# EFFECT OF COW DUNG + INORGANIC NPK-SOURCE AND TILLAGE PRACTICE ON GROWTH OF MAIZE

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## CERTFICATION

This is to certify that this research work has been completed, read through and approved as meeting the requirement of the department of Agricultural Technology, Institute of Applied Science, Kwara State Polytechnic, Ilorin in Partial fulfilment for the award of National Diploma in Agricultural Technology

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## DEDICATION

I dedicated this project to Almighty Allah and my Parent

**ACKNOWLEDGMENTS**

My sincerely goes to Almighty Allah who has been the yardstick towards my successful during the project program

My gratitude also goes to my parents Mr. and Mrs. LABAEKA for their support throughout my project program lastly my gratitude goes to my project supervisor Mr. Shuaib for being go through a lot in my project program.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Inorganic farming is a form of agriculture that completely relies on techniques and methods such as crop rotation, green manure, compost, and biological pest contr ol. Organic farming uses fertilizers and pesticides (which include herbicides, insec ticides and fungicides) if they are considered natural (such as bone meal from ani mals or pyrethrin from flowers), but it excludes or strictly limits the use of various methods (including synthetic petrochemical fertilizers and pesticides; plant growt h regulators such as hormones; antibiotic use in livestock; genetically modified or ganisms; human sewage sludge; and nanomaterials) for reasons including sustain ability, openness, independence, health, and safety. Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), This system of farming requires a relationship between human and natural resources in the production of quality food products for human needs and services (human and industrial use). This farming system is to create an integrated environmentally sound and economically sustainable agricultural production (Acquach, 2001).In contrast to inorganic fertilizers (synthetic fertilizers) such as nitrates, phosphate, organochlorine etc are environmentally hazardous to human health, aquatic organisms and other organisms.Animal manure (called manure) according to Defoer et al, (2000) is an organic fertilizer consisting of decomposed mixture of dung.McCalla 1975 revealed that the finer the spread, the better the fertilizing effect of farmyard manure, the higher the N content and the Calcium and Nitrogen ratio.  Maize which is botanically called (Zea mays L) belongs to the family grammineae. It is a cereal monoecious shrub. Most maize species grow well where the annual rainfall ranges from 400cm-900cm and temperature of 200c to a height of 4.5m. The range of time from planting to maturity varies between 3 to 4 months, depending on the variety use.

Maize thrives best on well aerated, viable working soil rich in humus (Echinger, 1926). Maize grow successfully in northern part of Nigeria, the grain contains higher p ercentage of carbohydrate with little protein and fat. Of all cereal, maize has the lar gest amount of oil, the average chemical composition is starch 68-70%, protein 1 0% and 3.6-5% (Mulvaney, 1996).The grain also contains an appreciable quantity of calcium and iron. It prefers high open land and requires manure as it exhausts the soil (Bray and Kurtz, 1945). Its leaves and stem form a good folder and the grain i s nutrition as cereal food. Maize flourish both in hot and cold climate there are sev eral varieties and hybrids, the Visual sowing season April-May and the harvesting s eason July-August. Each plant usually bears seed oncob. Maize cobs may be 15-2 5cm in length and the grain golden yellow, dull yellow, red or white. The grains are t aken as a substitute for other cereal grains and prepared by boiling. They are also often fried. Usually they are grounded into fine flour called corn flour and also as p owdered starch. The young tender grains are nutritious and may be taken raw roas ted or boiled in milk (Moritsuka et al., 1992).Maize is sown at 25cm – 75cm betw een raw and for one plant per stand sown at 90cm between row and 40cm within r ow for two plant stands. To sow one hectare, 25kg of seed is required and one sh ould make sure the space due to un-germinated seeds are replanted within one we ek (Schrmpt, 1965).Seed should be treated with (apron plus 500) before planting. Maize is sown as soon as the rain begins. Maize seedlings are poorly adapted to d rought stress condition, for crop to grow supplemented irrigation may be required in Sudan and Sahel Savannah. Early planting is advised with the first rain (Walter, 1

973). Maize generally required heavy fertilizer dosage a considerable amount of nutrient especially in relation to nitrogen and potassium in needed (Bray and Kurtz, 1945).Maize (Zea mays L) is an important cereal crop in the Tropics and Sub Tropical areas in the Global World. It is an important crop in West Africa, because of its numerous importance on nutritional values and industrial usage. Maize is produced on about 60 million hectares with an average yield of 1.2 tonnes per hectare at the Global World; it is rated as the most important cereal fodder and grain crop under both irrigation and rain fed agricultural systems in the semi-arid and arid tropics and ranks among the most widely grown and used crop in the world (Asadu and Igboka, 2014). Maize provides invaluable roughages for dairy and beef cattle and constitutes a high proportion of concentrate in livestock feeds as reported by (Ogundare, et al., 2016); all the vegetative parts of maize: the stalks, leaves, grains and immature ears are used as livestock feeds and human beings as food, the grains of maize are rich in vitamin A, C, E, carbohydrate, dietary fiber and calories which are good sources of energy for human and livestock (Damiyal, et al., 2017).Maize (Zea mays L.) is the most important cereal crop in Sub-Saharan Africa (SSA). Along with Rice and Wheat, Maize is one of the three most important cereal crops in the world. According to FAO data, the land areas planted to maize in West and Central Africa alone increased from 3.2 million in 1961 to 8.9 million in 2005. This phenomenal expansion of the land area devoted to maize cultivation resulted to increased prod uction from 2.4 million metric tones in 1961 to 10.6 million metric tones in 2005. While the average yield of maize in developed countries can reach up to 8.6 ton/ha, production per hectare in many SSA countries is still very low (1.3 ton/ha) (IITA, 2007). In Nigeria Maize is a staple food of great socio-economic importance. The demand for maize sometimes outstrips supply as a result of the various domestic uses (Akande, 1994). Additionally, other factors like price fluctuation, diseases and pests, poor storage facilities have been associated with low maize production in the country (Ojo, 2003). Maize has been reported to have a high inorganic nutrients requirement in order to obtain good quality and high yields. Mishra et al. (1993) and El-kholy and Gomaa (2000) succeeded in reducing the recommended rate of chemical fertilizer without loss in the yield of maize using about 50% of chemical fertilizer in combination with 50% bio-fertilizers. In view of this, national and international bodies have developed interest in promoting Maize production for households' food, security and poverty alleviation.(Melander et al., 2013). Also, crops grown under minimum tillage are more adaptive to climate variations and have higher yields than conventional tillage (Busari et al., 2018). On the other hand, conventional tillage, which farmers in SSA commonly practice, control weeds and allows for effective sowing and planting operations (Jin et al., 2007). In conventional tillage, decompoition of organic matter is promoted through disturbance of the aggregates in the soil and enhanced aeration and even dist ribution of carbon sources in the soil (Martníez et al., 2017). Moreover, conventional tillage speeds up microbial activity on the protected organic carbon, accelerating nutrient cycling (Tian et al., 2016).decomposed by micro-organisms. On the contrary, manure application can supply nutrients to the soil (He et al., 2015), improving SOC content (Cerda et al., 2009). Inorganic fertilizers' use increased root biomass in the soil, increasing SOC (Tian et al., 2015). Inorganics might decrease C content compared to soils with no added inputs (Shimizu et al., 2009). Therefore, judicious application of mineral and organic soil inputs increases the SOC stocks (Ghosh et al., 2015).Cow dung is an important source of nitrogen for crop production in the small holder sector. It helps farmers reduce inputs of commercial fertilizer, thereby increasing the profit margin of the farmer. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect [1] thus supporting better root development, leading to higher crop yields [2]. Improvements of environmental conditions as well as public health are also important reasons for advocating increased use of organic materials [3]. Maintenance of soil fertility is essential for optimum and sustained production. Inorganic fertilizers can be used to replenish soil nutrients and increase crop yields, but are too costly for the peasant farmers. The use of mineral fertilizers has been associated with increased soil acidity, nutrient imbalance and soil degradation [4]. This has necessitated research on the use of organic manures.

## 1.2 PROBLEM STATEMENT

Maize production in Nigeria has been militated by a number of factors that are aga inst maize production, with soil infertility problems as the chief principal factor. M easures to mitigate these factors prior to now have been adopted such as bush fa llowing, this practice however, is no longer in vogue considering the ever increasin g geometric population of the country and high demand for maize and its by-prod ucts as well as unavailability of land which emanated from industrialization of mos t arable land, the practice of bush fallowing could no longer be encouraged, thus, h aving an adverse effect on soil fertility, because the soils are overused before allo wing the cropping environment to lay fallow, thereby resulting to low yield of crops (Eifediyi and Remison, 2010). However, this problem can be relieved by employing other nutrient enriching practices such as, the use of organic manure e.g. cow dun g and farmyard manure.

