (K) $mgkg^{-1}$, in both CFL and BCF. The analysis results of CFL Before applied treatments showed that soil was very slightly saline, medium in SOM%, low in both N and P, while adequate in K $mgkg^{-1}$ (Table 2). In contrast, the analysis results of BCF showed that non-saline was low in SOM %, N%, P, and K mg/kg^{-1} (Table 1).

Table 1. Soil Basic Properties of the study areas before experiments

Parameters	Mean values (BCF)	Mean Values (CFL)
pH	7.5±0.23a	7.8±0.13a
EC (dSm^{-1})	0.52±0.02a	2.3±0.08a
ESC	0.2±0.01a	1.1±0.06a
SOM (%)	0.11±0.07a	0.32±0.01a
N (%)	0.01±0.03a	0.021±0.01a
P (mg kg^{-1})	25±7.39a	30±8.23a
K (mg kg^{-1})	80±15.61a	90±14.31a

Note: Soil basic properties of the experimental areas, pH, Electrical Conductivity (EC dsm^{-1}), ESC (Electron storage capacity), SOM (soil organic matter), N (Nitrogen), P (Phosphorous mg kg^{-1}), K (Potassium mg kg^{-1}), mean of triplicates with standard errors, results are not significant ($p<0.05$)

Whereas; post-harvesting analysis results showed that 1%B+C has more effect on soil properties than compost, biochar, and control in both soil CFL and BCF (Table 2 and Table 3). Mean maximum pH, EC (dSm^{-1}), ESP (mmol/100g) and CEC (meq/100g), N (%), P ($mgkg^{-1}$), and K ($mgkg^{-1}$) were recorded in CFL of B+C treatment 7.53±0.05, 3.30±0.67, 1.15±0.52 and 4.07±0.47 compared to BCF 7.93±0.11, 0.76±0.36, 0.54±0.26 and 6.79±0.19 respectively Figure 1. In contrast B+C and B in both land uses of CEC increase in BCF compared to CFL (Table 1 and Table 2). Overall the analysis results of CEC (meq/100g) were significantly different ($p<0.05$) under various treatments. In contrast, pH, EC, and ESP are non-significant ($p<0.05$) in (Table 1 and Table 2) both land use.

Table 2. Post-harvesting soil properties of the BCF

Treatments	Soil pH	Soil EC (dSm^{-1})	Soil ESC (mmolc/100g)	CEC (meq/100g)
Co	7.66±0.11a	3.15±0.69a	1.17±0.35a	2.05±0.25b
1%C	7.66±0.11a	3.29±1.38a	1.16±0.25a	3.41±0.28b
1%B	7.53±0.05a	3.27±0.85a	1.13±0.32a	6.25±0.64a
1%B+C	7.53±0.05a	3.30±0.67a	1.15±0.52a	4.07±0.47b

Note: BCF (Banana Cultivated Field) EC (electrical conductivity), ESC (Electron storage capacity), CEC (Cation Exchange Capacity), Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean with standard errors of triplicate data. Similarly the different alphabetic indicate the significant ($p<0.05$) differences among the parameters and treatments

Table 3. Post-harvesting soil properties of the CFL

Treatments	Soil pH	Soil EC (dSm^{-1})	Soil ESC (mmolc/100g)	CEC (meq/100g)
Co	7.66±0.11a	3.15±0.69a	1.17±0.35a	2.05±0.25b
1%C	7.66±0.11a	3.29±1.38a	1.16±0.25a	3.41±0.28b
1%B	7.53±0.05a	3.27±0.85a	1.13±0.32a	6.25±0.64a
1%B+C	7.53±0.05a	3.30±0.67a	1.15±0.52a	4.07±0.47b

Note: CFL (Coastal Fallow Land), EC (electrical conductivity), ESC (Electron storage capacity), CEC (Cation Exchange Capacity), Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean with standard errors of triplicate data. Similarly the different alphabetic indicate the significant ($p<0.05$) differences among the parameters and treatments

Biochar and compost effect on morphological characteristics: Figure 2 indicates the analysis results of plant height, leaf area (cm^2), and leaves/plant, results showed that B+C has more effect on plant height, leaf area, and leaves/plant in both lands compared to other treatments (Figure 1), and mean maximum trend was recorded in 1%B+C (174±1.162) followed 1%B, 1%C, and control of CFL compared to BCF (163.47±0.0146) followed by 1%B, 1%C, and Co respectively (Figure 1). On the other side leaf area (cm^2) of both fields under different treatments indicated mean maximum leaf area (cm^2) of maize plant was recorded in BCF 1%B+C 144.41±0.035 compared to 1%B+C 118.46±0.0408 of CFL, followed by 1%C, 1%B, and Co of both CFL and BCF (Figure 1). Likewise; the results of leaves/plant indicate that more leave/plant was recorded in BCL 20.34±0.0292 within 1%B+C compared to 1%B+C CFL 14.327±0.0350 (Figure 1). In the comparison of 1%B and 1%C of both fields, the mean maximum was recorded in 1%C (18.84±0.0320) of BCF compared to biochar of both fields and 1%C of CFL (Figure 1). Overall in comparison of treatments among the fields, BCF biochar and compost amendments have more effect than CFL. Overall the significance ($p<0.05$) among the treatments and within the field was recorded, similarly; the recorded trend was 1% B+C>1%B>1%C>1%C>Co of both CFL and BCF (Figure 1).

