EFFECTS OF MAGNESIUM (Mg) NANOPARTICLES ON THE GROWTH OF MAIZE (*Zea mays L.*) IN A FERRUGINOUS SOIL

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A PROJECT THESIS SUBMITTED TO THE DEPARTMENT OF PLANT BIOLOGY AND BIOTECHNOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR SCIENCE (B.Sc.) IN PLANT BIOLOGY AND BIOTECHNOLOGY.

SEPTEMBER,2023

CERTIFICATION

This is to certify that this work was carried out by Peace Isimen ACHIOYA in the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria.

Mrs. F. N. EGBENOMA	____________________________
Project Supervisor	Signature and Date

Prof. D. E. Vwioko	____________________________
Head of Department	Signature and Date

DEDICATION

This work is dedicated to my Dad, The Late Comrade Achioya Omodigie Andrew.

ACKNOWLEDGEMENTS

I appreciate God almighty for his grace, strength and enablement to complete this work. I appreciate my project supervisor Mrs. F. N. EGBENOMA for her guidance, patience and calmness all through this course of study, thank you for everything you taught me. I am also immensely grateful to Prof D. E. Vwioko (the head of department of plant biology and biotechnology), thank you for understanding and being a father. I also appreciate the project coordinator Dr. J. O. Erhabor, God bless you immensely, I deeply appreciate my Mother, (Mrs) Mary Achioya and my beloved Uncle, Anthony Odiase Imusen, your contributions in my life have made my path easier and it is my desire to always make you both proud. Lastly I would love to appreciate my Mentors and Spiritual parents Timi Erewejoh and Mega Erewejoh, Thank you for your prayers and my project partner Divine Okuigbedi.

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ABSTRACT

Magnesium nanoparticles have potentials on plant growth and development, Ferruginous soil is known for their high iron content and addition of maize nanoparticles may have several impacts on the maize plants. Magnesium is an essential nutrient for plants and play a crucial role in various physiological processes including photosynthesis, enzyme activation, nutrient uptake. The application of magnesium nanoparticles in ferruginous soil may also enhance the availability and uptake of magnesium by maize plants leading to improved growth, increased chlorophyll content, and enhanced photosynthetic efficiency. However, it is important to note that specific effects of magnesium nanoparticles on maize plant in ferruginous soil may depend on the following factors such as nanoparticle concentration, application method and soil conditions. This study reveals the effect of nanoparticles on maize, the plant extract used was the *Hibiscus sabdariffa* and varying concentrations of this magnesium nanoparticle was added to the plants. The parameters assessed include Plant height, Leaf length, Leaf breadth, Leaf area and Stem girth. The observed enhancement was attributed to the application of this Magnesium nanoparticles.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The 21st century saw the introduction of nanoparticles (NPs) in agriculture. In order to satisfy the demands of dietetic supplies for the rapidly expanding world population, more attention is now being paid to the use of nanoparticles to reduce dependency on chemically manufactured fertilizers for feasible plant development. Because of their extremely high surface area to volume ratio and rapid mass relocation, Nanoparticles increase the benefit of the efficient release of agrochemicals. The application of Nanomaterials in agriculture aims to reduce nutrient losses to increase yields, reduce the amounts of products for plant protection (Usman *et al*., 2020), and minimize the cost of production to maximize output.

1.2 MAGNESIUM

Magnesium (Mg) is a vital mineral nutrient for all living organisms and it is being considered as a non-toxic element in nature. In plants, the majority of Mg2+ is allied with proteins and chlorophyll molecules and works as a cofactor of enzymes participating in the photosynthetic fixation of carbon metabolism. Mg deficiency directly influences the growth, physiology and metabolism of plants. Magnesium oxi(MgO-NPs), which are non-toxic and cheaply available, can exert significant roles in themorpho-physiological functioning of the plants. They have effective antibacterial, anticancer and antioxidative properties offering plants stress resistance and increased plant growth. Photosynthetic attributes along with chlorophyll content has been reported to increase significantly in plants treated with MgO-NPs. Recent studies reported that MgO-NPs have been used for improving plant growth and development and preventing toxicity, and that green MgO-NPs significantly improved seed germination rate and growth contributing to agricultural sustainability.

