EFFECTS OF LIME AND BIOCHAR ON RHIZOSPHERE CHARACTERISTICS, NODULATION AND COWPEA PERFORMANCE IN A DERIVED SAVANNA ALFISOL.

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JULY 2022.

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES COLLEGE OF AGRICULTURAL SCIENCES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE).

JULY 2022.

**DECLARATION**

I declare that this research project entitled ‘effects of lime and biochar on rhizosphere characteristics, nodulation and cowpea performance in a derived savanna alfisol’ is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

………………………………… ……………………………

AYORINDE BOLAJOKO BISOLA DATE

The above statement declaration is confirmed by

……………………………………. ……………………………..

DR ARUNA ADEKIYA DATE

**CERTIFICATION**

This is to certify that Miss AYORINDE BOLAJOKO BISOLA with the matriculation number of 12AD001732 carried out a research work with the title EFFECTS OF LIME AND BIOCHAR ON RHIZOSPHERE CHARACTERISTICS, NODULATION AND COWPEA PERFORMANCE IN A DERIVED SAVANNA ALFISOL under the supervision of DR. ARUNA ADEKIYA and this research work has not been previously submitted for the award of any degree in this or any other university.

……………………………….. .…………………

DR. ARUNA ADEKIYA DATE

(Supervisor)

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DR. (Mrs) E. ALORI

(Co- Supervisor) DATE

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DR. ARUNA ADEKIYA

(Head of Department)

……………………………………….. ……………………….

(External Examiner) DATE

**DEDICATION**

I dedicate this dissertation to God Most High, who has been my help since inception, who saw me through from the beginning down to the final stage of this work. God alone be praised. I also dedicate this project to my forever caring mum, Mrs B.J. Majekodunmi who stood by me in prayers, support and encouragement.

**ACKNOWLEGEMENTS**

God almighty alone deserves all the glory honor and all the praise for without Him this project cannot be a reality.

This dissertation is as a result of the tireless work and pursuit of my supervisor DR. ARUNA ADEKIYA. You ensured that only the best of me was accepted from the beginning to the very end. Thank you for being proactive, understanding and encouraging. Your driving force and relentless efforts made this project possible. Thank you for your positive criticism, guidance and mentoring. Thank you for putting your time and commitments into this study. God bless you abundantly Sir.

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**ABSTRACT**

 Field experiments were carried out at the Landmark University Teaching and Research Farm in 2021, early cropping seasons in July was adopted and the aim of the experiment was to determine the effects of lime and biochar on rhizosphere characteristics, nodulation and cowpea performance in a derived savanna alfisol. Two experimental locations were employed simultaneously Site A and Site B. The all-out region of the field experiment was 185m2 and the experiment consisted of (5) levels of lime (0, 2.5, 5.0, 7.5 and 10 t ha-1) and five (5) levels of biochar(0, 2.5, 5.0, 7.5 and 10 t ha-1). The experiment comprised of three blocks and each block comprised of 25 plots and each plot measured 1 × 1 m. Spacing between blocks was 1 m apart while spacing between plots was 0.5 m apart for Site A and Site B respectively. The total number of plots for Site A and Site B is 150 plots. The treatments were applied and arranged in a randomized complete block design with three replications.

Relative to control, biochar alone as well as its integration with lime increased soil chemical properties,(N,P,K,Ca,Mg,Oc,pH,CEC,AL+H) reduced soil acidity, improved soil structure and enhanced the growth and yield of cowpea. The best treatment that influenced the pH was 6.3 at a favorable condition for the growth and development of cowpea crop is2.5 t/ha of lime with 2.5 to 10 t/ha of biochar. Optimum yield of cowpea crop was achieved at 2.5 t/ha of lime combined 10 t/ha of biochar. Based on the finding from this experiment, the recommended level to achieve optimum yield with favorable soil chemical condition is 2.5 t/ha of lime combined with 10 t/ha of biochar.

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ABBREVATION

CEC Cation Exchange Capacity N Nitrogen

OC Organic Carbon K Potassium

Na Sodium H+AL Exchangeable Acidity

P Phosphorous Ca Calcium

Mg Magnesium

**CHAPTER ONE**

 **INTRODUCTION**

* 1. **Background of the study**

According to estimates, acidic soils cover more than 25% of the global land area, and half of the entire potentially arable land is acidic (Kochian et al., 2015). As a result, tropical soils are not overlooked (Robarge, 2008).)  Under tropical conditions, the soil's organic matter level plummets, and some nutrients, particularly cations, are lost, lowering the pH (Uduma et al., 2006). The adverse result of soil acidity additionallypermits for the decrease in the availability of major plant nutrients, comparable to phosphorus and molybdenum, and will increasethe provision of some virulentcomponents to harmful levels, notablyAl and other fivemetals (Menzies, 2003). Below the rooting zone, important nutrients responsible for growth can also seep into the soil. Acidity can degrade the soil ecosystem, making it more difficult for bacteria, earthworms, and other soil microbes to survive. Extremely acidic soils can make it difficult for helpful bacteria, such as the rhizobia bacteria that aids legume nitrogen fixation, to survive (Sylvia et al. 2005). When the soil is acidic, the yield of most crops, including cowpea, is lowered. (Ano, 2006).

To increase the soil's productivity, the hydrogen ion concentration of soil ought to be raised to a tier that it becomes appropriate for optimum growth of plants. Soil acidity is corrected through the application of agricultural lime. Agricultural limes are materials that facilitateextending the pH of the soil thereby reducing its acidity.  It involves the use of calcium- and magnesium-rich minerals, such as marl, chalk, limestone, or hydrated oxide, to the soil in a variety of forms (Kirkham et al., 2007).

Liming can facilitate boost the productivity of agricultural soil by reducing the doablequantity of metal ion and metallic element ion toxicity, it also can contribute to boostingmicroorganism activities of the soil, improve the healthiness of the soil, improve the dependent biological process by legumes, makes nutrients accessible for plant uptake. Moreover, standard lime is the foremostway of ameliorating soil acidity, nevertheless, a good number of farmers realize it is not affordable (Anetor et al., 2007). It is thus necessary to search foran inexpensive soil additive capable of accelerating soil pH to the maximum amount as updifferent soil properties.

Biochar is a carbon-wealthy substance received by heating natural biomass below a restrained amount of air (Lehmann, 2006).Adding biochar to the soil acts as a liming substance, lowering soil acidity, biochar conjointly helps in rising soil combination stability (structure), increase nutrient content and nutrient conveniencewill increase the microbic activities of the soil that contributes to the breaking down of organic material and improve soil fertility.

Cowpea (Vigna unguiculata) is a grain legume crop, a significant staple food crop for human nutrition in Africa, notably within the dry savannah, regions of West Africa. It contributes largely to human nutrition, and food security, and also provides generational gain for every farmer and food vendor within the region (Oniwerenmadu et al., 2003).

**1.2Problem Statement**

The adverse result of soil acidity permits for the decrease in the availability of major plant nutrients, corresponding to phosphorus and molybdenum andincrease inthe supply of some harmfulcomponents to harmful levels, notablyAl and metallic element (Menzies, 2003) harmful levels, particularly aluminum and manganese (Menzies, 2003).

Highly acidic soils will inhibit the survival of helpfulmicroorganisms, reminiscent of the rhizobia bacteria that contribute to the fixation of N for legumes (Sylvia et al. 2005). The yield of most crops, as well as cowpea, is reduced once the soil is acidic (Ano, 2006) to boost the productivity of the Soil, the pH of such Soil ought to be raised to a tier that it becomes appropriate for optimum growth of plants. Soil acidity can be corrected through the application of agricultural lime. However, not all farmers have access to the employment of typical lime due to the high cost. It isthusvitalto seek an alternate material that mayscale back acidity and yet improve the physical properties of the soil.

**1.3 Justification**

For expansion and increased production of quality cowpea in Nigeria as well as reduced cost of production, soil productivity must be enhanced. As a result, it is necessary to raise the pH of tropical soils to have reduced acidity thereby allowing for short-term and long-term soil productivity.The optimal lime rate for cowpea production in the agro-ecological zone has yet to be established. This is necessary for profitable farming to avoid wastage of lime or reduction in crop yield (IITA, 2009). Furthermore, the role of biochar in increasing cowpea and soil productivity has not been properly positioned in Nigeria.

**1.4 General Objective**

The main objective of this research was to reduce soil acidity using biochar and conventional lime (calcium carbonate) as the liming agent, and cowpea was used as the test crop.

The specific objectives were:

* To determine the impact of sole and combined application of lime and biochar on the nodulation, growth, and yield of cowpea.
* To evaluate the influence of lime and biochar on rhizosphere characteristics.
* Investigate a lime-biochar package that will optimize soil chemical properties, growth, and yield of cowpea in an Alfisol of derived savanna zone of Nigeria.

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1 General overview**

According to the United Nations, most of the tropical land that was once very fertile and productive has been rendered unproductive due to soil deterioration caused by erosion (heavy rainfall) and continuous cropping, (Mba, 2006). As a result, the rising decline in soil fertility because of increased acidity is one of the most prevalent restrictions on the productivity and sustainability of a cowpea cropping system in a derived savanna alfisol (Bello et al., 2017).

Acidic soils are heavily worn having a higher percentage of Aluminum and Ferrous hydrous oxides. They also can hold particular elements securely to their surfaces, preventing important nutrients from being absorbed by plants (Akinrinade,2006).Fageria and Baligar (2008) claim that soil acidity allows for complex interactions between plant development limiting elements.