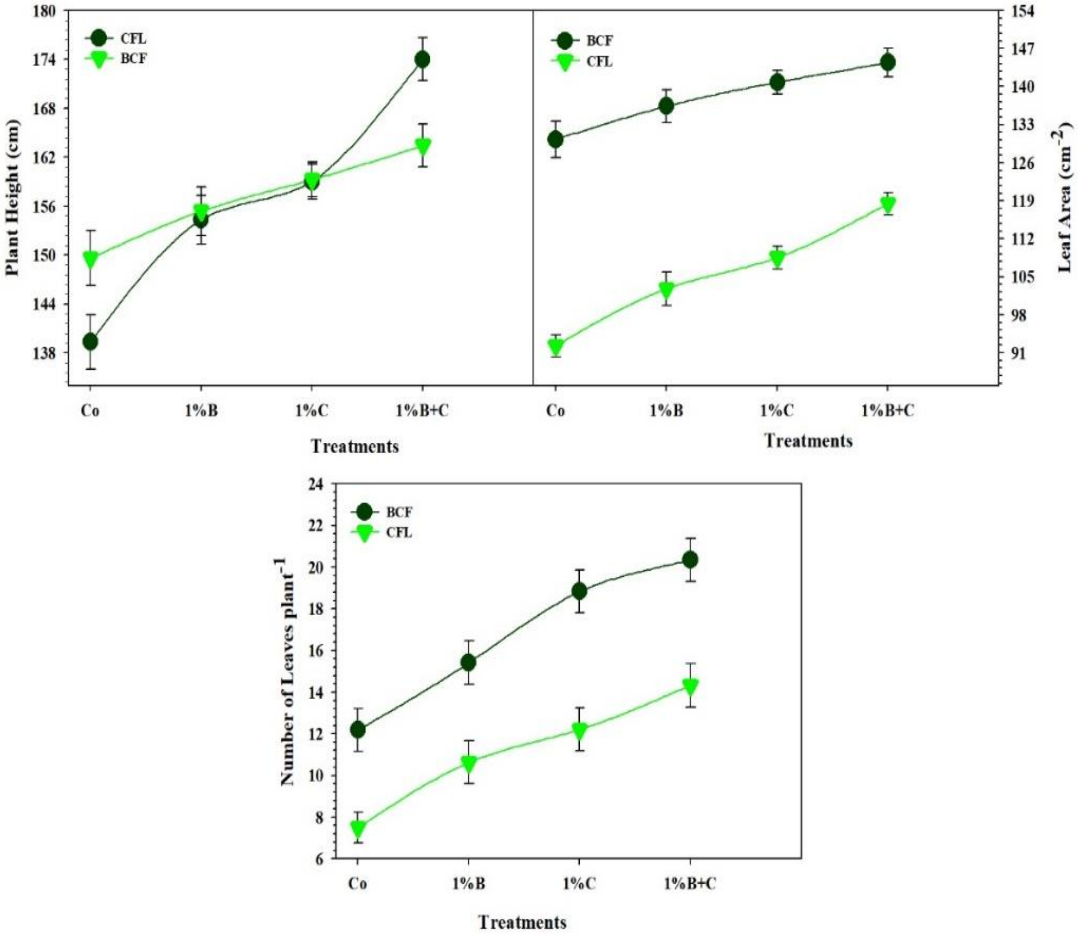

Figure 1. Present the analysis results of the biochar and compost effect on morphological characteristics i.e plant height (cm), leaf area (cm^2), and leaves $plant^{-1}$of Maize of BCF (Banana Cultivated Field), and CFL (Coastal Fallow Land), under various applications of biochar and compost Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean within triplicates analysis showed that the results are significantly different (p<o.o5) among various parameters and co-applications of biochar and compost

Biochar and Compost Effect on Available P and K: P and K are the essential micro-nutrients that play a key role in plant growth and ultimately affect crop yield. The analysis results of P and K up-taken by maize are presented in Figure 2 and showed that 1% B+C (52.33±1.59, 39.33±2.14, 165.0±90.1 and 770.00±173.49) amendment have a more positive effect on the up-taken of nutrients compared to control and followed by 1% B, and 1%C (50.33±9.57, 52.33±8.59, 43.33±15.14, 39.33±8.14, 160.3±99.1, 165.0±90.1, 1506.66±241.108, and 770.00±173.49) Figure 2 in both fields BCF and CFL; likewise in-comparison of both fields BCF and CFL, CFL perform significant ($p<0.05$) different under different treatments compared to BCF of 1% B+C, whereas; 1% C of CFL perform better than BCF Figure 2. Overall; the mean minimum of P and K up-taken was recorded in Co of CFL compared to BCF (38.67±2.88 and 27.33±2.88, 128.6±37.7 and 125.66±386.82) followed by 1%C, 1% B, and 1%B+C Figure 2 and in contrast, K maximum up-taken was recorded in CFL 770.00±173.49 compared to BCF 165.0±90.1 of 1% B+C Figure 2, overall the observation of this study is highly significant ($p<0.05$) different under different amendments of biochar and compost of both fields.