1.3 NANOPARTICLES

NPs are extremely small materials, ranging in size from 1 to 100 nm. Based on their characteristics, shapes, or sizes, they can be divided into many classifications. Fullerenes, metal NPs, ceramic NPs, and polymeric NPs are some of the various groupings. Due to their large surface area and nanoscale size, NPs have distinct physical and chemical characteristics. According to reports, the size influences their optical characteristics and imparts various hues through visible-range absorption. Their distinctive size, shape, and structure also affect their reactivity, toughness, and other qualities. (Khan *et al,*.2019).

1.4 THE MAIZE PLANT

The most frequently grown crop in the world is maize (*Zea mays L.*), a domesticated cereal grain that originated in Central America. One of the most adaptable developing crops, it has a wide range of uses. Due to its maximum genetic production potential, maize is referred to as the "queen of cereals" internationally. The only food cereal crop that can be cultivated in a variety of climates, ecosystems, and environments is maize. Other varieties of maize include regular yellow/white grain, sweet corn, baby corn, popcorn, waxy corn, high-amylase corn, high-oil corn, and quality protein maize, among others. In addition, maize is a significant industrial raw material that offers significant potential for value addition. The word “maize” is from the Spanish connotation maize which is the best way of describing the plant. Various other synonyms like zea, silk maize, makka, barajovar, etc. are used to recognize the plant (Kumar and Jhariya,2013).

1.4.1 TAXONOMY OF MAIZE.

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Liliopsida

Subclass: Commelinidae

Order: Cyperales

Family: Poaceae

Subfamily: Panicoideae

Tribe: Andropogoneae

Genus: Zea

Species: Zea mays

The genus Zea contains four species, the most important of which being Zea mays L. The remaining Zea species, known as teosintes, are mostly wild grasses native to Mexico and Central America. Zea mays has a total of 2n = 20 chromosomes. The tribe Andropogoneae consists of seven genera divided into old and new world groups. Coix (2n = 10/20), Chionachne (2n = 20), Sclerachne (2n = 20), Trilobachne (2n = 20), and Polytoca (2n = 20) are members of the old world group, while Zea and Tripsacum are members of the new world group. (Biology of maize,2011).

1.4.2 PHYTOCHEMICAL VALUE OF MAIZE

Phytochemicals are bioactive chemical substances found naturally in plants that have the ability to improve human health and reduce the risk of major chronic diseases (Liu, 2004). Maize is an important source of carotenoids, phenolic compounds, and phytosterols (Jiang and Wang, 2005; Kopsell *et al*., 2009; Lopez-Martinez *et al.,* 2009).

1.4.2.1 Carotenoids

Carotenoids are pigments that are red, orange, and yellow in color. Yellow maize grains contain a high concentration of carotenoid colors, particularly in the horny and floury endosperm (Liu, 2007). These pigments are classified into two types: carotenes, which are entirely hydrocarbons with no oxygen, and xanthophylls (lutein and zeaxanthin), which are oxygen-containing hydrocarbons.

1.4.2.2 Phenolic compounds

Phenolic compounds are the most abundant phytochemical class in plants (Saxena *et al*., 2013). Phenolic acids, flavonoids, stilbenes, coumarins, and tannins are among examples (Liu, 2004). These chemicals are prevalent in maize, particularly in the bran (Zhao, *et al.,* 2005). Ferulic acid (FA) or 4-hydroxy-3-methoxycinnamic acid and anthocyanins are the main phenolic chemicals found in maize. The highest FA content is found in refined maize bran, followed by barley and wheat (Zhao and Moghadasian,2008). Anthocyanins are common class of phenolic compounds collectively as flavonoids. They are the largest group of water-soluble plant pigments which are reddish to purple in color. Maize has the second highest concentration of anthocyanins (Abdel-Aal, *et al,* 2006). The most abundant anthocyanin compounds reported in maize are, pelargonidin-3-glucoside, peonidin-3-glucoside, pelargonidin-3-(6″malonylglucoside), cyanidin-3-glucoside, cyanidin-3-(3″, 6″-malonylglucoside) and cyanidin-3-(3″, 6″ dimalonylglucoside) (Salinas *et al*.,2005).