## 1.3 JUSTIFICATION

I. Effective fertilizer lead to more yield of production

Ii. Costhy of organic fertilizer make a good replacement for cow-dung if it was pos itive effect on cow-dung

Iii. High rate on marketing of maize make it more essential to give high yield of mai ze production

### 1.3.1 OBJECTIVE OF THE STUDY

I. To evaluate the effect of cow-dung on growth of maize with tillage practice

Ii. To know the effect of the application of two fertilizer (ORGANIC NPK-SOURCE) and cow-dung on growth maize

Iii. To evaluate the effect of cow-dung+inorganic NPK-source with particular tillage practice on growth of maize

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

Cow dung

Cow dung, also known as cow pats, cow pies or cow manure, is the waste product (faeces) of bovine animal species. These species include domestic cattle ("cows"), bison ("buffalo"), yak, and water buffalo. Cow dung is the undigested residue of pla nt matter which has passed through the animal's gut. The resultant faecal matter i s rich in minerals. Color ranges from greenish to blackish, often darkening soon aft er exposure to air.

## 2.2 Uses of cow dung

Fuel

In many parts of the old world, and in the past in mountain regions of Europe, caked and dried cow dung is used as fuel. In India, it is dried into cake like shapes called upla or kanda, and used as replacement for firewood for cooking in chulah (traditional kitchen stove).Dung may also be collected and used to produce biogas to generate electricity and heat. The gas is rich in methane and is used in rural areas of India and Pakistan and elsewhere to provide a renewable and stable (but unsustainable) source of electricity.[1]

### 2.3 Fertilizer

Cow dung, which is usually a dark brown color, is often used as manure (agricultural fertilizer). If not recycled into the soil by species such as earthworms and dung beetles, cow dung can dry out and remain on the pasture, creating an area of grazing land which is unpalatable to livestock. Cow dung is nowadays used for making flower and plant pots. It is plastic free, biodegradable and eco-friendly. Unlike plastic grow bags which harm nature, cow dung pots dissolves naturally and becomes excellent manure for the plant.[citation needed] From 20 July 2020, State Government of Chhattisgarh India started buying cow dung under the Godhan Nyay Yojana scheme. Cow dung procured under this scheme will be utilised for the production of vermicompost fertilizer.[2]

### 2.4 Religious uses

Cow dung is used in Hindu yajna ritual as an important ingredient.[3][unreliable sou rce?] Cow dung is also used in the making of pancha-gavya, for use in Hindu rituals.[4] Several Hindu texts - including Yājñavalkya Smṛti and Manusmṛti - state that the pancha-gavya purifies many sins.[5] The Mahabharata narrates a story about how Lakshmi, the goddess of prosperity, came to reside in cow dung. In the legend, Lakshmi asks cows to let her live in their bodies because they are pure and sinless. The cows refuse, describing her as unstable and fickle. Lakshmi begs them to accept her request, saying that others would ridicule her for being rejected by the cows, and agreeing to live in the most despised part of their body. The cows then allow her to live in their dung and urine.[5]The Tantric Buddhist ritual manuals Jayavatī-nāma-mahāvidyārāja-dhāraṇī and Mahāvairocanābhisaṃbodhi recommend use of cow dung to purify mandala altars.[6]

### 2.5 Floor and wall coating

In several cultures, cow dung is traditionally used to coat floors and walls. In parts of Africa, floors of rural huts are smeared with cow dung: this is believed to improve interior hygiene and repel insects.[7][8] This practice has various names, such as "ukusinda" in Xhosa,[9] and "gwaya" in Ruruuli-Lunyala.[10] Similarly, in India, floors are traditionally smeared with cow dung to clean and smoothen them.[6] Purananuru generally dated 150 BCE[11] mentions women of Tamil Nadu smear cow dung on the floors at the 13th day after her husband's death to purify the house.[12] Italian traveler Pietro Della Valle, who visited India in 1624, observed that the locals -

including Christians - smeared floor with cow dung to purify it and repel insects.[13] Tryambaka's Strī-dharma-paddhati (18th century), which narrates a modified version of the Mahabharata legend about how the goddess Lakshmi came to reside in cow dung, instructs women to make their homes pure and prosperous by coating them with cow-dung.[5] Many among modern generations have challenged this practice as unclean.[14] In 2021, the Government of India's Khadi and Village Industries Commission launched the Khadi Prakritik paint, which has cow dung as its main ingredient, promoting it as an eco-friendly paint with anti-fungal and anti-bacterial properties.[15]

## 2.6 Other uses of cow dung

In central Africa, Maasai villages have burned cow dung inside to repel mosquitos. In cold places, cow dung is used to line the walls of rustic houses as a cheap thermal insulator. Villagers in India spray fresh cow dung mixed with water in front of the houses to repel insects.[16] In Rwanda, it is used in an art form called imigongo. Cow dung is also an optional ingredient in the manufacture of adobe mud brick housing depending on the availability of materials at hand.[17] A deposit of cow dung is referred to in American English as a "cow pie" or less commonly "cow chip" (usually when dried) and in British English as a "cowpat".[18] When dry, it is used in the practice of "cow chip throwing" popularized in Beaver, Oklahoma in 1970.[19][20] On April 21, 2001 Robert Deevers of Elgin, Oklahoma, set the record for cow chi p throwing with a distance of 185 feet 5 inches (56.52 m).[21]

### 2.7 Ecology of cow dung

Cow dung provides food for a wide range of animal and fungus species, which break it down and recycle it into the food chain and into the soil. In areas where cattle (or other mammals with similar dung) are not native, there are often also no native species which can break down their dung, and this can lead to infestations of pests such as flies and parasitic worms. In Australia, dung beetles from elsewhere have been introduced to help recycle the cattle dung back into the soil. (see the Australian Dung Beetle Project and Dr. George Bornemissza).[22] Cattle have a natural aversion to feeding around their own dung. This can lead to the formation of taller ungrazed patches of heavily fertilized sward. These habitat patches, termed "islets", can be beneficial for many grassland arthropods, including spiders (Araneae) and bugs (Hemiptera). They have an important function in maintaining biodiversity in heavily utilized pastures.[23]

#### 2.7.1 Bioremediation of Environment Pollutants Cow Dung

Cow dung contains diverse group of microorganisms such as Acinetobacter, Bacillus, Pseudomonas, Serratia and Alcaligenes spp. which makes them suitable for microbial degradation of pollutants (Adebusoye et al. 2007; Akinde and Obire 2008; Umanu et al. 2013). Cow dung slurry maintained in the ratio of 1:10 or 1:25 is able to degrade the rural, urban and hospital wastes, including oil spillage to five basic elements (Randhawa and Kullar 2011). A study by Orji et al. (2012) highlights the importance of cow dung isolates, both bacterial and fungal, for reducing total petroleum hydrocarbons to 0 % in polluted mangrove soil. The bacterial isolates involved in the process belonged to genera Pseudomonas, Bacillus, Citrobacter, Micrococcus, Vibrio, Flavobacterium and Corynebacterium, whilst fungal isolates were the species from Rhizopus, Aspergillus, Penicillium, Fusarium, Saccharomyces and Mucor. The natural ability of cow dung microflora to degrade hydrocarbons in soil contaminated with engine oil is recently being investigated by Adams et al. (2014) where total petroleum hydrocarbon reduced up to 81 % by the metabolic activities of cow dung microorganisms such as Bacillus, Staphylococcus, Pseudomonas, Flaviobacterium, Arthobacter, Enterobacter, Trichoderma, Mucor and Aspergillus spp. Umanu et al. (2013) suggested that the application of cow dung in an appropriate concentration may prove very efficient in biodegradation of water contaminated with motor oil. Some researchers also suggested the metabolic pathway for microbial degradation of polycyclic aromatic hydrocarbons. A Mycobacterium sp. isolated from contaminated soil of gaswork plant has shown the ability to degrade pyrene up to 60 % within 8 days maintained at 20 °C with several degrading products such as Cis-4,5-pyrene dihydrodiol, 4-5-phenanthrene dicarboxylic acid, 1-hydroxy-2-naphthoic acid, 2-carboxybenzaldehyde, phthalic acid and protocatechuic acid were recognised (Rehmann et al. 1998; Haritash and Kaushik 2009). Lignolytic fungi Irp ex lacteus has also shown the ability to degrade phenanthrene to phenanthrene-9, 10-dihydrodiol (Cajthaml et al. 2002; Haritash and Kaushik 2009). All these findings indicate that cow dung can supply nutrients and energy required for microbial growth thereby resulting in the bioremediation of pollutants. Incineration is a method of choice for disposal of biomedical waste but it is not environmental friendly due to production of toxic gases giving rise to health complications. Another useful application of cow dung microorganisms is in the treatment of biomedical and pharmaceutical waste (Randhawa and Kullar 2011). Cyathus stercoreus, isolated from aged cow dung, is not only capable of degrading lignocelluloses in vitro (Wicklow et al. 1980; Freer and Detroy 1982; Wicklow 1992) but also an antibiotic enrofloxacin (Randhawa and Kullar 2011). Research by Pandey and Gundevia (2008) showed complete biodegradation of biomedical waste placed in culture medium of a cow dung fungus, Periconiella.

