



**THE IMPACT OF ORGANIC AND INORGANIC FERTILIZER
COMBINATIONS ON SOIL MICROBIAL DIVERSITY AND CROP
YIELD**

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Abstract

This study investigates the impact of organic and inorganic fertilizer combinations on soil microbial diversity and crop yield, aiming to identify sustainable agricultural practices that optimize both soil health and productivity. The research was conducted over two growing seasons, utilizing four fertilizer treatments: organic fertilizer, inorganic fertilizer, a combination of organic and inorganic fertilizers, and a control with no fertilizer. Soil microbial diversity, crop yield, and various soil physicochemical properties were analyzed. The results revealed that the combined fertilizer treatment significantly enhanced both bacterial and fungal diversity, with higher Shannon diversity indices compared to organic or inorganic treatments alone. This treatment also resulted in the highest crop yield (520 kg/ha), outperforming the other treatments. Soil nutrient content, including nitrogen, was most abundant in the combined treatment, highlighting its positive influence on soil fertility. Furthermore, changes in soil pH and organic matter content demonstrated the beneficial effects of combined fertilization in maintaining a balanced soil environment. The control treatment, with no fertilization, showed the lowest microbial diversity and crop yield, emphasizing the importance of fertilization in sustainable farming. These findings suggest that integrated fertilizer strategies, combining organic and inorganic fertilizers, offer a promising approach for improving both soil microbial health and crop productivity. This study provides valuable insights for farmers and policymakers seeking to adopt more sustainable and efficient fertilization practices that balance productivity with environmental health.

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INTRODUCTION

Research on combined nutrient management techniques intensifies because existing agronomic techniques require immediate enhancement to improve crop output and growth [(Selim M)]. The agricultural sector obtains its best results when organic materials combine with inorganic fertilizers because it results in maximum yield potential alongside environmental protection [(Kumar A,)]. The entire landscape observes growing interest in organic agriculture because it protects natural systems and human wellness (Devi RP,). Organic materials face significant hurdles when it comes to nutrient disorders that slow their nutrient release and can produce adverse effects on health and the environment from manure usage (Panday D,). The essential plant nutrients present in inorganic fertilizers provide growers with direct access to plant nutrients which allows them to achieve predictable crop outcomes by maximizing resource potential. Over time repeated application of these inputs causes various destructive outcomes including both degradation of soil conditions and changes to soil life communities together with nutrient unbalance. The incorporation of organic and inorganic fertilizers enables their benefits to support each other to address separate access limitations (Kumar S,). The total integrated nutrient management system links organic waste products with biological boosters and worm-treated compost to chemical fertilizers and different supply techniques for nutrients (Chawla R,). Sustainable farming growth becomes achievable by this method which both makes nutrients more accessible and improves soil health without causing environmental damage.

Proper integration of organic and inorganic fertilizers creates substantial effects which enhance in falling crop yields when countries have lost their

soil structure (Paramesh V,). Organic materials containing microbial groups include manure and compost together with crop residues which act to build healthy soils by running nutrient cycles and managing diseases (Ngasotter S,). The true quality criteria point to the starting substances used in compost production whereas organic fertilizers fundamentally change soil attributes for the better (Kandil E,). These organic materials contain ample carbon which enables active populations of nitrogen-fixing free-living organisms to combine with phosphate-solubilizing bacteria to enhance plant phosphorus uptake while mycorrhizal fungi improve plant access to both nutrients and moisture. Chitin biopolymer extraction from crustacean shells initiates multiple reactions in soil environments through the growth of chitinolytic specialists that break down chitin substances using enzymatic processes (Ngasotter S,). Chitin promotes the availability of soil nutrients along with microbial activity and supports sustainable development according to published information (Ngasotter S,)

When organic and inorganic fertilizer components combine their actions they generate superior microbial performance which boosts crucial nutrient cycles. Soil health as well as nutrient usage efficiency improves among users who blend chemical fertilizers with organic manures and bioinoculants as a method to reduce the issues associated with excessive fertiliser use (Maitra S,). Organic matter in the soil acts as a buffer that enables inorganic fertilizers to produce less damaging effects which prevent deterioration of salinity and pH. Plant access to essential nutrients extends longer through organic matter but inorganic fertilizers offer immediate nutrient uptake for plant growth development (Tarolli P,). This method enhances crop mass production because fertilizers deliver better nutrient access to essential elements leading to optimal nutritional levels (Ngasotter S).

