**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of the Study**

Maize requires human intervention for its propagation. The kernels of its naturally propagating teosinte ancestor fall off the cob on their own, while those of domesticated maize do not (Benz, 2001). All maize arose from a single domestication in southern Mexico about 9,000 years ago. Maize spread from this region to the lowlands and over the Americas along two major paths (Matsuoka et al., 2002). The centre of domestication was most likely the Balsas River Valley of South-Central Mexico (Piperno, 2011). Maize reached highland Ecuador at least 8,000 years ago (Pagan-Jimenez *et al.,* 2016). The earliest maize plant grew a single, small ear per plant (Davidson, 2014). The Olmec and Maya cultivated maize in numerous varieties throughout Mesoamerica; they cooked, ground, and processed it through nixtamalization for various foods.

Maize spread to the rest of the world because of its ability to grow in diverse climates. It was cultivated in Spain just a few decades after Columbus’s voyages and then spread to Italy, West Africa, the Philippines, and elsewhere (Earle, 2012; Salazar, 2016). When maize was introduced into Western farming systems, it was welcomed for its productivity (Langer, 2009).

Biochar is charcoal obtained from biomass meant to be incorporated into the soil (Lemann *et al.,* 2006). In the past years, biochar grew into one of the great promises to improve soil fertility and in addition, to migrate climate change through carbon sequestration (Roberts *et al.,* 2010; Biederman and Harpole, 2013). Biochar has received particular interest for improving the inherently poor soils in the humid tropics, where large amount of fallow vegetation from shifting cultivation at present usually burned could be used to feedstock for charring (FAOSTAT, 2016). However, although considerable research on biochar in recent years has yielded promising results, these are in consistent and the mechanisms leading to better soil fertility and higher yields are not yet well understood (Shackley *et al.,* 2009; Jeffery *et al.,* 2011). The use of biochar has a good impact on the availability of water, improving soil nutrients that help increase plant growth. Biochar implementation can increase the growth of maize hybrid especially in the addition of crop height and nutrients absorption in the soil (Verdiana *et al.,* 2017). Some studies show an interaction between biochar and fertilizer at the fresh weight of maize hybrid, this is because the provision of biochar is able to increase the quality and quantity of soil so that it affects plant growth (Praing *et al.,* 2018).

Biochar a multifunctional porous material with a small particle size, high surface area, low bulk density, high absorption capacity, and abundant carbon content, has attracted much attention because of its great potential on improving soil physiochemical properties (Khalili *et al.,* 2020; Obia *et al.,* 2021; Hale *et al.,* 2021; Tian *et al.,* 2021). Several studies have addressed the positive effects of biochar treatment on soil physiochemical properties, crop growth and yield and water and fertilizer use efficiency (Lychuk *et al.,* 2015; Li *et al.,* 2018); Danso *et al.,* 2019; Shahzad *et al.,* 2019; Zhang *et al.,* 2020). Additionally, for deficit irrigation, biochar addition/application to agricultural soils is effective in enhancing soil fertility, maize yield, water use efficiency and economic return under low rainfall conditions in Akure, Nigeria (Faloye *et al.,* 2019). For continual biochar application under limited irrigation in arid and semi-arid regions, previous studies have reported improvement in crop yield, water productivity and fertilizer use efficiency through the use of straw biochar (Faloye *et al.,* 2019); Danso et al., 2019; Khalili *et al.,* 2020). It has been previously shown that a single application of 30+/ha of biochar in the first year was beneficial for an increase in crop yield and soil organic matter under the rainfall mulching (Yang *et al.,* 2020).

**1.2 Statement of the Problem**

Maize is an important food crop cultivated throughout the world for food to man and feds to livestock animals. However, despite the number of farmers engaging the cultivation and production of maize there is still low production efficiency/output. This could largely be attributed to poor soils, climate conditions, inadequate fertilizer, inadequate farm inputs, lack of improved variety of seeds and government policies on agriculture. However, many farmers do not follow appropriate cultural practices especially as regards improving and maintaining soil fertility so this study seeks to examine the effects of biochar on the growth and yield of maize in Mubi North Local Government Area.