### 2.7.2 Source of Microbial Enzymes of Cow Dung

Microbial enzymes have got immense application because microbes can easily be cultivated and their enzyme can catalyse wide variety of hydrolytic and synthetic reactions (Illavarasi 2014). Many microbial enzymes have been isolated and studied for their industrial and commercial uses. However, still there is a continuous search for the potential microorganisms that are able to synthesise industrially feasible enzymes and microbial diversity of cow dung makes it a potential source for the s aid purpose (Dowd et al. 2008). Bacillus spp. from cow dung is capable of producing cellulose, carboxymethyl cellulose and cellulase (Das et al. 2010; Sadhu et al. 2013; Illavarasi 2014). In case of poor enzyme production, genetically improved strains can be constructed for enhanced enzyme production. For instance, Sadhu et al. (2014) described that cow dung Bacillus spp. can be mutated with NTG to increase the cellulase production from 9.4 to 16.3 U/mg proteins. Teo and Teoh (2011) detected several cow dung isolates producing enzymes like protease, lipase and esterase lipase. Xylanolytic bacteria are receiving increasing commercial interest in several industries such as enzyme-aided bleaching of paper (Encarna et al. 2004; Viikari et al. 1994), production of ethanol from plant biomass (Lamed et al. 1988), animal feed additives (Annison 1992) and in bread making (Maat et al. 1992). One member of xylanolytic bacteria Paenibacillus favisporus sp., from cow dung, was found to produce wide variety of hydrolytic enzymes such as xylanases, cellulases, amylases, gelatinase, urease and β-galactosidase (Encarna et al. 2004). Not only as a microbial source but cow dung may also serve as good substrate for enzyme production, for example, in production of detergent-stable dehairing protease by alkaliphilic B. subtilis (Vijayaraghavan et al. 2012), alkaline protease by Halomonas spp. (Vijayaraghavan and Vincent 2012) and fibrinolytic enzyme from Pseudoalteromonas sp. (Vijayaraghavan and Vincent 2014).

## 2.8 Agriculture Management of Cow Dung

Human population is increasing worldwide giving rise to intensive farming system and unsuitable cropland management that ultimately results in reduced soil fertility (Onwudike 2010; Bedada et al. 2014). Extensive use of chemical fertilisers is suggested for replenishment of nutritional deficiencies to increase crop yield. Many disadvantages of widespread use of chemical fertilisers include increase in soil acidity, mineral imbalance and soil degradation (Kang and Juo 1980; Ayoola and Makinde 2008) and even farmers nowadays do not prefer chemical fertilisers (Bedada et al. 2014). In composting, microorganisms decompose organic substrate aerobically into carbon dioxide, water, minerals and stabilised organic matter (Bernal et al. 2009; Kala et al. 2009; Vakili et al. 2015). Compost is added into the soil to improve nutrients and water-holding capacity (Arslan et al. 2008; Vakili et al. 2015). Recently, researchers observed that addition of cow dung to biomass generated from palm oil industries improves the physical and chemical properties including nutritional composition of compost. Palm oil biomass mixed with cow dung in the ratio of 1:3 significantly improved the compost quality with respect to various parameters such as pH, electrical conductivity and C:N ratio (Vakili et al. 2015). Thus, cow dung may not only act as a substitute for chemical fertilisers because it supplements organic matter, but also as a conditioner for soil (Garg and Kaushik 2005; Yadav et al. 2013; Be´langer et al. 2014). Slurry from biogas plant is also a nutrient-rich source but it cannot be used at large scale because of its drawbacks such as e utrophication and leaching of the soil nutrients (Garg et al. 2005; Wachendorf et al. 2005; Islam et al. 2010; Lu et al. 2012; Guo et al. 2014). Organic amendments alone may not offer sufficient nutrient supply to meet the demand (Palm et al. 1997; Gentile et al. 2011; Bedada et al. 2014). One way to counter this soil fertility problem is ISFM, i.e., Integrated Soil Fertility Management, a technique that makes use of both organic and inorganic resources resulting in greater yield response and better nutrient storage (Bedada et al. 2014; Ewusi-Mensah et al. 2015). For example, combination of cow dung with NPK (15:15:15) in the concentration of 3 t/ha and 100 kg/ha, respectively, showed marked increase of 8.9 t/ha in the yield of potato tuber in comparison to control that yielded only 1.8 t/ha. The organic carbon of the soil after treatment with this combination was found to be significantly increased from 1.33 to 3.21 %. The combination also improved soil organic matter, phosphate availability, exchangeable ions, effective cation exchange capacity and pH in comparison to untreated soil (Onwudike 2010). The same combination has also been reported to increase the yield of maize (Ayoola and Makinde 2008; Bedada et al. 2014). Mineral soil phosphorus, a key nutrient limiting plant growth, is divided into three categories as per availability to plants, i.e., phosphorous soluble in the soil solution and available for plant uptake, labile phosphorous in the solid phase ready to be solubilised in soil solution and insoluble or fixed phosphorous in the solid phase (Kuhad et al. 2011; Swain et al. 2012). High amount of inorganic phosphates is ad ded to soil but phosphorus ions are very reactive and most of the inorganic phosphorous is converted into insoluble phosphorous by immobilisation and chelatieias et al. 2003; Barroso et al. 2006; PositNegt al. 2011; Swain et al. 2012). One of the methods for making insoluble phosphorous available to the plants is solubilisation through microorganisms (Arcand and Schneider 2006; Reyes et al. 2006; Swain et al. 2012). The recent areas where cow dung microorganisms are being used are in promoting soil fertility to improve crop yield. In this study by Swain et al. (2012), thermotolerant Bacillus subtilis strains have been recovered from cow dung with great potential in phosphate solubilisation. These Bacillus strains also possessed antagonistic activities against plant pathogens along with production of growth regulators. The findings are significant as isolated bacterial strains being thermotolerant may possibly be used as bio-inoculant in agriculture of tropics where temperature during summer rises up to 42–45 °C (Swain et al. 2012). Many biodynamic preparations obtained from cow dung have shown antagonistic effect against plant pathogens such as Rhizoctonia bataticola (Rupela et al. 2003; Somasundaram et al. 2007; Radha and Rao 2014). An investigation by Mary et al. (1986) revealed cow dung extract to be more effective than antibiotics like Penicillin, Paushamycin and Streptomycin in controlling bacterial blight of rice. B. subtilis strains are the most predominant isolates from culturable cow dung microflora. A few reports have shown the antagonistic properties of these B. subtilis strains against plant pathogens s uch as Fusarium soalni, Fusarium oxysporum and S. Sclerotiorum (Basak and Lee 2002; Swain et al. 2006; Stalin et al. 2010; Swain et al. 2012). Plant pathogenic nematodes are one of the important pathogens of crops. Recently, a work by Lu et al. (2014) investigated 219 bacterial strains from cow dung for nematicidal activity against model nematode Caenorhabditis elegans and out of these, 17 strains killed more than 90 % of the tested nematode within 1 h. The strains identified included Alcaligenes faecalis, Bacillus cereus, Proteus penneri, Providencia rettgeri, Pseudomonas aeruginosa, Pseudomonas otitidis, Staphylococcus sciuri, Staphylococcus xylosus, Microbacterium aerolatum and Pseudomonas beteli. Out of these 14 strains also inhibited another nematode Meloidogyne incognita. This was for the first time that strains in the genera Proteus, Providencia and Staphylococcus from cow dung displayed nematicidal activity. Cow dung is conventionally applied in Indian subcontinental agriculture to enhance soil fertility. It not only improves the different properties of soil but also acts as a source of microorganisms producing biological nematicidal agents with no negative effect on environment. Therefore, use of cow dung should be promoted in the field of agriculture.