1.4.2.3 Phytosterols

Phytosterols also called as plant sterols are the essential components of plant cell walls and membranes (Piironen *et al*.,2000). More than 250 different phytosterols have been found so far which are divided into three classes based on their number of methyl groups at C-4 position: simple sterols or 4-desmethylsterols, 4, 4-dimethylsterols, and 4-monomethylsterols. Maize oil is very rich in phytosterols (Verleyen et al.,2002). The most commonly consumed phytosterols from maize oil are sitosterol, stigmasterol, and campesterol. Their distribution varies in different fractions of maize kernel such as endosperm, pericarp, and germ (Harrabi et al.,2008).

1.4.3 ORIGIN OF MAIZE

The primary Centre of origin of maize is considered by most authorities to be the Central America and Mexico, where many diverse types of maize are found. The discovery of fossil maize pollen with other archaeological evidence in Mexico indicates Mexico to be the native of maize.

1.4.4 GEOGRAPHIC DISTRIBUTION

Maize is cultivated throughout the world. From 58°N latitude to 40°S latitude, the crop spreads and cultivated over 139 million ha of area and around 600 million tons of maize is produced. Crop occupies the third position next to rice and wheat in area and production. USA, China, Brazil, Mexico, India, Romania, Philippines, Indonesia are some of important countries cultivate maize crop. In India, Rajasthan, UP, MP, Bihar, Karnataka, Gujarat, AP, J&K, HP and Maharashtra are important states that produce maize.

1.4.5 ECONOMIC IMPORTANCE

It is staple human food, feed for livestock, for fermentation and many industrial uses. It is having abundant starch (65%). There are two types of milling. Wet milling produces industrial starch like sweeteners, also produces various modified maize starch for paper lamination, textile wrap, sizing and laundry finishing. Dry milled products are animal feed, brewing, breakfast cereals, other food. In India, dry milling is the predominant process for flour and animal feed, fermentation and distilling industries and composite flours. In the new millennium, it is an alternate crop to rice and wheat. About 35% production is consumed by human, 25% poultry and cattle feed, 15% food processing.

1.4.6 MAIZE GRAIN TYPES

1. Flint corn *(Zea mays indurata*)

Entire outer portion of kernel is hard starch. Flint comes in many colours such as white, yellow, red-blue or their variable.

2. Dent corn (*Zea mays indentata*)

About 95% of production in USA is dent corn. Hard starch is confined to kernel only. The amylose of soft starch in the core contracts when the grain is dried producing characteristic dent in the top of the kernel. May be yellow, white and red colour of kernel.

3. Sweet corn (*Zea mays saccharata*)

Grown for food and harvested at 70% moisture content. It is good source of energy. About 20% of dry matter is sugar compared to 3% in dent corn. It is also a good source of vitamin C & A.

4. Flour corn *(Zea mays amylacea*)

Kernel is largely composed of soft starch with little or no hard starch. Kernels are easy to grind. Primarily used by natives of Andean Highlands of South America.

5. Pop corn *(Zea mays everta*)

It`s kernel is small and extreme form of flint corn. When heated to 170°C, the grain swells and burst and turning inside out. At this temperature, the water held in the starch turns to steam and the pressure causes the explosion.