**1.3 Objectives of the Study**

The main objectives of this study is to assess the effects of biochar on the growth and yield of maize, while the specific objectives are to:

1. Determine the effects of different application rates of biochar on the growth and yield of maize.
2. Determine the best application rate(s) of biochar on the growth and yield of maize.

**1.4 Significance of the Study**

This study would provide agricultural practitioners with information on the effect of biochar application on the growth yield of maize so as to boast agricultural production.

**1.5 Scope of the Study**

The study will be limited to Mubi North LGA and maize variety on the effects of biochar application on growth and yield of maize (*Zea mays*) in 2025 cropping season.

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1 History and Origin of Maize**

Maize requires human intervention for its propagation. The kernels of its naturally – propagating teosinte ancestor fall off the cob on their own, while those of domesticated maize do not (Benz, 2001). All maize arose from a single domestication in southern Mexico about 9,000 years ago, the oldest surviving maize types are those of the Meximan highlands and maiz spread from this region to the lowlands and lower the Americans along two major paths (Matsuoka *et al.,* 2002). The center of domestication was most likely the balsas river valley of southcentral Mexico (Piperno, 2011). Maize reached highland Ecuador at least 8,000 years ago (pagan-Jimenez *et al.,* 2016). It reached lower central America by 7600 years ago and the valleys of the Colombian Andes between 7,000 and 6,000 years ago (Piperno, 2011). The earliest maize plants grew a single, small ear per plant (Davidson, 2014). The Olmec and Maya cultivated maize in numerous varieties throughout Mesoamerica; they cooked, ground and processed it through mixtamalization (Roney, 2009). By 3000 years ago, maize was central to Olmec culture including their calendar, language and Myths (Fussell, 1999). Maize is the domesticated variant of the four species of teosintes, which are its crop wild relatives (Whipple et al., 2011). The teosinte origin theory was proposed by the Russian botanist Nikolai Ivanovich Vavilov in 1931 and the American Noble prize winner George Beadle in 1932 (Wilkes, 2004). In the late 1930s, Paul Mangelsdorf suggested that the domesticated maize was the result of a hybridization event between an unknown wild maize and a species of Tripsacum a related genus (Wilkes, 2004). Maize pollen dated to 7,300 years ago from San Andres, Tabasco has been found on the Caribbean coast (Ranere et al., 2009). A primitive corn was being grown in Southern Mexicon Central America and Northern South America 7,000 years ago. Archaeological remains of early maize wars forund at Guila Naquitz cave in the Oaxaca valley are 6,250 years old, the oldest ears from caves near Tehuacan, Puebla are 5,450 years old (Roney, 2009).

**2.2 Botanical Description**

Maize is a tall annual grass with a single stem ranging in height from 1.2 – 4m (4 – 13ft) (Solaimalai et al., 2020). The long narrow leaves arise from the nodes or joints, alternately on opposite sides on the stalk (Solaimalai et al., 2020). Maize is Monoecious, with separate male and female flowers on the same plant at the top of the stem is the tassel, an inflorescence of male flowers and their anthers release pollen which is dispersed by wind (FAO, 2018). Like other pollen, it is an allergen but most of it falls within a few meters of the tassel and the risk is largely restricted to farm workers (Oldenburg et al., 2011). The female inflorescence some way down the stem from the tassel is first seen as a silk, a bundle of soft tabular hairs one for the carpel in each female flower which develops into an ear or corn cob enveloped by multiple leafy layers or husks (Solaimalai et al., 2020). The ear leaf is the leaf most closely associated with a particular developing ear. This leaf and those above it contribute over three quarters of the carbohydrate (starch), that fills the grain (integrated crop management, 2021). The grains are usually yellow or white in modern varieties, other varieties have orange, red, brown blue, purple or black grains. They are arranged in 8 to 31 rows around the cob; there can be up to 1200 grains on a large cob (Davidson, 2014). Yellow maize derive their colour form carotenoids; red maize are coloured by anthocyanins and phlobaphenes; and orange and green varietis may contain combination of these pigments (Chatham et al., 2019).