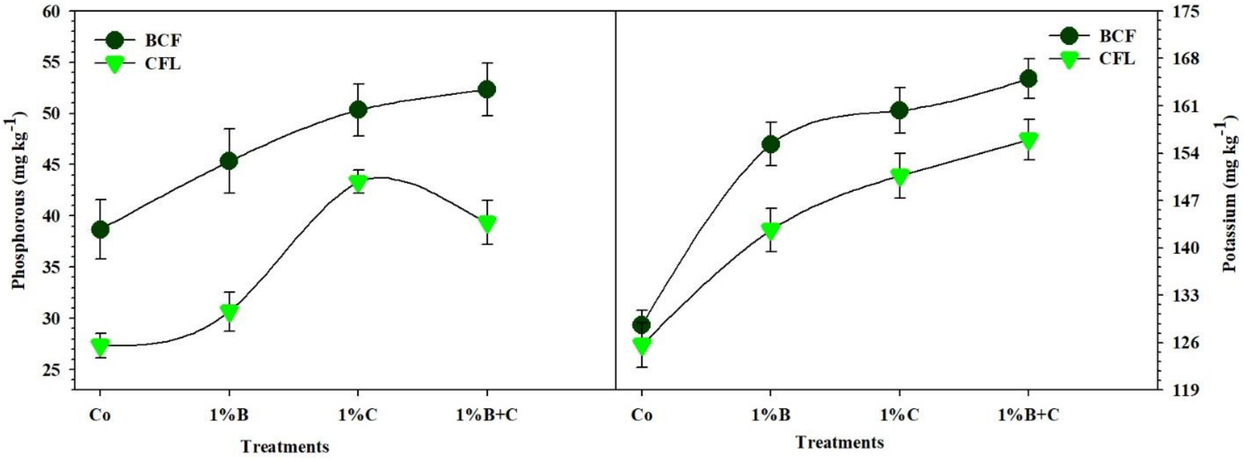

Figure 2. Illustrate the post-harvesting soil properties of available phosphorous (mg kg^{-1}) and available potassium (mg kg^{-1}) of BCF (Banana Cultivated Field), and CFL (Coastal Fallow Land), under various treatments of biochar and compost Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean within triplicates analysis showed that the results are significantly different (p<o.o5), among various parameters and co-applications of biochar and compost

Post-harvest Biochar and Compost Effect on N, SOM, and OC (%): Nitrogen is one of the most essential nutrients, entirely at all growth stages this nutrient is required by plants in large amounts compared to all other essential nutrients. The results of N, SOM, and OC are present in Figure 3 and show the mean maximum total N, SOM, and SOC% were observed in 1%B+C (0.18±0.01) of BCF compared to 1%B+C CFL, followed by 1%C, 1%B and Co Figure 3. In comparison of 1%C and 1%B 1%C record highly significant in total N compared to 1%B of both fields. Overall total N trends were recorded as 1%B+C, 1%C, 1%B, and Co in both fields Figure 3. Likewise; SOM and SOC% of both fields showed that the mean maximum was recorded in 1%B+C (1.19±0.18, 0.16±0.01 and 0.69±0.10) of CFL compared to BCF (0.34±0.01 and 0.19±0.05). Furthermore; compared to both fields of 1%C and 1%B, 1%B recorded more SOM and SOC% (1.17±0.26, 0.35±0.22, 0.20±0.12, 0.67±0.15) compared to 1%C (0.91±0.56, 0.61±0.51, 0.52±0.32 and 0.35±0.29) of both fields. Overall the mean minimum of SOM and SOC% were recorded in Co BCF (0.19±0.03 and 0.11±0.01) compared to Co CFL (0.88±0.61 and 0.51±0.35) Figure 3. Overall the findings of this study are significantly ($p<0.05$) different among both fields and under different treatments of biochar and compost Figure 3.

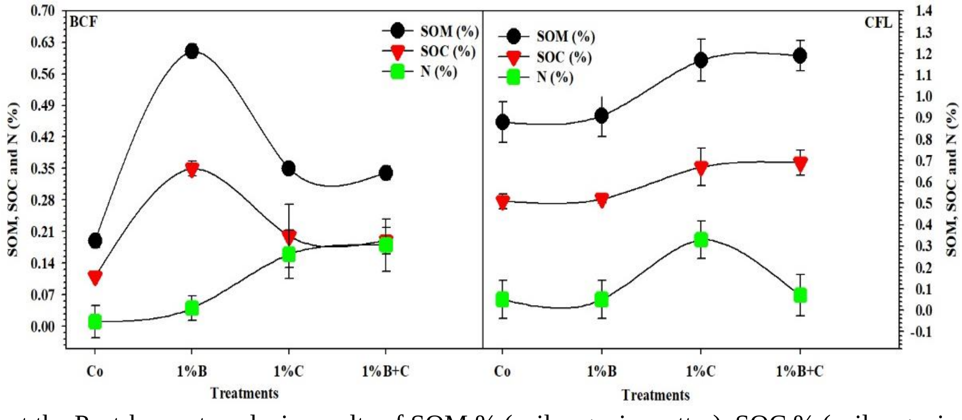

Figure 3. Present the Post-harvest analysis results of SOM % (soil organic matter), SOC % (soil organic carbon), and N % (Nitrogen) of BCF (Banana Cultivated Field), and CFL (Coastal Fallow Land), under various treatments of biochar and compost Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean within triplicates analysis indicated the significantly different ($p<0.05$), among various parameters and co-applications of biochar and compost

Biochar and compost effect on the maize grain and cob yield attributes: The analysis results of cob/plant are presented in (Figure 4) and indicated that the mean maximum cob yield was recorded in BCF (96.52±0.0204) with 1%B+C compared to other treatments of both fields, while; the minimum was recorded in Co of CFL (92.32±0.0320) followed by BCF (130.29±0.0204) compared to other applied treatments (Figure 4). In the comparison of 1%B and 1%C of both fields mean maximum of cob/plant was recorded in 1%C (93.8±0.0321) of BCF compared to 1%C (55.84±0.0234) of CFL followed by 1%B 89.41±0.026, and 49.21±0.0211 of both BCF and CFL, while the minimum was recorded in Co

85.8±0.0381 and 45.65±0.0177 of both field and in-comparison Co of BCF (12.19±0.0113) more cob/plant compared to CFL (7.503±0.0331) figure 4. Overall the findings of cob/plant of this study are significantly ($p<0.05$) different among treatments and both field BCF and CFL (Figure 4).