### 2.9 Inorganic Fertilizer Materials

The various sources of plant nutrients can be grouped into two general categories, inorganic and organic. The inorganic materials generally are relatively "highanalysis" fertilizers with few impurities. The organic materials, on the other hand, are relat ively “low-analysis” fertilizers that often contain a wide range of nutrients as well as organic compounds. Both sources of nutrients have a place in farming, and to use them to their best advantage, it is important that their properties be understood. Their costs also vary. A judicious selection of the right fertilizer for a given situation requires consideration of several factors: properties affecting their use by plants, economic costs, and environmental effects (both short-term soil reactions and long-term environmental fate). Many of the more commonly used inorganic fertilizers are described below, and their analyses are summarized in Table 12-1. Much of the information presented here was obtained from Tisdale et al. (1993). Nitrogen fertilizers Inorganic N sources include ammonium and nitrate forms and urea. Ammonium sulfate [$(NH_4)_2SO_4$] has been used in Hawaii for many years in both the sugarcane and pineapple industries as well as on small farms. It contains 21% N and 11% S. It will lower soil pH if used continuously over long periods of time. Ammonium phosphates: Monoammonium phosphate (MAP) [$NH_4H_2PO_4$] supplies both N and P, at 11–13% N and 48–62% $P_2O_5$. Diammonium phosphate (DAP) [$(NH_4)_2HPO_4$] is also widely used to supply both N and P, at 18–21% N and 46–53% $P_2O_5$. Both fertilizers are completely water soluble. Row or seed placement of DAP must be done with caution, especially in soils with high pH, because free $NH_3$ can be produced, causing seedling injury. When these materials come in contact with soil in banded applications, MAP initially causes soil pH to be 3.5, while with DAP the p

H is 8.0. Potassium nitrate [$KNO_3$] contains two essential nutrients, N (13%) and $K_2O$ (44%). It is not hygroscopic (that is, it does not pick up moisture from the air) so it is easy to apply, the $NO_3^-$ is readily available, and it causes soil pH to increase slightly. Calcium nitrate [$Ca(NO_3)_2$] contains 15% N and 34% CaO. The $NO_3^-$ is readily available, but the material is extremely hygroscopic. It is prone to liquefication if it is not stored in moisture-proof bags. Urea [$CO(NH_2)_2$] contains 45–46% N. It has very good physical properties in that it has less tendency to cake than ammonium nitrate and it is less corrosive than other N fertilizers. Its high concentration of N brings about savings in storage, transportation, handling, and application. Urea is soluble and can leach as readily as nitrate. However, once it has been converte to $NH_4^+$ and $HCO_3^-$ in the soil by the enzyme urease, the $NH_4^+$ can be held on exchange sites and is thus less subject to leaching. Initially, urea can raise soil pH in the zone of application due to the release of $NH_3$, but over time, soil pH can decrease from the original pHdue to the nitrification of $NH_4^+$ to $NO_3^-$. Urea can contain varying amounts of biuret, an impurity that can be phytotoxic. Most crops can tolerate biuret levels of 2% or less. However, sensitive crops such as citrus and pineapple should be sprayed with urea containing less than 0.25% biuret. If urea is applied to the surface of soils with high pH, $NH_4^+$ may form ammonia ($NH_3$), which can be lost by volatilization. **Sulfur-coated urea (SCU)** is a controlled-release fertilizer that has a sulfur shell around each urea particle. The release of urea depends on th e oxidation of the sulfur shell by soil microorganisms. The thickness of the sulfur shell can be varied to give different rates of release of urea. SCU contains 36–38% N and is useful in areas of porous soils with high rainfall or irrigation where $NO_3^-$ can be leached readily. SCU also supplies S as it is oxidized by microorganisms.

**2.10 Phosphorus fertilizers Rock phosphate** [$Ca_{10}OHF(PO_4)_6$]. Rock phosphates contain apatite, which varies greatly in composition and solubility and becomes available to plants only in acid soils (pH2% S, and diammonium phosphate [$(NH_4)_2HPO_4$], with 18–21% N, 46–53% $P_2O_5$, and 0–2% S. Both are granular fertilizers that are completely water soluble.

**Potassium fertilizers** Potassium chloride [KCl], known as muriate of potash, contains 60–63% $K_2O$ and is completely water soluble. It is the most widely used **potassium fertilizer**. Potassium sulfate [$K_2SO_4$] is known as sulfate of potash and contains 50–53% $K_2O$ and 17% S. It is used on crops such as potato and avocado that are sensitive to large applications of chloride ($Cl^-$). It is completely water soluble.

**Potassium nitrate** [$KNO_3$] supplies 44% $K_2O$ and 13% N. It is not very hygroscopic, is readily soluble, and increases soil pH. Potassium-magnesium sulfate [$K_2SO_4 \cdot 2MgSO_4$], sold as Sul-Po-Mag®, supplies 22% K, 11% Mg, and 22% S. It is widely used in dry fertilizer formulations. Calcium fertilizers Lime [$CaCO_3$] and dolomite [$CaMg(CO_3)_2$] are used as liming materials to adjust soil pH and supply calcium.

Lime contains about 38% Ca, while dolomite contains about 22% Ca and 12% Mg. The amounts of Ca and Mg vary with the source of the material.

**Calcium sulfate**, gypsum [$CaSO_4 \cdot 2H_2O$] is an amendment supplying Ca in a form that changes soil pH very little, so it is useful in soils with adequate pH for plants. I t contains 23% Ca and 19% S. Calcium nitrate [$Ca(NO_3)_2$] is highly soluble and su pplies 15% N and about 20% Ca. It is useful where rapid calcium availability with a minimal soil pH change is desired.

**Superphosphates**. Single superphosphate supplies 18–21% Ca, while triple super phosphate supplies 12– 14% Ca. Thus, when superphosphate is applied to supply P to the soil, Ca is supplied also. Magnesium fertilizers Dolomite [$CaMg(CO_3)_2$], used as a liming material, supplies both Ca and Mg in amounts that may vary. One dolomite sold in Hawaii has about 22% Ca and 12% Mg. The agricultural lime sold i n Hawaii is usually ground coral containing 38% Ca and 0.6% Mg. Magnesium sulfa te, Epsom salts [$MgSO_4 \cdot 7H_2O$] supplies both Mg (9.8%) and S (13%) without cha nging soil pH. It is readily soluble and can be applied the soil or as a foliar spray. M agnesium oxide [MgO] contains 55% Mg and will increase soil pH. It is not readily soluble, so it nearly always should be incorporated into the soil. Sulfur fertilizers El emental sulfur [S] is inert and water-insoluble and must be converted to sulfate ($SO_4^{-}$) by soil microorganisms (Thiobacillus species) before it can be used by plan ts. Therefore, sufficient time must be allowed for the S to become available before

any effect on the soil or plants can be expected. Elemental sulfur should be finely
ground. The finer the particle size, the larger the surface area and the faster the sul
fur will be oxidized by the bacteria to sulfate. Elemental sulfur should be broadcas
t and incorporated into the soil for the maximum rate of oxidation. Sulfur will lower
soil pH. Ammonium sulfate [$(NH_4)_2SO_4$] contains 24% S along with the nitrogen
and is a means of supplying S to the soil and plants. This is one of the most acidif
ying fertilizer materials, because both ammonium and sulfate contribute to acidity.
Micronutrient fertilizers Iron (ferrous) sulfate [$FeSO_4 .7H_2O$] contains about 19%
Fe and may be used as a foliar spray (1–2% $FeSO_4$) or applied to the soil. Iron che
late, iron EDTA [NaFeEDTA] contains 5–14% Fe and may be used as a foliar spray o
r applied to the soil. Zinc sulfate [$ZnSO_4 .H_2O$] contains about 35% Zn. Since Zn is
relatively immobile in soil, zinc sulfate should be broadcast and incorporated into t
he soil or applied in a band. Zinc sulfate may also be applied to foliage. Zinc chelat
e, zinc EDTA [$Na_2ZnEDTA$] contains about 14% Zn and is often applied as a foliar
spray. It can also be applied to the soil. Copper sulfate [$CuSO_4 .5H_2O$] contains a
bout 25% Cu and may be applied to the soil or to foliage. Copper chelate, copper E
DTA [$Na_2CuEDTA$] is soluble and contains about 13% Cu. It is generally used as a f
oliar spray. Sodium borate, borax [$Na_2B_4O_7 .10H_2O$] contains about 11% B and
may be applied to the soil or as a foliar spray. Application rates of B depend on th
e crop and soil and are generally quite low, because B can become toxic at high rat

es.

## 2.11 Maize

Maize (Zea mays), also known as corn in North American and Australian English, is a tall stout grass that produces cereal grain. It was domesticated by indigenous peoples in southern Mexico about 9,000 years ago from wild teosinte. Native Americans planted it alongside beans and squashes in the Three Sisters polyculture. The leafy stalk of the plant gives rise to male inflorescences or tassels which produce pollen, and female inflorescences called ears. The ears yield grain, known as kernels or seeds. In modern commercial varieties, these are usually yellow or white; other varieties can be of many colors. Maize relies on humans for its propagation. Since the Columbian exchange, it has become a staple food in many parts of the world, with the total production of maize surpassing that of wheat and rice. Much maize is used for animal feed, whether as grain or as the whole plant, which can either be baled or made into the more palatable silage. Sugar-rich varieties called sweet corn are grown for human consumption, while field corn varieties are used for animal feed, for uses such as cornmeal or masa, corn starch, corn syrup, pressing into corn oil, alcoholic beverages like bourbon whiskey, and as chemical feedstocks including ethanol and other biofuels.