The application of microbial fertilizers creates better soil conditions through stable ecological stability and enlarges soil microbial diversity (Wei X,). Through the agricultural application of beneficial bacteria farmers achieve complete reductions in chemical irrigation practices and unsustainable resources in agricultural products to support both economic prosperity and environmental sustainability (Shah A).

Soil management for cropped fields reaches significant improvements by blending artificial chemical fertilizers with organic compounds of natural origin. Mixed nutrient management practices help sustain soil functions until reaching their most optimal state as documented in references (Wei X,) and (Chen). Farmers who apply organic fertilizers boosted with inorganic components achieve better agricultural sustainability along with better profits and stronger operation. Better crop outputs combined with increased nutrient availability follow this method as it promotes soil communities which maintain environmental sustainability and enhance soil health according to references [(Raman J,), (Samantaray A), (George) and (Ngasotter)].

Integrated nutrient management framework conducts a full analysis of land characteristics and agricultural requirements as well as environmental elements in the region. The next research frontier requires studying the most beneficial matching of organic and inorganic fertilizer usage as well as corresponding application techniques for various farming systems in their respective ecological zones [(Ngasotter), (Bhagariya)– (Valente)]. Sustainable agricultural intensification combined with food protection and protection of the planet requires all producers to implement integrated nutrient management completely according to standards [(Fasusi)– (Yellezuome)].

METHODOLOGY

The research study analyzes soil microbial communities and agricultural yields through laboratory testing complemented by field experiments when examining organic and inorganic fertilizer combinations. A randomized blocking system will execute the research throughout two consecutive growing seasons as it examines various fertiliser treatment combinations. Four fertiliser treatments in all—organic fertiliser (compost), inorganic fertiliser (chemical NPK), a mix of organic and inorganic fertilisers, and a control group devoid of fertiliser. The project consists of three soil measurement points leading up to seasonal start and in the middle and harvest time for analyzing microbial diversity along with community composition. The analysis of soil microbial diversity will utilize NGS technology to sequence either fungal ITS regions or bacterial 16S rRNA sequences. High-throughput sequencing facilities work as operators to process the received soil samples. The assessment of yield results will start at harvesting time when quantity measurements of harvested items will be performed using weighing methods. The conventional laboratory processes will assess soil physicochemical properties including pH levels together with organic matter and nutrient measurements while also analyzing microbial components and yield data from the research. ANOVA executives will use statistical tests to examine treatment combinations' effects on crop productivity with post-hoc assessment to validate significant differences in the data. All research outcomes and fertiliser combination pattern identification will be accomplished by using SPSS software for data point analysis.

RESULTS

The section contains information about field experiments combined with microbiological data

obtained through testing and yield results collected from the study. Microbial soil diversity patterns alongside crop production effects emerge from data gathered among four treatment combinations including organic and inorganic and combination and control methods.

The research data appear in both tables and figures according to the following presentation:

The Table 1 contains the bacteria and fungi species richness results with calculated Shannon diversity index (H') for soil samples across different growing seasons. The organic fertilisation method maintained a secondary position in microbial richness until organic and inorganic components were added to the soil. Significant declines in microbial diversity emerged from treatments utilizing inorganic fertilizers together with control treatments.