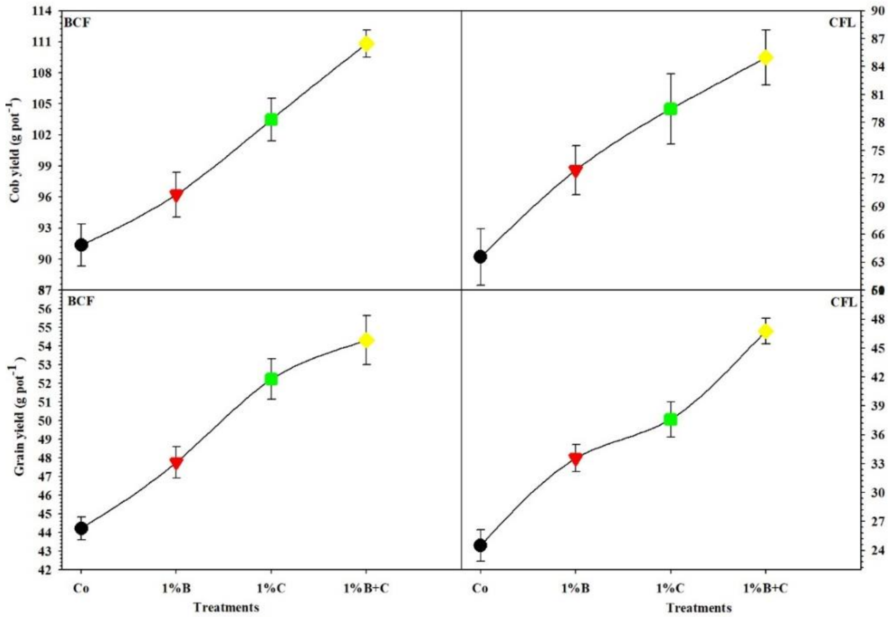

Figure 4. Illustrate the analysis results of Maize gain and Cob Yield (g/pot) of BCF (Banana Cultivated Field), and CFL (Coastal Fallow Land), under various treatments of biochar and compost Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean within triplicates analysis showed that the results are significantly different ($p<0.05$), among various parameters and co-applications of biochar and compost

BCF

	PH	*LA*	*NL*	*CY*	*GY*	*Soil EC*	*pH*	*ESC*	*CEC*	*N%*	*P (mg/kg)*	*K (mg/kg)*	*SOC*	*SOM*
PH	1.000													
LA	0.999	1.000												
NL	0.990	0.996	1.000											
CY	0.984	0.978	0.975	1.000										
GY	0.990	0.994	0.999	0.983	1.000									
Soil EC	0.842	0.815	0.758	0.824	0.759	1.000								
pH	0.915	0.913	0.928	0.968	0.945	0.683	1.000							
ESC	0.541	0.542	0.488	0.393	0.451	0.644	0.156	1.000						
CEC	0.777	0.810	0.847	0.713	0.830	0.359	0.685	0.466	1.000					
N%	0.941	0.949	0.971	0.960	0.979	0.637	0.974	0.271	0.833	1.000				
P (mg/kg)	0.986	0.994	0.995	0.954	0.990	0.758	0.888	0.562	0.870	0.949	1.000			
K (mg/kg)	0.940	0.948	0.935	0.864	0.918	0.776	0.738	0.760	0.851	0.830	0.964	1.000		
SOC	0.205	0.213	0.163	0.033	0.118	0.336	-0.205	0.929	0.282	-0.062	0.253	0.502	1.000	
SOM	0.229	0.236	0.186	0.058	0.141	0.361	-0.182	0.938	0.293	-0.040	0.275	0.521	1.000	1.000

CFL

	PH	*LA*	*NL*	*CY*	*GY*	*Soil EC*	*pH*	*ESC*	*CEC*	*N%*	*P (mg/kg)*	*K (mg/kg)*	*SOC*	*SOM*
PH	1.000													
LA	0.997	1.000												
NL	0.991	0.996	1.000											
CY	0.980	0.991	0.997	1.000										
GY	0.999	0.999	0.993	0.986	1.000									
Soil EC	0.858	0.843	0.874	0.857	0.845	1.000								
pH	-0.795	-0.842	-0.844	-0.877	-0.822	-0.540	1.000							
ESC	0.858	0.843	0.874	0.857	0.845	1.000	-0.540	1.000						
CEC	-0.569	-0.628	-0.676	-0.723	-0.596	-0.569	0.845	-0.569	1.000					
N%	0.170	0.245	0.300	0.364	0.205	0.205	-0.632	0.205	-0.905	1.000				
P (mg/kg)	0.746	0.797	0.824	0.862	0.771	0.629	-0.958	0.629	-0.959	0.776	1.000			
K (mg/kg)	0.960	0.970	0.987	0.990	0.963	0.912	-0.836	0.912	-0.753	0.401	0.860	1.000		
SOC	0.846	0.886	0.885	0.912	0.870	0.588	-0.995	0.588	-0.811	0.563	0.943	0.868	1.000	
SOM	0.845	0.886	0.889	0.916	0.868	0.608	-0.996	0.608	-0.836	0.591	0.957	0.879	0.999	1.000

