PREPARATION AND CHARACTERIZATION OF ORGANIC COMPOST AS AN ECO-FRIENDLY ALTERNATIVE TO CHEMICAL FERTILIZERS

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A thesis submitted to Bahria University, Islamabad in partial fulfilment of the requirement for the degree of Bachelor of Science in Environmental Sciences

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DEDICATION

We, with immense pleasure, dedicate this research to our beautiful homeland Pakistan.
This research is also dedicated to our respected parents.

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With our hearts full of respect and regard, we would firstly thank Allah Almighty, whom we bow before in submission, for blessing us and enabling us to perform this research. Our hearts possess great love respect and gratitude for our parents and witnesses of their utmost dedication, love, care, prayers, and hard work to make us what we are. We likewise thank our prestigious and highly esteemed university and respective department for being our identity and providing us opportunities to dwell, grow and prosper professionally. We also offer our sincere thanks, regards and respect to our supervisor Dr. Asma Jamil for her priceless guidance, true hard-work, and profound efforts and for patiently helping us throughout, this thesis of ours. We are extremely grateful for his extraordinary guidance and genuine support. We are also thankful to Head of Department Dr. Said Akbar Khan for providing all lab facilities. Special thanks are also extended to Mr. Imtiaz, Lab Assistant of Earth/Chemical Lab, and Bahria University Islamabad for his guidance and assistance in conducting sample analysis. We also appreciate our friends and colleagues support, assistance, and affection. We would want to express our gratitude to everyone who has assisted us in the completion of our thesis, whether directly or indirectly.

ABSTRACT

This study investigates the feasibility of compost as a sustainable alternative, preparation and characterization of compost to evaluate its efficacy as a substitute for chemical fertilizers in agricultural practices and examines the effects of compost application on soil fertility, plant growth, and environmental sustainability. The preparation process involves the collection and segregation of organic waste materials, including kitchen scraps, yard trimmings, poultry manure. Plant trials are conducted to compare the performance of compost with chemical fertilizers in terms of crop yield, nutrient uptake, and soil health indicators. Characterization of the compost is conducted through physio - chemical analyses. Physical properties such as pH (6.44) (calculated with digital multimeter) and moisture content (33.4) (measured by Digital oven) are assessed to determine the suitability of compost for soil application. Chemical analysis includes the quantification of compost and chemical fertilizer such as nitrogen (measured with Micro Kjeldahl method), phosphorus and potassium (measured with Spectrophotometry method), along with organic matter content (measured with Incinerator). The percentage for compost (NPK) is (0.7%, 0.75%, 2.5%) and chemical fertilizer (0%, 2.50%, 0%).

According to this research, composting offers a comprehensive way to support sustainable agriculture in the face of climate change challenges by increasing soil fertility, lowering environmental pollution, and promoting agricultural resilience. Composting is a sustainable alternative to chemical fertilizers.

ABBREVIATIONS

NPK	NITROGEN, PHOSPHORUS, POTASSIUM
MCC	MICROBIAL CULTURE COLLECTIONS
SOM	SOIL ORGANIC MATTER
SOC	SOIL ORGANIC CARBON
OM	ORGANIC MATTER
MO	MOISTURE CONTENT
OW	ORGANIC WASTE
PH	POWER OF HYDROGEN
AR	AERATION RATE
MSW	MUNCIPAL SOLID WASTE
NUE	NUTRIENT USE EFFICIENCY
NIFA	NUCLEAR INSTITUTE FOR FOOD AND AGRICULTURE

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CHAPTER 1

INTRODUCTION

1.1 Chemical fertilizers and Formulations

Chemical fertilizers, produced in factories and widely accessible in various forms in the market, come in diverse compositions. These fertilizers are known for their rapid effects and affordability. They are available in solid forms such as granules, crystals, powder, and pills, as well as in slow-release alternatives like spikes, pellets, liquids, and tablets. Typically, they contain primary nutrients like nitrogen, phosphorus, and potassium in specific proportions. Additionally, chemical fertilizers may also include micronutrients and secondary macronutrients to cater to a broader spectrum of plant requirements. (Shazia et al. 2020)

Figure 1.1 Chemical fertilizer pellets

1.2 Types of Chemical Fertilizers

The 3 types of synthetic fertilizers are accessible: nitrogenous, phosphorus, and potassium fertilizers. Chemical fertilizers comprise elements like nitrogen, potassium, and phosphorus, and they are employed to enhance land productivity.(Dar et al. 2021)

1.2.1 Nitrogenous Fertilizer

This fertilizer contains nitrogen in various forms: ammoniacal nitrogen, like ammonium chloride and ammonium sulphate; amide nitrogen, such as urea; and nitrate-nitrogen, like calcium ammonium nitrate, which contains both ammoniacal and nitrate nitrogen. It is utilized to address nitrogen deficiencies in the soil and is highly advantageous for plants. This fertilizer not only provides essential nutrients to the plants but also enhances soil fertility.

1.2.2 Phosphorus Fertilizer

Phosphorus is found in fertilizers as readily accessible phosphate. This fertilizer is essential for use on land. It requires less in comparison to fertilizer containing nitrogen.

1.2.3 Potassium Fertilizer

Potassium chloride (muriate) and potash sulphate can be used to satisfy the requirement for potassium. Potassium sulphate is vital for promoting robust plant growth as it aids in carbohydrate formation within plants. Potassium is categorized into two subtypes: potash in non-chloride form and potash in chloride form. Examples of potash in non-chloride nature include Sulphate of Potash, while potash in chloride form includes Muriate of Potash.

1.3 Environmental Challenges Pose by Chemical Fertilizer

1.3.1 Soil Quality

The decline in soil quality is often linked to the widespread use of chemical fertilizers, notably single super phosphate (SSP), potash, urea and in efforts to increase crop productivity. As the primary source of important nutrients, soils must be controlled well in order to mitigate global food security issues and reduce the negative impact of nutrient runoff on the quality of water and air. Various factors pose risks to soil health: Salination, acidification, erosion, contamination, soil compaction, and decline in organic matter, which can affect P and N eliminate to water and air. . (Velthof et al. 2011)

1.3.2 Physicochemical Properties of Soil

Soil nutrient management plays a critical role in maintaining soil quality and ensuring sustained productivity in nursery systems. Fertilization practices impact the levels of nitrogen (N) and carbon (C) in soil through changes in soil structure and the organic N and C content of the soil (Hai et al. 2010), and soil aggregation (Su 2007). The ongoing application of chemical fertilizers distinctly affects the biochemical characteristics of soil, leading to changes in microbial communities. The continuous use of fertilizers in various crops like corn, wheat, and others has been observed to cause shifts in nitrogen (N) levels, soil organic content (SOC), moisture levels, pH, and the availability of nutrients (NPK) to microorganisms. (Bohme et al. 2005). The application of fertilizer has resulted in a reduction in soil bulk density, possibly attributed to an increase in the soil's organic carbon content. (Selvi et al. 2005The higher rate of root growth that produced more soil residues, which may have raised the amount of SOC after degradation, is responsible for the greater SOC level. (Kumpawat and Jat 2005). Sradnick et al. (2013) The variance in soil organic carbon (SOC) levels and soil pH due to fertilization has been identified as a contributing factor to the diversity of microorganisms within sandy soil profiles.