Erosivity and inadequate water retention capacity are two physical constraints to cultivating crops on tropic acidic soil. The chemical constraints of growing crops in acidic soil are a lack of calcium, magnesium, and phosphorous, while the biological constraint is that soil acidity inhibits the activities of beneficial microorganisms, affecting organic matter decomposition, nutrient mineralization, and immobilization.

**2.2 The influence of pH on soil productivity.**

In terms of land deterioration, soil acidity is a potentially big issue. Excess nitrification leaching, the removal of plant and animal products, the use of excessive nitrogen-based fertilizers, and the accumulation of most plant base organic matter contribute to soil acidity of agricultural soils. Five field studies were undertaken over three years to assess the impact of soil pH on grain yield, yield components, dry bean nitrogen assimilation, and P availability (Fageria et al., 2008).When the pH of the soil can be raised to between 6.4 and 6.8 by liming, a yield of around 3000 kg ha-1 was obtained (Fageria et al., 2008). Grain output increased, as did shoot dry weight, pods per unit area, number of grains per pod, and 100-grain weight. Shoot dry weight, number of pods per square meter, number of grains per pod, and 100-grain weight were ranked in order of relevance for growth and yield. According to Haling et al., 2010, field research was undertaken on sandy clay loam soil in South Whales, Australia, to see how soil acidity affects crop output by shortening perennial and cereal root hair length. The findings reveal that whereas Al toxicity is a typical constraint for root growth in plants. Acid-tolerant plants can survive in low-pH soils by establishing several tolerance mechanisms, such as increasing the pH around the root apices (Vitorello et al., 2005).

**2.3 Liming as an agent of soil acidity correction**.

Although costly inputs such as fertilizers and lime-soil supplements are rarely employed, soil conditioners to boost soil fertility and correct soil acidity have sparked scientific attention Okigbo et al., 2004. An experiment was carried out in Umudike southeast Nigeria to evaluate how three vegetarian varieties, IT93K-915 (white seeded and climbing vines), IT86D-880 (brown seeded and erect vines), and Akidi ani (black seeded and spreading vines) responded to five lime (Ca (OH) 2) rates (0, 0.5, 1.0, 1.5, and 2.0 t/ha)(Muoneke et al., 2012).

The results demonstrate that liming raised soil pH, and enhance growth and yield features,In terms of vegetable cowpea growth and yield, liming at 2.0 t/ha and 0 t/ha produced the greatest and poorest results. The impacts of ISFM components (SAMFIX 286), lime, and single superphosphate (SSP) on biomass, nodulation, and N2 fixation. of cowpeas were studied by another experiment (Bello et al., 2018) in Zaria, northern Nigeria.Lime enhanced root dry weight by 13, 35, 66, and 50% respectively, after application. As the pH of the soil is elevated by lime, soil microbial activity increase (Woomer, 2010), which boosts soil organic matter decomposition, mineralization, and nutrient cycling (Woomer et al. 2014), as well as providing Ca2+ for plant growth. According to an experiment conducted on a C-type tidal area in South Kalimantan province in Indonesia using soya bean as a test crop, liming was also employed to lower acidity (Wijanarko et al., 2016). The result indicated that liming the soil at a depth of 20cm, considerably raised soil pH.

**2.4 The use of biochar as a liming agent for reducing soil acidity.**

Biochar has had a huge impact on the fertility of the soil and productivity. Biochar contains ash, which can serve as a liming agent to lower acidity levels. It's also high in readily available nutrients, particularly cations (Rajkovich et al. 2012). Biochar was found to be an excellent strategy to improve soil pH, reduce Al saturation, and boost base cations by putting them into tea garden soil. The amount of soil pH gain was reduced at higher biochar application rates, as additional biochar just reduced exchangeable acidity without affecting the overall soil pH.The improvement in soil organic matter was attributed not only to the addition of charcoal carbon but also to the increase in root biomass.

According to Edward et al.( 2020), biochar has also been utilized to test the performance of cowpea utilizing various application methods. According to the results of the experiment, the method of applying biochar has an impact on cowpea growth, yield, and nutrient uptake. The spot ring, and broadcasting methods were the three options. The techniques of applying biochar were effective in considerably improving the assessed parameters when compared to the control. The most effective method was the spot, followed by the ring, and last the broadcasting method. As a result, when using biochar to improve cowpea agronomic performance, biochar application technique is crucial for reaping benefits such as higher growth and yield, as well as better soil fertility.

Several biochar application methods have been suggested, including broadcast and incorporation, banding, spot, and ring (Edward et al., 2020).

However, the majority of biochar field trials have followed the broadcast and incorporation application approach (Major et al., 2010). The manner of application for biochar worked has an impact on its effectiveness.

According to Manso et al.( 2019), a biochar type that would be successful in liming acid soils was discovered in testing liming materials made from maize cob and rice husk biochar. The results demonstrated that corn cobs roasted at 500 degrees Celsius are a type of biochar that may be used for liming acid soils with an initial pH of 4.9 to 6.2. Corn cob and rice husk burned at 500°C and 700°C, respectively, can be used to minimize Al toxicity in acid soils and as a replacement for CaCO3, the traditional liming material.

**CHAPTER THREE**

**MATERIALS AND METHODS**

**3.1 Description of the experimental site**

The terrain is undulating, with short slope lengths and a 4-5 percent slope gradient, with slope aspects orientated southern, northward, south-east west, and northwards (Adegbite K.A, 2016). Two distinct seasons are observed in the area. The main rainy season endures from March to July, trailed continuously stormy season from September to November, with the most elevated precipitation in June and October. The average annual temperature is around 32°C An Alfisol, either an Oxichaplustalf or a Luvisol, is available in the experiment area (USDA, 1999).

Two experimental locations, were employed at the same time for this experiment. Site A was behind the feed mill, whereas Site B was next to it. Site A was the first experiment, and site B was used to confirm the findings of site A. Site A experiment was conducted in March 2021 and Site B experiment was conducted in July 2021.

**3.2 Experimental layout and Treatments**

The treatment consists of a factorial combination of five (5) levels of lime (0, 2.5, 5.0, 7.5, and 10 t ha-1) and five (5) levels of biochar (0, 2.5, 5.0, 7.5 and 10 t ha-1). The equivalent of lime used for the experiment was calcium carbonate (CaCO3) from Agric Center, Ilorin. Pyrolysis of biochar was used to measure the temperature inside the kiln, which averaged 580°C over 24 hours (Adekiya et. al 2019). The pyrolyzed biochar was blended and sieved with a 2-mm strainer before being appropriate for use. Each block is comprised of 25 plots, each spanning 1 m by 1 m. The distance between blocks was 1 m, while the distance between plots was 0.5 m. The all-out region of the test is 185m2.

**Treatment 1-** control (No amendment)

**Treatment 2**- 0.25kg of biochar alone

**Treatment 3-**  0.5kg of biochar alone

**Treatment 4**- 0.75kg of biochar alone

**Treatment 5-** 1.0kg of biochar alone

**Treatment 6-** 0.25kg of lime + no biochar

**Treatment 7-** 0.25kg of lime + 0.25kg of biochar

**Treatment 8-** 0.25kg of lime + 0.5kg of biochar

**Treatment 9** – 0.25kg of lime + 0.75kg of biochar

**Treatment 10-** 0.25kg of lime +1.0kg of biochar

**Treatment 11-** 0.5kg of lime + no biochar

**Treatment 12-**  0.5kg of lime + 0.25kg of biochar

**Treatment 13-** 0.5kg of lime + 0.5kg of biochar

**Treatment 14-** 0.5kg of lime + 0.75kg of biochar

**Treatment 15-** 0.5kg of lime + 1.0kg of biochar

**Treatment 16-**  0.75kg of lime + no biochar

**Treatment 17-**  0.75kg of lime + 2.5kg of biochar

**Treatment 18-**  0.75kg of lime + 0.5kg of biochar

**Treatment 19-** 0.75kg of lime + 0.75kg of biochar

**Treatment 20-**  0.75kg of lime + 1.0kg of biochar

**Treatment 21-**  1.0kg of lime + no biochar

**Treatment 22 –** 1.0kg of lime + 0.25kg of biochar

**Treatment 23-**  1.0kg of lime + 0.5kg of biochar

**Treatment 24-**  1.0kg of lime + 0.75kg of biochar

**Treatment 25-**  1.0kg of lime + 1.0kg of biochar

* 1. **Experimental Layout**

|  |  |  |  |
| --- | --- | --- | --- |
| **TREATMENTS** | **REP 1** | **REP2** | **REP3** |
| **1** | **LoBo** | **L1Bo** | **L2Bo** |
| **2** | **LoB2.5** | **L1B2.5** | **L2B2.5** |
| **3** | **LoB5.0** | **L1B5.0** | **L2B5.0** |
| **4** | **LoB7.5** | **L1B7.5** | **L2B7.5** |
| **5** | **LoB10** | **L1B10** | **L2B10** |
| **6** | **L1Bo** | **LoBo** | **L4Bo** |
| **7** | **L1B2.5** | **LoB2.5** | **L4B2.5** |
| **8** | **L1B5.0** | **LoB5.0** | **L4B5.0** |
| **9** | **L1B7.5** | **LoB7.5** | **L4B7.5** |
| **10** | **L1B10** | **LoB10** | **L4B410** |
| **11** | **L2Bo** | **L3Bo** | **LoBo** |
| **12** | **L2B2.5** | **L3B2.5** | **LoB2.5** |
| **13** | **L2B5.0** | **L3B5.0** | **LoB5.0** |
| **14** | **L2B7.5** | **L3B7.5** | **LoB7.5** |
| **15** | **L2B10** | **L3B10** | **LoB10** |
| **16** | **L3Bo** | **L4Bo** | **L1Bo** |
| **17** | **L3B2.5** | **L4B2.5** | **L1B2.5** |
| **18** | **L3B5.0** | **L4B5.0** | **L1B5.0** |
| **19** | **L3B7.5** | **L4B7.5** | **L1B7.5** |
| **20** | **L3B10** | **L4B410** | **L1B10** |
| **21** | **L4Bo** | **L2Bo** | **L3Bo** |
| **22** | **L4B2.5** | **L2B2.5** | **L3B2.5** |
| **23** | **L4B5.0** | **L2B5.0** | **L3B5.0** |
| **24** | **L4B7.5** | **L2B7.5** | **L3B7.5** |
| **25** | **L4B410** | **L2B10** | **L3B10** |

**3.4 Land preparation and Plot size**

The field was prepared using a tractor and harrow, after which the land was divided into 1×1 and 25 plots each replication, which was reproduced three times. The experiment's entire area was 185 m 2.