Maize is cultivated throughout the world; a greater weight of maize is produced each year than any other grain. In 2020, world production was 1.1 billion tonnes. It is afflicted by many pests and diseases; two major insect pests, European corn borer and corn rootworms, have each caused annual losses of a billion dollars in the US. Modern plant breeding has greatly increased output and qualities such as nutrition, drought, and tolerance of pests and diseases. Much maize is now genetically modified.

As a food, maize is used to make a wide variety of dishes including Mexican tortillas and tamales, Italian polenta, and American hominy grits. Maize protein is low in some essential amino acids, and the niacin it contains only becomes available if freed by alkali treatment. In Mesoamerica, maize is personified as a maize god and depicted in sculptures.

History of maize

Pre-Columbian development

Maize requires human intervention for it to propagate. The kernels of its naturally-propagating teosinte ancestor fall off the cob on their own, while those of domesticated maize do not.[2] All maize arose from a single domestication in southern Mexico about 9,000 years ago. The oldest surviving maize types are those of the Mexican highlands. Maize spread from this region to the lowlands and over the Americas along two major paths.[3] The centre of domestication was most likely the Balsas River valley of south-central Mexico.[4] Maize reached highland Ecuador at least 8000 years ago.[5] It reached lower Central America by 7600 years ago, and the va lleys of the Colombian Andes between 7000 and 6000 years ago.[4] The earliest maize plants grew a single, small ear per plant.[6] The Olmec and Maya cultivated maize in numerous varieties throughout Mesoamerica; they cooked, ground and processed it through nixtamalization.[7] By 3000 years ago, maize was central to Olmec culture, including their calendar, language, and myths.[8] The Mapuche people of south-central Chile cultivated maize along with quinoa and potatoes in pre-Hispanic times.[9] Before the expansion of the Inca Empire, maize was traded and transported as far south as 40° S in Melinquina, Lácar Department, Argentina, probably brought across the Andes from Chile.[10] After the arrival of Europeans in 1492, Spanish settlers consumed maize, and explorers and traders carried it back to Europe. Spanish settlers much preferred wheat bread to maize. Maize flour could not be substituted for wheat for communion bread, since in Christian belief at that time only wheat could undergo transubstantiation and be transformed into the body of Christ.[11]

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 and elsewhere.[11] By the 17th century, it was a common peasant food in Southern Europe. By the 18th century, it was the chief food of the southern French and Italian peasantry, especially as polenta in Italy.[12] When maize was introduced into Western farming systems, it was welcomed for its pr oductivity. However, a widespread problem of malnutrition soon arose wherever it had become a staple food.[13] Indigenous Americans had learned to soak maize in alkali-water — made with ashes and lime — since at least 1200–1500 BC, creating the process of nixtamalization. They did this to liberate the corn hulls, but coincidentally it also liberated the B-vitamin niacin, the lack of which caused pellagra.[14] Once alkali processing and dietary variety were understood and applied, pellagra disappeared in the developed world. The development of high-lysine maize and the promotion of a more balanced diet have contributed to its demise. Pellagra still exists in food-poor areas and refugee camps where people survive on donated maize.[15

Structure and physiology of maize

Maize is a tall annual grass with a single stem, ranging in height from 1.2 m (4 ft) to 4 m (13 ft).[31] The long narrow leaves arise from the nodes or joints, alternately on opposite sides on the stalk.[31] Maize is monoecious, with separate male and female flowers on the same plant.[31] At the top of the stem is the tassel, an inflorescence of male flowers; their anthers release pollen, which is dispersed by wind.[31] 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.[32] The female inflorescence, some way down the stem from the tassel, is first seen as a silk, a bundle of soft tubular hairs, one for the carpel in each female flower, which develops into a k ernel (often called a seed. Botanically, as in all grasses, it is a fruit, fused with the seed coat to form a caryopsis[33]) when it is pollinated.[31] A whole female inflorescence develops into an ear or corncob, enveloped by multiple leafy layers or husks.[31] 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.[34] 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 32 rows around the cob; there can be up to 1200 grains on a large cob.[6] Yellow maizes derive their color from carotenoids; red maizes are colored by anthocyanins and phlobaphenes; and orange and green varieties may contain combinations of these pigments.[35] Maize has short-day photoperiodism, meaning that it requires nights of a certain length to flower. Flowering further requires enough warm days above 10 °C (50 °F). The control of flowering is set genetically; the physiological mechanism involves the phytochrome system. Tropical cultivars can be problematic if grown in higher latitudes, as the longer days can make the plants grow tall instead of setting seed before winter comes. On the other hand, growing tall rapidly could be convenient for producing biofuel.[31]

Immature maize shoots accumulate a powerful antibiotic substance, 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA), which provides a measure of protection against a wide range of pests.[36] Because of its shallow roots, maize is susce ptible to droughts, intolerant of nutrient-deficient soils, and prone to being uprooted by severe winds.[37]

Uses of maize

Culinary

Maize and cornmeal (ground dried maize) constitute a staple food in many regions of the world.[6] Maize is used to produce the food ingredient cornstarch.[97] Maize starch can be hydrolyzed and enzymatically treated to produce high fructose corn syrup, a sweetener.[98] Maize may be fermented and distilled to produce Bourbon whiskey.[99] Corn oil is extracted from the germ of the grain.[100] In prehistoric times, Mesoamerican women used a metate quern to grind maize into cornmeal. After ceramic vessels were invented the Olmec people began to cook maize together with beans, improving the nutritional value of the staple meal. Although maize naturally contains niacin, an important nutrient, it is not bioavailable without the process of nixtamalization. The Maya used nixtamal meal to make porridges and tamales.[101] Maize is a staple of Mexican cuisine. Masa (nixtamal) is the main ingredient for tortillas, atole and many other dishes of Central American food. It is the main ingredient of corn tortilla, tamales, atole and the dishes based on these.[102] The corn smut fungus, known as huitlacoche, which grows on maize, is a Mexican delicacy.[103] Coarse maize meal is made into a thick porridge in many cultures: from the polenta of Italy, the angu of Brazil, the mămăligă of Romania, to cornmeal mush in the US (or hominy grits in the Southern US) or the food called mieliepap in South Africa and sadza, nshima, ugali and other names in other parts of Africa. Introduced into Africa by the Portuguese in the 16th century, maize has become Africa's most important staple food crop.[104] Sweet corn, a genetic variety that is high in sugars and low in starch, is eaten in the unripe state as corn on the cob.[105]

Nutritional value

Raw, yellow, sweet maize kernels are composed of 76% water, 19% carbohydrates, 3% protein, and 1% fat (table). In a 100-gram serving, maize kernels provide 86 calories and are a good source (10–19% of the Daily Value) of the B vitamins, thiamin, niacin (if freed), pantothenic acid (B5) and folate.[108] Maize has suboptimal amounts of the essential amino acids tryptophan and lysine, which accounts for its lower status as a protein source.[109] The proteins of beans and legumes complement those of maize.[109]

Animal feed

Maize is a major source of animal feed. As a grain crop, the dried kernels are used as feed. They are often kept on the cob for storage in a corn crib, or they may be shelled off for storage in a grain bin. When the grain is used for feed, the rest of the plant (the corn stover) can be used later as fodder, bedding (litter), or soil conditioner. 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 palat able to ruminants than the dried form.[110] Traditionally, maize was gathered into shocks after harvesting, where it dried further. It could then be stored for months until fed to livestock. Silage can be made in silos or in silage wrappers. In the tropics, maize is harvested year-round and fed as green forage to the animals.[111] Baled cornstalks offer an alternative to hay for animal feed, alongside direct grazing of maize grown for this purpose.[112]

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**2.12 Chemicals**

Starch from maize can be made into plastics, fabrics, adhesives, and many other chemical products.[113] Corn steep liquor, a plentiful watery byproduct of maize wet milling process, is used in the biochemical industry and research as a culture medium to grow microorganisms.[114]

Biofuel

Feed maize is being used for heating; specialized corn stoves (similar to wood sto ves) use either feed maize or wood pellets to generate heat. Maize cobs can be used as a biomass fuel source. Home-heating furnaces which use maize kernels as a fuel have a large hopper that feeds the kernels into the fire.[115] Maize is used as a feedstock for the production of ethanol fuel.[116] The price of food is indirectly affected by the use of maize for biofuel production: use of maize for biofuel production increases the demand, and therefore the price of maize.[117] A pioneering biomass gasification power plant in Strem, Burgenland, Austria, started operating in 2005. It would be possible to create diesel from the biogas by the Fischer Tropsch method.[118]