1.3.3 Soil Compaction

Soil compaction involves the development of dense, compacted layers that form in cultivated areas, often resulting from the application of compressive forces exerted by wheels on soil with compressible properties. (Hamza and Anderson 2005). Soil compaction arises from reduced utilization of synthetic fertilizers (such as compost), extensive use of heavy machinery, continuous application of chemical fertilizers, and repeated shovelling at a uniform depth. (Mari et al. 2008). Furthermore, soil compaction leads to issues such as insufficient air circulation, increased soil strength, diminished drainage capabilities, erosion, runoff, and degradation of soil quality. (Batey 2009). Soil compaction is a significant component of land degradation syndrome and poses a substantial threat to agriculture, adversely affecting almost all soil characteristics.. It modifies the soil structure by disrupting aggregate units, reducing the size of pore spaces between soil particles, diminishing soil volume and porosity, consequently leading to an elevation in soil bulk density. (Weisskopf et al. 2010)

1.3.4 Effects on Soil Biota

Microbial activity plays a crucial role in maintaining soil health. Soil microflora, comprising bacteria, fungi, protozoa, algae, and viruses, are integral components of the agricultural ecosystem, performing essential functions such as enhancing soil fertility, facilitating nutrient cycling, improving productivity by increasing the availability of limited nutrients, and decomposing both inorganic and organic matterGlobal food security depends mostly on soil biodiversity in addition to other aspects of agro-biodiversity, such as plant and animal services. The impact of fertilizers on soil microorganisms can be either beneficial or detrimental, depending on factors such as the duration, quantity, quality, and method of fertilizer application. Recently, the importance of diversity in microbial culture collections (MCC) has been emphasized for maintaining soil health.

(Mele and Crowley 2008; Shen et al. 2008 Due to their involvement in shaping soil structure, decomposing (SOM), and facilitating the biogeochemical cycling of nutrients, soil microorganisms play a significant role. (Paul 2007). The resource Accessibility, such as nitrogen (N), phosphorus (P), and carbon (C), controls primarily the soil microbial population's diversity of function. (Lupwayi et al. 2012). Hence, there exists a crucial correlation between microbial communities and soil organic carbon (SOC), as well as the activities of microorganisms. (Bohme et al. 2005).

1.3.5 Effects on Plants

Soil fertility and plant health heavily rely on an adequate supply of important nutrients and minerals. Overuse of nutrients creates an imbalance in soil nutrient levels, leading to the degradation of stable soil. While chemical fertilizers promote rapid plant growth, they often hinder proper root development. Consequently, plants grown with chemical fertilizers may have weaker stems and produce less nutritious fruits and vegetables. Under these conditions, plants are more vulnerable to diseases and pests, reducing their chances of survival. Additionally, chemical fertilizers can impede water absorption by plants, potentially causing root or fertilizer burn. (Dar, Bhat, Mehmood, & Hakeem, 2021)

1.4 Organic Waste

Organic waste (OW) encompasses biodegradable materials originating from plants or animals. Biodegradable waste refers to organic matter capable of decomposing into carbon dioxide, methane, or simple organic compounds. In agriculture, organic wastes (compost) are primarily used to enhance soil's physical and chemical characteristics and serve as nutrient sources for crop cultivation. Examples of organic wastes include animal manures, crop residues, and fruit and vegetable scraps.

1.5 Types of Organic Waste

Organic waste is described as "Substances composed of material containing carbon compounds." A significant quantity of organic waste is produced daily in both rural and urban regions of Pakistan.

For Example:

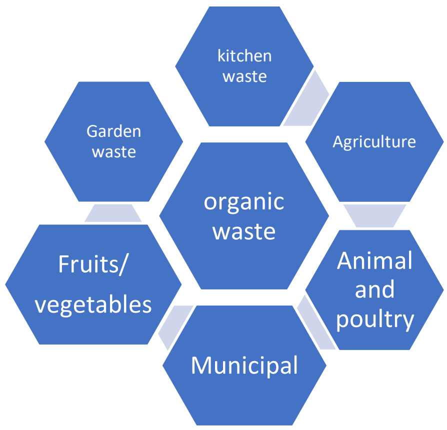

Figure 1.2 Types of organic waste

1.6 Utilization of Organic Waste for Organic Compost Generation

Organic solid waste, such as spoiled vegetables and fruits, is produced across rural and urban regions of Pakistan. The primary focus of our thesis is on producing organic compost from waste materials like fruit and vegetable scraps, as well as poultry manure collected from households. This thesis aims to aid in waste segregation, disposal, and the production of organic compost, ultimately leading to the creation of organic fertilizers for crops, thereby reducing reliance on chemical fertilizers. (Sorathia, Rathod et al. 2012).

1.7 Compost

Compost is created through the decomposition of organic matter, breaking down complex compounds into simpler organic and inorganic substances through the composting process. This method involves repurposing various organic materials that would otherwise be considered waste. Good compost contains useful microbes and is abundant in plant nutrients. It can be applied to sustainable farming, agriculture in cities, gardening, horticulture, and gardens to increase soil fertility. Composting is a controlled decomposition process, naturally converting raw OW into biologically stable, humic substances that serve as effective soil amendments. Compared to raw manure and other organic materials, compost is easier to manage, store, and handle, and it is also free of unpleasant odors.

Composting is an ancient technique that is currently employed across a range of scales, from small backyard compost heaps to large-scale commercial operations. George Washington, the first president of the United States, was among the earliest advocates of composting. Recognizing the soil degradation caused by farming practices, Washington constructed a "dung repository" to compost animal manure and replenish the soil's organic content. (Cooperband 2002)

1.8 Utilization of Compost as a Fertilizer and Soil Enhancer

Different forms of waste, including food waste (FW), aquatic waste, and biowaste, have been repurposed into organic fertilizers and soil amendments due to their demonstrated effectiveness similar to commercial chemical fertilizers. For example, FW contains a wealth of organic materials like carbohydrates, proteins, lipids, and organic acids, along with essential nutrients like nitrogen, phosphorus, and potassium, making it an excellent source material for producing high-quality compost. (Chew et al., 2018a; Ma and Liu, 2019). Compost serves as a valuable source of organic matter, possessing unique properties that enhance the physical, chemical, and biological characteristics of soils. It improves water retention in sandy soils and enhances soil structure in clay soils by promoting stability in soil aggregates. Integrating compost into soil enhances soil fertility, boosts cation exchange capacity, and can reduce fertilizer needs by up to fifty percent. Increased microbial activity facilitated by compost accelerates the decomposition of pesticides and other synthetic organic compounds. Additionally, compost amendments reduce the bioavailability of heavy metals, offering significant benefits in remediating contaminated soils.. (Cooperband 2002)

1.9 Compost Technologies

- Static piles
- Windrow composting
- Passively aerated windrows
- Forced aeration, static piles
- Enclosed, or in-vessel, composting (enclose bin)
- Vermicomposting

1.10 Enclosed Composting Technology

Composting is conducted in enclosed facilities primarily situated indoors, often within buildings. These facilities necessitate short retention periods and are primarily employed for the initial or interim processing of organic wastes. Compost bins or clay pots are then used to fully cure or fix the partially recovered organic materials. (Boldrin et al. 2009).