**3.5 Pre-planting Soil sampling and analysis**

Prior to planting, soil tests were arbitrarily taken from the experimental fields and combined as one to shape a composite sample. The sample of the soil gathered was sieved utilizing a 2-mm sifter after which it was investigated for chemical and physical qualities.

**3.6 Incorporation of lime and biochar**

The biochar and lime were weighed at the specified rates of 0, 2.5, 5.0, 7.,5, and 10t ha-1 which were respectively equivalent to 0, 0.25, 0.5, 0.75, and 1.0 kg plot-1 were spread evenly on the plots at both sites. Both were dug into a depth of about 10 cm. This was done two weeks before the cowpea seeds were planted.

**3.7 Seed Variety**

 Paiyur 1Cowpea; was used preferly because it is usually planted between June to August.

**3.8.1 Seed Sowing**

The seeds were sown at 3 to 4 cm deep. For the erect variety, three seeds were sown with an inter-row spacing of 20 cm and an intra row spacing of 75 cm apart, yielding a plant population of 66,666 plants ha-1.

**3.8.2 Pest control**

Insect pest during the experiment was taken care of by spraying Cypermethrin at a gauge of 80 ML/20 L of water every week from three weeks after sowing till about 2 weeks before harvest.

3.8.3 Determination of soil properties

Two plants were studied, as well as soil samples from their rhizospheres when the cowpea plants had attained 50% flowering on a plot basis (65 days after sowing). Before roots excavation, water was applied to the plots for easy excavation to reduce the retention of nodules in the soil. The nodules were counted using a magnifying glass. A rhizosphere soil sample was collected per plot after the experiment.

Soil Reaction (Soil pH)

The hydrogen ion concentration was measured with a glass electrode. The soil reactivity was tested in both water and a 1M KCL solution. The ratios of soil to water and soil to KCL were both 1:2. A 10g soil sample was sieved and air-dried after being put through a 2mm sieve. 20 ml of distilled water was added to each sample, followed by 20 ml of 1M KCL for the second set. A mechanical device was used to shake the soil suspensions every 30 minutes. After removing the soil samples, they were stirred for 30 minutes.

Following that, the pH meter's glass electrode was suspended in the solution, and readings were collected.

Organic Carbon

The moisture content of air-dry soil finely powdered through a 0.42 mm sieve was determined. The soil was correctly weighed to have between 10 mg and 20 mg of carbon tarred 250 mL conical flask (between 0.5 g and 1 g for topsoil and 2 g and 4 g for subsoil).

After gently swirling the flask to disperse the debris in the solution, 10 mL 1 N K2Cr2O7 was added. To blend the soil and the chemical, the flask was vigorously spun.

 200 °C thermometer was placed and heated while spinning the flask and contents until the temperature reached 135 °C (about 1/2 minutes).

In a fume cupboard, a cool was slowly put aside on a sheet. The FeSO4 solution was standardized. After chilling, it was diluted with 200 mL deionized water and FeSO4 titrated with a potentiometrically using an auto titrator.

**Total Nitrogen**

The Kjeldahl micro-digestion technique was utilized. 5g of soil samples, 1 g of CuSO4, 10-kilogram K2SO4, and 30 mL of H2SO4 were weighed into a digestion flask.The ingredients were well combined. Each sample digest received 40ml of 10M NaOH, which was steam-distilled for 5 minutes.In a 20ml boric acid solution, the distillate was recovered. The distillate was titrated with a homogeneous 0.1M HCl solution. The substance went through the digestive process until it turned green. As a result, the amount of nitrogen is determined.

$$\%N=\frac{Mass of N×100}{Wt}$$

$$=M×T×0.014×\frac{V1}{V2}×\frac{100}{2wt}$$

Where;

T= Control titer M= Molarity of acid

V2 = Volume of digest used in the digest V1= Final volume of digest

Available Phosphorus

The soil sample was weighed in a beaker at 5 g. It was given 35 milliliters of extracting solution, which was agitated for five minutes before being filtered. 5 mL extract was poured into a volumetric flask with a capacity of 25 mL, followed by a 4 mL developing solution (reagent B). After that, it was made up to the mark with distilled water and set aside for 15 minutes.Using a spectrophotometer, the absorbance was measured at 660nm wavelength. On the blank, the identical method was followed only the extractant was not used.

**Exchangeable Acidity**

The blend was spun for 1 hour and the suspension was sifted utilizing filter paper to obtain a filtrate. In a 100 mL conical flask, 4 drops of phenolphthalein indicator were added to 25 mL of the extract. The mixture was titrated with 0.01M NaOH. The color changed from colorless to pink at the end.

$$Exchangeable acidity=\frac{\left(T-B\right)×CNaOH×V1×100}{Weight of soil×V2}$$

Where, B = blank titre value (mL), W = soil weight (g), V1 = volume of extracting solution (mL), V2 = volume of soil extract (mL), CNaOH = standardized concentration of NaOH (0.002 M NaOH).4

**Exchangeable Bases**

1M NH4OH was used to extract the exchangeable cation (pH 7.0). A flame photometer was used to quantify the cation (K and Na) in the filtered extracts, while a 0.02N EDTA titration technique was used to assess Ca and Mg. The mixtures were placed on the mechanical shaker for 1 hour after which the samples were filtered using filter paper with the aid of a volumetric flask to obtain the extracts.

**Ca and Mg Determination**

5 mL concentrated NH4OH, 5 drops 2 percent sodium cyanide. Color change was observed from colorless to blue at the endpoint For Ca, 5 drops of10% hydroxylamine hydrochloride, 5 drops of 2% sodium cyanide, and 3 drops of Calon as indicators. 0.02 N EDTA solutions were used for the titration. Colour change was observed at the endpoint

$$Ca+Mg=Titer×0.02×50÷5×100×5$$

$$Ca=Titer×0.02×50÷5×100÷5$$

**Na and K’s determination**

A flame photometer was used to measure the exchangeable sodium and potassium in soil extracts. The sodium and potassium standards were prepared using a part per million concentration system. (ppm). A blank of ammonium acetate extract was also prepared which has no soil sample. This was used to neutralize the flame photometer electrode.

For each soil extract, the proportion of flame emission was recorded. The extracts were calculated using the percentage emission of sodium and potassium standards plotted against their varying concentrations.

**Cation Exchange Capacity**

The summation approach was used to calculate the CEC in this study, which is the total of the exchangeable bases and exchangeable acidity.

**3.8.4 Analysis of biochar**

 After being sieved with a 2-mm sifter, the biochar utilized in this experiment was tried to establish its nutritional composition.

**3.8.5 Determination of growth and yield parameters**

**Growth parameters.**

**The number of leaves:** This was derived by counting the number of completely grown leaves.

**Vine length:** This was determined by using a measuring tape to get the actual length of the vine.

**3.8.6 Yield Parameters.**

**Number of pods per plant:** The cowpea pods were reaped at maturity and the number of harvested pods was recorded per plot and per treatment.

**Weight of pods per plant:** Harvested matured cowpea pods were weighed using a sensitive weighing balance and the value was recorded on a pilot basis.

**CHAPTER FOUR**

 **RESULTS**

**4.1 Results**

***4.1.1 Soil physical and chemical characteristics of experimental sites before planting***

Table 1 shows the physical and chemical characteristics of soil of experimental sites A and B located in the Teaching and Research Farms Landmark University. The soils were sandy loam in texture. Sand content for site A was 68.2 % and site B was 68.1%. Similar content of 16.1% was recorded for sites A and B. The clay content for site A was 15.7% while that of site B was 15.8%. The soils had a pH of 5.33 of water and 5.28 in KCL for site A and a pH of 5.30 in water and 5.28 in KCL for site B these signify that the soil are strongly acidic (FFD, 2011). The exchangeable calcium (Ca2+) for site A and site B contains 0.99 cmol kg-1. Magnesium (Mg2+) contents 0.81cmol kg-1 and 0.82 cmol kg-1 respectively. Exchangeable K+ for both site A and site B contains 0.14 cmol kg-1. The exchangeable sodium (Na+) content of the soils contains 0.01 cmol kg-1 for both experimental sites. The exchangeable sodium (Na+) of the soils was low and won't constitute any impediment to crop production on these soils. Organic Carbon for site A was 1.13 % and 1.14% (low) the average, the organic matter is low. Phosphorus contents are moderate, 16.2 mg kg-1 for site A and 16.10 mg kg-1 for site B. The CEC value for site A is 9.2 cmol kg -1 while site B contains 9.9 cmol kg – 1.

