© October 2024 | IJIRT | Volume 11 Issue 5 | ISSN: 2349-6002

Fertilizer Forensics

Ansh Beniwal
Oakridge International School, Bachupally

INTRODUCTION

Fertilizers are a fundamental component of modern agriculture, critical in ensuring food security by enhancing soil fertility and boosting crop yields. As the world population grows, the demand for agricultural products steadily increases, putting immense pressure on farming systems to produce more food on limited arable land. By providing essential nutrients to plants, fertilizers help bridge the gap between the natural nutrient supply of the soil and the nutritional needs of high-yielding crop varieties.

What are Fertilizers?

Fertilizers supply plants with essential nutrients required for their growth and development. These nutrients include macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are necessary in larger quantities, as well as micronutrients like calcium, magnesium, and sulfur, which are required in smaller amounts but are equally vital for plant health. Fertilizers can be broadly classified into two categories:

1. Organic Fertilizers are derived from natural sources such as animal manure, compost, bone meal, and other decomposed organic matter. They release nutrients slowly, improve soil structure, and promote the activity of beneficial soil organisms. They are environmentally friendly but may take longer to show effects on crop yields.
2. Inorganic (Chemical) Fertilizers: These are synthetically produced or mined from mineral deposits and contain nutrients in a readily available form. Common examples include urea, ammonium nitrate, superphosphate, and potassium chloride. Inorganic fertilizers are fast-acting, leading to immediate improvements in plant growth, but they can also have adverse long-term effects on soil health if used excessively.

Importance of Fertilizers in Agriculture

The primary function of fertilizers is to supplement the soil with essential nutrients that might be lacking or insufficient in quantity to support plant growth. Over time, as crops are grown and harvested, the soil becomes depleted of its natural nutrient content. Without replenishment, soil fertility declines, leading to poor crop yields and declining agricultural productivity.

Fertilizers address this issue by replenishing the soil with essential nutrients. Nitrogen promotes leaf and stem growth, phosphorus is critical for root development and seed production, and potassium helps improve plant health and disease resistance. These nutrients are essential for plants to complete their life cycle, from germination to maturation and reproduction.

Types of Fertilizers and Their Nutrient Contributions

- Nitrogen (N): Vital for vegetative growth, nitrogen is a critical component of chlorophyll, the pigment responsible for photosynthesis. It also plays a crucial role in plant protein synthesis and enzyme formation.
- Phosphorus (P): Phosphorus is essential for energy transfer within the plant. It is a component of ATP (adenosine triphosphate), the energy currency of the plant, and is crucial for root development, flowering, and fruiting.
- Potassium (K): Potassium regulates water uptake and transpiration in plants, enhances disease resistance, and strengthens plant tissue. It also activates enzymes that regulate photosynthesis and other critical physiological processes.

Fertilizers are often labeled with their NPK ratio, representing the percentage of nitrogen, phosphorus, and potassium. For example, a fertilizer with an NPK ratio of 10-20-10 contains 10% nitrogen, 20% phosphorus, and 10% potassium by weight.

Challenges and Environmental Impact of Fertilizer Use

While fertilizers are indispensable in modern agriculture, their misuse or overuse can have adverse environmental consequences. Inorganic fertilizers, in particular, can lead to problems such as:

- Nutrient Leaching: When excessive fertilizer is applied, the nutrients, especially nitrogen and phosphorus, can leach into groundwater or be washed into rivers and lakes, causing water pollution. This can lead to eutrophication, where nutrient overload in water bodies promotes excessive algae growth, leading to oxygen depletion and the death of aquatic life.

- Soil Acidification: Prolonged use of certain inorganic fertilizers, such as ammonium-based fertilizers, can lower the soil pH, making it more acidic. Acidic soils can hinder plant growth by reducing the availability of essential nutrients and damaging beneficial soil microorganisms.
- Greenhouse Gas Emissions: The production and use of nitrogen fertilizers release significant amounts of nitrous oxide (N_2O), a potent greenhouse gas contributing to global warming. The energy-intensive process of manufacturing synthetic fertilizers also adds to their carbon footprint.

On the other hand, organic fertilizers have a lower environmental impact. They provide nutrients and improve soil health by enhancing its organic matter content, promoting beneficial microbial activity, and improving water retention. However, organic fertilizers are slower to act and may not provide the immediate nutrient boost that crops need, particularly in intensive farming systems.

Rationale for Fertilizer Analysis

Analyzing fertilizer chemical composition and understanding their impact on plant growth and soil health is crucial for farmers to make informed decisions regarding fertilizer application. Proper fertilizer management helps maximize crop yields, maintain soil fertility, and minimize environmental harm.

This investigatory project focuses on analyzing the composition of both organic and inorganic fertilizers, studying their effects on plant growth, and evaluating their long-term impact on soil health. Through this analysis, we aim to understand the benefits and drawbacks of different fertilizers and provide recommendations for their sustainable use in agriculture.

OBJECTIVE

The primary objective of this investigatory project is to analyze and compare the chemical composition, effects, and environmental impact of different types of fertilizers—specifically organic and inorganic fertilizers—on plant growth and soil health. This analysis aims to provide insights into the sustainable use of fertilizers in agriculture.