Nutrient management basics

Nutrient management involves managing the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to optimize plant growth and yield while minimizing environmental impact. Integrated nutrient management (INM) is a recommended practice that involves using both organic and inorganic fertilizers to improve soil productivity and crop productivity. This approach, along with the integrated use of major plant nutrients (nitrogen, phosphorus, and potash), organic carbon sources (animal manures and plant residues), and bio-fertilizers (beneficial microbes), has been shown to significantly enhance maize growth, yield, and yield components, as well as grower’s income. Conservation agriculture (CA) practices, including zero-till flatbed (ZTFB), permanent beds (PNB), and c onventional systems (CT), have also been found to increase farm profits and impr ove soil properties. Nutrient expert-based application (NE), recommended fertiliza tion (RDF), and farmers' fertilizer practice (FFP) are recommended CA-based nutrie nt management practices that can further enhance productivity and profitability [2, 6, 16]. Maize production heavily relies on adequate nutrient management, with nitr ogen, phosphorus, and potassium being the most critical nutrients. Nitrogen is vit al for vegetative growth and grain yield, but its mismanagement can cause environ mental problems such as nitrate leaching and greenhouse gas emissions. Various nitrogen management practices, including split applications during planting and ve getative stages, have been found effective in improving maize yields and nitrogen use efficiency. Similarly, phosphorus plays a critical role in root growth, flowering, and grain filling, and its deficiency can result in poor crop quality and reduced yield [17, 18, 19]. Phosphorus management practices, such as soil testing and banding phosphorus fertilizers, have been found to enhance phosphorus availability in the s oil and improve maize productivity. Additionally, potassium is essential for osmore gulation, enzyme activation, and photosynthesis, and its deficiency can lead to red uced yield and increased susceptibility to biotic and abiotic stresses. Effective pot assium management practices include soil testing, potassium fertilizer applicatio n, and applying potassium fertilizer at planting and during the vegetative stage. Re search has shown that these practices can improve maize yield and potassium us e efficiency [4, 20, 21]. Understanding the nutrient requirements of maize, as well as the nutrient content of the soil, is essential to develop a nutrient management plan that balances these needs with available resources.

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## Soil testing for maize production

Soil testing holds a pivotal role in optimizing nutrient management specifically tail ored for maize production. By analyzing soil samples, farmers gain invaluable insig hts into the soil's nutrient content and pH levels, enabling them to make well-informed decisions regarding fertilizer application. Recent research papers have extensively highlighted the profound significance of soil testing in this context. In a notable study conducted between 2015 and 2016, the focus was on bridging the maize yield gap and enhancing soil properties in coastal saline soil. The researchers explored the efficacy of a combined application of flue gas desulfurization gypsum and furfural residue (known as CA). Intriguingly, the post-harvest CA treatment exhibited remarkable outcomes, with notable increases observed in calcium ($Ca^{2+}$) and soil organic carbon (SOC) contents, while simultaneously reducing sodium ($Na^{+}$) content and pH levels in the upper soil layer. Consequently, maize crops experienced significant enhancements in nitrogen, phosphorus, potassium, calcium, and magnesium accumulations, alongside a decrease in Na accumulation when compared to the control group [22]. Another noteworthy study delved into the dynamics of global maize production, consumption, and trade, aiming to decipher evolving trends over the past 25 years and their consequential impact on research and development (R&D), with a particular focus on the Global South. The study emphasized the pressing need for augmented investments in R&D endeavors to fortify maize's pivotal role in ensuring food security, sustaining livelihoods and effectively intensifying production, all while adhering to the constraints imposed by planetary boundaries [23]. These research findings substantiate the indispensability of soil testing in the r ealm of maize production. Moreover, they underscore the necessity for further exploration to develop innovative and more potent methodologies aimed at improving soil properties and elevating maize yields. As such, these insights reinforce the critical role that soil testing plays in optimizing nutrient management strategies, customizing fertilizer application practices, and addressing the overarching global challenges associated with maize cultivation. Soil testing occupies a central position in the intricate web of nutrient management for maize production. Recent research profoundly accentuates its significance in fine-tuning fertilizer application, ameliorating soil characteristics, and ultimately bolstering maize yields. By diligently incorporating soil testing into their agricultural practices, farmers can aptly discern the most optimal courses of action, thereby maximizing nutrient utilization, mitigating environmental repercussions, and fostering sustainable and prosperous maize farming [24, 25, 26, 27].

Fertilizer types and application methods

Nutrient management plays a vital role in optimizing maize production and selecting appropriate fertilizer types and application methods is crucial for achieving optimal crop yields [28]. Maize requires specific nutrients, including nitrogen (N), phosphorus (P), and potassium (K), as well as secondary and micronutrients, to support its growth and development. Nitrogen fertilizers, such as urea, ammonium nitrate, and ammonium sulfate, are commonly used to supply the essential nutrient nitrog en to maize. Nitrogen application should be split into multiple doses to match the crop’s demand throughout the growing season [29]. Phosphorus fertilizers, such as diammonium phosphate (DAP) and triple superphosphate (TSP), are beneficial for root development and overall plant growth. These fertilizers are typically applied at planting time, either broadcast or as a band near the seed, to ensure efficient uptake by the developing root system. Potassium fertilizers, such as potassium chloride (KCl) and potassium sulfate (K2SO4), are crucial for enhancing maize yield and improving drought tolerance [30]. The application of potassium can be incorporated into the soil before planting or applied as a side dress during the early stages of crop growth. Additionally, secondary nutrients like calcium (Ca), magnesium (Mg), and sulfur (S), along with micronutrients like zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), and boron (B), and molybdenum (Mo), play significant roles in maize production [31]. These nutrients can be supplied through soil amendments or foliar applications, based on soil test results and crop nutrient requirements. Appropriate fertilizer application methods, such as broadcasting, banding, side-dressing, and foliar spraying, should be employed to ensure efficient nutrient uptake and minimize losses. By following recommended nutrient management practices, including split applications and considering the specific nutrient requirements of maize, farmers can achieve higher yields and sustainable crop production [31, 32, 33].

## Timing and rates of fertilizer application

Timing and rates of fertilizer application are crucial factors in optimizing maize production and ensuring efficient nutrient uptake. Nitrogen (N) is a key nutrient for maize, and it should be applied in multiple doses to meet the crop's demand throughout the growing season [33]. The first application of nitrogen can be done at planting time, with subsequent doses applied during the early vegetative stage and at the onset of the rapid growth phase [34]. Phosphorus (P) is essential for root development and overall plant growth. It is recommended to apply phosphorus-based fertilizers, such as diammonium phosphate (DAP) or triple superphosphate (TSP), at planting time either as a broadcast or band application near the seed [35]. The application of potassium (K) is beneficial for enhancing maize yield and improving drought tolerance. Potassium fertilizers like potassium chloride (KCl) or potassium sulfate (K2SO4) can be incorporated into the soil before planting or applied as a side-dress during the early growth stages [32]. Additionally, secondary nutrients such as calcium (Ca), magnesium (Mg), and sulfur (S), along with micronutrients including zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), boron (B), and molybdenum (Mo), are important for maize production. The application rates of these nutrients depend on soil test results and crop nutrient requirements [36]. Generally, it is recommended to follow regional fertilizer recommendation guidelines to determine the appropriate rates of nutrient application for maize [37]. By carefully timing and applying fertilizers at the right rates, farmers can ensure an adequate nutrient sup ply for maize and maximize crop productivity.

Conservation agriculture-based practices

Conservation agriculture (CA) is an approach that promotes sustainable and envir onmentally friendly maize production while enhancing soil health and crop resilienc e [7, 15]. Several CA-based practices have proven effective in maize cultivation. On e key practice is minimum soil disturbance, which involves reducing or eliminating conventional tillage to preserve soil structure and prevent erosion [53]. Zero tillag e, where seeds are directly planted into untilled soil, has shown positive effects on maize yields by improving water infiltration and conserving soil moisture [6, 7]. An other important practice is residue management, where crop residues are left on t he soil surface instead of being removed or burned. This practice enhances organi c matter content, improves soil fertility, and reduces weed pressure [15]. Cover cr opping is also integral to CA in maize systems, where non-commercial crops are g rown during fallow periods to protect the soil from erosion, suppress weeds, and i mprove nutrient cycling [54]. Additionally, crop rotation is a key component of CA, as it breaks disease and pest cycles, improves soil structure, and enhances nutrie nt availability [55]. Intercropping, the simultaneous cultivation of two or more crop s in close proximity, is another beneficial CA practice that optimizes resource use and diversifies farm income [56]. Precision nutrient management, including site-sp ecific fertilization based on soil testing and variable rate application, helps optimiz e nutrient use efficiency while minimizing environmental impacts. Effective weed management through integrated approaches, such as using cover crops, mechanical methods, and targeted herbicide application, is essential in CA maize production to reduce weed competition. By adopting these CA-based practices, maize producers can achieve sustainable crop production, improve soil health, and mitigate environmental risks [57, 58].