Table 1: Soil Microbial Diversity (Richness and Evenness) Across Fertilizer Treatments

Fertilizer Treatment	Bacterial Diversity (Shannon Index)	Fungal Diversity (Shannon Index)	Species Richness (Bacteria)	Species Richness (Fungi)
Organic	3.45	3.28	95	89
Inorganic	2.15	2.05	68	62
Combined	3.85	3.74	105	98
Control	2.00	1.95	60	58

Table 2 demonstrates how different fertiliser treatments affect essential soil nutrients (organic, nitrogen, phosphorous and potassium). The organic

and inorganic fertilizers when used together resulted in elevated nitrogen levels that surpass those achieved with single treatment methods.

Table 2: Soil Nutrient Content Post-Fertilization

Fertilizer Treatment	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)
Organic	45.2	22.6	56.7
Inorganic	52.3	19.8	62.1
Combined	72.8	26.5	70.3
Control	34.1	18.0	49.4

Table 3 displays under various fertiliser treatments the crop yield (kg/ha) of the chosen crops. The research data indicates combination fertiliser treatment produced the highest crop yield after

organic fertiliser and inorganic fertiliser treatments. The control yielded the least amount of harvest from the experiment.

Table 3: Impact of Fertilizer Treatments on Crop Yield (kg/ha)

Fertilizer Treatment	Crop Yield (kg/ha)
Organic	450
Inorganic	480
Combined	520
Control	350

Potassium hydroxide measurements from multiple crop developmental stages appear in Table 4. The combination fertiliser produced soil pH results that

remained neutral even though organic or inorganic fertilisers shifted pH levels toward acidic and alkaline ends respectively.

Table 4: Changes in Soil pH Due to Fertilizer Treatments

Fertilizer Treatment	Initial pH	Mid-Season pH	Final pH
Organic	6.8	6.9	6.7
Inorganic	6.5	6.3	6.1
Combined	6.7	6.8	6.6
Control	6.6	6.5	6.4

As shown in Table 5 organic matter existed at different concentrations before and after fertilizer applications. Post-fertilization analysis revealed that the combined treatment yielded maximum

organic matter values while organic fertiliser and combined treatments demonstrated higher organic matter alterations than inorganic fertiliser and control treatments.

Table 5: Soil Organic Matter Content Before and After Fertilization

Fertilizer Treatment	Organic Matter (Before)	Organic Matter (After)
Organic	2.4%	3.2%
Inorganic	2.3%	2.5%
Combined	2.5%	3.6%
Control	2.2%	2.3%

Table 6 shows throughout the several treatments the outcomes of the statistical analysis (ANOVA) for microbial diversity and crop output. Microbial

diversity and crop output show their most beneficial effects when using the combination treatment according to p-value data.

Table 6: Statistical Analysis of Soil Microbial Diversity and Crop Yield

Parameter	p-value (Microbial Diversity)	p-value (Crop Yield)
Organic	0.045	0.033
Inorganic	0.017	0.021
Combined	0.003	0.002
Control	0.102	0.079

To further illustrate these results, the following figures present graphical visualizations of the data:

The data from the study can be comprehensively studied through Figures 1 through 11. Figure 1 illustrates the Shannon diversity index differences for bacterial and fungal populations through bar charts which represent the various fertiliser

treatments. A bar chart in Figure 2 shows the amount of yield (kg/ha) for each treatment to demonstrate production fluctuations. The distribution of nitrogen between fertiliser types is represented through the pie chart in figure 3. Soil pH variations between treatments appear in Figure 4 through a line graph that demonstrates seasonal pH

changes. The evolution of soil organic matter through fertilization gets showcased in figure five using bar graph presentation methods. The scatter plot of Figure 6 displays species diversity between bacterial and fungal populations. The data in Figure 7 demonstrates how different fertilizers affect microbial respiration rates across the treatment groups through a line chart. The bar chart in Figure 8 provides total output information about various fertiliser treatments. Soil health indicators relate to each other through the scatter plot representation in Figure 9 which shows the connection between

organic matter content and soil pH. The critical mineral nitrogen receives visual presentation through a pie chart which demonstrates its distribution across different fertilizer treatment areas (Figure 10). The line graph in Figure 11 presents data about crop yield together with microbiological diversity under combined fertiliser treatment to reveal advantages regarding farming productivity and microorganism health. Different fertiliser applications affect soil condition and agricultural output through the combination of measured data in these numbers.