6. Waxy corn *(Zea mays ceretina*)

Due to waxy appearance of the kernel, it is called as waxy corn. The starch is entirely amylopectin whereas dent has 78% and 22% amylose. Hybrids of waxy are raw materials for wet milling starch industry for textile and paper sizing and corn oil.

1.4.7 SOIL AND CLIMATIC REQUIREMENT

1.4.7.1 Soil requirement

Deep, fertile, rich in organic matter and well drained soils are the most preferred ones for the crop; however, maize can be grown on a variety of soil types. The soil should be medium textured with good water holding capacity. The crop is very sensitive to water logging and since it is mainly grown during rainy season, care should be taken to assure that water does not stagnate on the soil surface for more than 4-5 hours. Loamy or silty loam soil or silty clay loam soil having fairly permeable sub soil is ideal soil types. Thus, the ideal soil is neither clayey or sandy and has a pH between 6.5 and 7.5 along with an exchangeable capacity of around 20 mill-equivalent/100g, base saturation of 70-90%, bulk density of about 1.3 g/cc and water-holding capacity of about 16cm/m depth.

1.4.7.2 Climatic requirement

Maize requires 9 to 30°C from planting to emergence. Emergence to silking, leaf number increases with temperature and photoperiod. Increase in time to tassel as the diurnal variation increase from 0-17°C. Maximum rate of maize growth is at 30°C. Longer the grain filling period, higher the grain yield provided no freezing temperature. Higher the solar radiation, higher will be the photosynthesis in maize.

1.4.8 SEASON AND VARIETIES

Maize is grown in three seasons, viz., Adipattam (July -August), Purattasipattam (September-October) and Thaipattam (January-February). The cultivars such as CO 1, COH (M)4, COH (M) 5, COBC 1 (Baby corn) suit in Tamil Nadu.

1.4.9 USES OF MAIZE

1. Livestock feed: It is used as livestock feed particularly for chickens, cattle and pigs. Maize is rich in protein and energy that supports growth and productivity.

2. Pharmaceuticals: Certain elements of corn such as corn silk and corn oil have a long history of use on traditional medicine due to their various health promoting properties.

3. Food and nutrition: Maize is diet for millions of people around the globe, it is eaten as cornmeal, corn flour, syrup, oil and popcorn, carbohydrates, fiber and important vitamins (A, B, and C) and minerals (iron, zinc) are all abundant in maize.

1.5 FERRUGINOUS SOIL

Of or containing iron or iron rust. A ferruginous soil is a very deep, zonal soil found in warm temperature climates without a day season or in tropical savannas/ bushlands. The A horizon is dark red-brown with a weak crumbling structure; the B horizon is strained red by ferruginous gravel. In US soil classification, a ferruginous soil is an ultisol. (Warkentin,2006). In Nigeria it is found in some southern states such as Edo State occupying about seven zones including North and Central Benin (Dayou *et al*.,2017). The availability and movements of nutrients may be hindered by the presence of ferruginous soil due to high concentration of iron in the soil. The plants may experience nutrient deficiencies since the iron oxides in the soil can interact with the nutrients, making the plant roots to easily obtain nutrients such as magnesium, potassium and phosphorus.

1.6 LITERATURE REVIEW.

(Tapan Adikhari ,2019) made an investigation on utilizing the property for increasing rate of photosynthesis of maize plant and subsequently higher root exudations which enhance the microbial activities in soil. Green house experiments were conducted to evaluate the effect of MgO Nano particles spray on maize plant (Zea mays L.) in three benchmark soils of India which are phosphorus (P) deficient. Results revealed that application of MgO Nano particles sprays 10 mg/L (viz. 15, 28, and 35 days after sowing) enhanced the enzymatic activities like phytase and phosphatase particularly in roots of P deficient plant. With the application of both P doses (viz. 0, 13, 26, and 52 mg kg-1) and MgO Nano particles spray increased the different growth parameters of plants like root length, root volume, dry weight of shoot and root etc. irrespective of soils. The results can enhance our understanding on the role of MgO nano particles spray in plant root exudation and as well as in increasing maize's drought resistance.