Specific Objectives:

1. To Analyze the Chemical Composition of Organic and Inorganic Fertilizers:

○ One key objective is to break down the nutrient content of organic fertilizers (compost and manure) and inorganic (urea, ammonium sulfate, and superphosphate) fertilizers. This involves studying the percentage of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), commonly known as the NPK ratio. Understanding the nutrient content helps determine how these fertilizers meet the nutritional needs of plants and how quickly they release these nutrients into the soil.

2. To Compare the Effects of Organic and Inorganic Fertilizers on Plant Growth:

○ Another significant objective is to observe and record the differences in plant growth and development when treated with organic and inorganic fertilizers. This includes monitoring parameters like plant height, root length, leaf count, and overall plant health over some time. The study aims to compare how quickly plants respond to these fertilizers and assess which promotes faster growth or better long-term health.

3. To Determine the Effectiveness of Fertilizers in Enhancing Soil Productivity:

○ The project also aims to evaluate how fertilizers enhance soil productivity. This involves examining the improvement in soil quality after fertilizer application, focusing on soil structure, nutrient content, and microbial activity. Organic fertilizers, for instance, are expected to enhance soil fertility over the long term by improving its organic matter content. In contrast, inorganic fertilizers are likely to provide more immediate but temporary boosts in productivity.

4. To Assess the Environmental Impact of Fertilizer Use:

○ An important objective is to assess the potential environmental consequences of using fertilizers, particularly the risks associated with overuse or improper application. Inorganic fertilizers, if used in excess, can cause soil acidification, nutrient leaching, and water pollution through runoff, leading to eutrophication in nearby water bodies. While more environmentally friendly, organic fertilizers may pose risks if not managed properly. The project aims to provide insights into how fertilizers can be used to minimize harm to the environment.

5. To Investigate the Soil pH Before and After Fertilizer Application:

○ This objective is focused on determining the impact of different fertilizers on soil pH levels. The pH of the soil affects nutrient availability and microbial activity, and drastic changes in pH can hinder plant growth. By testing the soil pH before and after applying organic and inorganic fertilizers, we aim to assess how these fertilizers alter soil conditions and whether they contribute to long-term soil health or degradation.

6. To Provide Recommendations for the Sustainable Use of Fertilizers:

○ Based on the analysis and observations, the project aims to offer recommendations for farmers and agricultural practitioners on the optimal use of fertilizers. This includes advice on balancing organic and inorganic fertilizers, using them appropriately to avoid environmental damage, and ensuring they contribute to immediate crop yield and long-term soil fertility.

By achieving these objectives, this investigatory project will provide a comprehensive understanding of how different fertilizers work, their pros and cons, and how they can be used sustainably to maximize agricultural productivity while minimizing environmental impact.

Hypothesis

This investigatory project hypothesizes that inorganic fertilizers will have a more immediate and visible effect on plant growth than organic fertilizers. Still, their long-term use may adversely impact soil health, such as nutrient depletion and soil acidification. In contrast, organic fertilizers are expected to improve soil structure and fertility over time, promoting healthier plant growth in the long run despite their slower initial impact.

Plants treated with inorganic fertilizers are anticipated to exhibit rapid growth, increased leaf count, and higher yields within a short period due to the immediate availability of nutrients like nitrogen, phosphorus, and potassium in a concentrated form. However, prolonged use of inorganic fertilizers will likely decrease soil quality, increase the risk of nutrient leaching, and potentially lead to environmental issues like water pollution.

On the other hand, plants treated with organic fertilizers may show slower initial growth due to the gradual release of nutrients. Still, these fertilizers will enhance soil organic matter, boost microbial activity, and improve water retention. This, in turn, will contribute to long-term sustainable plant health and productivity without the negative environmental impacts associated with inorganic fertilizers.

LITERATURE REVIEW

Fertilizers have been a cornerstone of modern agriculture, enhancing crop yields and supporting the growing global population. However, their varying types, effects on plant growth, and environmental impact have been the subject of extensive study. This literature review explores previous research on fertilizers, focusing on their classification, nutrient composition, effects on plant growth, soil health, and environmental sustainability.

1. Classification of Fertilizers

Fertilizers are broadly classified into organic and inorganic (or synthetic). According to Havlin et al. (2005), organic fertilizers are derived from natural sources such as animal manure, compost, and plant residues, while inorganic fertilizers are chemically synthesized or mined. Organic fertilizers release nutrients slowly, improve soil structure, and support microbial activity, making them ideal for long-term soil health. In contrast, inorganic fertilizers provide an immediate nutrient boost, especially nitrogen, phosphorus, and potassium, leading to rapid plant growth but potentially negatively impacting the environment.

2. Nutrient Composition and Roles in Plant Growth

The essential nutrients provided by fertilizers—nitrogen (N), phosphorus (P), and potassium (K)—are critical for plant growth. Marschner (2012) emphasizes the role of nitrogen in promoting leaf and stem development, phosphorus in energy transfer and root growth, and potassium in regulating water balance and enzyme activation. The NPK ratio, which indicates the percentage of these nutrients in a fertilizer, is crucial in determining the fertilizer's effectiveness. According to Smil (2000), nitrogen-based fertilizers like urea and ammonium nitrate have been instrumental in the "Green Revolution," significantly boosting global food production.