**2.3 Pest and Diseases**

Many pest and diseases can affect maize growth and development, including invertebrates, weeds and pathogens (Muller and Pope, 2009). Maize is susceptible to a large number of fungal bacterial and viral plant diseases (Wise, 2024). Those of economic importance include diseases of the leaf, smuts, ear rats and stalk rots (Adkins, 2018). Northern corn leaf blight damages maize throughout its range, whereas banded leaf and sheath blight is a problem in Asia (Juroszek and Von, 2013). Some fungal diseases of maize produce potentially dangerous mycotoxins such as aflatoxin (Ostry et al., 2015). Another serious pests is the fall army worm (*Spodoptera frugiperda*). The maize weevil (*Sitophilus zemais*) is a serious pest of stored grain (pest web, 2011). The northern armyworm, oriented armyworm or rice ear cutting caterpillar (*Mythimna separata*) is also or a major pest of maize (Thakur et al., 1987). Nematodes too are pests of maize crop. It is likely that every maize plant harbours some nematodes parasites and populations of pratylenchid lesion nematodes in the roots can be enormous and its effects is stunting of growth and sometimes of whole fields especially when there is also water stress and poor control of weeds (Norton, 1983).

**2.4 Soil and climatic requirements**

The maize crop is grown in climates ranging from temperate to tropic during the period when moan daily temperatures are above 15oC and frost free (Akande et al., 2007). Adaptability of varieties in different climates varies widely, successful cultivation markedly depends on the right choice of varieties so that the length of growing period of the crop matches the length of the growing season and the purpose for which the crop is grown (Akande, 2005; Vasanthi and Kumarawamy, 2000). When mean daily temperatures during the growing season are grwter than 20oC, early grain varieties take 80 – 110 days and medium varieties 110 – 140 days to mature (Bahrani et al., 2007). The maize crop thrives in warm climates with temperature above 15oC, requiring well-drained, fertile and loamy soils with good aeration and drainage and a pH range between 5.8 – 6.8 (Feng and Vin, 2009). While the crop can tolerate drought, it requires sufficient rainfall, especially during flowering and grain filling periods. Maize requires adequate levels of Nitrogen (N), Phosphorus (P), and Potassium (K) as well as other essential elements and nutrients (Rasool et al., 2008). It is sensitive to water logging, so well-drained soils are essential, especially during flowering and yield formation (Sakurai and Kolchtar, 2005). The crop does not do well in compacted, muddy and clayey soils, as well as areas with tress, shaded regions and ant hills (Nagassa et al., 2005).

2.5 Weed Control

Weed management is a severe issue in forage crop production and weeds play a large piece in fodder maize production. World wide yield losses in maize due to weeds are estimated to be around 37% (kumawat et al., 2019). Farmers usually give prime attention and importance to few cultural practices and neglect other factors like weed control (Tanisha et al., 2022). Maize crop are infested with a variety of weeds and subjected to intense weed competition, resulting in huge losses (Verma et al., 2022). Weeds are a major problem in rainy season crops due to favourable growth conditions, primarily wide spacing and initial slow growth, frequent rains, causing huge losses ranging from 28 to 100% (Shukla et al., 2022; Sahu et al., 2022). Herbicides control measure is one of the ways to get higher productivity with lower cost involvement. However, continuous use of these herbicides causes shift in weed flora and development of resistance to herbicides (Verma et al., 2022; Patel et al., 2023). Herbicides are used to retain weed-free conditions during the early stage of growth either by cultural or mechanical means or through pre-planting, pre-emergence and post-emergence applications (Sahu et al., 22023; Shiv et al., 2023). Pre-emergence or early post-emergence atrazine application followed by inter cultivation has been shown to be quite successful in Kharif maize (Heap, 2019). Farmers sometimes fail to apply atrazine as a pre-emergence spray due to excessive soil moisture as a result of exceptional rains. In such cases, applying a post-emergence herbicide may be viable option (Kumawat et al., 2021).