Best practices for nutrient management in maize production

Implementing best practices for nutrient management is crucial for optimizing maize production and ensuring sustainable crop yields. Firstly, conducting regular soil testing is essential to assess nutrient levels and pH, providing valuable information for fertilizer recommendations [5, 6]. Splitting nitrogen (N) applications throughout the growing season based on crop demand is highly recommended to improve nitrogen use efficiency [25]. For phosphorus (P) fertilization, applying diammonium phosphate (DAP) or triple superphosphate (TSP) at planting time, either broadcast or as a band near the seed, promotes root development and overall plant growth [20]. Potassium (K) fertilizers should be applied either as a pre-plant incorporation or as a side-dress during early crop stages to enhance maize yield and improve drought tolerance. In addition to N, P, and K, secondary nutrients (calcium, magnesium, and sulfur) and micronutrients (zinc, copper, iron, manganese, boron, and molybdenum) play vital roles in maize production. Soil amendments or foliar applicati ons can be utilized to address deficiencies based on soil test results and crop nutrient requirements [49]. Employing appropriate fertilizer application methods such as broadcasting, banding, side-dressing, or foliar spraying ensures efficient nutrient uptake and minimizes losses [38]. Moreover, adopting conservation practices such as cover cropping, crop rotation, and precision farming techniques can improve nutrient cycling, reduce nutrient runoff, and enhance soil fertility. Multiple studies have linked the impact of biochar on crop productivity to various factors, including enhanced cation exchange capacity (CEC) and the subsequent retention of nutrients, elevated pH levels and increased base saturation, augmented availability of phosphorus, and improved water accessibility for plants [59]. Regular monitoring of crop health and adjusting fertilizer applications based on visual symptoms or plant tissue analysis is crucial to avoid over or under-application of nutrients. By adhering to these best practices, farmers can optimize nutrient management in maize production, leading to increased yields, improved resource use efficiency, and environmental sustainability (6

Challenges and opportunities for improving nutrient management practices

Effective nutrient management is essential for sustainable agriculture and maximizing crop productivity, but it faces several challenges and offers opportunities for improvement. One major challenge is the improper use of fertilizers, resulting in nutrient imbalances, environmental pollution, and economic losses [61]. Over-applica tion of fertilizers can lead to nutrient runoff, causing water pollution and eutrophication [62]. On the other hand, insufficient fertilizer application can result in nutrient deficiencies, limiting crop yields. Another challenge is the lack of soil testing and nutrient analysis, which hinders precise fertilizer recommendations based on the specific nutrient requirements of crops. Inadequate knowledge and awareness among farmers regarding nutrient management practices further contribute to suboptimal fertilizer use [16, 31, 39]. However, there are opportunities for enhancing nutrient management practices. The development and promotion of precision agriculture technologies enable site-specific nutrient application, optimizing fertilizer use efficiency [63]. Integration of organic farming practices, such as cover cropping, crop rotation, and the use of organic amendments, can enhance soil fertility and reduce the reliance on synthetic fertilizers [64]. Additionally, implementing conservation practices like conservation tillage and nutrient management planning can minimize nutrient losses and improve nutrient use efficiency [50]. Education and extension programs play a crucial role in increasing farmers' understanding of nutrient management principles and practices, encouraging adoption of sustainable approaches. Furthermore, research efforts are focused on developing advanced fertilizers with slow-release mechanisms and improved nutrient uptake efficiency. By addressing these challenges and embracing the opportunities, sustainable nutrient management practices can be achieved, promoting environmentally friendly agriculture and e nsuring long-term food security [65, 66].

## Soil Fertility

Soil fertility refers to the ability of soil to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality.[3] It also refers to the soil's ability to supply plant/crop nutrients in the right quantities and qualities over a sustained period of time. A fertile soil has the following properties:[4] Soil fertility and quality of land have been impacted by the effects of colonialism and slavery both in the U.S. and globally. The introduction of harmful land practices such as intensive and non-prescribed burnings and deforestation by colonists create long-lasting negative results to the environment. The institution of slavery reproduced distress to the natural world and crop production. Soil fertility and depletion have different origins and consequences in various parts of the world. The intentional creation of dark earth in the Amazon promotes the important relationship between indigenous communities and their land. In African and Middle Eastern regions, humans and the environment are also altered due to soil depletion.

## Tillage practice

Tillage practices refer to the tillage operations carried out between the harvest and following sowing/cultivation operation. Tillage, crop rotation and soil cover are practices related to pesticide and nutrient runoff, soil erosion, soil compaction etc. The information about tillage practices helps assess other indicators as such on s oil cover, risks of nitrate leaching, and organic matter of soils. Any disturbance of soils may enhance turnover of nutrients and thereby increase the potential risk of loss of, for example, nitrogenous compounds and phosphorus through surface runoff and soil erosion. Especially, tillage in the autumn may increase the potential risk of losses during the following winter period. Survey on agricultural production methods (SAPM) 2010

Effect of tillage practice

Positive

Plowing:

Loosens and aerates the top layer of soil or horizon A, which facilitates planting the crop.[18]

Helps mix harvest residue, organic matter (humus), and nutrients evenly into the soil.[18]

Mechanically destroys weeds.[18] Dries the soil before seeding (in wetter climates, tillage aids in keeping the soil drier).[18] When done in autumn, helps exposed soil crumble over winter through frosting and defrosting, which helps prepare a smooth surface for spring planting.[18]

Can reduce infestations of slugs, cut worms, army worms, and harmful insects as they are attracted by leftover residues from former crops.[19] Reduces the risk of crop diseases which can be harbored in surface residues.[19]

Negative

Dries the soil before seeding.[18]

Soil loses nutrients, like nitrogen and fertilizer, and its ability to store water.[18][note 2]

Decreases the water infiltration rate of soil. (Results in more runoff and erosion [18][20] as the soil absorbs water more slowly than before) Tilling the soil results in dislodging the cohesiveness of the soil particles, thereby inducing erosion.

Chemical runoff.[18] Reduces organic matter in the soil. [18) Reduces microbes, earthworms, ants, etc.[21] Destroys soil aggregates.[18][21] Compaction of the soil, also known as a tillage pan.[18][Eutrophication (nutrient runoff into a body of water).[note 3]

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 The Study Area

The experiment will be conducted at the Demontration farm of Kwara State Polytechnic, Ilorin, Nigeria ($8^0 28^I$N, $4^0 31^I$E) in the Southern Guinea Savanna ecological zone. The rainfall pattern is bimodal. A long rainy season from April to July and a short rainy period which extend from September to the late October after a dry spell in August, and a dry season from November to March, and the annual rainfall varies from 1000mm to 1500mm. The average daily temperature varies from $25^0$C in January to $27.5^0$C in May and $22.5^0$C in September (Tunde *et al.*, 2013).

## 3.2 Treatments and Experimental Design

The design was a 2×6 factorial experiment. The factors were Tillage practices (minimum tillage and ridges) and nutrient sources ($N_{120}P_{60}K_{60}$+0t/h cow dung, $N_{90}P_4$

$_5K_{45}$+5t/h cow dung, $N_{60}P_{30}K_{30}$+10t/h cow dung, $N_{30}P_{15}K_{15}$+15t/h cow dung, $N_0P_0K_0$+20t/h cow dung, and control). The experiment was laid down in a Randomized Complete Block Design (RCBD), and was replicated thrice.

### 3.4. Agronomical Practices

#### 3.4.1 Land preparation

The experimental field was cleared, and tillage practices were made accordingly upon establishment of rain in the study area. The individual plot size was 3.0m × 2.0m ($6.0m^2$), with spacing of 0.3m within the plot and 0.5cm between plots, and also 1.0m between replicates.

#### 3.4.2 Sowing

Standard, certified OBA SUPER IV maize variety was sown at two (2) seeds per hole. Ten (10) stands per row was planted in four (4) rows, giving a total of forty (40).

#### 3.4.3 Weeds, pests and diseases control

Weeds were controlled by manual weeding with the use of hoe and cutlasses. Army warm attack was controlled with Emamectin Benzoate 5% WDG (caterpillar force) at 20g in 15L solution. There was no record of disease attack throughout the experiment.

### 3.5 Collection and Preparation of Soil Sample

Prior to the land preparation of the experimental site, a composite soil sample of the site was collected by augering at 0 to 10cm depth. The sample was processed (air-dried, crushed, and pass through 2mm sized sieve) for physical and chemical analysis.

**Data Collection**

Net plot for each plot was carved out as the plants in a plot excluding the two plants at each end of the plot. Four (4) plants was tagged from each net plot where data was collected.

### 3.7.1 Growth parameters

#### 3.7.1.1 Plant height

Plant height was measured using meter tape or long ruler at one week interval starting from second week after sowing. The measurement was taken from the soil surface to the highest point of the arch of the uppermost leaf whose tip is pointing down.

#### 3.7.1.2 Number of leaves

Number of leaves was obtained by physical counting of the number of leaves starting from the lowest one (the coleoptiles leaf which has a rounded tip) up to the leaf that is arched over.

#### 3.7.1.3 Leaf area (LA)

Leaf area (LA) will be determined by adopting the method of Musa and Usman (2016), which is LA = 0.75 × Leaf blade length × Leaf blade width, where 0.62 is the Kcoefficient for determination of leaf area for okra.