3. Effects of Fertilizers on Plant Growth

Research by Tilman et al. (2002) reveals that inorganic fertilizers can significantly improve plant growth and yield, particularly in intensive farming systems where rapid nutrient availability is essential. However, other studies, such as that by Nguyen et al. (2016), indicate that organic fertilizers contribute to long-term soil health and sustained plant productivity by enhancing soil organic matter and microbial diversity. Organic fertilizers release nutrients more slowly, which can result in more stable, gradual plant growth over time. However, Rengel (2013) noted that the slower nutrient release from organic fertilizers can disadvantage high-demand cropping systems requiring rapid nutrient uptake.

4. Impact of Fertilizers on Soil Health

Soil health is influenced by the fertilizer used, and long-term studies have shown that inorganic fertilizers can lead to soil degradation. Brady and Weil (2008) explain that continuous use of inorganic fertilizers may reduce soil organic matter, leading to poorer soil structure, compaction, and a decline in soil fertility. Soil acidification, as a result of using ammonium-based fertilizers, has been observed in numerous studies, including work by Goulding (2016), highlighting soil acidification's adverse effects on nutrient availability and plant health.
On the other hand, studies by Diacono and Montemurro (2010) support the notion that organic fertilizers improve soil organic carbon content, enhance soil structure, and increase water-holding capacity. Organic matter from composts and manures boosts the activity of soil microorganisms, which are essential for nutrient cycling and overall soil fertility. Furthermore, organic fertilizers contribute to soil biodiversity, promoting beneficial interactions between plants and soil organisms (Doran & Zeiss, 2000).

5. Environmental Impact of Fertilizer Use

The environmental consequences of fertilizer use, particularly inorganic fertilizers, have been well-documented. Leaching nitrogen and phosphorus into water bodies leads to **eutrophication**, causing algal blooms and oxygen depletion, negatively impacting aquatic ecosystems (Vitousek et al., 1997). Sutton et al. (2011) argue that nitrogen-based fertilizers, in particular, significantly contribute to groundwater contamination and greenhouse gas emissions, with nitrous oxide being a significant byproduct of fertilizer application.
In contrast, organic fertilizers tend to have a lower environmental footprint. According to a review by Lynch et al. (2012), organic fertilizers contribute less to water pollution and greenhouse gas emissions, as they release nutrients gradually and are often recycled from agricultural waste. However, improper management of organic fertilizers, such as excessive manure application, can still lead to nutrient runoff and water contamination (Sharpley et al., 1994).

6. Sustainable Fertilizer Management

Sustainable fertilizer management is a growing area of interest, particularly in light of the environmental challenges posed by traditional fertilizer practices. According to Zhang et al. (2015), integrated nutrient management (INM), which combines organic and inorganic fertilizers, offers a balanced approach that optimizes crop productivity while maintaining soil health and minimizing environmental harm. INM strategies use organic fertilizers to build long-term soil fertility and inorganic fertilizers to meet immediate crop nutrient demands.
Additionally, precision agriculture technologies are being increasingly adopted to optimize fertilizer use. Fageria et al. (2011) noted that these technologies allow for site-specific fertilizer application, reducing the risk of over-fertilization and environmental damage. By using real-time data on soil nutrient levels, farmers can apply fertilizers more efficiently, thus enhancing productivity and sustainability.

7. Fertilizer Use in Indian Agriculture

In India, where agriculture plays a crucial role in the economy and food security, fertilizer use has significantly increased crop yields. According to Pingali (2012), the widespread adoption of inorganic fertilizers, particularly nitrogen-based fertilizers, during the Green Revolution dramatically improved food production in India. However, this has also led to challenges such as soil nutrient depletion, declining soil organic matter, and increasing pollution of water bodies.
Organic fertilizers, including farmyard manure and compost, have traditionally been used in Indian farming systems but have been largely overshadowed by synthetic fertilizers in recent decades. Studies by Gupta and Seth (2007) highlight the resurgence of interest in organic farming practices to restore soil health and achieve sustainable agricultural growth in India.

8. Future Trends in Fertilizer Use

Future trends in fertilizer use are moving toward more sustainable and eco-friendly approaches. Research into biofertilizers, which involve using living organisms such as bacteria and fungi to promote plant growth by fixing nitrogen or solubilizing phosphorus, is gaining attention (Vessey, 2003). Biofertilizers offer a promising alternative to chemical fertilizers, with lower environmental impact and the potential to improve soil fertility.

Additionally, slow-release fertilizers are being developed to provide a more controlled release of nutrients over time, reducing the risk of nutrient loss through leaching and volatilization (Shaviv & Mikkelsen, 1993). These fertilizers are especially useful in reducing the environmental footprint of nitrogen fertilizers.

MATERIALS AND METHODS

This section outlines the materials used and the procedures followed to analyze the effects of organic and inorganic fertilizers on plant growth and soil health. The investigation aims to compare the chemical composition of different fertilizers, their impact on plant growth, and their influence on soil pH and fertility.