**2.6 Effects of biochar application on Maize**

To minimize the effects of the climate change to agricultural soils and crop production, biochar has been introduced since last two decades (Laird, 2008; Lehman and Joseph, 2009). When biochar is applied to the soil, its health is improved in terms of increased water retention, sorption capacity, nutrients availability, plant growth, carbon sequestration and less leaching (Laird, 2008). Biochar made from different sources and at different temperatures have different chemical composition (Lehman et al., 2011). Most of the oxygen and hydrogen present in organic matters are lost when subjected to pyrolysis (FAO, 2016). On the other hand, biochar is much more stable carbon content than original organic matter (Keiluweit, 2010). By using biochar as soil amendment, CO2 (carbon monoxide) emission can be reduced in atmosphere, which helps in mitigating global warming (Lehman, 2007). Biochar contain almost all plant nutrients needed to support the growth and yield of maize but their concentration may vary depending on the type of parent material used beside oxygen, all other nutrients are retained in biochar after pyrolysis (Chan and Xu, 2009).

Chan et al. (2007) observed that plant nutrient uptake and availability of elements such as phosphorus, potassium and calcium are typically increased while free aluminum is decreased in solution in biochar amended soils. Biochar at the rates of 20 and 40 t/ha with nitrogenous fertilization on maize showed 5.8% and 7.3% increase in yield respectively, while with the same rates of biochar when nitrogen is added, an increase of 8.8% and 12.1% respectively was observed (Zhang et al., 2011).

**2.7 Utilization/Importance of Maize**

Maize and cornmeal (ground dried maize) constitute a staple food in many regions of the world (Davidson, 2014). Maize is used to produce the food ingredients corn starch (Merriam, 2016). Mize starch can be hydrolyzed and enzymatically treated to produce high fructose corn syrup, a sweetener (European Starch Association, 2013). Maize may be fermented and distilled to produce bourbon whiskey, corn is extracted from the germ of the grain as well (Kiniry, 2013).

Although maize naturally contains niacin an important nutrient, it is not bioavailable without the process of nixtamalization. The Maya people used nixtamal meal to make porridges and tamales (Pilcher, 2012). Maize is also a major source of animal feed, as a grain crop the dried kernels are used as feeds for animals (Adkins et al., 2020). When the whole maize plant (grain plus stalks and leaves) is used for fodder, it is usually chopped and made into silage as this is more digestible and more palatable to ruminants than the dried form (Heuze et al., 2017). In the tropics, maize is harvested year round and fed as green forage to the animals (Heuze et al., 2017). Baled cornstalks offer an alternative to hay for animal feed, alongside direct grazing of maize grown for this purpose (Bale cornstalks, 2023). Starch form maize can be made into plastics, fabrics, adhesives and many other chemical products (Corn Refiners Association, 2013). Corn steep liquor a plentiful water byproduct of maize wet milling process is used in the biochemical industry and research as a culture medium to grow microorganisms (Liggett and Koffler, 2021).

**CHAPTERTHREE**

**MATERIALS AND METHODS**

**3.1 Location of the study**

A field experiment will be carried out at the teaching and research farm Department of Agricultural Technology, Federal Polytechnic, Mubi, Adamawa State during the 2025 rainy season to determine the effect of biochar application on the growth and yield of maize crop. Mubi is in the Northern guinea savannah of Nigeria situated between latitude 10o10 and 10o30 North of the equator and between longitude 13o10 and 13o30 East of Greenwich meridian and at an altitude of 696 meters above mean sea level (Adebayo, and Tekwa, 2010).