(Ahmed *et a*l.,2021) report the green synthesis and characterization of magnesium oxide nanoparticles (MgO-NPs) from a native Enterobacter sp. strain RTN2, which was genetically identified through 16S rRNA gene sequence analysis. The biosynthesis of MgO-NPs in reaction mixture was confirmed by UV–vis spectral analysis. X-ray diffraction (XRD) and Fourier transform-infrared spectroscopy (FTIR) analysis showed the crystalline nature and surface properties of MgO-NPs, respectively. Moreover, electron microscopy (SEM-EDS, and TEM) imaging confirmed the synthesis of spherical shape of MgO-NPs with variable NPs sizes ranging from 38 to 57 nm. The results revealed that application of MgO-NPs (200 mg kg−1) in As contaminated soil significantly increased the plant biomass, antioxidant enzymatic contents, and decreased reactive oxygen species and acropetal as translocation as compared with control treatment. The study concluded that biogenic MgO-NPs could be used to formulate a potent Nano fertilizer for sustainable rice production in metal contaminated soils.

(Kaur *et al.,*2022) in his article reports that nanotechnology is speedily gaining significance and a prominence interest among the farmers. In the present study, the chemical and green synthesize

MgO nanoparticles are used for the treatment of maize seeds germination. The green method is a simple, reducing toxic chemical's concentration, an eco-friendly and economically viable. Hence, a locally available plant *Cissus quadrangularis* was selected for MgO nanoparticle's synthesis. The result of XRD, TG/DTA, SEM, TEM, and PSA analysis confirmed formation of MgO nanoparticles. XRD showed the crystalline size of chemical and green synthesized nanoparticles are 25 nm and 24 nm, and the morphology is spherical analysed by SEM. This study is carried out to determine the nanoparticles penetration inside the seed coat, root growth, shoot growth and stimulate the growth hormones. The MgO nanoparticles capability to amplify the dry weight by delivering water to the whole seedling which help to enhance the water nutrient transport and the biomass. The experiment was administered under greenhouse conditions. From the results obtained it is suggested that a green MgO could be used effectively in agricultural fields.

1.7 AIMS AND OBJECTIVES.

The following are the aims and objectives for carrying out this research;

1. To provide detailed information for the agricultural application of magnesium nanoparticles to enhance the production of maize in a ferruginous soil.

2. To determine the optimal concentration of magnesium nanoparticles to enhance growth of maize in a ferruginous soil.

3. To evaluate the Physiological response of maize plants when exposed to magnesium nanoparticles.

4. To investigate growth parameters of maize plants in a ferruginous soil affected by the application of magnesium nanoparticles.

CHAPTER TWO

MATERIALS AND METHOD

2.1. MATERIALS USED

The materials used include; Nylon planting bags, a measuring cylinder, disposable hand gloves, maize seeds, heavy metals, weighing balance, zobo leaves.

2.1.1 STUDY AREA

This study was conducted at the botanic garden of plant biology and biotechnology close to the environmental management and toxicology lecture theatre.

2.1.2 SOURCE OF PLANTED SEEDS.

The seeds of *zea mays* were gotten from Lagos street, Ibiwe at ring road.

2.1.3 SOURCE OF SOIL.

The soil was gotten from a field at the back of Faculty of Agriculture farm close to Keystone hostel, University of Benin, Benin City

2.1.4 DISTILLED WATER

This was gotten from the Department of Chemistry, Faculty of Physical Sciences, University of Benin, Benin City.

2.1.5 POLYTHENE BAGS

2.1.6 SOURCE OF HEAVY METAL

The materials were gotten from Pyrex-ig scientific company, shop 14 Gabano plaza opposite Ubth main gate, Ugbowo, Lagos road Benin city.