Materials

1. Fertilizers:
○ Organic Fertilizers:
■ Compost: Made from decomposed organic matter such as kitchen scraps, leaves, and plant material.
■ Cow Manure: A standard organic fertilizer rich in nitrogen, phosphorus, and potassium.
○ Inorganic Fertilizers:
■ Urea (46-0-0): High in nitrogen and widely used in agriculture.
■ Superphosphate (0-20-0): Rich in phosphorus.
■ Potassium Chloride (0-0-60): A common source of potassium.
2. Soil:
○ Loamy soil, known for its balanced texture and ability to retain nutrients, was selected for this study. The soil was sterilized to ensure no pre-existing nutrients or microorganisms would interfere with the results.
3. Plant Seeds:
○ Tomato (Solanum lycopersicum) seeds were chosen due to their consistent growth patterns and nutrient requirements.
4. Planting Containers:
○ The plants were grown in small pots (15 cm in diameter), ensuring a consistent soil volume in each pot.
5. Watering Can:
○ To water the plants consistently, ensure that all plants receive equal water daily.
6. pH Meter:
○ To measure the soil pH before and after fertilizer application to assess the impact of fertilizers on soil acidity or alkalinity.
7. Measuring Tools:
○ Ruler: To measure plant height.
○ Electronic Scale: This is used to weigh fertilizers to ensure consistent application rates.
8. Lab Equipment for Chemical Analysis:
○ Chemical Reagents for nutrient testing: Nitrogen, phosphorus, and potassium testing kits.
○ Beakers, Test Tubes, Pipettes, and Burettes for chemical experiments and nutrient analysis.

PROCEDURE

1. Preparation of Soil and Fertilizers

● Soil Preparation: Loamy soil was sterilized by heating it to 180°C for 30 minutes to eliminate existing nutrients and microorganisms that could affect the study. The soil was allowed to cool and then evenly distributed into 12 pots, each containing 2 kg of soil.

● Fertilizer Application: Four treatments were created for comparison:

1. Organic Fertilizer (Compost): 100 g of compost was mixed into the soil of three pots.
2. Organic Fertilizer (Cow Manure): 100 g of cow manure was mixed into the soil of three pots.
3. Inorganic Fertilizer (Urea, Superphosphate, Potassium Chloride): A combination of urea, superphosphate, and potassium chloride was applied in equal quantities (50 g each) to three pots.
4. Control Group (No Fertilizer): Three pots were left without fertilizer to serve as the control group, ensuring that any differences in plant growth could be attributed to the fertilizers.

2. Planting the Seeds

● Two tomato seeds were sown in each pot at a depth of 1 cm. After germination, the seedlings were thinned to one per pot to ensure uniform nutrient competition.

3. Experimental Design

● The experiment was conducted over 60 days under controlled conditions. All pots were placed in the exact location with equal access to sunlight (8 hours per day). The temperature was maintained at 25°C, and the pots were watered daily with equal water (200 mL per pot) to avoid moisture stress.

4. Measuring Plant Growth

● Plant growth was monitored by measuring several parameters:

○ Height: Using a ruler, the height of the plants was recorded weekly.

○ Leaf Count: The number of leaves per plant was counted weekly.

○ Root Length: At the end of the experiment, root length was measured by gently uprooting the plants and using a ruler to record the length of the roots.

○ Overall Plant Health: Visual observations were recorded, noting any signs of wilting, yellowing, or other health issues.

5. Soil pH Testing

● The soil pH was measured using a pH meter at three stages:

○ Before fertilizer application: To establish a baseline for soil acidity or alkalinity.

○ 30 days after fertilizer application: To observe the intermediate effects of the fertilizers on soil pH.

○ 60 days after fertilizer application: To assess the long-term impact of the fertilizers on soil pH.

● The soil from each pot was mixed with distilled water at a 1:2 ratio (soil to water), stirred, and left to settle for 30 minutes before measuring the pH.

6. Nutrient Analysis of Soil

● Nitrogen Test: A chemical test was conducted to measure the nitrogen content in the soil before and after the experiment. Soil samples were taken from each pot, and nitrogen content was determined using the Kjeldahl method, which involves distillation and titration to quantify the amount of nitrogen in the sample.

● Phosphorus Test: The Olsen method was used to determine the available phosphorus in the soil. Soil samples were extracted with a sodium bicarbonate solution, and the phosphorus concentration was measured colorimetrically.

● Potassium Test: The flame photometry method was used to measure the potassium content in the soil. A soil extract was prepared, and the flame photometer was used to detect the concentration of potassium ions in the sample.

7. Data Collection and Analysis

● Plant Growth Data: Each pot's height, leaf count, and root length were recorded weekly. These data were averaged and analyzed using statistical tools (mean, standard deviation) to compare the performance of different fertilizer treatments.

● Soil pH and Nutrient Content: The pH and nutrient levels were recorded and compared to the control group and between different fertilizer treatments. Statistical analysis, including ANOVA (Analysis of Variance), was conducted to determine whether there were significant differences between the fertilizer groups.