Correlation among various soil, growth, and yield attribute analysis: The analysis of the correlation among various parameters of both BCF and CFL (Figures 5). Results showed the positive and highly significant under different parameters such as N, P, K SOM, and SOC is an indication of the positive effect of co-application of 1%B+C in BCF compared to CFL (Figure 5). Similarly; correlation matrix of growth parameters such as plant height (cm), leaf area (cm^2), cob/plant, and grain yield of maize. N, P, and K leaf concentrations were highly significant in BCF compared to CFL (Figure 5) under different biochar and compost amendments. Similar findings were also recorded by some authors (Hanyabui et al., 2024; Fagbenro et al., 2018).

Figure 5. presents the co-relationship of both fields among various parameters of soil and plant analysis such as PH (plant height), LA (leaf area), NL number of leaves/plant), CY (Cob yield g/pot), GY (grain yield g/pot), EC (electrical conductivity dsm^{-1}), pH, ESC (Electron storage capacity), CEC (cation exchange capacity meq/100g), N % (nitrogen), P (phosphorous mg kg^{-1}), K (potassium mg kg^{-1}), SOC % (soil organic carbon), and SOM % (soil organic matter) of BCF (banana cultivated field), and CFL(coastal fallow land), white and light green highlights indicated the positive significant ($p<0.05$), whereas; dark green highlights indicated negative significant and non-significant different among various parameter

DISCUSSION

This present study was conducted under two different soil conditions i.e. BCF and CFL, to estimate the effect of biochar and compost both Co-application and alone on maize growth. The Findings of soil physicochemical properties under different treatments are present in (Table 2 and 3) the decreasing trend in the soil of CFL was recorded within 1%B+C compared to other treatments of both lands. The increase of CEC (meq/100g) is a positive sign in both fields BCF and CFL within in recorded trend 1%B+C, 1%B, and 1%C our findings are in line with the observations of (Sanchez-Monedero et al., 2019; Madeira, 2003) whereas the increasing trend of soil EC (dsm^{-1}) of CFL compared to BCF possibly resulting from both side soil is alkaline (Table2 and 3), though compared 1%B, 1%C negligible difference were recorded (Table 2 and 3) and such trend of 1%C possible indicate the presence of highly soluble salt and mineral of the 1%C. our study findings are compatible with (Das et al., 2020; Naeem et al.,2018; Izilan et al., 2022) that biochar increased by 0.05 soil EC (dsm^{-1}) compared to compost. Furthermore; findings also indicated the non-significant effect on soil pH and EC in both fields, while an increasing trend of CEC (meq/100g) is the significant effect of 1%B, 1%C, and 1%B+C on both fields (Tables 2 and 3). The higher CEC (meq/100g) should increase soil fertility with the supply of nutrients and that directly affects plant growth and yield (Tables 2 and 3), such findings are in line with the observations (Purnamasari et al., 2021) researched CEC on different lands and revealed that the increasing trend in CEC is the positive effect on the availability of soil nutrients.

The increased plant height within the combined application of biochar and compost could be accredited to the possible effect on the soil physicochemical properties, such as pH, EC (dsm^{-1}), ESC (mmolc/100g), SOM (%) SOC (%), total N, available p ($mgkg^{-1}$), available k ($mgkg^{-1}$) and influenced CEC (meq/100g). All such improved soil properties could increase cell division, growth, and morphological characteristics in the plant (Seehausen et al., 2017; Mensah & Frimpong, 2018). The highest maize growth result was recorded in 1%B+C (Figure 1) of BCF compared to 1%B+C of CFL and 1%B and 1%C (Figure 1). This may be due to the adequate supply of NPK from 1%B+C of BCF compared to CFL (Manirakiza & Şeker, 2020). Furthermore; Hanyabui et al. (2024) growth of plants increased quite rapidly because of the enrichment of N and P nutrients with combined applications of biochar, compost, and chemical fertilization. Schulz & Glaser (2012) revealed that the combined applications of biochar increased plant height in arid and semi-arid regions of the world. Additionally; the maximum number of leaves/plants recorded in BCF within a soil amendment of 1%B+C, compared to 1%B and 1%C of both fields (Figure 1) may be endorsed the maximum supply of nutrients from soil amendments (Fischer & Glaser, 2012).

The co-applications of both organic and inorganic fertilization could improve the capability to supply nutrients to the plant compared to the alone application of inorganic fertilization (Fischer & Glaser, 2012; Schulz & Glaser, 2012). Also; Oladele et al. (2019) reported that the combined application of biochar and inorganic fertilizers has a significant effect on plant growth leading to increased nutrient up-taken, limited nutrient losses, and improved CEC leading to increased cations availability (Razzaghi et al., 2021), such phenomenon accountable for increasing the number of leaves/plant. Meanwhile increasing number of leaves/plant and leaf development/plant showed the combined application of biochar and compost with inorganic fertilizers (Figure 1) as revealed by some authors in previous studies (Islam et al., 2017; Fagbenro et al., 2018).

Similarly, co-applications of both biochar and compost recorded the maximum crop yield compared to alone applied applications of NPK fertilizers. Such findings agreed with the observations of (Karimi et al., 2022; Phares & Akaba 2022), revealed that reported that the improved physiological characteristic in plants leads to increased leaf length, size, and leaves/plant, and ultimately affect the yield of the crop.