2.1.7 WEIGHING BALANCE

CAMRY EMPEROR (44lbs×20oz = 20kg50g). Made in China was used to measure the weight of the soil. It was gotten from the Mushroom Research Centre, Department of Plant Biology and Biotechnology, University of Benin, Benin City.

2.1.8 RULER.

A 30cm Avanti ruler (made in Nigeria) was used to measure plant parameters which includes the plant height, leaf length and leaf breadth.

2.1.9 PLANT EXTRACT

Dried *Hibiscus sabdariffa* (sorreal leaves) which is locally known as zobo leaves was used as the plant extract for the nanoparticles synthesis and it was gotten from a Confectionary store located at Newton Street, Ekosodin, Benin City.

METHOD/EXPERIMENTAL

2.2 PREPARATION OF SOIL SAMPLE

The soil obtained was carefully sieved to remove debris, measured at 7.5kg for each polythene bags and then poured into 60 polythene bags. Each bag was also perforated 25 times to prevent water logging of the soil.

2.2.1 SITE PREPARATION

The proposed site for the study, which was the botanical garden of the Department of Plant Biology and Biotechnology was cleared to get rid of weeds and a black polythene tarp was laid on the ground before the 60 polythene bags containing soil was placed on it.

2.2.2 POLLUTION OF SOIL

The 60 bags of soil were to be polluted with iron (ii) sulphate and as such were divided into three different sections; 1ESV, 3ESV and 5ESV with each section containing 20 bags. For the 1ESV section,0.3g of iron (ii) sulphate was weighed and mixed in 1 litre of water which was then poured on each bag; the same process was done for 3ESV, 0.9g of iron (ii) sulphate was weighed mixed in 1 litre of water and then poured on each bag of soil; this same process was done for all 20bags of soil in the 3ESV section. For the 5ESV section, 1.5g of iron (ii) sulphate was weighed, mixed in 1 litre of water and thereafter poured in each bag; the same process was done for all 20bags in the 5ESV section. The polluted soil was left for 2 days before planting.

2.2.3 RANDOMIZATION OF THE POLYTHENE BAGS

The polythene bag was later randomized after the pollution of the soil into 5 different blocks with each block or sector consisting of 4 bags from the 1ESV section, 4 bags from the 3ESV section and 4 bags from the 5ESV section making 12 bags in a block.

2.2.4 VIABILITY TEST

The *Zea mays* seed to be used were soaked in water for 30 minutes using floatation techniques to test if seeds are viable.

2.2.5 SOWING OF SEED

A hole 3cm was dug in each bag containing soil, a total of 4 seeds were planted in each bag. Germination started 5 days after planting and the various readings of the plant which include the height, length, breadth, area and girth was taken.

PLATE 1: 10 DAYS AFTER THE MAIZE WAS PLANTED.

2.2.6 PREPARATION OF LEAVES EXTRACT OF PLANT USED FOR STUDY

10g of dried *Hibiscus sabdariffa* leaves was weighed and put in a beaker. Distilled water was added to the beaker up to 100ml mark. The beaker containing the *Hibiscus sabdariffa and* distilled water was heated in a pressure cooker for about 30minutes and then it was allowed to cool down. The solution was then filtered and the filtrate used for nanoparticles synthesis.

PLATE 2: ZOBO LEAVES PREPARED FOR NANOPARTICLE SYNTHESIS.

2.2.7 SYNTHESIS OF MAGNESIUM NANOPARTICLES

5ml of aqueous leaves extract of the leaves were added to 50ml of aqueous solution of 0.2 M of Magnesium sulphate ($MnSO_4$) while heating and stirring at 700c and PH 7 for 30 mins.

2.3 DETERMINATION OF GROWTH PARAMETERS.

This was taken weekly to note tangible results in plant growth.

2.3.1 MEASUREMENT OF PLANT HEIGHT.

A 30cm ruler was used to measure the height of the plant from the ground level to the terminal bud.

2.3.2 DETERMINATION OF LEAF NUMBER.

This was counting the number of leaves on the plant and taking note of leaves lost and the ones that withered.