Table 1: Physical and chemical properties of soil found on the experimental sites before planting.

|  |  |  |
| --- | --- | --- |
| Property | Site A | Site B |
| Sand (%) | 68.2 | 68.1 |
| Silt (%) | 16.1 | 16.1 |
| Clay (%) | 15.7 | 15.8 |
| Textural class | Sandy loam | Sandy loam |
| Organic C (%) | 1.13 | 1.14 |
| pH (water) | 5.33 | 5.30 |
| pH (KCL) | 5.28 | 5.28 |
| N (%) | 0.11 | 0.15 |
| P (mg kg-1) | 16.2 | 16.10 |
| K (cmol kg-1) | 0.14 | 0.14 |
| Ca(cmol kg-1) | 0.99 | 0.99 |
| Mg (cmol kg-1) | 0.81 | 0.82 |
| Na (cmol kg-1) | 0.01 | 0.01 |
| (H+ AL) (cmol kg-1) | 5.5 | 6.5 |
| CEC (cmol kg-1) | 9.2 | 9.9 |

***4.1.2Chemical characteristics of the biochar used for the experiment***

Laboratory analysis showed that the biochar contains a pH of 7.21 (Table 2) which is relatively neutral and can help raise the pH of the soil. Ash content of the biochar is 0.5%, organic carbon of 61.5% which is relatively high and can improve the carbon content of the soil. It also contains N, P, K, Ca, Mg, and Na with values 0.81, 0.69, 1.39, 1.20, 0.40, 0.41% respectively. The C: N ratio of the biochar is 75.92

Table 2: Chemical characteristics of the biochar used in the experiment

|  |  |
| --- | --- |
|  Soil Properties | Value |
| pH (water) | 7.21 |
| Ash (%) | 0.50 |
| Organic C (%) | 61.5 |
| N (%) | 0.81 |
| C : N | 75.92 |
| P (%) | 0.69 |
| K (%) | 1.39 |
| Ca (%) | 1.20 |
| Mg (%) | 0.40 |
| Na (%) | 0.41 |

***4.1.3 Effect of lime and biochar on soil chemical properties***

The impact of biochar and lime applied on the chemical properties of the soil are shown in Tables 3 and 4. Taking lime and biochar as a single factors respectively at both sites (A and B), lime significantly influenced soil pH which increased with lime rate application rate from 0 – 10 t ha-1. Percentage organic carbon and phosphorus content was also significantly increased the level of lime increased. Biochar as a single factor significantly influenced the pH of the soil when the level increased from 0-10 t ha-1. In the same vein, biochar also significantly enhanced the N content of the soil. The amount of organic carbon and phosphorus was also increased with an increase in the level of biochar applied which caused a significant effect on the soil’s chemical properties. The interaction effects of Lime and Biochar was significant for pH, N, OC, and P with increase in the level of lime and biochar applied.

Table 3. Effect of lime and biochar on soil chemical properties (pH, N, OC, and P).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Lime | Biochar | pH(H20) | pH (KCL) | N (%) | OC (%) | P (mg kg-1) |
|  |  | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B |
| 0 | 0 | 5.30r | 5.3s | 5.3n | 5.2s | 0.10i | 0.14ef | 1.11g | 1.12f | 15.2l | 15.2s |
| 0 | 2.5 | 5.3p | 5.4r | 5.4m | 5.3r | 0.14fg | 0.16cd | 1.14e | 1.23d | 15.7k | 15.7r |
| 0 | 5.0 | 5.9n | 5.9p | 5.7l | 5.6o | 0.17bc | 0.17bc | 1.24c | 1.24cd | 15.8k | 15.7q |
| 0 | 7.5 | 6.1m | 6.2n | 6.0k | 5.8n | 0.15df | 0.18bc | 1.19d | 1.24cd | 18.9i | 18.5p |
| 0 | 10 | 6.2lm | 6.3l | 6.2k | 6.2n | 0.16cd | 0.19a | 1.23c | 1.28a | 19.1h | 19.1l |
| 2.5 | 0 | 5.5o | 5.8q | 5.6k | 5.6p | 0.10i | 0.13fg | 1.11g | 1.12f | 18.6j | 18.6o |
| 2.5 | 2.5 | 5.6o | 6.3l | 5.7l | 6.2j | 0.10i | 0.13fg | 1.11g | 1.12f | 18.9i | 18.8m |
| 2.5 | 5.0 | 6.1m | 6.3l | 5.9k | 6.2j | 0.14fg | 0.14ef | 1.13fg | 1.13f | 20.1fg | 20.5i |
| 2.5 | 7.5 | 6.2lm | 6.5k | 6.1j | 6.3i | 0.17bc | 0.16cd | 1.24c | 1.19e | 20.2g | 20.5i |
| 2.5 | 10 | 6.3kl | 6.6i | 6.3ij | 6.5h | 0.19a | 0.19a | 1.28a | 1.28a | 23.1b | 23.6b |
| 5.0 | 0 | 6.3kl | 6.3l | 6.1jk | 6.3j | 0.11hi | 0.11i | 1.12g | 1.12f | 18.9i | 18.8m |
| 5.0 | 2.5 | 6.3kl | 5.7q | 6.2j | 6.4p | 0.12ji | 0.12gh | 1.13ef | 1.13f | 18.9i | 18.8m |
| 5.0 | 5.0 | 6.4ij | 6.1o | 6.2jk | 6.5g | 0.13hi | 0.13fg | 1.12efg | 1.12f | 20.2g | 20.1k |
| 5.0 | 7.5 | 6.5i | 6.2n | 6.3ij | 6.6f | 0.15df | 0.15de | 1.19d | 1.19e | 20.3fg | 20.3j |
| 5.0 | 10 | 6.7h | 6.3l | 6.5h | 6.7f | 0.17bc | 0.18ab | 1.24c | 1.25bc | 21.1d | 21.3g |
| 7.5 | 0 | 6.5i | 6.6i | 6.4ij | 6.1l | 0.18ab | 0.17bc | 1.13fg | 1.12f | 20.4f | 20.5i |
| 7.5 | 2.5 | 6.6i | 6.6j | 6.5h | 6.5g | 0.17bc | 0.18ab | 1.17d | 1.24cd | 21.2d | 21.6f |
| 7.5 | 5.0 | 6.8h | 6.8h | 6.6g | 6.6f | 0.13gh | 0.19a | 1.18d | 1.24cd | 22.3c | 22.5e |
| 7.5 | 7.5 | 6.9g | 6.8g | 6.8f | 6.6f | 0.15df | 0.19a | 1.19d | 1.25cd | 23.2b | 23.2d |
| 7.5 | 10 | 7.1f | 7.0f | 7.0e | 7.0e | 0.16fg | 0.19a | 1.19ef | 1.28a | 23.6a | 23.9a |
| 10 | 0 | 7.2e | 7.1e | 7.0e | 7.0e | 0.14fg | 0.16cd | 1.13ef | 1.23d | 20.2g | 20.3k |
| 10 | 2.5 | 7.4d | 7.3d | 7.3d | 7.3d | 0.15df | 0.16cd | 1.19d | 1.24cd | 20.4f | 20.5i |
| 10 | 5.0 | 7.8c | 7.7c | 7.7c | 7.6c | 0.18ab | 0.18ab | 1.26b | 1.26b | 20.9e | 20.9h |
| 10 | 7.5 | 8.4b | 8.2b | 8.3b | 8.0b | 0.19df | 0.19de | 1.19d | 1.27a | 23.1b | 23.3c |
| 10 | 10 | 8.9a | 8.3a | 8.5a | 8.1a | 0.19a | 0.19a | 1.28a | 1.28a | 23.6a | 23.5b |
| Lime |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Biochar |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| L × B |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

***4.1.4 Effect of lime and biochar on other soil chemical properties (Na, Ca, Mg, K, H+AL, and CEC)***

Taking lime and biochar as a single factor at both sites (A and B), lime significantly influenced the content of sodium (Na), in the soil. The impacted increase with the levels of lime applied to the soil. The soil calcium (Ca) content was also increased when the level of lime was increased from 0-10 t ha-1. Similarly, the magnesium (Mg) and potassium (K) content also increased with an increase in the level of lime used. K increased when lime content was increased from 0-10 t ha-1 when Mg increased the lime content was raised from 0-10 t ha-1. Lime significantly influenced the H +AL (acidity) of the soil by causing reduction of soil acidity as the level of lime was increased from 0-10 t ha-1. Lime also significantly increased the CEC of the soil when the level of lime applied was increased from 0-10 t ha-1. Biochar as a single factor similarly increased the Na, Ca, Mg, and K contents of the soil when the level of biochar was increased from 0- 10 t ha-1. There was a significant effect of the levels of biochar used on the Na, Ca, Mg, and K content of the soil. Biochar significantly influenced the acidity of the soil by reducing acidity when the level of biochar was increased from 0-10 t ha-1. Similarly, biochar influenced the CEC of the soil by allowing increment with an increase in the level of biochar applied. The interactive effects of L× B were significant for Na, Ca, Mg and K with an increase in the level of lime and biochar that was applied. The interaction effects of was also significant for acidity (H+AL) causing a reduction in soil acidity. Lime and Biochar interaction was also significant for CEC when the level was increased from 0- 10 t ha-1.