**3.2 Source of Seed**

The seeds will be bought from the main market in Mubi.

**3.3 Treatment and experimental design**

The experimental design will be laid out in a Randomized Complete Block Design (RCBD) the treatments will consist of four different rates of biochar fertilizer (200kg/ha, 150kg/ha, 100kg/ha and 50kg/ha) respectively. All treatment will be replicated three times accordingly each with a control. The total land area will be 17m x 11m = 187m2 and each sub plot will be 3m x 3m = 9m2.

experiment.

The treatment will comprise of four different rates of biochar fertilizer; 0kg/ha (control), 50kg/ha, 100kg/ha, 150kg/ha, and 200kg/ha laid out in a Randomized Complete Block Design (RCBD), replicated three times. The total land area will be 32m x 11m = 352m2 and each plot will be 3m x 6m = 18m2.

11m

T1

T3

T2

T3

T4

T5

T5

T1

T3

3m

6m

REP III

REP II

REP I

T2

T1

T4

.

1m

T4

T2

T5

17m

Figure 1: Field layout of the experiment

**Key:**

**Rep I -** means replication 1

**Rep II -** means replication 2

**Rep III -** means replication 3

**T1** - Control

**T2** - 50kg/ha

**T3** - 100kg/ha

**T4** - 150kg/ha

**T5** - 200kg/ha

**3.4 Cultural Practices**

***3.4.1 Land preparation***

The land will be cleared manually using hoe, cutlass and then ploughed using tractor. The area will be marked out into plots replicated in a Randomized Complete Block Design (RCBD).

***3.4.2 Sowing***

The sowing will be done in June when rainfall is well established and two seeds will be placed by hole in a depth of 1.5 – 2.0cm.

***3.4.3 Thinning***

The thinning operation will be done at two weeks after sowing (2WAS) and excess seedlings will be removed.

***3.4.4 Spacing***

The spacing will be done at 75cm x 50cm inter and intra spacing

***3.4.5 Weeding***

Weeding will be done at three to four weeks after sowing and when necessary to keep the experimental plots free from weed competition.

***3.4.6 Fertilizer Application (Biochar)***

The application of biochar will be done at different rates of 200kg/ha, 150kg/ha, 100kg/ha and 50kg/ha respectively.

***3.4.7 Harvesting***

The maize crop will be harvested manually by hand plucking the matured cobs at 12 weeks after sowing.

**3.5 Collection of Data**

***3.5.1 Plant Height (cm)***

The plant height will be measured using a meter rule from the base to the tip (top) of the plant at 4, 6 and 8 weeks after sowing and the average mean recorded.

***3.5.2 Number of leaves/plant***

This will be done by counting the leaves manually on the randomly selected 5 plants at 4, 6 and 8 weeks after sowing and the average mean recorded.

***3.5.3 Stem girth (mm)***

Will be taken at 4, 6, and 8 weeks after sowing (WAS) with the help of a digital vernier caliper and their average computed and recorded.

***3.5.4 Days to tasslings***

This will be done first by visual observation when the crop plant produces its first tasslings and the mean average recorded.

***3.5.5 Weight of fresh cob***

This will be done by weighing the fresh cob of maize using an electronic scale in grams and mean recorded.

***3.5.6 Days to Silking***

This will be done by observing the time when the crop produce its first silk and the mean average recorded.

***3.5.7 One thousand seed weight***

This will be done by counting 1000 seeds from each treatment and then weighed and the average mean recorded.

***5.5.8 Grain yield (kg/ha)***

This will be obtained at harvest.

**3.6 Statistical Analysis**

Data collected will be subjected to analysis of variance (ANOVA), using SAS (2020) version and treatment means will be separated by Duncan’s multiple range test (DMRT) ≤ at P 0.05.