1.11 Choosing Compost over Conventional Chemical Fertilizers

1.11.1 Nutrient Restoration

While chemical fertilizers offer readily accessible nutrients such as nitrogen crucial for plant enhancement, they have a short lifespan in the soil due to their tendency to be quickly washed away into groundwater through leaching.

(Claassen and Carey 2007). It impacts the fertility of the top layer of soil, which is critical for agricultural prosperityBy raising the amount of soil organic carbon (SOC), which is essential for microbial viability. Compost serves an essential function in preserving soil health. The heightened SOC levels stimulate microbial communities, facilitating the breakdown of nutrients into forms readily absorbed by plants. Although the release of nutrients from compost occurs over a longer period compared to chemical fertilizers, it provides benefits for sustainable land management in the long run. Furthermore, the production of humus during composting enhances soil nutrient levels, promoting improved plant growth and overall plant well-being. (Al-Bataina et al. 2016) Compost gradually releases its nutrients, resulting in less loss of nutrients. Fertile soil is essential within our biosphere as it supports robust plant growth, enhances yields of fruits and vegetables, strengthens root systems, and promotes biodiversity.

1.11.2 Soil Conditioning

While inorganic fertilizers enhance soil nutrient levels, they have not proven to be cost-effective as soil conditioners. (Mtaita 2003). Conversely, organic fertilizer, such as compost, provides essential nutrients to the soil while also enhancing its physical properties, including soil quality and structure. (Huang et al. 2016). Composted organic material added to soil enhances soil aggregate strength.

1.11.3 Moisture Management

Compost enhances both surface percolation for land-leveling and moisture retention and distribution, similar to the effect of a soft soil cover. These benefits in water retention from composting result in decreased water consumption during plant irrigation and minimize harmful water runoff. (Eden et al. 2019).

1.11.4 Public Health

Exposure to chemical fertilizers may induce specific allergies in susceptible individuals, resulting in illness. In contrast, compost is environmentally friendly, while chemical fertilizers can pose health risks through leachates that contaminate water bodies.

1.11.5 Organic Waste Reduction

Effectively managed composting procedures can stabilize organic waste and yield nutrient-rich compost (known as bio fertilizer) that improves soil ecological characteristics.

1.12 Factors Influencing Composting Process

1.12.1 Temperature

Composting conducted within the temperature range of 105 to 160°F, encompassing both mesophilic and thermophilic conditions, is emphasized for its advantages in destroying pathogens, eliminating weed seeds, and efficiently breaking down waste. The recommended optimal composting temperature falls between 130 and 150°F, as temperatures surpassing 160°F are deemed detrimental to microbial efficiency. During the mesophilic stage, nutrient metabolism and heat generation occur, while the thermophilic phase is essential for eliminating pathogens and indicates the decomposition and stabilization of organic matter. (Zhang and Sun 2014)

1.12.2 pH

The pH fluctuations throughout the composting process have diverse effects on microbial functions (Chen et al., 2015a, 2016). Typically, pH levels decrease in the initial composting stages before rising in later phases. This shift contributes to an increase in the NH3/NH4 ratio, resulting in elevated rates of volatilization, indicating enhanced biological activity (Turan, 2008). Low pH levels impair the overall functions of microbes by having a negative impact on their conversion from mesophilic to thermophilic phases. (Paradelo et al., 2013; Sundberg et al., 2004). Different studies emphasize an optimal pH range for microbial activity, varying from 5.5 to 9, with differing recommendations to support robust microbial processes (Rich and Bharti, 2015). While pH is considered less critical for compost stability, mature compost is advised to maintain a pH within the range of 6.0–8.5 (Fernandez-Delgado et al., 2015).

1.12.3 Aeration/oxygen content

Aeration rate (AR) is recognized as the primary factor determining the success of composting. Inadequate aeration may result in anaerobic conditions due to oxygen deficiency, whereas excessive aeration can escalate costs and slow down the composting process by causing heat, water, and ammonia losses (Diaz et al., 2002). If the material is not turned, composting will still occur but at a slower rate, sometimes taking a year or 18 months, and may potentially become anaerobic.

1.12.4 Moisture content

Optimal moisture content in the beginning of the composting process is crucial, and it should remain within the range of 50-60%. Moisture plays a vital role in microbial activity as it enhances metabolic rates. Microbial activity is minimal when moisture levels are low (Tiquia et al., 1996). A decrease in moisture content towards the end of composting indicates successful decomposition and results in mature compost (Epstein et al., 1995).

1.12.5 Nutrients

Microorganisms break down organic constituents of feedstock during composting to obtain essential nutrients (carbon, nitrogen, phosphorus, and potassium) and energy for their metabolism. Effective composting microorganisms primarily rely on carbon, nitrogen, phosphorus, and potassium for optimal efficiency. Some carbon compounds exhibit resistance to decomposition, whereas nitrogen-containing compounds are typically more readily degradable (Chen et al., 2011).

1.13 Effects on Soil's Physical, Biological, and Chemical Properties

1.13.1 Effects on Soil's Microbial Interactions and Activities

When organic waste goes into composting, it promotes the growth of good microorganisms, mostly bacteria and fungi, which breaks down organic substances to create humus. Consequently, the interactions and functions of soil microbiota are augmented owing to the increased presence of organic materials (Onwosi et al., 2020).

1.13.2 Effects on Soil Structure

Compost boosts the retention of water and nutrients, enhances microbes' activity, and facilitates the slowly release of vital nutrients and moisture. In sandy soils, it increases moisture retention, assisting plant transpiration during drought conditions. In dense clay soils, it improves air circulation and water flow, counteracting the adverse impacts of excessive moisture on plants. Composting fosters the proliferation of beneficial microbes, transforming organic waste into humus, thereby enhancing soil structure, moisture retention, and nutrient content. Additionally, compost can sequester metals, diminishing their absorption by plants (Eden et al., 2019).

1.13.3 Effects on Soil pH

The ability of compost-amended soils to act as a buffer aid in maintaining the ideal pH of the soil, which is essential for the development of microorganisms that help in plant growth and metabolism.