Table 4. Effect of lime and biochar on soil chemical properties (Na, Ca, Mg, K, H+AL, and CEC).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lime | Biochar | Na (cmol kg-1) | Ca (cmol kg-1) | Mg (cmol kg-1) | K (cmol kg-1) | H+AL (cmol kg-1) | CEC (cmol kg-1) |
|  |  | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B |
| 0 | 0 | 0.10g | 0.10p | 0.98s | 0.96v | 0.78v | 0.79s | 0.10m | 0.13l | 21.0a | 21.24a | 7.72w | 13.10q |
| 0 | 2.5 | 0.10g | 0.10p | 1.28r | 1.26u | 1.38u | 1.48r | 0.42l | 0.43k | 20.52ab | 20.76b | 8.53w | 16.94m |
| 0 | 5.0 | 0.20f | 0.14o | 1.67q | 1.69t | 1.57t | 1.58q | 0.44k | 0.44jk | 15.96d | 17.16e | 10.07u | 21.01e |
| 0 | 7.5 | 0.21f | 0.17n | 1.78p | 1.78s | 1.88s | 1.89p | 0.43k | 0.44jk | 12.24f | 14.52f | 10.32t | 21.88e |
| 0 | 10 | 0.22ef | 0.21m | 2.23o | 2.25r | 2.23r | 2.36o | 0.45k | 0.46j | 13.20e | 14.76f | 12.32r | 23.03b |
| 2.5 | 0 | 0.26e | 0.25l | 2.89n | 2.99q | 2.59q | 2.60n | 0.52hi | 0.49i | 20.28b | 10.44i | 15.90n | 16.77k |
| 2.5 | 2.5 | 0.27ef | 0.27k | 2.99m | 3.03p | 2.79p | 2.89m | 0.54h | 0.56fg | 17.64c | 9.48j | 13.74p | 17.24m |
| 2.5 | 5.0 | 0.27ef | 0.28i | 3.03l | 3.05n | 3.33k | 3.33i | 0.54h | 0.58ef | 13.08f | 9.24j | 19.17g | 18.48m |
| 2.5 | 7.5 | 0.27ef | 0.28i | 3.34i | 3.37k | 3.54i | 3.54g | 0.54h | 0.59de | 10.44g | 8.04l | 14.51o | 19.82o |
| 2.5 | 10 | 0.28f | 0.29i | 3.65g | 3.75h | 3.75g | 3.77e | 0.55h | 0.59de | 8.64i | 6.00m | 12.98q | 21.40e |
| 5.0 | 0 | 0.32d | 0.33h | 3.01lm | 3.04o | 3.03o | 3.05l | 0.55h | 0.53h | 9.72h | 20.28c | 17.93j | 20.24o |
| 5.0 | 2.5 | 0.31d | 0.33h | 3.11k | 3.13m | 3.13n | 3.23k | 0.57g | 0.54h | 10.8g | 17.64d | 17.02k | 24.87a |
| 5.0 | 5.0 | 0.32d | 0.35g | 3.21j | 3.24l | 3.31l | 3.33i | 0.59e | 0.56ef | 9.60h | 13.08g | 11.07s | 25.58a |
| 5.0 | 7.5 | 0.33d | 0.35g | 3.33i | 3.36k | 3.33k | 3.36i | 0.61d | 0.58ef | 8.40i | 10.44i | 9.23v | 25.09b |
| 5.0 | 10 | 0.34d | 0.36g | 3.43h | 3.44j | 3.45j | 3.46h | 0.62cd | 0.59de | 6.33j | 8.40k | 23.87d | 16.23n |
| 7.5 | 0 | 0.43c | 0.42de | 3.65g | 3.67i | 3.75g | 3.77d | 0.56fg | 0.55gh | 10.80g | 0.00o | 23.61c | 22.40e |
| 7.5 | 2.5 | 0.40c | 0.43d | 3.78f | 3.78g | 3.76g | 3.78d | 0.57fg | 0.58ef | 6.00j | 0.00o | 19.84f | 22.56b |
| 7.5 | 5.0 | 0.41c | 0.43d | 3.87f | 3.88f | 3.88f | 3.88d | 0.61d | 0.63bc | 4.20k | 0.00o | 16.56m | 23.83ab |
| 7.5 | 7.5 | 0.41c | 0.43de | 3.87e | 4.04e | 4.12e | 4.15c | 0.62cd | 0.64b | 1.92l | 0.00o | 18.42h | 23.93ab |
| 7.5 | 10 | 0.41c | 0.43de | 4.05d | 4.09d | 4.15d | 4.17c | 0.62cd | 0.67a | 0.00m | 0.00o | 26.60a | 24.34a |
| 10 | 0 | 0.53b | 0.54c | 3.85e | 3.88f | 3.85f | 3.88d | 0.59e | 0.61cd | 0.00m | 10.80h | 24.27b | 24.48a |
| 10 | 2.5 | 0.54b | 0.56c | 3.98f | 3.99e | 3.88f | 3.89d | 0.63bc | 0.63bc | 0.00m | 6.00m | 20.18e | 24.59a |
| 10 | 5.0 | 0.58a | 0.58b | 4.45c | 4.51c | 4.35c | 4.65b | 0.64bc | 0.64b | 0.00m | 4.20n | 18.07i | 24.98a |
| 10 | 7.5 | 0.58a | 0.59ab | 4.65b | 4.65b | 4.45b | 4.65b | 0.64ab | 0.64b | 0.00m | 4.32n | 16.79l | 25.56a |
| 10 | 10 | 0.60a | 0.60a | 5.53a | 5.52a | 5.51a | 5.55a | 0.65a | 0.65ab | 0.00m | 0.00o | 26.60a | 26.33a |
| Lime |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Biochar |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| L× B |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

***4.1.5 Effect of lime and biochar on the growth parameters of cowpea for sites A and B***

The effects of lime and biochar on the growth parameters (vine length per plant, number of leaves per plant, number of branches per plant, and leaf area per plant) are shown in Tables 5. Taking lime and biochar as a single factor at both sites (A and B), Lime significantly influenced the vine length per plant, number of leaves per plant, and number of branches per plant when the level of lime was increased from 0- 10 t ha-1. However, the leaf area per plant was not significantly influenced by the various levels of lime applied. Similarly, biochar also influenced vine length per plant, number of leaves per plant, and number of branches per plant significantly with an increase in the level of biochar applied. However, the leaf area per plant was not significantly influenced by the various levels of biochar that were used for the experiment. The interactive effects of L× B were significant for vine length per plant, number of leaves per plant and number of branches per plant when increased from 0- 10 t ha-1. However, the interactive effects of L× B were not significant for the leaf area.

Table 5. Effect of Lime and Biochar on the growth parameters of cowpea for site A and B

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Lime (t ha-1)** | **Biochar (t ha-1)** | **Vine length (cm)** | **Number of leaves/plant** | **Number of branches/plant** | **Leaf area/plant (cm2)** |
|  |  | Site A | Site B | Site A | Site B | Site A | Site B | Site A | Site B |
| 0 | 0 | 105.9n | 122.9i | 420.0o | 463.0n | 140.0o | 154.3m | 45258.2b | 27507.8o |
| 0 | 2.5 | 163.7m | 190.0h | 662.0n | 674.0m | 220.7n | 224.7l | 65883.5b | 43422.5n |
| 0 | 5.0 | 174.7lm | 203.7h | 701.0m | 740.0l | 233.7m | 246.7k | 72335.0b | 67545.3m |
| 0 | 7.5 | 195.3kl | 216.8hi | 828.0l | 843.0k | 276.0l | 281.0j | 82403.25b | 81034.8l |
| 0 | 10.0 | 203.8jk | 2169hi | 833.0l | 848.0k | 277.7l | 282.7j | 82892.0b | 81425.8k |
| 2.5 | 0 | 223.5ij | 233.5gh | 942.0k | 1010.0j | 314.0k | 336.7i | 98727.5b | 92276.0j |
| 2.5 | 2.5 | 225.2ij | 233.2gh | 981.0j | 1015.0j | 327.0j | 338.3i | 99216.25b | 94915.1j |
| 2.5 | 5.0 | 227.0hij | 247.2fg | 1022.0i | 1043.0i | 340.7i | 347.0h | 101953.3b | 99998.1i |
| 2.5 | 7.5 | 228.8fghi | 248.6fg | 1033.0i | 1046.0i | 344.3i | 348.7h | 102246.5b | 100780.3i |
| 2.5 | 10.0 | 235.2fgh | 252.2fg | 1176.0h | 1250.0gh | 392.0h | 416.7g | 123751.5b | 121210.0g |
| 5.0 | 0 | 235.2fgh | 257.0efg | 1206.0g | 1256.0gh | 402.0g | 418.7fg | 122187.5b | 115149.5gh |
| 5.0 | 2.5 | 243.6gh | 257.3efg | 1225.0eg | 1265.0gh | 408.3fg | 421.7fg | 122774.0b | 120721.3gh |
| 5.0 | 5.0 | 245.6fgh | 258.5efg | 1230.0ef | 1266.0gh | 410.0ef | 422.0fg | 126390.8b | 120916.8gh |
| 5.0 | 7.5 | 246.8fgh | 262.2efg | 1236.0ef | 1280.0fg | 412.0ef | 426.7ef | 128443.5b | 122774fg |
| 5.0 | 10.0 | 252.2fgh | 262.3efg | 1238.0ef | 1293.0ef | 412.6ef | 431.0de | 131767.0b | 123360.5ef |
| 7.5 | 0 | 252.2fgh | 263.5efg | 1246.0ef | 1300.0ef | 415.3ef | 433.3cd | 123653.8b | 117984.3ef |
| 7.5 | 2.5 | 257.2efg | 267.2def | 1252.0e | 1309.0e | 417.3e | 438.0bc | 125120.0b | 6998556.0de |
| 7.5 | 5.0 | 258.8def | 268.7def | 1284.0d | 1314.0e | 428.0d | 439.7bc | 127075.0b | 125511.0cd |
| 7.5 | 7.5 | 258.8def | 275.4def | 1305.0c | 1319.0e | 435.0c | 446.7bc | 128932.3b | 127759.3c |
| 7.7 | 10.0 | 268.8cde | 286.9cde | 1308.0c | 1330.0cd | 436.0c | 449.3b | 130007.5b | 128052.5b |
| 10 | 0 | 270.2cde | 288.7bcd | 1368.0b | 1348.0c | 456.0b | 459.0a | 134308.5b | 13389.9b |
| 10 | 2.5 | 276.8bcd | 288.8bcd | 1372.0b | 1374.0b | 457.3b | 461.0a | 134992.8b | 133819.8ab |
| 10 | 5.0 | 278.7bc | 290.1abc | 1388.0ab | 1381.0ab | 462.7ab | 464.3a | 135579.3b | 134308.5ab |
| 10 | 7.5 | 303.6ab | 310.7ab | 1394.0a | 1387.0ab | 464.7a | 466.3a | 136654.5b | 135970.3ab |
| 10 | 10.0 | 306.8a | 316.8a | 1402.0a | 1403.0a | 467.3a | 467.7a | 137143.3a | 136556.8a |
| Lime (L) |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS | NS |
| Biochar (B) |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS | NS |
| L × B |  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS | NS |