2.3.3 MEASUREMENT OF STEM GIRTH (THE WIDTH OF THE PLANT)

This was measured with the aid of a twine, the twine as wrapped around the plant 3cm away from ground level and then marking the spot, next you take that measurements on a 30cm ruler.

2.3.4 LEAF AREA

The leaf area was gotten by multiplying the length× breadth×0.75.

2.4 STATISTICAL ANALYSIS

The data collected from the measurements of the plant height, leaf length, leaf breadth, leaf area and stem girth were analyzed using Microsoft Excel to derive the mean and standard problem.

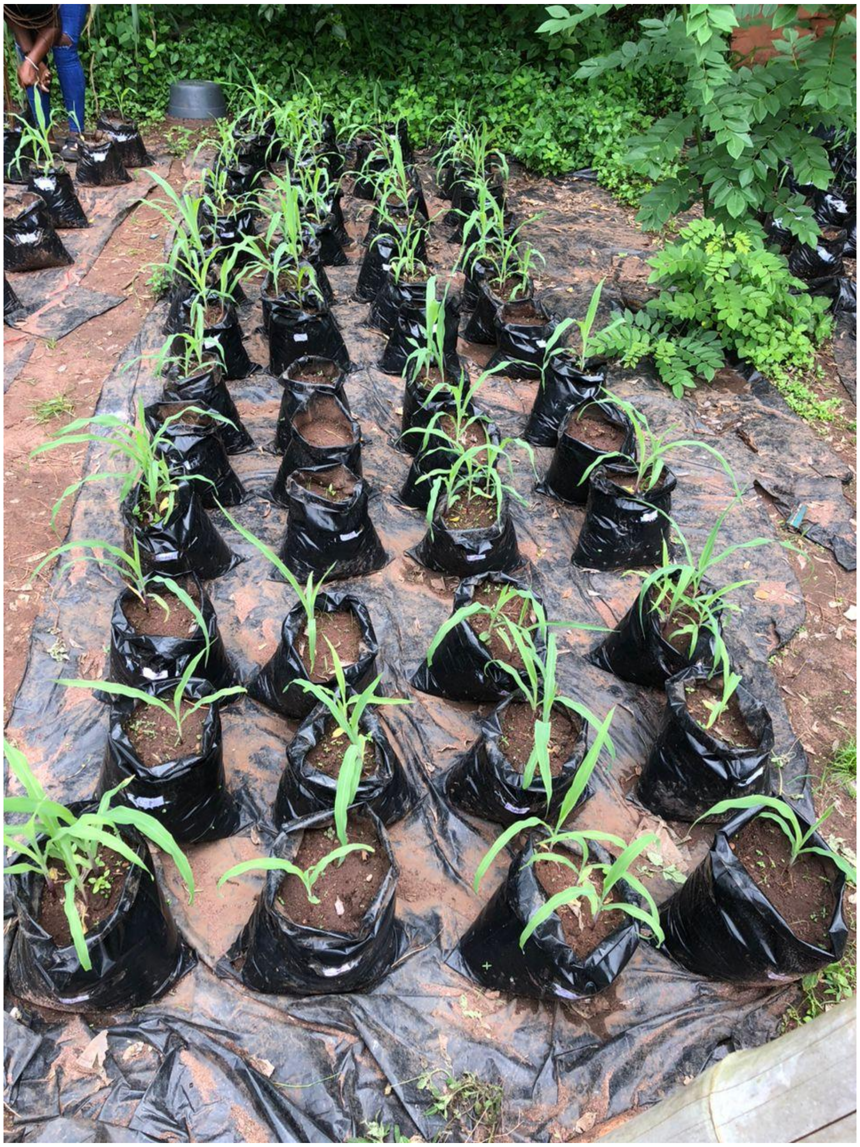

PLATE 3:2 WEEKS AFTER GERMINATION OF MAIZE