1.13.4 Effects on Climate Change

The significant health and environmental hazards associated with landfill disposal of food waste are well-documented. When food waste, comprising a substantial portion of household and municipal waste, is dumped in landfills, it introduces organic matter that leads to contamination. This disposal method not only pollutes the environment but also proves costly and poses health risks. To address these challenges, diverting food waste from landfills through composting is recommended as a sustainable approach. Composting offers an eco-friendlier waste management solution by averting methane generation, preventing degradation of wastewater, and mitigating the health and environmental dangers linked with landfill disposal (Means et al., 2005).

1.13.5 Effects on Soil-Borne Pathogens and Plant Diseases

The composting procedure enriches the soil by boosting its humus content, consequently enhancing its nutrient levels. This nutrient enrichment stimulates the proliferation of soil microorganism, with microorganisms which promote plant growth outcompeting harmful counterparts due to their superior competitive capabilities.

Moreover, the humic-like components found in composts not only enhance plant health and growth but also exhibit biocontrol properties against soil phytopathogens like fungi (Traversa et al., 2010).

1.13.6 Effects on the Qualities of Agricultural Yield

By supplying vital nutrients and ideal conditions for plants and soil microbes in the soil, composts help to increase agricultural yields. Using compost and biological amendments in the right amounts promotes soil sustainability, enhances tuber yields, reduces plant illnesses, and enhances soil health. (Bernard et al., 2012).

1.14 Challenges of Using Compost (Organic Fertilizer)

Uncontrolled composting poses significant challenges, particularly regarding nitrogen loss through NH3 and N2O emissions, which results in the production of low-nutrient compost unsuitable for sustainable agriculture (Powers and McSorley, 2000). Additionally, the use of municipal solid wastes (MSWs) in compost production introduces heavy metals, potentially harming soil productivity due to their phytotoxic effects.

The quality of compost suffers when low-nutrient organic wastes undergo stabilization, a consequence of inadequate composting management. Odor generation is another issue, influenced by decomposition rate and feedstock type. Materials like biosolids decompose faster and emit more odors than slower-decomposing ones like clean yard trimmings. The technology or facility used for composting has an impact on odor generation; impermeable buildings with internal composting facilities can use biological filters to capture odorous gases.

Temperature and moisture levels also impact odor in pile composting systems. Odor generation increases with lower temperatures and higher moisture levels. Elevated temperatures support enzyme activity and the enhancement of thermotolerant microbes, which produce fewer anaerobic by-products. Conversely, high moisture content can lead to clogged pore spaces, creating anaerobic conditions favoring odor generation due to reduced oxygen solubility in water (Onwosi et al., 2020).

1.15 Literature review

Agriculture is currently encountering significant challenges, including issues like diminished soil organic carbon levels, inefficiencies in fertilizer use, and a growing disparity between nutrient depletion and soil replenishment. The agricultural landscape is at a critical juncture, necessitating a revaluation and enhancement of agricultural practices to fulfill the aspirations of millions. Preserving and enhancing soil fertility, along with sustaining crop production, is a global imperative. Odour generation can be affected by the composting system or operation facility, indoor composting facilities in air tight buildings can use bio filters to collect odourus gases. Maintaining biological diversity and a sustainable agricultural output depend on efficient management of soil health. Production in modern agriculture has increased as a result of the predominance of inputs like fertilizers with chemicals, insecticides, reliable irrigation, better seeds, and herbicides. But their incorrect application raises serious concerns since it degrades soil production and the quality of the surrounding ecosystem (Dar and Bhat 2020).

Inorganic fertilizers are synthetic compounds containing high concentrations of essential nutrients required for plant growth. Compost generation is influenced by the composting system or operational facility; indoor composting facilities in airtight houses can use biofilters to collect odorous gases. They are generally synthetic materials that supply the essential nutrients to plants (Khanday et al., 2016; Dar et al., 2013; Bhat et al., 2018a, b; Mushtaq et al., 2018; Singh et al., 2018). Even if fertilizers are linked to certain problems in agriculture that cannot be avoided, like pesticides, they are nonetheless essential to guaranteeing the safety of food worldwide. But their negative repercussions are unavoidable, particularly given that sustainable agriculture is a top goal for the world. Chemical fertilizers are essential for improving agricultural yield and soil fertility (Hera, 1996; Bhatti et al., 2017).

Various nations exhibit diverse levels of fertilizer usage; for instance, Turkey applies a lower amount of chemical fertilizer per hect compared to numerous developing and developed countries. The figures regarding chemical fertilizer utilization in different countries illustrate this variability. With a noticeable imbalance in fertilizer distribution, India's use of chemical fertilizers increased dramatically from 2.65 million tons (mt) of NPK in 1971–1972 to 28.12 Fertilization practices can contribute to the accumulation of heavy metals in the soil system. As plants absorb fertilizers through the soil, these substances enter the food chain. Particularly during peak seasons, substantial amounts of inorganic fertilizers are utilized in greenhouse and aquaculture.

The continual application of synthetic fertilizers has caused agricultural soil quality to decline, increasing soil acidity and environmental pollution while also lowering the amount of soil organic matter (SOM) (Dinesh et al., 2010; Dar et al., 2016).
Synthetic fertilizers present a risk to agriculture because of their elevated salt content, which can have detrimental effects on plants and soil. They diminish crucial soil minerals and nutrients, unable to adequately replenish soil fertility. Agriculture in Ethiopia plays a pivotal role in human welfare, economic progress, and overall economic contribution. To improve soil fertility, farmers utilize fertilizers, whether organic, inorganic, or a blend of both, as sources of plant nutrients (Tilahun et al., 2022).

Chemical fertilizers provide cost-effectiveness, concentrated nutrients, and rapid absorption by plants. However, excessive use can result in a range of issues such as soil nutrient depletion, contamination of surface and groundwater, soil acidification or alkalization, and reduction of beneficial soil microbes. Consequently, modern agricultural approaches are increasingly emphasizing the search for alternatives to non-renewable chemical fertilizers, prompted by concerns regarding high costs and environmental pollution. There is a rising call for the creation of a streamlined method for producing environmentally friendly, affordable, and efficient organic fertilizers (Tilahun et al., 2022).

Studies indicate that use of chemical fertilizers in Ethiopia has led to an increase in crop yields, although there is still room for enhancement. Currently, fewer than 45 percent of farmers utilize fertilizers, covering approximately 40 percent of cultivated land, often at insufficient dosage levels. Although application rates exceed the sub-Saharan African average, evidence suggests that the efficacy of fertilizers in Ethiopia may not be fully optimized. For instance, maize nutrient use efficiency (NUE), which refers to the yield per kilogram of nutrient applied, ranges from 9 to 17 kilograms of grain per kilogram of nitrogen (N) applied, whereas in Kenya and Tanzania, equivalent NUEs range from 7 to 36 and 18 to 43, respectively (Dercon et al., 2009).

Integrated soil fertility management (ISFM) initiatives implemented in Ethiopia and other sub-Saharan African countries have demonstrated favorable outcomes in terms of crop yields and economic benefits. Combining manure with 75 percent of the recommended fertilizer dosage (or employing a similar combination of compost and fertilizer) resulted in potato yields 10 to 20 percent higher compared to using 100 percent fertilizer application alone. Notably, the utilization of both organic and inorganic nutrient sources led to significantly increased grain yields compared to relying solely on inorganic fertilizers, which is particularly noteworthy considering the prevalent acidic soil conditions in the region (Zelleke et al., 2019).