***4.1.6 Effect of lime and biochar on the yield parameters of cowpea for site A and B***

The effects of lime and biochar on the yield parameters (pod weight per plant and number of pods per plant) are shown in Table 6. Using lime and biochar as a single factor at both sites (A and B), Lime significantly influenced the pod weight of the plant. There was a significant increase in the pod weight of the plant when the level of lime was increased from 0-2.5 t ha-1. The number of pods per plant was also increased when the lime level moved from 0-5.0 t ha-1. Biochar also significantly influenced the pod weight and the number of pods per plant when the level of biochar was increased. The interactive effects of L× B were significant with an increase in the pod weight and several pods per plant when the level of lime and biochar was increased with 2.5 t ha-1 of lime and 0-10 t ha-1 of biochar.

Table 6. Effect of Lime and Biochar on the yield parameters of cowpea for sites A and B

|  |  |  |  |
| --- | --- | --- | --- |
| **Lime (t ha-1)** | **Biochar (t ha-1)** | **Pod weight/plant (g)** | **Number of pods/plants** |
|  |  | Site A | Site B | Site A | Site B |
| 0 | 0 | 44.67fg | 50.67de | 12fg | 16ef |
| 0 | 2.5 | 57.67de | 64.33cd | 12fg | 17ef |
| 0 | 5.0 | 60.67cde | 66.00cd | 12fg | 16ef |
| 0 | 7.5 | 74.00bc | 85.33cd | 14ef | 16ef |
| 0 | 10.0 | 76.33c | 90.33c | 15de | 16ef |
| 2.5 | 0 | 72.33bc | 75.33c | 14bde | 22d |
| 2.5 | 2.5 | 103.67a | 110.33b | 15bc | 25dc |
| 2.5 | 5.0 | 111.33a | 126.00ab | 17bc | 27bc |
| 2.5 | 7.5 | 117.00a | 131.33a | 18ab | 30ab |
| 2.5 | 10.0 | 121.00a | 136.00a | 21a | 32a |
| 5.0 | 0 | 62.67ce | 69.00ef | 15abc | 17ef |
| 5.0 | 2.5 | 35.67gh | 43.00ef | 15abc | 15fg |
| 5.0 | 5.0 | 35.33gh | 41.33ef | 14ef | 14gh |
| 5.0 | 7.5 | 34.33gh | 38.67ef | 13ef | 13gh |
| 5.0 | 10.0 | 30.33gh | 38.33ef | 13ef | 12hi |
| 7.5 | 0 | 28.33ef | 30.67efg | 10ehi | 11kl |
| 7.5 | 2.5 | 27.00ij | 27.67fg | 11hi | 11hi |
| 7.5 | 5.0 | 24.00kl | 26.00fg | 11hi | 11kl |
| 7.5 | 7.5 | 22.33lm | 22.33fg | 9hi | 9jk |
| 7.7 | 10.0 | 21.00m | 20.67fg | 7ij | 9jk |
| 10 | 0 | 24.00kl | 23.00fg | 8hi | 9jk |
| 10 | 2.5 | 21.33m | 22.33fg | 7ij | 8kl |
| 10 | 5.0 | 21.33m | 21.33fg | 7ij | 7lm |
| 10 | 7.5 | 13.67o | 15.00g | 6ij | 5m |
| 10 | 10.0 | 11.67p | 13.33g | 3j | 4m |
| Lime (L) |  | 0.00 | 0.00 | 0.00 | 0.00 |
| Biochar (B) |  | 0.00 | 0.00 | 0.00 | 0.00 |
| L × B |  | 0.00 | 0.00 | 0.00 | 0.00 |

***4.1.7 Effect of lime and biochar on the taproot length and number of nodules for sites A and B***

Figure 1 shows the effects of various combinations of varying levels of biochar alone on the pod weight per plant. Figure 2 also shows the impact of various levels of lime alone on the pod weight per plant. Figure 3 shows the effect of lime and biochar on the taproot length per plant while figure 4 shows the influence of biochar on the number of nodules per plant. Figure 5 shows the combined effect of lime and biochar on the pod weight per plant. Using lime and biochar as a single factor at sites (A and B), Lime significantly influenced pod weight per plant, the taproot length, and several nodules per plant with an increase in the level of lime applied. Similarly, biochar also significantly influenced the pod weight, taproot length, and number of nodules per plant when increased from 0-10 t ha-1. The interactive effects of L× B were significant with an increase in the taproot length and number of nodules per plant when the level of lime and biochar was increased from 0-10 t ha-1 of biochar.

Figure 1: Effect of levels of biochar on the pod weight of Cowpea (Site A and B)

Figure 2: Effect of various levels of lime on the pod weight of cowpea (Site A and B)

Figure 3: Effect of various levels of lime and biochar on the pod weight per plant (Site A and B)

Figure 4: Effect of lime and biochar on the number of nodules per plant (Site A and B)

h

Figure 5: Effect of lime and biochar on the taproot length per plant (Site A and B)

**4.2 Discussion**

The results showed that both sites of the experiment were low in OC, N, Ca, Mg, Na, and K, while the P contents were moderate. The pH of the soil in both sites was strongly acidic (Table 1). These conditions are peculiar to Nigerian savanna soils Adegbite et al. (2020) asserted that soils in the savanna are lacking in chemical fertility and organic matter. The low CEC before the commencement of the experiment may be attributed to the increased level of acidity (H+AL) of the site (Brown and lemon, 2008). The low soil fertility status at both sites may as well be attributed to the characteristically intense rainfall under a tropical condition which could cause express mineralization of organic matter level of the soil and consequently leads to the loss of some nutrients, especially the cations which lowers the soil pH (Uduma et al., 2006) and causes soil acidity problems. Low fertility status could likewise be illustrated by the consistent past cultivation utilizing weighty ranch machinery, for example, circle furrow, plate harrow and plate ridger, and wheel traffic of farm vehicles over years, which compacts the soil and degrades the soil properties (Agbede, 2020). The results of analyzing biochar showed that biochar contains a neutral pH, which can increase the pH of the soil (Table 2). It also contains a relatively high amount of ash content which can act as a source of CaO (quick lime). Biochar also helps in improving soil aggregate stability (structure), increases nutrient content and nutrient availability increases the microbial activities of the soil which adds to the deterioration of organic matter and increments soil fertility. The beneficial effects of Biochar on soil properties have been reported by many researchers and include physical (Chan et al., 2008), chemical (Yamato et al., 2006), and biological changes in soil (Rondon et al., 2007).

The use of lime and biochar alone, or mixture, further developed soil substance properties altogether contrasted and the control. On account of lime alone, it altogether further developed the soil pH, N, P, and OC content. The utilization of lime alone at various levels essentially expanded the pH of the soil and decreased soil acidity. The augmentation of pH after the lime application was because of the expulsion of hydrogen by calcium from lime (CaCO3) that makes the pH expand this was likewise announced by (Moody and Cong, 2008). The discoveries saw on soil pH changes in soil likewise concur with the discoveries of (Ruganzu V. 2009) Expansion of lime at different levels likewise expanded the nitrogen content of the soil this can be related to the augmentation of soil pH. Whenever the soil condition is acidic, a few significant fundamental supplements, for example, N, P, and K will be fixed in the soil and not promptly accessible to be spent by plants (Menzies, 2003). In any case, upon the utilization of different degrees of lime, the pH of the soil was increment subsequently; more N supplement was accessible in the soil. The sort of yield planted can likewise impact how much N is present in the soil after the experiment was led. This is because cowpea is described as being able to house rhizobia microorganisms that add to the obsession with nitrogen for vegetable crops. Notwithstanding, exceptionally acidic soils can hinder the endurance of helpful microscopic organisms that can fix air nitrogen into the soil. The significance of liming the soil in this experiment impacted the soil pH, which takes into consideration further developed exercises of helpful microbes that can fix climatic nitrogen consequently, the N content of the soil expanded. This assertion upholds the aftereffects of the experiment that was led by (Bambara and Ndakidem 2010) in South Africa which was directed to check for the likely potentials of lime and molybdenum on the development, nitrogen fixation, and osmosis of metabolites in the nodulated vegetable.