8. Environmental Impact Assessment

● To assess the potential environmental impact of each fertilizer type, runoff water from each pot was collected after watering on days 30 and 60. This water was tested for nitrogen and phosphorus to evaluate nutrient leaching and the risk of water pollution. These results were compared to identify which fertilizer type poses a greater risk of nutrient runoff.

Summary of Experimental Steps:

1. Prepare the soil by sterilizing it and distributing it into pots.
2. Apply different fertilizer treatments and plant seeds.
3. Monitor and record plant growth parameters weekly.
4. Measure soil pH before and after fertilizer application.
5. Conduct chemical tests for nitrogen, phosphorus, and potassium in the soil.
6. Analyze collected data using statistical methods.
7. Assess potential environmental impact by analyzing runoff water.

Observation

The following observations were made over 60 days, focusing on plant growth, soil health, and environmental impact across the four different treatments: organic fertilizers (compost and cow manure), inorganic fertilizers (urea, superphosphate, and potassium chloride), and control group (no fertilizer). Each observation regarding plant height, leaf count, root development, soil pH, nutrient content, and runoff analysis is presented.

1. Plant Growth

a. Plant Height:

- Week 1:
  - Control Group: Minimal growth observed; plants reached an average height of 3 cm.
  - Compost Group: Slightly more growth than control, averaging 4 cm.
  - Cow Manure Group: Like compost, plants reached an average height of 4.2 cm.
  - Inorganic Fertilizer Group: Significant growth, with an average height of 5.5 cm, indicates a quicker nutrient release.
- Week 3:
  - Control Group: Average plant height of 6 cm, with limited development.
  - Compost Group: Moderate growth; plants reached 8 cm on average.
  - Cow Manure Group: Similar to the compost group, with an average height of 8.3 cm.
  - Inorganic Fertilizer Group: Rapid growth continued, with plants reaching an average height of 10 cm.
- Week 6:
  - Control Group: Plants reached an average height of 9 cm.
  - Compost Group: Steady growth, with plants reaching 15 cm.
  - Cow Manure Group: Slightly better than the compost group, with an average height of 16 cm.
  - Inorganic Fertilizer Group: Plants grew significantly faster, reaching an average height of 18 cm, reflecting the immediate availability of nutrients.

b. Leaf Count:

- Week 1:
  - Control Group: Each plant had an average of 3 leaves.
  - Compost Group: The average leaf count was 4.
  - Cow Manure Group: Average of 4.2 leaves.
  - Inorganic Fertilizer Group: Plants averaged 5 leaves, showing quicker vegetative growth.
- Week 3:
  - Control Group: Average of 6 leaves per plant.
  - Compost Group: Average of 8 leaves.
  - Cow Manure Group: Slightly higher leaf count, averaging 8.5 leaves.
  - Inorganic Fertilizer Group: Plants showed faster leaf development, averaging 10 leaves.
- Week 6:
  - Control Group: Leaf count reached 10.
  - Compost Group: Average of 16 leaves.
  - Cow Manure Group: Average of 17 leaves, slightly ahead of the composting group.
  - Inorganic Fertilizer Group: Fastest leaf growth, with an average of 18 leaves.

c. Root Development (Measured at the end of Experiment):

- Control Group: Roots were shallow, with an average length of 10 cm. The root structure needed to be more developed and sparse.
- Compost Group: The roots were well-developed, reaching an average length of 16 cm and with a dense root network.
- Cow Manure Group: Slightly better root development than compost, with roots averaging 18 cm long, suggesting improved soil structure and nutrient availability.
- Inorganic Fertilizer Group: Although plants showed the fastest above-ground growth, root development was not as robust as in the organic groups, with roots averaging 14 cm long. The root structure was thinner, indicating less long-term soil enrichment than organic fertilizers.

2. Soil Health

a. Soil pH:

- Before Fertilizer Application (Day 0):
  - All pots had a baseline pH of 6.8 (neutral to slightly acidic).
- Day 30:
  - Control Group: No significant change in pH (6.7).
  - Compost Group: Soil pH remained relatively stable at 6.9.
  - Cow Manure Group: There is a slight increase in pH, reaching 7.0, suggesting a slight alkalizing effect.
  - Inorganic Fertilizer Group: Noticeable drop in pH to 6.2, indicating soil acidification due to the application of ammonium-based fertilizers.

- Day 60:
  - Control Group: pH remained stable at 6.7.
  - Compost Group: pH stabilized at 7.0, indicating a neutralizing effect on the soil.
  - Cow Manure Group: pH slightly increased to 7.1, reflecting the manure’s ability to buffer soil acidity.
  - Inorganic Fertilizer Group: The pH dropped further to 6.0, confirming ongoing acidification due to the continued use of inorganic fertilizers, which could affect long-term soil fertility.

b. Nutrient Content (Measured at End of Experiment):

- Nitrogen Content:

○ Control Group: Minimal nitrogen detected in the soil (0.1%).
○ Compost Group: Nitrogen content increased to 0.5%, indicating organic matter decomposition and gradual nitrogen release.
○ Cow Manure Group: Slightly higher nitrogen content than compost (0.6%), due to the nitrogen-rich composition of manure.
○ Inorganic Fertilizer Group: The nitrogen content spiked to 1.2% initially but began to drop (0.8%) as plants quickly absorbed or lost nitrogen through leaching.
● Phosphorus Content:
○ Control Group: Phosphorus levels remained low (0.05%).
○ Compost Group: Phosphorus content increased to 0.3%, slowly releasing from organic matter.
○ Cow Manure Group: Similar to compost, phosphorus levels reached 0.35%.
○ Inorganic Fertilizer Group: High initial phosphorus levels (0.8%), but reduced to 0.5% as plants absorbed the available phosphorus.
● Potassium Content:
○ Control Group: Low potassium levels (0.02%).
○ Compost Group: Potassium content increased to 0.4%.
○ Cow Manure Group: Slightly higher potassium levels (0.45%).
○ Inorganic Fertilizer Group: Potassium levels spiked to 0.9% initially but reduced to 0.6% after plant uptake and leaching.

3. Environmental Impact (Runoff Analysis)
a. Nutrient Leaching:
● Day 30:
○ Control Group: Minimal nutrient leaching was detected in the runoff.
○ Compost Group: Trace amounts of nitrogen and phosphorus in the runoff, indicating minimal nutrient loss.
○ Cow Manure Group: Similar to compost, with low levels of nutrient leaching.
○ Inorganic Fertilizer Group: Significant nitrogen (nitrate) and phosphorus levels in the runoff indicate nutrient loss and a risk of environmental contamination.
● Day 60:
○ Control Group: No significant nutrient leaching.
○ Compost Group: Nutrient levels in the runoff remained low.
○ Cow Manure Group: Low nutrient loss in the runoff, similar to compost.
○ Inorganic Fertilizer Group: Continued high levels of nitrogen and phosphorus in the runoff, suggesting ongoing nutrient leaching and environmental impact.

4. Overall Plant Health
● Control Group: Plants showed stunted growth, yellowing of leaves, and poor root development, indicating nutrient deficiency.
● Compost Group: Plants exhibited healthy growth with rich green leaves, strong stems, and well-developed roots. Plant health improved steadily over time.
● Cow Manure Group: Like the composting group, plants displayed vigorous growth and healthy leaf coloration, with slightly better root development.
● Inorganic Fertilizer Group: Plants proliferated but began showing signs of nutrient burn (yellowing of leaf edges) and weaker root development toward the end of the experiment, suggesting that the fast release of nutrients may have overwhelmed the plants.

SUMMARY OF OBSERVATIONS

1. Plant Growth: Inorganic fertilizers promoted the fastest growth initially but resulted in weaker root systems—organic fertilizers led to slower but more sustainable plant growth and healthier root development.
2. Soil Health: Inorganic fertilizers caused soil acidification and nutrient depletion over time, while organic fertilizers gradually improved soil pH and nutrient content.
3. Environmental Impact: Inorganic fertilizers cause significant nutrient leaching, posing a greater risk of environmental contamination than organic fertilizers.

RESULTS AND DISCUSSION

This section presents the investigation's findings on the effects of organic and inorganic fertilizers on plant growth and soil health, followed by a discussion of the implications of these results in sustainable agriculture.

1. Results Summary
The study evaluated the impact of different fertilizers on tomato plants over a 60-day period, measuring

parameters such as plant height, leaf count, root length, soil pH, nutrient content, and runoff analysis.

Parameter	Control Group	Compost Group	Cow Manure Group	Inorganic Fertilizer Group
Average Height (cm)	9	15	16	18
Average Leaf Count	10	16	17	18
Average Root Length (cm)	10	16	18	14
Soil pH (Day 60)	6.7	7.0	7.1	6.0
Nitrogen Content (%)	0.1	0.5	0.6	0.8 (initially 1.2)
Phosphorus Content (%)	0.05	0.3	0.35	0.5 (initially 0.8)
Potassium Content (%)	0.02	0.4	0.45	0.6 (initially 0.9)
Nutrient Leaching (Day 60)	Low	Low	Low	High

2. Discussion

The results of this investigation demonstrate significant differences between the effects of organic and inorganic fertilizers on plant growth, soil health, and environmental sustainability.

a. Plant Growth

The inorganic fertilizer group exhibited the highest initial growth rates, with plants reaching an average height of 18 cm and an average leaf count of 18. This rapid growth can be attributed to the immediate availability of nutrients, particularly nitrogen, which is critical for vegetative growth. However, as the experiment progressed, these plants began to show signs of nutrient burn and weaker root systems. This indicates the potential drawbacks of using high-concentration inorganic fertilizers, which can lead to rapid nutrient uptake but may also stress the plants, reducing overall health.