According to Bouajila and Sanaa (2011), incorporating both manure and household waste compost resulted in a significant elevation of organic carbon levels, with compost application showing the highest effectiveness. Their study revealed that applying 120 tons per hectare of household waste compost and manure led to an increase in organic carbon content (reaching 1.74% and 1.09%, respectively), compared to the control group, which had 0.69% organic carbon.

Using compost, specially made from plant and other organic waste, is a great way to increase the amount of organic matter in the soil. However, how much the soil improves depends on a few important things, like how much compost you use, what kind it is, and how well it's broken down. The type of soil and how you take care of it also play a big role. Compost that has fully broken down and turned into mature compost is best for increasing organic matter in the soil because it has more stable carbon in it (Bouajila and Sanaa, 2011).

Mohammed and colleagues (2004) carried out a study on Guam, a tropical island, where they tested using composted organic waste instead of synthetic fertilizers during both wet and dry seasons. The results showed that applying organic compost to the soil improved its quality, boosted fertility, and increased crop yields.

At the University of Guam, they also conducted a similar experiment on Akina series soil, focusing on corn growth. They found that using 30 and 60 tons of compost per acre increased yields, but using 120 tons actually led to lower yields, possibly because it caused too much plant growth. This suggests that there's an ideal amount of compost to use, and using more than that might not be beneficial for grain production. They also observed that higher compost rates improved the quality of the corn crop.

The study by Soheil et al. (2012) involved a pot experiment to examine the effects of Municipal Waste Compost (MWC) on soil chemical properties and corn plant responses. They found that applying waste compost increased the levels of available nitrogen (N), phosphorus (P), potassium (K), and micronutrients/heavy metals in the soil. These increases were particularly notable across all concentrations tested, with the treatment using 60 tons per hectare showing the most significant enhancement. Furthermore, they analyzed the concentrations of N, P, K, and micronutrient elements in the aerial parts of the plants. The results revealed that as the compost concentration increased, so did the content of N, P, and K, along with the concentration of micronutrients in the plants. Overall, the application of waste compost substantially elevated the concentrations of both macro and micronutrients in the dry matter of the plants.

Brown and Cotton (2011) found that soils amended with compost have similar levels of nutrients available to plants compared to soils treated with conventional fertilizers. Additionally, compost-amended soils contain higher levels of both macro- and micronutrients compared to untreated soils. They also discovered that microbial activity in compost-amended soils is significantly higher, about 2.23 times more than in untreated soils. This boost in microbial activity is credited to the organic matter present in compost, which acts as a food source for microorganisms.

Similarly, Gamal (2009) conducted an experiment where compost was applied at rates of 0, 5, and 10 tons per hectare, and nutrient levels were measured at harvest. He observed increased levels of nitrogen (N), phosphorus (P), and potassium (K) in all plots treated with compost, with the greatest increase seen in plots receiving 10 tons per hectare of compost.

Seran et al. (2010) investigated the effectiveness of using half the suggested amount of chemical fertilizers combined with compost at a rate of 4 tons per hectare for growing onions. They discovered that this approach could lead to profitable outcomes while potentially cutting down on production expenses. Similarly, applying half the recommended doses of nitrogen (N) and phosphorus (P) along with half the recommended amounts of manure and compost, equal to the chemical nitrogen dose, resulted in a 129% increase in yield compared to the control group.

Tayebeh et al. (2010) conducted experiments to see how both organic and chemical fertilizers affect wheat grain yield and protein patterns. Their findings strongly support using a combination of organic and chemical fertilizers to get the best yields without sacrificing seed quality. The study showed that using compost can replace 30% of the needed nitrogen fertilizer because it helps plants use nitrogen better and reduces fertilizer costs. By managing nitrogen carefully, it's possible to lower the need for nitrogen while still getting good wheat grain yields and protein levels. Plus, using less nitrogen fertilizer helps protect the environment.

Studies have demonstrated that the decrease in compost pile temperature, typically occurring between 40°C to 70°C (104°F to 158°F), is closely linked to various parameters used to assess compost stability and maturity. Researchers have come to the conclusion that a quick and easy way to gauge compost maturity is to check the temperature. Boulter-Bitzer et al. (2006) also highlighted the importance of monitoring temperature changes, along with oxygen levels, in compost management (Tiquia, 2005).

The research monitored compost temperature throughout the mesophilic and thermophilic stages. After adding raw materials, temperatures gradually increased, reaching thermophilic levels by the fourth day. The highest temperature recorded was 48°C on the thirteenth day, exceeding the ambient temperature of 31°C. Regular compost turning every 15 days boosted microbial activity, causing temperature fluctuations and speeding up decomposition (Noor et al., 2020).

In a study on yard waste compost, researchers observed a rise in pH from an initial value around 5 to a level close to neutral (6.5 to 7.0) in mature composts. They found that, in the case of yard trash compost, pH might be the only signal of maturity; nevertheless, in general, pH would be a better measure of total compost quality. (Brewer & Sullivan, 2001).

At the National Research Center's experimental site in the northern Egyptian region of Beheira Governorate, two field tests were conducted, to evaluate the effects of different rates of bio and chemical fertilizers (NPK) on the growth of spinach plants, their overall yield, and chemical characteristics. The findings of the study indicated that applying a high dosage of bio fertilizer sourced from pigeon manure at 2 kg per feddan significantly improved various growth parameters of spinach plants. The measurements included overall amount of chlorophyll, the area of leaves per plant, the dry and fresh weights of the entire plant, and total leaf production (tons per feddan). Additionally, this treatment resulted in the highest percentages of protein, nitrogen (N), phosphorus (P), potassium (K), and nitrate (NO3) content in the plants.

Using a smaller amount of chemical fertilizer compared to bio fertilizer resulted in taller and heavier spinach plants with higher total leaf yield (tons per feddan) and better nutritional values such as protein, nitrogen (N), phosphorus (P), potassium (K), and nitrate (NO3) content in the leaves.

Both bio and chemical fertilizers, when applied in specific ratios and combined, showed positive effects on spinach plant growth, yield, and nutritional content. Combining a high amount of bio fertilizer with a lower amount of chemical fertilizer seemed to give the best results in terms of overall plant performance and yield.

Ahmadi et al. (2010) discovered that increasing the application of chemical fertilizer NPK led to higher total yield, more leaves per plant, and higher nitrate content in leaves. Different levels of fertilizer did not have a important effect on petiole length. Using bio-fertilization and organic fertilizer can potentially address pollution issues and reduce the high costs associated with chemical fertilizers, thus improving agricultural productivity. Therefore, there is a pressing need to decrease reliance on chemical fertilizers.