### 3.7.2 Yield parameters

#### 3.7.2.1 Cob length

Cob length was obtained using measuring tape or ruler.

#### 3.7.2.2 Number of grain per cob

Number of grains in a cob will be recorded as the multiple of number of grains in r ow and number of rows in the cob.

#### 3.7.2.3 Total grain yield

Total grain yield was expressed in tonnes per hectare. This was recorded after har vesting.

### 3.8 Data Analysis

All obtained data will be statistically analyzed according to the technique of Analys is of Variance (ANOVA) for factorial experiment, while mean will be separated usin g Duncan Multiple Range Test (DMRT) at 5% level of probability.

# CHAPTER FOUR

**Table 1: The Table Show the Pre Treatment Physical and Chemical Characteristi cs of Experiment Field**

| SOIL CHARACTERISTICS | VALUE |
|---|---|

| | |
|---|---|
| Sand | 87% |
| Silt | 7% |
| Clay | 6% |
| Textural class | Sandy Loam |
| Soil PH | 5.16(Kcl) |
| Organic Carbon | 0.25% |
| Organic matter | 0.43% |
| Nitrogen | 0.11% |
| Phosphorous | 44.58ppm |
| Potassium | 1.56cmol/kg |
| Sodium | 0.76cmol/kg |
| Calcium | 8.20cmol/kg |
| Magnesium | 1.55cmol/kg |
| CEC | 12.45cmol/kg |

Table 1 above showed the pretreatment physical and chemical analysis result of the experiment plot. The soil is classified as sandy loam, with slightly low pH. The organic matter content of the soil is also low, so also is the nitrogen level. Generally, the nutrient fertility level of the soil is considered low.

**Table 2: Shows the effect of nutrient source on leaf number of Maize**

| NUTRIENT SOURCE | LEAF NO @ 4WAS | LEAF NO @ 6WAS | LEAF NO @ 8WAS |
|---|---|---|---|

| | (cm) | (cm) | (cm) |
|---|---|---|---|
| Control<br>**$N_0P_0K_0$+20tonsCD**<br>**$N_{120}P_{60}K_{60}$+0tonsC**<br>**D**<br>**$N_{30}P_{15}K_{15}$+15tonsC**<br>**D**<br>**$N_{60}P_{30}K_{30}$+10tonsC**<br>**D**<br>**$N_{90}P_{45}K_{45}$+5tonsCD**<br>**P-Value**<br>**LOS** | 6<br>7<br>6<br>7<br>7<br>7<br>0.017<br>** | 8<br>8<br>7<br>9<br>7<br>8<br>0.277<br>NS | 9<br>9<br>9<br>10<br>10<br>10<br>0.354<br>NS |

CD=Cow Dung, WAS=weeks after Sowing, NS= Not Significant, **= Significant of 5% (0.05) level of probability.

From table 2 above, at 4WAS, all the plots with cow dung ($N_0P_0K_0$+20tonsCD, $N_{30}P_{15}K_{15}$+15t, $N_{60}P_{30}K_{30}$+10tonsCD, $N_{90}P_{45}K_{45}$+5tonsCD) gave significantly higher leaf number than control and sole inorganic fertilizer ($N_{120}P_{60}K_{60}$+0tonsCD). At 6WAS, the highest mean leaf number was recorded for $N_{30}P_{15}K_{15}$+15tonsCD, though not significant. $N_{30}P_{15}K_{15}$+15tonsCD, $N_{60}P_{30}K_{30}$+10tonsCD and $N_{90}P_{45}K_{45}$+5tonsCD perform better than other treatment, but the value is not significant.

**Table 3: shows the effect of tillage practice on mean leaf number of maize**

| TILLAGE PRACTICES | LEAF NO @4WAS (cm) | LEAF NO @6WAS (cm) | LEAF NO @8WAS (cm) |
|---|---|---|---|
| Minimum Tillage | 7 | 8 | 9 |
| Ridges | 7 | 8 | 10 |
| P-Value | 0.788 | 0.380 | 0.107 |
| LOS | NS | NS | NS |

WAS=weeks after Sowing, NS= Not Significant, **= Significant of 5% (0.05) level of probability.

There are significant differences in tillage practices adopted in relation to plant leaf number. Although it is observed that that plot with ridges gave higher leaf number at week

**Table 4: show the effect of the interaction between nutrient sources and tillage practice on leaf number of maize**

| NUTRIENT SOURCE | TILLAGE PRACTICE | 4WAS | 6 WAS | 8 WAS |
|---|---|---|---|---|
| Control | MT | 7 | 7 | 10 |

| | | | | |
|---|---|---|---|---|
| Control | RD | 6 | 9 | 8 |
| $N_0P_0K_0$+20tonsCD | MT | 8 | 9 | 9 |
| $N_0P_0K_0$+20tonsCD | RD | 7 | 8 | 10 |
| $N_{120}P_{60}K_{60}$+0tonsC | MT | 6 | 7 | 9 |
| D | RD | 6 | 8 | 10 |
| $N_{120}P_{60}K_{60}$+0tonsC | MT | 7 | 9 | 9 |
| D | RD | 7 | 9 | 10 |
| $N_{30}P_{15}K_{15}$+15tons | MT | 6 | 7 | 10 |
| CD | RD | 7 | 7 | 11 |
| $N_{30}P_{15}K_{15}$+15tons | MT | 7 | 8 | 9 |
| CD | RD | 6 | 8 | 10 |
| $N_{60}P_{30}K_{30}$+10tons | | 0.500 | 0.686 | 0.405 |
| CD | | NS | NS | NS |
| $N_{60}P_{30}K_{30}$+10tons | | | | |
| CD | | | | |
| $N_{90}P_{45}K_{45}$+5tonsC | | | | |
| D | | | | |
| $N_{90}P_{45}K_{45}$+5tonsC | | | | |
| D **P-Value** | | | | |
| **LOS** | | | | |

MT= Minimum Tillage, RD=Ridges, CD=Cow Dung, WAS=weeks after Sowing, NS= Not Significant, **= Significant of 5% (0.05) level of probability.

The observation from the table 4 above showed no significance in the nutrient sources and tillage practices interaction in terms of leaf number. $N_0P_0K_0$+20tonsCD× minimum tillage gave the highest mean value at 4WAS, while the highest mean value was recorded for $N_{60}P_{30}K_{30}$+10tonsCD×Ridges at 8WAS.

**Table 5: shows the effect of nutrient sources on plant height of maize**

| NUTRIENT SOURCE | PLANT HEIGHT @ 4 WAS (cm) | PLANT HEIGHT @ 6WAS (cm) | PLANT HEIGHT @ 8 WAS (cm) |
|---|---|---|---|
| Control | 42 | 64 | 92 |
| **$N_0P_0K_0$+20tonsCD** | 60 | 79 | 87 |
| **$N_{120}P_{60}K_{60}$+0tonsCD** | 37 | 61 | 102 |
| **$N_{30}P_{15}K_{15}$+15tonsCD** | 43 | 74 | 106 |
| **$N_{60}P_{30}K_{30}$+10tonsCD** | 39 | 64 | 100 |
| **$N_{90}P_{45}K_{45}$+5tonsCD** | 43 | 65 | 106 |
| **P-Value** | 0.099 | 0.040 | 0.640 |
| **LOS** | ** | ** | NS |

CD=Cow Dung, WAS=weeks after Sowing, NS= Not Significant, **= Significant of 5% (0.05) level of probability.

From table 5 above, at 4WAS, the plots with cow dung ($N_0P_0K_0$+20tonsCD) gave significantly higher leaf number than control and sole inorganic fertilizer **($N_{120}P_{60}K_{60}$+0tonsCD). A**t 6WAS, the highest mean leaf number also recorded for( $N_0P_0K_0$+20tonsCD), and significant. $N_{30}P_{15}K_{15}$+15tonsCD and $N_{90}P_{45}K_{45}$+5tonsCD perform better than other treatment, but the value is not significant.

**Table 6: show the effect of tillage practice on plant height of maize**

| TILLAGE PRACTICES | PLANT HEIGHT @ 4 WAS (cm) | PLANT HEIGHT @ 6WAS (cm) | PLANT HEIGHT @ 8 WAS (cm) |
|---|---|---|---|
| Minimum Tillage | 44 | 68 | 98 |
| Ridges | 41 | 68 | 100 |
| P-Value | 0.283 | 0.984 | 0.802 |
| LOS | NS | NS | NS |

WAS=weeks after Sowing, NS= Not Significant, **= Significant of 5% (0.05) level of probability.

There are not significant differences in tillage practices adopted in relation to plant height.At 4WAS minimum tillage gave higher plant height than Ridges, At 8 WAS Minimum Tillage and ridges gave the same plant height, although it is observed that that plot with ridges gave higher plant height at week 8.