Biochar banana content high amounts of nutrients may be due to the maximum supply of inorganic fertilizers, and such type of co-application of biochar and compost leads to minimized N losses and improved N up-taken (Figure 6). Similar findings were also recorded by Tewodros et al. (2018) and revealed that the co-application of biochar minimizes the demand for N fertilizations leading to minimized N leaching, and increased N efficiency for crop yield. The co-application of biochar affects the bioavailability of N, increases the C: N ratio Chung et al. (2022), and increases the availability of P and K nutrients. N concentration of leaves increased with the fertilizer application of Urea, such findings were also recorded by Zheng et al. (2013). Such findings were variable with the observation of Mohd Hadi et al. (2013), who reported increasing P concentration of leaves within co-application of soil amendments. This study's findings also showed that maximum P content was recorded in BCF within the co-application of 1%B+C (Figure 6). Such findings are in line with the observations of Hossain et al. (2019) and revealed that a significant effect of K content was recorded in biochar amendment soil compared to inorganic fertilizers. Darnaudery et al. (2016) also reported the significant effect of biochar K content in plant tissue.

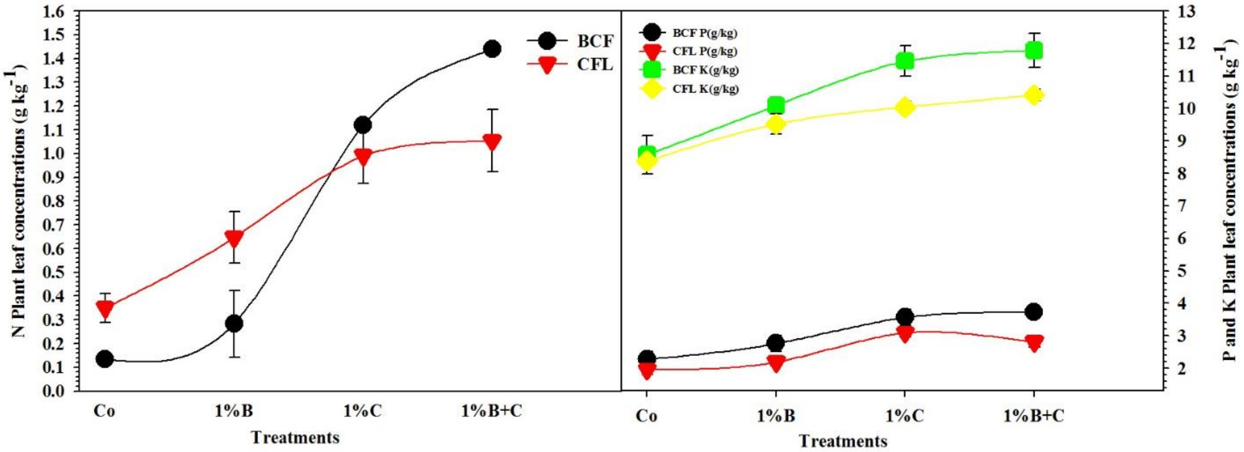

Figure 7. Illustrate the analysis results of NPK leaf concentration of both field BCF (Banana Cultivated Field), and CFL (Coastal Fallow Land) among various treatments of biochar and compost Co (Control), 1%C (compost), 1%B (Biochar), 1%B+C (Biochar+Compost), mean within triplicates analysis showed that the results are significantly different ($p<0.05$), among various parameters and co-applications of biochar and compos

CONCLUSION

Based on the present study observations research study showed that the Co-application of 1%bichar+compost has a significant effect on soil properties such as pH, EC, ESC, CEC SOM, SOC, total nitrogen, available phosphorous, and available potassium significantly ($p<0.05$) increased with the co-application of banana cultivated field compared to coastal fallow land soil samples. Nitrogen, phosphorous, and potassium are the most essential nutrients required by plants in large quantities. Our findings showed that the maximum NPK uptake and availability in both fields were recorded within a co-application of 1%B+C. Maize growth parameters such as plant height, leaf area, cob/plant, and leaves/plant increased within the 1 combined biochar and compost of BCF compared to CFL. Additionally; the findings of this study also added the selection of raw material for the preparation of biochar and compost, the addition of tea straw indicates the positive effect on the soil pH and CEC that play a key role in the availability of nutrients from soil. Conclusively; the co-application of banana biochar and compost (tea straw and manure) along with the recommended application of inorganic fertilizer could be beneficial for sustainable agriculture and soil health.

Author's contribution statement: Sher Jan-conducted research and wrote the original draft, Shahmir Ali Kalhoro-overall supervision, Punhoon Khan Korai and Ammar Rasheed-critical revised MS, Qamar Sarafraz-prepared compost, Abdul Hafeez Mastoi-graphical data organized, Honak Baloch and Usama Rasheed-collected soil sample, Gulab Jan-agronomic observation, Muhammad Abuzar Jaffar-reviewed article, shah mohammad and Sidra Majeed-conducted lab experiments, Abdul salam-prepared soil and plant sample, Shabir Ahmed-collected biochar material, Naguman Ali-collected compost material, Ghulam Haider Angaria -connect with local farmers, Iftakhar Ahmed-statistical analysis Khurram Shahzad-prepared Biochar.