1.16 Research Objectives

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- To prepare compost from organic waste.
- To characterize the compost and chemical fertilizer which (include N: P: K ratio, moisture content, Organic Matter and pH).
- To observe the impact of compost and chemical fertilizer on plant growth.

CHAPTER 2

METHODOLOGY

MATERIAL AND METHODS

2.1 Preparation of Compost

Composting (Organic waste) was conduct at home to make it eco-friendly. Collecting the carbon- and nitrogen-rich organic matter (OM) was an essential phase in the production of compost. Organic waste collecting from different areas such as kitchen, backyard and poultry coop day by day. After that, these organic wastes were mechanically Cut into smaller pieces with the help of scissor.

Fig. 2.1 Organic waste(sample)   Fig. 2.2 Poultry manure(sample)

2.2 Sample Collection

Table 2.1: Organic waste collection

Waste type	Categories	Total Weight
Kitchen waste	Fruit and vegetable peels, Egg shells, card board, paper	2.5 kg
Poultry waste	Hen, parrot and pigeon feces, nesting material	2.5 kg
Backyard	grass, leaves and brush trimmings	300 g

2.3 Compost Making Process

Once the waste materials were prepared in this way, they were composted using two equal clay terracotta pots measuring 12 cm diameter and 15 cm depth under aerobic conditions, which improved the aeration of the compost pots. The dried leaves (2 to 4 inches or 5 to 10 cm) were filled in bottom of pot, for good drainage system in compost pot. The terra-cotta was filled to four layers of the pot volume with the desired waste samples. Each layer consists about 1 kg of organic waste collecting every five days for layering in compost pot.

2.3.1 Bottom Layer

Start with a layer of bulky materials such as sticks, twigs, or coarse woody material. This layer provides aeration to the compost pile, allowing air to circulate and preventing compaction.

Figure 2.3 Bottom leaves for drainage

Figure 2.4 Two same pot for aeration in compost

2.3.2 Second Layer

Add a layer of "brown" materials, which are high in carbon. This can include dry leaves, shredded newspaper, cardboard, or straw. Brown materials help balance the carbon-to-nitrogen ratio in the compost pile and provide structure.

Figure 2.5 Brown material layer

2.3.3 Third Layer

Follow with a layer of "green" materials, which are high in nitrogen. This can include kitchen scraps (fruit and vegetable peels, coffee grounds, eggshells), fresh grass clippings, or other plant material. Green materials provide nitrogen, which is essential for microbial activity and decomposition.

Figure 2.6 Fruit -vegetable peels(400g)

Figure 2.7 Hen and pigeon manure0.5kg

Figure 2.8 OW (vegetable peels) (255 g)

Figure 2.9 Banana peels (323 g)

2.3.4 Top Layer

Finish with a thin layer of finished compost or soil. This layer helps introduce beneficial microorganisms to the compost pile and covers the green materials, reducing odor and deterring pests.

Figure 2.10 Partially Decompose material after 15 days

2.4 Compost Finishing

The composting materials in the pot were turned over every 3 -5 days a week, during 30 days. When necessary, water was added to the composting materials to keep the water level at roughly 50%.

After 30 days, the compost was considered to have done decomposing when its temperature dropped to a normal temperature, it turned a unique dark brown or black color, it stopped emitting unpleasant odors, and its final volume had decreased by approximately 40%. The sample weighed 5.3 kg in total, decrease to 4 kilogram of compost due to evaporation of water from wet compost. General compost qualities (color, odor, volume) were noted at the conclusion of the experiment.

Figure 2.11 Compost after 30 days

Figure 2.12 Sprouts showing in compost

2.5 Compost Screening

After the decomposition of organic material, compost (humus) screening involves the use of vibrating screening equipment with various mesh sizes or perforations to sort compost material based on particle size. As the compost is fed into the screening equipment, it undergoes separation, with finer particles passing through the screen while larger pieces are retained on top. Throughout the screening process, we visually inspect the compost to ensure it meets quality standards, allowing for the manual removal of any remaining large debris. Once the compost has been screened to the desired grade, the remaining compost is stored and used for soil amendment, such as agriculture.

Figure 2.13 Screening remaining material

Figure 2.14 Screened material

2.6 Characteristics of compost and chemical fertilizer

Screened compost sample were taken from screening equipment and analysed for some Physio-chemical characteristics (pH, and moisture content), nutrients [Nitrogen (N), phosphorus (P), potassium (K)] and organic matter.

2.6.1 Methods for Physio-Chemical Analysis of the compost

The Physio-Chemical parameters were analyzed in Environmental lab of Bahria University H-11/4 Campus, including pH, Moisture content, organic matter, and nutrient analysis by using different methods shown in figure 2.2

Table 2.2: Physio-Chemical Analysis of the compost

Parameters	Methods
Nitrogen ratio	Micro Kjeldahl
Potassium and phosphorus ratio	Spectrophotometry
Moisture content	Digital oven
Organic matter	Incinerator
pH	digital multimeter

2.6.1.1 pH

The pH of the samples was measured using pH meter. The probe of the meter was rinsed with distilled water to avoid mixture of any other samples and to record the accurate readings. The beaker used is also rinsed with distilled water. The 50 ml of distilled water was added along with 2 g of compost sample in a beaker and probe of the pH meter was dipped in the sample for few minutes until the accurate reading was noticed after it was stabilized.

Figure 2.15 Sample (2 g) for pH

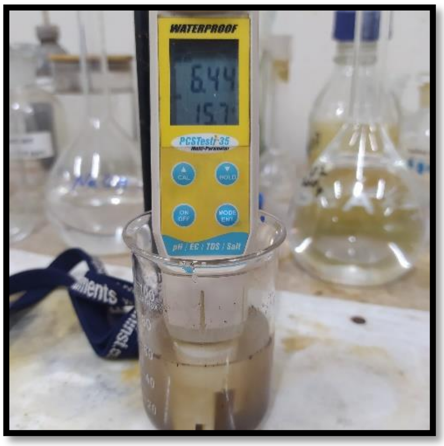

Figure 2.16 pH of compost

2.6.1.2 Moisture content

At the beginning of the composting process, the compost pot was filled to a 50% moisture content. A 20 g sample was put in a crucible and baked at 105 C for 5 hours to determine the moisture content of the compost. After reweighing the sample, the moisture content was calculated by dividing the weight loss values from the starting weight (Ameen et al., 2016).

Figure 2.17 Calculating Moisture content by oven

Calculation

W1= crucible weight

W2= crucible weight + wet weight

W3= crucible weight +dry weight

$$Moisture\ content\ \% = \frac{W2 - W3}{W2 - W1} \times 100$$

2.6.1.3 Organic matter

First, weight an empty, clean, and dry crucible using an analytical balance, noting its weight as W1. Transfer the compost sample into the crucible and record the total weight as W2. Place the crucible in an oven set to a low temperature (around 350°C) for 3 hours to thoroughly remove all moisture, ensuring the compost is completely dry. Once dried, remove the crucible from the oven and allow it to cool to room temperature in a desiccator or sealed container to prevent moisture absorption. Finally, weight the container with the dried compost and record its weight as W3. These steps enable precise measurement of organic matter content in the compost sample by eliminating moisture interference and ensuring accurate weight measurements.