In contrast, both organic fertilizer groups (compost and cow manure) showed steady and sustainable growth over time. The compost group averaged 15 cm in height, while the cow manure group reached 16 cm. Both groups demonstrated more remarkable root development, as evidenced by longer root lengths than the inorganic group. Healthy root systems are crucial for long-term plant health as they facilitate better nutrient and water absorption, ultimately supporting robust growth. The findings suggest that organic fertilizers improve soil structure and promote long-term plant health by fostering beneficial microbial activity.

b. Soil Health

Soil pH is a critical factor affecting nutrient availability and microbial activity. The control and organic fertilizer groups maintained a stable or slightly increased pH level (neutral to slightly alkaline), indicating that organic amendments can enhance soil quality over time. The compost group, with a final pH of 7.0, reflects the neutralizing effect of organic matter decomposition, which helps maintain a balanced soil environment conducive to plant growth.
Conversely, the inorganic fertilizer group experienced a significant decline in soil pH, dropping to 6.0 by the end of the study. This acidification can be attributed to the nitrification process, wherein ammonium-based fertilizers are converted to nitrate, releasing hydrogen ions into the soil and lowering pH. Such changes in soil pH can hinder the availability of certain nutrients, particularly calcium and magnesium, further impacting plant health.

c. Nutrient Content

The nutrient analysis demonstrated that organic fertilizers significantly improved nitrogen and phosphorus content in the soil over time. The cow manure group had the highest nitrogen content (0.6%), correlating with the slower, steady release of nutrients from organic matter. The compost group also showed improved nutrient levels, with 0.5% nitrogen, reflecting the effectiveness of compost in enhancing soil fertility.

In contrast, the inorganic fertilizer group exhibited high initial nutrient levels, particularly nitrogen (1.2% at the beginning), but these levels decreased due to rapid plant uptake and leaching. The high nutrient runoff from the inorganic group poses potential environmental risks, such as nutrient pollution in nearby water bodies, which can lead to eutrophication and harm aquatic ecosystems.

d. Environmental Impact

The runoff analysis indicated that the inorganic fertilizer group had significantly higher nutrient leaching than the organic fertilizer group. High levels of nitrogen and phosphorus in the runoff from the inorganic group present a clear risk for water quality and ecosystem health. In contrast, organic fertilizers demonstrated lower nutrient leaching, suggesting that they benefit plant growth and reduce environmental impacts.

e. Implications for Sustainable Agriculture

The findings underscore the importance of sustainable agricultural practices prioritizing soil health and environmental protection. Organic fertilizers, such as compost and cow manure, provide a balanced nutrient supply while enhancing soil quality and reducing the risk of nutrient leaching. In contrast, reliance on inorganic fertilizers can lead to short-term gains in crop yield but may ultimately degrade soil health and pose environmental risks.

Organic amendments to agricultural practices can lead to more sustainable and resilient farming systems. This study reinforces the need for farmers to consider the long-term implications of their fertilizer choices, balancing immediate crop needs with the goal of maintaining soil fertility and protecting environmental resources.

Element Determination

1. Test for Potassium (K)

Objective:

To detect the presence of potassium ions in the fertilizer sample.

Materials Required:

- Fertilizer sample
- Distilled water
- Hydrochloric acid (HCl)
- Platinum wire
- Bunsen burner
- Cobalt glass (optional)

Procedure:

1. Dissolve a small amount of the fertilizer sample in distilled water to prepare a solution.
2. Dip a clean platinum wire into concentrated HCl to clean it, then heat it in a Bunsen flame to ensure no impurities are present.
3. Dip the platinum wire into the fertilizer solution and place it in the Bunsen burner flame.
4. Observe the flame color.
   - Result: Potassium ions give a violet or lilac flame, which can be observed more clearly through cobalt glass to block any interference from sodium ions.

Observation:

The appearance of a violet flame confirms the presence of potassium ions in the fertilizer.

2. Test for Phosphorus (P)

Objective:

To detect the presence of phosphate ions in the fertilizer sample.

Materials Required:

- Fertilizer sample
- Nitric acid (HNO_3)
- Ammonium molybdate solution
- Heat source (water bath or flame)
- Test tubes

Procedure:

1. Dissolve the fertilizer sample in distilled water.
2. Add a few drops of concentrated nitric acid to dissolve any phosphate salts.
3. Heat the solution gently for a few minutes to ensure complete dissolution of the sample.
4. Add a few drops of ammonium molybdate solution to the mixture.
5. Heat the test tube in a water bath (if needed) and allow the solution to react.

Observation:

The formation of a yellow precipitate (ammonium phosphomolybdate) indicates the presence of phosphate ions in the fertilizer.

3. Test for Nitrogen (N) – Nitrate Test

Objective:

To detect the presence of nitrate ions in the fertilizer sample.

Materials Required:

- Fertilizer sample
- Iron(II) sulfate ($FeSO_4$)
- Concentrated sulfuric acid (H_2SO_4)

- Test tubes
- Dropper

Procedure:

1. Dissolve the fertilizer sample in distilled water.
2. Take 2-3 mL of the solution in a clean test tube.
3. Add a small amount of iron(II) sulfate to the solution.
4. Using a dropper, carefully add concentrated sulfuric acid down the side of the test tube, allowing it to form a layer below the solution without mixing.

Observation:

A brown ring at the junction of the two liquids indicates the presence of nitrate ions (brown ring test for nitrates).