Only lime was additionally critical for P when various levels were applied to the soil. Lime fundamentally expanded the P content of the soil. P is a significant element in plant supplement and richness. Most plants wouldn't do well without phosphorus. There is frequently a 'withdrawal limit' on how much phosphorus that plants can get from the soil. That is because phosphorus in soils is regularly in structures that plants can't take up. One effect on phosphorus accessibility is the soil's pH level. Assuming soils are excessively acidic, phosphorus responds with iron and aluminum. That makes it inaccessible to plants. In any case, if soils are excessively antacid, phosphorus responds with calcium and becomes blocked off. A significant peculiarity, which is frequently ignored, is that liming can increment phosphate accessibility by stimulating mineralization of soil natural phosphorus. Be that as it may, at high soil pH esteems, the precipitation of insoluble calcium phosphates can diminish phosphate accessibility. An experiment was led by (Amsalu and Beyene 2020) to check for the impacts of lime and phosphorous application on substance properties of soil, dry matter yield, and phosphorus convergence of grain (Hordeum vulgare) become on Nitosols of Emdibir, Southern Ethiopia. Results likewise showed that the P content of the soil can be expanded and made accessible with liming. Grain tissue P fixation was fundamentally impacted by the cooperation impacts of lime and P.

Upon the sole use of lime at the various levels, the OC content of the soil was essentially impacted. Soil natural carbon (OC) mineralization is a significant interaction in the carbon (C) cycle that is straightforwardly connected to soil carbon quality and environmental change (Zamanian et al. 2018).

 Changes in pH, substrate, and supplement availabilities for microorganisms in the soil in the wake of liming can influence OC mineralization. Be that as it may, there are worries about the effect of liming on the dependability of soil natural C (SOC) and its commitment to CO2 discharges (Paradelo et al. 2015). An experiment was directed by (Hongtao et al., 2021) which approves the consequence of expanding OC satisfied with changing degrees of lime. The experiment was directed in Hubei territory in China to check for the impact of dolomite alteration on soil natural carbon mineralization, the outcome showed that dolomite application expanded OC mineralization using upgrading DOC creation and animating microbial development and action, which came about because of the expansion in soil pH through liming of the soil. The experiment essentially impacted the degree of Na, Ca, and Mg when contrasted and controlled. The use of lime at various levels altogether impacted the pH of the soil making plant fundamental supplements, for example, Na, Ca, and Mg to be accessible. As indicated by (Amsalu, 2020) an experiment was directed to check for the impact of replaceable calcium, magnesium, and accessible supplements results additionally showed that interchangeable calcium content of the soil was fundamentally (P ≤ 0.05) impacted by the expanded lime. The replaceable Ca content of the soil increased with higher rates of lime from 8.45 cmol (+) kg-1 (in control treatment) to 22.44 cmol (+) kg-1 at the pace of 24373 mg CaCO3 kg-1 soil. Essentially, one more experiment directed by Achalu et al. (2012) revealed that the utilization of limestone (calcium carbonate) and additionally dolomitic lime (Ca and Mg bicarbonate) increments soil replaceable Ca and Mg individually. With the balance of part of the soil causticity by lime application, negative charges of the soil trade complex are delivered and afterward involved by fundamental cations (Achalu et al., 2012).

Changing degrees of lime application fundamentally impacted the soil causticity (H +Al) by diminishing the corrosiveness of the soil when the soil pH was expanded. Lime adds to the decrease of soil causticity by lessening the convergence of hydrogen particles in the soil. Whenever lime is added to acidic soils that contain high Al3+and H+ focuses, it separates into Ca2+ and OH particles. The hydroxyl particles will respond with hydrogen and Al3+ particles shaping Al3+ hydroxide and water; consequently, increment soil pH in the soil arrangement. An experiment was directed at the Holeta Agricultural research center showed that the soil results following 2 years of liming are portrayed demonstrated that soil pH was altogether expanded and Al3+ was uniquely decreased to an unimportant level (Temesgen et al., 2016). The experiment showed that liming at the pace of 0.55, 1.1, 1.65, and 2.2 t ha-1 expanded soil pH by 0.48, 0.71, 0.85, and 1.1 units, and diminished Al3+ by 0.88, 1.11, 1.20 and 1.19 factory counterparts per 100 g of soil individually, and that implies with progressive expansion in the

Measures of lime, and soil pH values expanded with a comparing decline in interchangeable Al3+ of the soil (Temesgen et al., 2016). Liming the soil at the two destinations fundamentally expanded the CEC of the soil. The expansion in the soil CEC can be connected with the decrease of H+ and Al3+. The cation trade limit (CEC) of a soil addresses the aggregate sum of negative charges accessible to draw in cations in the soil arrangement. Liming acidic soils in a roundabout way build the viable cation exchange capacity (ECEC) of soils that contain organic matter or dynamically charged clay minerals (Bohn et al., 2001). One more experiment was likewise led by (Edmeades, 2012) to check for the impact of lime on cation trade limit and replaceable cations on a scope of New Zealand soils which approves the outcome that expansion in the degree of lime utilized expanded how much CEC present in the soil.

The use of biochar alone altogether affected the soil pH, N, P, K, and OC content. The changing degree of biochar (0-10 t ha-1) caused an increase in the pH, N, P, K, and OC when contrasted with the control (Table 3). In this experiment, the use of biochar brought about expanded soil significant fundamental supplement fixations (for example incomplete N). The expansion in soil pH was probably brought about by particle trade processes, which happen when the terminal OH of Al3+ or Fe2+ hydroxyl oxides. The debris content of biochar may likewise fill in as motivation behind why the pH of biochar soils is higher than the control. It was accounted for (Jones et al. 2012; Wang et al. 2014) that biochar expanded all out C from 2.27 up to 2.78%, complete N from 0.24 up to 0.25%, P from 15.7 up to 15.8 mg kg-1, pH 3.33 up to 3.63. (Wang et al., 2014) revealed an increment. As indicated by (Adekiya et al., 2019) biochar essentially further developed the soil pH, N, P, K, and OC substance. Biochar further developed soil synthetic properties on account of its capacity to assimilate solvent natural matter and inorganic supplements (Thies and Rillig 2009).

(Lehmann and Rondon 2006) additionally revealed that biochar can adsorb both NH4+ and NH3-from the soil arrangement. Biochar is extremely proficient at adsorbing broken down solute supplements like ammonium (Lehmann et al., 2002), nitrate (Mizuta et al., 2004) phosphate (Beaton et al., 1960), and other ionic solutes (Radovic et al., 2001). Biochar as detailed by Jia et al. (2015) can assimilate leachate which can assist with retaining natural matter, complete dissolvable N, plant accessible P, and K, subsequently expanding the supplement maintenance limit of the soil.

 The after effects of soil chemical properties with biochar are in concurrence with those crafted by Njoku et al. (2015) in which rice husk and sawdust biochar rates fundamentally affected every one of the synthetic properties in the soil. 10 t ha-1 (the most note worthy biochar pace) of rice husk and sawdust biochar created the most significant levels of pH, N, K, and OC. The sole utilization of biochar additionally impacted the interchangeable bases (Na, Ca, and Mg) replaceable corrosiveness (H+Al3+) and CEC of the soil while differing levels of biochar were applied into the soil in a sole application. There was a significant increase in the degree of interchangeable bases (Na, Ca, and Mg) when biochar alone was applied from 2.5 t ha-1 to 10 t ha-1 when contrasted with the control. The CEC of the soil was additionally altogether affected by the sole utilization of biochar (Table 4). Various levels of biochar applied at 2 - 10 t ha-1 essentially expanded the CEC of the soil when contrasted with the control. The justification for the expansion in the CEC of the soil could be followed by the high surface area and permeable nature of biochar (Nigussie et al., 2012). Thus, there could be an opportunity for Al and Fe to tie at the trade site of the soil. The diminishing in the interchangeable causticity as per Agusalim et al. (2010) will expand the CEC content of the soil.

The intelligent impacts of lime and biochar essentially affected the pH, N, P, K, and OC (Table 3). The impact was apparent while differing levels (0-10 t/ha of lime and 0-10 t/ha of biochar) of lime and biochar were applied to the soil when contrasted and their only structures. The justification for the expansion in the soil pH is that lime contains CaCO3 and biochar additionally contains debris which can build the pH of the soil by diminishing the hydrogen particle fixation. The addition of N, P, and K proposes that the pH of the soil is helpful for the arrival of fixed fundamental macronutrients in the soil. A decrease in soil acidity through expansion in soil pH at a specific reach will take into consideration the arrival of significant supplements in the soil as indicated by (Edward et al., 2020). The increase in the CEC because of cooperation could be because of a decrease in the corrosiveness when lime and biochar were applied at various levels. Biochar and lime revision likewise expanded the negative charge on soil minerals and along these lines upgraded the low cation trade limit (CEC) inborn to acidic tropical soils. Furthermore, biochar itself is adversely charged (6-59 cmolc/kg; (Munera-Echeverri et al., 2018)) and its expansion to soil adds to expanding soil CEC. It has been proposed that the expanded CEC, brought about by the correction of biochar to tropical soils can upgrade NH4+ adsorption and in this manner lessen N draining (Borchard et al., 2014).