Figure 2.18 Crucible weight

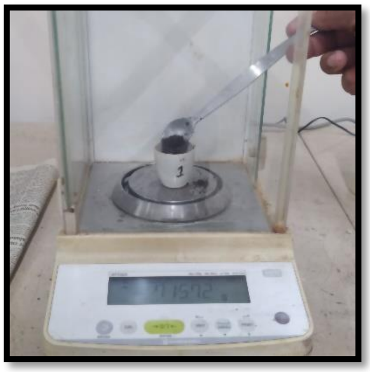

Figure 2.19 Sample (20g) for OM%

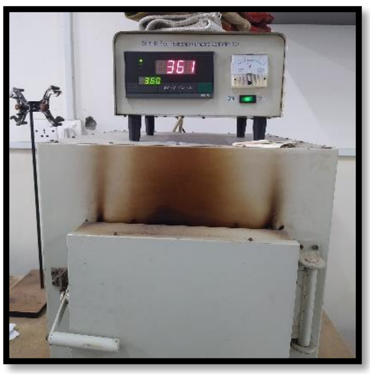

Figure 2.20 Incinerator to measure OM%

Calculation

$Organic\ matter\ \% = (W_2 - W_3)/(W_2 - W_1) \times 100$

OM%=44%

OM%= 20*0.43=8.6 g

It means, 8.6-gram organic matter present in 20 grams of compost

2.6.1.4 Nutrient analysis of the Compost and chemical fertilizer

The analysis of compost and chemical fertilizers conducted in a Nuclear Institute for Food and Agriculture (NIFA) setting involves assessing their nutrient content, particularly nitrogen (N), phosphorus (P), and potassium (K), commonly referred to as NPK. These nutrients analyzed by Micro Kjeldahl and Spectrophotometry method. These procedures help to determine the suitability and effectiveness of these materials for promoting plant growth.

Figure 2.21 Samples for testing (NIFA)

2.6.1.4.1 Nutrient analysis of compost

To find Nitrogen in compost, use 0.5 g of compost (sample) and add 10 ml. H_2 SO with 2 g of digestion mixture (CuSO45H2O, K2SO4 and selenium) and keep in digestion tecator for digestion with temperature from 100°C to 350°C. (NIFA)

Figure 2.22 Micro Kjeldahl for N%

To find phosphorus and potassium, use 0.5 g of sample in conical flask and add 10 ml of ($HClO_4$: HNO) (1:5) and keep on hot plate for digestion. When white fumes start it mean digestion completed. After digestion cool the sample with volume 50 ml with distilled water, then take 5 ml from the digest sample and 10 ml color reagent and make volume 50 ml with distilled water, taking reading on spectronic+20 at 470 nm(wavelength). (NIFA)

2.6.1.4.2 Nutrient analysis of chemical fertilizer

Chemical fertilizer taken from nursery located at H-9 sector Islamabad.

To find Nitrogen in chemical fertilizer, take 0.5 g chemical fertilizer (sample), add 100 ml with sample in volumetric flask with distilled water. then take 5 ml from 100 ml solution adding in 50 ml another flask with 10ml color reagent, so volume is 50 ml with distilled water, take reading on spectronic+20 at 470nm wavelength.

2.7 Plant Experimental Design

After the composting process was completed, the resulting compost was prepared for use in a seedling experiment. Two plastic pots were employed for this purpose: one containing a blend of home garden soil and compost, while the other held only garden soil with added chemical fertilizer. Each pot has wire mesh in the bottom for best drainage system. The ratio of compost to soil in the first pot was maintained at 40% compost and 60% soil, following standard procedures.

Figure 2.23 Plastic wire mesh for drainage

Figure 2.24 Compost: soil (40:60)

Figure 2.25 Seed pots with thoroughly watered

2.7.1 Seedling Growth: Sprout Stage

Upon planting the spinach seeds, both pots exhibited signs of germination after nine days. At this early sprout stage, differences in growth patterns became noticeable. While the seedlings in the compost-enriched soil showed in figure 2.26 gradual emergence and growth, those in the chemical fertilizer-treated soil displayed more rapid development shown in figure 2.27.

Figure 2.26 Seedling in the compost soil

Figure 2.27 Seedling in chemical fertilizer

2.7.2 Seedling Growth: Young Stage

As the seedlings grew older, the same growth patterns continued. The ones in the compost-enriched soil kept growing steadily and looked healthy shown in figure 2.28. However, the ones in the chemical fertilizer-treated soil grew faster but seemed stressed, with some leaves turning yellow and the roots crowding together shown in figure 2.29.

Figure 2.28 Growing steadily and healthy   Figure 2.29 Spinach grew faster but yellow leaves

2.7.3 Seedling Growth: Adult Stage

As the seedlings grew into adults, the differences in how they were growing became even more obvious. The ones in the compost-enriched soil kept growing slowly and steadily, and they still looked green and healthy. On the other hand, the ones in the chemical fertilizer-treated soil kept growing quickly, but they started showing more signs of not having enough nutrients and being stressed out shown in figure 2.30.

Figure 2.30 After 90 days spinach plant growth

2.7.4 Maintenance and Nutrient Application

Throughout the experiment, regular maintenance was conducted to ensure optimal growth conditions for both sets of seedlings. Every 15 days, additional compost was added to the pot with compost-enriched soil, supplementing the soil with 20 grams of compost each time. In contrast, the pot containing chemical fertilizer received additional fertilizer application, with 5 pallets of fertilizer added every 15 days. Furthermore, both sets of seedlings received thorough watering to maintain adequate moisture levels in the soil.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Results of compost and chemical fertilizer

Analysis of compost and chemical fertilizer, give results to show the comparative between both fertilizers. The differences in result shows which fertilizer have environmental benefits and plant growth. Results for compost and chemical fertilizer are given,

3.2 pH value in compost

The pH value of 6.44 falls within the optimal range (6.0 – 7.5) for most plants, indicating that the compost is suitable for enhancing soil pH and promoting plant growth. However, pH requirements may vary depending on specific plant species and soil conditions, necessitating further research or adjustments if targeting specific crops.

3.3 Moisture content in compost

The moisture content of 33.4% in compost is beneficial for plant growth due to several key factors. This moisture level falls within the optimal range (30-50%) for promoting plant growth without causing waterlogging. It facilitates nutrient release and uptake, supports healthy root development, and ensures good water retention in the soil. Additionally, it fosters microbial activity, contributing to soil fertility. Plants grown with compost at this moisture level exhibited robust growth compared to those treated with chemical fertilizer.