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Reference

1. Ahmed, S., Kalhoro, S. A., Ahmed, B., Sarfaraz, Q, Rodeni, M. A., Hameed, K & Ullah, S. (2024). Impact of Humic Acid on the Morphological Components and Growth Parameters of Wheat (Triticum Aestivum L.) Under Dry Climate of Uthal. Journal of Applied Research in Plant Sciences, 5(02), 226-236.
2. Ayilara, M. S., Olanrewaju, O. S., Babalola & Odeyemi, O. (2020). Waste management through composting: Challenges and potentials. *Sustainability*, *12*(11), 4456.

3. Black, J. W., Duncan, W. A & Shanks, R. G. (1965). Comparison of some properties of pronethalol and propranolol. *British Journal of Pharmacology and Chemotherapy*, *25*(3), 577.
4. Borchard, N., Schirrmann, M., Cayuela, M. L., Kammann, C, Wrage-Mönnig, N,, Estavillo, J. M & Novak, J. (2019). Biochar, soil and land-use interactions that reduce nitrate leaching and N2O emissions: a meta-analysis. *Science of the Total Environment*, *651*, 2354-2364.
5. Choudhary, T. K., Khan, K. S, Hussain, Q & Ashfaq, M. (2021). Nutrient availability to maize crop (Zea mays L.) in biochar amended alkaline subtropical soil. *Journal of Soil Science and Plant Nutrition*, *21*(2), 1293-1306.
6. Chung, W., Shim, J., Chang, S. W & Ravindran, B. (2022). Effect of biochar amendments on the co-composting of food waste and livestock manure. *Agronomy*, *13*(1), 35.
7. Darnaudery, M., Fournier, P & Lechaudel, M. (2018). Low-input pineapple crops with high quality fruit: promising impacts of locally integrated and organic fertilisation compared to chemical fertilisers. *Experimental Agriculture*, *54*(2), 286-302.
8. Das, S. K., Ghosh, G. K & Avasthe, R. (2020). Application of biochar in agriculture and environment, and its safety issues. *Biomass Conversion and Biorefinery*, 1-11.
9. Estefan. G. (2013). Methods of soil, plant, and water analysis: a manual for the West Asia and North Africa region.
10. Fagbenro, J. A., Oshunsanya, S. O., Oyeleye, B & Aduayi, E.A. (2018). Effect of two biochar types and inorganic fertilizer on soil chemical properties and growth of maize (Zea mays L.). *International Educational Scientific Research Journal*, *2*(4), 43-50.
11. Fischer, D & Glaser, B. (2012). Synergisms between compost and biochar for sustainable soil amelioration. *Management of organic waste*, *1*, 167-198.
12. Franchini, J. C., Debiasi, H., Junior, A. A. B., Tonon, B. C., Farias, J. R. B., de Oliveira, M. C. N & Torres, E. (2012). Evolution of crop yields in different tillage and cropping systems over two decades in southern Brazil. *Field Crops Research*, *137*, 178-185.
13. Gomez, K. A & Gomez, A. A. (1984). Statistical procedures for agricultural research. John wiley & sons.
14. Gupta, K. K., Aneja, K. R & Rana, D. (2016). Current status of cow dung as a bioresource for sustainable development. Bioresources and Bioprocessing, 3 (1), 28.
15. Hanyabui, E., Frimpong, K. A., Annor-Frempong, F & Atiah, K. (2024). Effect of pineapple waste biochar and compost application on the growth and yield of pineapple varieties in Ghana. Frontiers in Agronomy, 6, 1331377.
16. Hossain, M. F., Piash, M. I & Parveen, Z. (2019). Effect of biochar and fertilizer application on the growth and nutrient accumulation of rice and vegetable in two contrast soils. *Acta Scientific Agriculture*, *3*(3), 74-83.
17. Islam, M. A., Islam, S., Akter, A., Rahman, M. H & Nandwani, D. (2017). Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. *Agriculture*, *7*(3), 18.
18. Izilan, N. I. S., Sari, N. A., Othman, N. M. I & Mustaffha, S. (2022). The effects of biochar-compost on soil properties and plant growth performance grown in a sandy-loam soil. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1059, No. 1, p. 012021). IOP Publishing.
19. Jackson, M. L. (2005). Soil chemical analysis: advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility, and soil genesis. UW-Madison Libraries parallel press.
20. Jeffery, S., Verheijen, F. G., Kammann, C & Abalos, D. (2016). Biochar effects on methane emissions from soils: a meta-analysis. *Soil Biology and Biochemistry*, *101*, 251-258.
21. Karimi, A., Moezzi, A, Chorom, M & Enayatizamir, N. (2020). Application of biochar changed the status of nutrients and biological activity in a calcareous soil. *Journal of Soil Science and Plant Nutrition*, *20*, 450-459.
22. Liu, G., Xie, M & Zhang, S. (2017). Effect of organic fraction of municipal solid waste (OFMSW)-based biochar on organic carbon mineralization in a dry land soil. *Journal of Material Cycles and Waste Management*, *19*, 473-482.
23. Manolikaki, I & Diamadopoulos, E. (2019). Positive effects of biochar and biochar-compost on maize growth and nutrient availability in two agricultural soils. Communications in Soil Science and Plant Analysis, 50(5), 512-526.
24. Madeira, M., Auxtero, E & Sousa, E. (2003). Cation and anion exchange properties of Andisols from the Azores, Portugal, as determined by the compulsive exchange and the ammonium acetate methods. *Geoderma*, *117*(3-4), 225-241.
25. Manirakiza, N & Şeker, C. (2020). Effects of compost and biochar amendments on soil fertility and crop growth in a calcareous soil. *Journal of Plant Nutrition*, *43*(20), 3002-3019.
26. Mclennon, E., Solomon, J. K, Neupane, D & Davison, J. (2020). Biochar and nitrogen application rates effect on phosphorus removal from a mixed grass sward irrigated with reclaimed wastewater. *Science of the Total Environment*, *715*, 137012.
27. Mensah, A. K & Frimpong, K. A. (2018). Biochar and/or compost applications improve soil properties, growth, and yield of maize grown in acidic rainforest and coastal savannah soils in Ghana. *International journal of agronomy*, *2018*(1), 6837404.
28. Mfilinge, A., Mtei, K & Ndakidemi, P. (2014). Effects of rhizobium inoculation and supplementation with P and K, on growth, leaf chlorophyll content and nitrogen fixation of bush bean varieties.
29. Mia, S., Van Groenigen, J. W., Van de Voorde, T. F. J., Oram, N. J., Bezemer, T. M., Mommer, L & Jeffery, S. (2014). Biochar application rate affects biological nitrogen fixation in red clover conditional on potassium availability. *Agriculture, ecosystems & environment*, *191*, 83-91.