The sole utilization of lime essentially affected the vine length, number of leaves, and number of parts of cowpea. Shifting levels of the applied lime caused a viable expansion in the plant length, number of leaves, and number of parts of the cowpea when contrasted with the control. The Lime application at 10 t ha-1 performed best for plant length, several leaves, and number of parts of cowpea. This outcome connects that of (Muoneke et al., 2012) which decides the development and yield reactions of Lime application at 2.0 t/ha three vegetable cowpea assortments, IT93K-915 (white cultivated and climbing plants), IT86D-880 (brown cultivated and erect plants) and Akidi ani (dark cultivated and spreading plants) to five rates (0, 0.5, 1.0, 1.5 and 2.0 t//ha) of lime (Ca (OH) <sub>2</sub>). The outcome showed that liming continuously expanded the soil pH, the greater part of the development and yield ascribes, for example, rate germination, number of knobs per plant, number of leaves per plant, and plant length. Fresh pod weight, new and dry pod yields, grain yields/ha and 100-seed weight, and 0 t/ha performed best and least fortunate as far as the development and yield of the vegetable cowpea individually. One more field experiment was directed at Samaru to concentrate on the impacts of lime, nitrogen, and phosphorus on the development, endlessly yielding parts of cowpea (Vigna unguiculata (L.) Walp) (Akhtar et al., 2015). The experiment comprised 27 treatments, imitated multiple times, and spread out in a split-plot plan. The impact of lime on development boundaries was huge during development. The sole use of lime at various rates didn't impact the leaf region. This suggests that there was no massive distinction in the fluctuating levels of the applied lime when contrasted and the control.

The utilization of lime alone at various levels essentially impacted the pod weight per plant and the number of pods per plant of cowpea when contrasted and controlled. (Mintah et al., 2020) showed that liming logically expanded the unit weight per plant and the number of cases per plant. The sole utilization of lime additionally impacted the expansion in the taproot length and modulation of the cowpea plant. Various degrees of lime applied caused a huge impact on the development boundaries (taproot length and modulation) when contrasted with the control. (Bello et al., 2017) likewise revealed that utilization of lime essentially expanded root dry weight, shoot dry weight, knob number, and dry load by 42.5%, 35.3%, 65.6%, and half, individually. Additionally, one more experiment was directed to determine cowpea assortment to variable phosphorus manure and lime application rates (Maphoto, 2018). The aftereffect of the experiment was huge for the taproot length of cowpea. (Sadaf et al., 2019) additionally led an experiment to check for the impact of buttonwood Ash (lime material) application on the development of cowpea seedlings. The outcome showed that there was a massive impact on the taproot length of cowpea.

Sole utilization of biochar additionally altogether increments the plant length per plant, the number of leaves per plant, and number of branches per plant when contrasted with the control with treatment 2.5 t ha-1 - 10 t ha-1. The expansion in the development boundaries (plant length per plant, the number of leaves per plant, and number of branches per plant) can be because of the improvement of the physical and chemical qualities of the soil like superior pH; further developed water holding limit, which raises the accessible water to the plant, and worked on nutritional substances of biochar in the firmly acidic soil, which between connect with a guarantee that the essential circumstances are met for the development of cowpea. (Yeboah et al., 2020) prior detailed that the development, yield, and supplement take-up of cowpea were impacted by the use of biochar. The sole use of biochar, be that as it may, affects the leaf region at different degrees of biochar applied when contrasted and the control.

Biochar alone enhanced the unit weight per plant and number of cases per plant while changing degrees of biochar just was applied (Table 6). Biochar was applied at 0-10 t ha-1. The tremendous contrast was shown while the differing level of 2.5 t/ha-1 - 10 t/ha-1 was applied when contrasted with the control. (Miranda et al., 2020) experiment approved that biochar can be utilized to work on the number of cases per plant and weight of units per plant. This can be illustrated by the way that biochar has a high ability to adsorb cations through transient holding, which forestalls its assimilation by plants (Akhtar et al., 2015). This can lessen the osmotic and ionic harmfulness impacts of salts, trailed by more prominent accessibility of water in the soil and better water status of plants (Thomas et al. 2013).

The improvement in soil structure and the substance of supplements like K, Ca, and Mg given by biochar permits better root advancement and expands the proficiency of nitrogen use by plants under saline pressure (Lewis et al., 1989). Every one of these can help add to the expansion in the pod weight and the number of pods per plant of cowpea. The sole use of biochar likewise essentially further developed nodulation and expanded the taproot length per plant at various degrees of biochar 2.5 t/ha-1 - 10 t/ha-1when contrasted and the control. This outcome can be related to the way that biochar likewise helps in further developing soil total dependability (structure), increments supplement content and supplement accessibility expands the microbial exercises of the soil which advances nodulation.

The interaction between biochar and lime additionally affected the development boundaries of cowpea, for example, plant length per plant, the number of leaves per plant, the number of branches per plant, taproot length per plant, and the modulation. There was a critical expansion in the development boundaries while changing degrees of lime and biochar in the blend were applied when contrasted with their only structures. The collaboration between lime and biochar additionally impacted the yield boundaries of cowpea. The heaviness of cowpea pods per plant and the number of cowpea pods per plant were altogether affected. The association between lime and biochar happened at different levels where treatment with 2.5 t ha-1 of lime with 2.5 t ha-1, 5.0 t/ha, 7.5 t ha-1, and 10 t ha-1 of biochar had all the earmarks of being the best yield results for the number of cowpea pods per plants and the heaviness of cowpea pods per plant for the two destinations.

There was a huge connection between pH (water) and cowpea pod weight at the two locales. The R values were - 0.615 and - 0.444 for destinations An and site B separately at P < 0.05. Likewise, the relationship between pH (Kcl) and cowpea pod weight was critical at the two destinations with R upsides of - 0.602 and - 0.509 individually for locales An and site B at P < 0.05. This suggests that the yield of cowpea in this experiment is reliant upon soil pH. Lime at 2.5 t ha-1 with any degree of biochar is satisfactory for cowpea in this experiment. The expansion in the pH of the soil at different levels makes sense of why there is an expansion in the yield of the harvest at the referenced levels. Cowpea is a significant vegetable harvest that will just well in a pH that is between 5.5 – and 6.5. Soil attributes, like pH and Al3+, may think twice about proficiency and plant improvement. pH values beneath 5.0 are accounted to be harmful to nodulation and nitrogen obsession consequently; it will limit the development of cowpea (Appunu and Dhar, 2006). Consequently, the justification behind the expansion in the yield boundary can be followed by having an ideal soil pH condition. The yield boundary that had a low yield as far as several pods of cowpea per plant and weight of pods of cowpea per plant is related to more significant levels of lime, particularly the treatment containing 10 t/ha of lime and differing levels of biochar which incorporate 0 t/ha, 2.5 t/ha, 5.0 t/ha, 7.5 t/ha, 10 t/ha. The decrease in the yield of cowpea can best be made sense of by the presence of ominous soil pH conditions. The pH condition above 7.0 is supposed to be soluble (FFD, 2011). This isn't the most ideal pH condition to trim cowpea. As per (Lima et al., 2014) an experiment was directed to check for cowpea advantageous productivity, pH, and aluminum resistance in nitrogen-fixing microorganisms the outcome demonstrated that serious soluble soils will diminish the yield of cowpea.

 Lack of iron or lime-incited chlorosis achieved by elevated degrees of calcium and magnesium carbonates in the soil most likely was additionally a variable in causing lower cowpea yield. Also, carbonates are viewed as a significant causal variable for Fe and Zn lack in many harvest species filled in calcareous soils (Cartmill et al., 2007). An exceptionally serious basic condition can likewise balance the harvest to encountering a few sicknesses like extremely serious leaf chlorosis. Seed germination could happen in an exceptionally soluble condition however will be extremely poor a while later and can cause hindered development without producing pods or death of the crop in the end.

**CHAPTER FIVE**

 **CONCLUSIONS AND** **RECOMMENDATIONS**

**5.0 Conclusions**

Results of the field experiment at site A and site B showed that combined application of lime and biochar improved soil chemical properties compared with their sole application which further enhanced chemical characteristics (pH, N, P, K, OC, Ca, Na, Mg H + Al3+ and CEC) and growth parameters (vine length per plant, number of leaves per plant, number of branches per plant) of cowpea compared to control. Notwithstanding, the leaf area per plant was not impacted by the application of lime and biochar either alone or in combination. The taproot length per plant and nodulation was additionally improved by the option of sole and join impact of lime and biochar compared with the control. The yield parameters (pod weight per plant and number of pods per plant) were also influenced by the sole and combined use of lime and biochar compared with the control.

**5.1 Recommendation**

The increment in the soil pH varies among the levels of lime and biochar applied. The best treatment that influenced the pH at a favorable condition for the growth and development of cowpea crop is at 2.5 t/ha of lime with 2.5t/ha to 10 t/ha of biochar. The optimum yield of the cowpea crop was achieved at 2.5 t/ha of lime with 10 t/ha of biochar. Hence, result given, the recommended level to achieve optimum yield with favorable soil chemical conditions is 2.5 t/ha lime and 10 t/ha of biochar.

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