3.4 Organic matter content in compost

The organic matter content of 43% indicates a high-quality compost with significant nutrient value. Organic matter serves as a source of essential nutrients for plants and improves soil structure and fertility over time. Incorporating compost with a high organic matter content can enhance soil health, promote microbial diversity, and increase crop productivity.

Table 3.1. Physio-chemical parameters of Compost

Sample	pH	Moisture content%	Organic matter%
compost	6.44	33.4	44

3.5 NPK % in Chemical Fertilizer

Nitrogen (%): According to results, this fertilizer contains no nitrogen shown in table 3.2. Nitrogen is essential for leaf and stem growth, as well as overall plant Vigor. Its absence in chemical fertilizer suggests that supplemental nitrogen may be required from other sources for optimal plant growth when using this type of fertilizer.

Phosphorus (%): Phosphorus content is recorded at 2.50% shown in table 3.2. Phosphorus is vital for root development, flowering, and fruiting. The significant presence of phosphorus in chemical fertilizer indicates its suitability for promoting robust root systems and reproductive growth in plants.

Potassium (%): There is no potassium present in this chemical fertilizer. Potassium plays a critical role in various plant functions such as water uptake, photosynthesis, and disease resistance. Its absence suggests that plants relying solely on this chemical fertilizer may be deficient in potassium, which could lead to decreased resilience against environmental stressors.

3.6 NPK % in Compost

Nitrogen (%): Compost contains 0.7% nitrogen shown in table 3.2. While lower than chemical fertilizer, compost still provides a notable nitrogen source. Nitrogen aids in the production of chlorophyll, enzymes, and proteins crucial for plant metabolism and growth. Compost can contribute to maintaining soil fertility and promoting healthy plant development.

Phosphorus (%): The phosphorus content in compost is measured at 0.75% shown in table 3.2. Although lower than in chemical fertilizer, compost still offers a moderate phosphorus supply. Incorporating compost into soil can enhance phosphorus availability, supporting root establishment and overall plant Vigor.

Potassium (%): Compost contains 2.5% potassium shown in table 3.2. This significant potassium content is beneficial for promoting sturdy plant structure, disease resistance, and improved nutrient uptake. Incorporating compost into soil can help maintain potassium levels necessary for optimal plant health and productivity.

Table 3.2. Nutrient content (NPK %) of Compost and Chemical Fertilizers

Sample	Nitrogen% g^{-1}	Phosphorus% g^{-1}	Potassium% g^{-1}
Chemical fertilizer	0	2.50	0
Compost	0.7	0.75	2.5

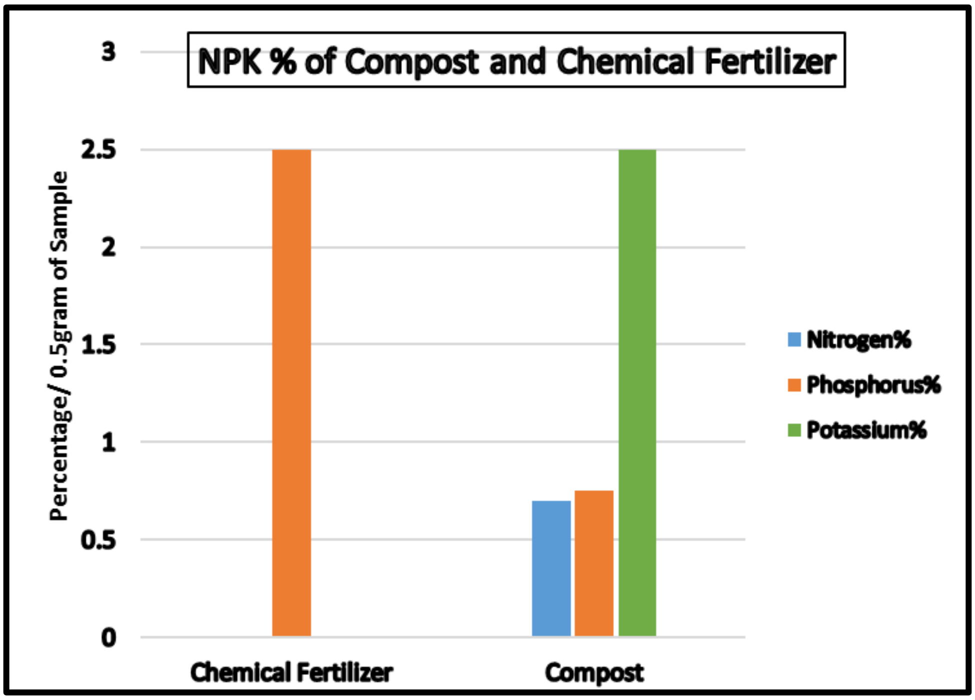

Figure 3.1 NPK % of Compost and Chemical Fertilizers

3.7 Comparative analysis of compost and chemical fertilizer effect on plant

Table 3.3 comparative analysis of compost and chemical fertilizer effect on spinach plant

Observation Period	Soil Condition	Dose of each fertilizer after 15 days	Plant Health	Growth Pattern
15 days	Compost-enriched soil	20 grams	Vibrant and green	Slow, steady growth
15 days	Chemical Fertilizer-treated soil	6 pellets	Stunted growth	Rapid growth
Extended observation period	Compost-enriched soil	20 grams	Light green appearance	Continued Steady growth
Extended Observation Period	Chemical Fertilizer-treated soil	6 pellets	Nutrient deficiency	Stunted growth

Table 3.4 Comparative analysis of compost and chemical fertilizer treated on Spanish Plant and their physical parameters

Parameter	Compost Treatment	Chemical Fertilizer Treatment
Plant Growth (Height)	13cm	6.5 cm
Plant Weight	13.1g	15.1g

Figure 3.2 Compost treated plant

Figure 3.3 Chemical fertilizer treated plant

CONCLUSIONS

1. By using organic waste, compost was prepared successfully.
2. Evaluating the N: P: K ratio of compost (1:1:3) which was greater as compared to chemical fertilizer (0:3:0) and compost provides sustainable perspectives in agriculture.
3. The observed impact on Spinach plant showed more growth and yield in chemical fertilizer as compared to compost.
4. Achieving efficient and ecologically sustainable farming practices is facilitated by promoting composting and understanding its characteristics.
5. Standardizing composting procedures aids in better comprehension of its purpose in sustainable farming.
6. Efficient nutrient management is crucial for maximizing the benefits of organic waste compost in agriculture.

RECOMMENDATION

1. Promote the extensive use of organic composting techniques, underscoring their environmentally friendly attributes as alternatives to chemical fertilizers.
2. Advocate for policymakers to support and incentivize organic composting initiatives, fostering sustainable agricultural practices.
3. Emphasize the diverse advantages of organic compost, ranging from enhancing soil health and mitigating environmental impact to improving plant nutrition.
4. Give priority to educating farmers and gardeners on composting methods, highlighting the potential agricultural benefits and encouraging widespread adoption.
5. Back further research on the long-term effects of organic compost on soil fertility and crop yields, aiming to enhance understanding and refine agricultural approaches

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