30. Mohd Hadi, A. B., Arifin Abdu, A. A., Shamshuddin Jusop, S. J., Osumanu Haruna Ahmed, O. H. A, Hazandy Abdul-Hamid, H. A. H, Mohd-Ashadie Kusno, M. A. K & Nasima Junejo, N. J. (2013). Effects of mixed organic and inorganic fertilizers application on soil properties and the growth of kenaf (Hibiscus cannabinus L.) cultivated on BRIS soils.
31. Naeem, M. A., Khalid, M., Aon, M., Abbas, G., Amjad, M., Murtaza, B & Ahmad, N. (2018). Combined application of biochar with compost and fertilizer improves soil properties and grain yield of maize. *Journal of Plant Nutrition*, *41*(1), 112-122.
32. Olsen, S. R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.
33. Oladele, S., Adeyemo, A., Awodun, M., Ajayi, A & Fasina, A. (2019). Effects of biochar and nitrogen fertilizer on soil physicochemical properties, nitrogen use efficiency and upland rice (Oryza sativa) yield grown on an Alfisol in Southwestern Nigeria. *International Journal of Recycling of Organic Waste in Agriculture*, *8*, 295-308.
34. Phares, C. A & Akaba, S. (2022). Co-application of compost or inorganic NPK fertilizer with biochar influences soil quality, grain yield and net income of rice. *Journal of Integrative Agriculture*, *21*(12), 3600-3610.
35. Purnamasari, L., Rostaman, T, Widowati, L. R & Anggria, L. (2021). Comparison of appropriate cation exchange capacity (CEC) extraction methods for soils from several regions of Indonesia. In *IOP conference series: earth and environmental science* (Vol. 648, No. 1, p. 012209). IOP Publishing.
36. Razzaghi, F., Arthur, E & Moosavi, A. A. (2021). Evaluating models to estimate cation exchange capacity of calcareous soils. *Geoderma*, *400*, 115221.
37. Sánchez-García, M., Sánchez-Monedero, M. A., Roig, A., López-Cano, I., Moreno, B., Benitez, E & Cayuela, M. L. (2016). Compost vs biochar amendment: a two-year field study evaluating soil C build-up and N dynamics in an organically managed olive crop. Plant and Soil, 408, 1-14.
38. Sánchez-Monedero, M. A., Cayuela, M. L., Sánchez-García, M., Vandecasteele, B., D'Hose, T., López, G & Mondini, C. (2019). Agronomic evaluation of biochar, compost and biochar-blended compost across different cropping systems: Perspective from the European project FERTIPLUS. *Agronomy*, *9*(5), 225.
39. Schulz, H & Glaser, B. (2012). Effects of biochar compared to organic and inorganic fertilizers on soil quality and plant growth in a greenhouse experiment. *Journal of Plant Nutrition and Soil Science*, *175*(3), 410-422.
40. Seehausen, M. L., Gale, N. V., Dranga, S., Hudson, V., Liu, N., Michener, J & Thomas, S. C. (2017). Is there a positive synergistic effect of biochar and compost soil amendments on plant growth and physiological performance? *Agronomy*, *7*(1), 13.
41. Tewodros, M., Mesfin, S., Getachew, W., Ashenafi, A & Neim, S. (2018). Effect of inorganic N and P fertilizers on fruit yield and yield components of pineapple (Annanas comosus MERR L. Var. Smooth cayanne) at Jimma, Southwest Ethiopia. *Agrotechnology*, *7*(178), 2.
42. Tomczyk, A., Sokołowska, Z & Boguta, P. (2020). Biochar physicochemical properties: pyrolysis temperature and feedstock kind effects. *Reviews in Environmental Science and Bio/Technology*, *19*(1), 191-215.
43. Walkley, A & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), 29-38.
44. Yang, X., Zhang, S., Ju, M & Liu, L. (2019). Preparation and modification of biochar materials and their application in soil remediation. *Applied Sciences*, *9*(7), 1365.
45. Yu, H., Zou, W., Chen, J., Chen, H., Yu, Z., Huang, J & Gao, B. (2019). Biochar amendment improves crop production in problem soils: A review. *Journal of environmental management*, *232*, 8-21.
46. Zheng, H., Wang, Z., Deng, X., Herbert, S & Xing, B. (2013). Impacts of adding biochar on nitrogen retention and bioavailability in agricultural soil. *Geoderma*, *206*, 32-39.