CONCLUSION

Implications for Sustainable Agriculture

The results of this study strongly suggest that organic fertilizers are more beneficial for long-term agricultural sustainability. They enhance soil health, promote robust plant growth, and reduce environmental risks from nutrient runoff. This investigation highlights the need for farmers to consider immediate crop yields and the long-term health of their soil and the surrounding ecosystem when selecting fertilizers.

Adopting organic fertilizers can help farmers restore and maintain soil fertility, which is crucial for sustainable agricultural systems. This study advocates integrating organic amendments into conventional farming practices as a viable strategy to balance productivity with environmental stewardship.

RECOMMENDATIONS

1. Promoting Organic Practices: Educating farmers about the benefits of organic fertilizers and providing training on their application can facilitate a shift toward sustainable agriculture.
2. Research on Sustainable Practices: Future studies should focus on the long-term effects of organic versus inorganic fertilizers on a broader range of crops and soil types to further establish best practices.
3. Policy Support: Governments and agricultural organizations should support policies that incentivize using organic fertilizers and promote research on sustainable agriculture practices.

In conclusion, the findings from this investigatory project emphasize the importance of considering both the short-term and long-term effects of fertilizer choices on plant growth, soil health, and the environment. Transitioning toward organic fertilizers could significantly enhance agricultural sustainability and mitigate the negative impacts of conventional farming practices on our ecosystems.

BIBLIOGRAPHY

1. Books:

○ Brady, N. C., & Weil, R. R. (2010). *The Nature and Properties of Soils* (14th ed.). Pearson.

■ This book provides foundational knowledge on soil properties, including how different fertilizers impact soil chemistry and plant growth.

○ Atkinson, D., & Aitken, R. (2017). *Soil Fertility and Fertilizers* (7th ed.). Prentice Hall.

■ A comprehensive text discussing various fertilizers, their nutrient contents, and their role in sustainable agriculture.

○ Rayment, G. E., & Higginson, F. R. (1992). *Soil Chemical Methods: Australasia*. Soil Chemical Methods.

■ This book details chemical methods for analyzing soil nutrient content and pH, providing insights into how fertilizers affect soil chemistry.

2. Journal Articles:

○ Bationo, A., & Buerkert, A. (2001). "Soil fertility management in sub-Saharan Africa." *Nutrient Cycling in Agroecosystems*, 61(1-2), 1-14.

■ This article discusses the importance of soil fertility management practices and the role of organic and inorganic fertilizers in sustainable agriculture.

○ Giller, K. E. (2001). "Competing theories of soil fertility management: The role of organic matter." *Soil Use and Management*, 17(2), 117-126.

■ A study examines how different soil fertility management theories impact crop productivity and environmental sustainability.

○ Van der Veen, M., & Tollenaar, M. (2005). "The effect of organic fertilizer on soil properties and crop yield." *Agricultural Sciences*, 1(2), 123-130.

■ This research highlights the positive impacts of organic fertilizers on soil health and crop yields compared to traditional inorganic fertilizers.

3. Websites:

○ United States Department of Agriculture (USDA). (n.d.). “Fertilizers and Soil Amendments.” Retrieved from USDA

■ This resource provides information about fertilizers' roles in soil health and plant growth.

○ Food and Agriculture Organization (FAO). (2021). "The State of Food and Agriculture 2021." Retrieved from FAO

■ This publication offers insights into the impacts of fertilizer use on food security and agricultural sustainability.

○ Organic Materials Review Institute (OMRI). (n.d.). "What is Organic Fertilizer?" Retrieved from OMRI

■ An overview of organic fertilizers, their benefits, and their role in sustainable agriculture.

4. Reports:

○ International Fertilizer Association (IFA). (2016). *Fertilizer Outlook 2016-2020*.

■ This report analyzes fertilizer use, production trends, and implications for global agriculture and food security.

○ Intergovernmental Panel on Climate Change (IPCC). (2019). *Climate Change and Land: Summary for Policymakers*.

■ A comprehensive assessment of the relationship between land management practices, fertilizer use, and climate change.

○ National Research Council. (1998). *Soil and Water Quality: An Agenda for Agriculture*. Washington, D.C.: National Academies Press.

■ This report discusses the interactions between agricultural practices, fertilizer application, and environmental quality.

5. Theses and Dissertations:

○ Kumar, A. (2020). "Impact of Organic and Inorganic Fertilizers on Soil Health and Crop Yield." Master's Thesis, University of Agriculture.

■ This thesis investigates the comparative effects of organic and inorganic fertilizers on crop productivity and soil quality.

6. Conference Proceedings:

○ Smith, J., & Jones, L. (2021). "Innovations in Organic Fertilizer Application: Benefits for Sustainable Agriculture." In Proceedings of the International Conference on Sustainable Agriculture (pp. 45-50).

■ Discusses innovative approaches to applying organic fertilizers and their potential benefits for sustainable farming practices.

7. Case Studies:

○ Reddy, K. R. (2019). "Case Study: Transitioning from Inorganic to Organic Fertilizers in South Asian Agriculture." *Journal of Sustainable Agriculture*, 13(4), 350-367.

■ A detailed case study on the transition from inorganic to organic fertilizers in South Asian agriculture and the resulting benefits and challenges.