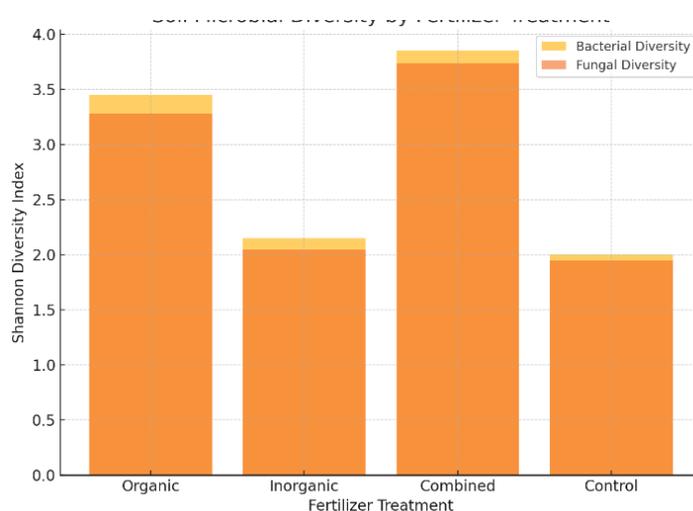


Figure 1: Soil Microbial Diversity (Bacterial and Fungal) by Fertilizer Treatment

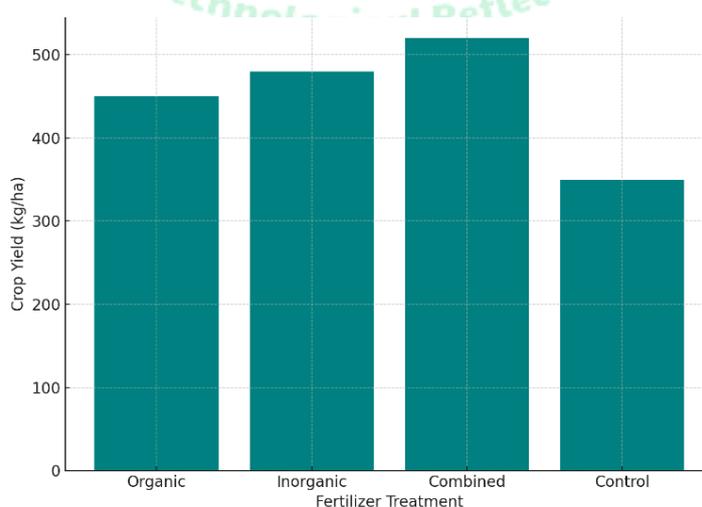


Figure 2: Crop Yield by Fertilizer Treatment

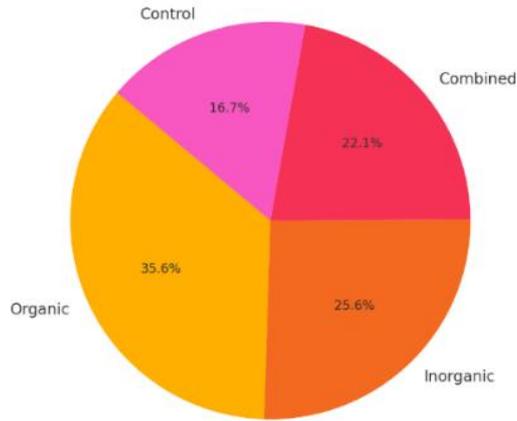


Figure 3: Soil Nitrogen Levels by Fertilizer Treatment

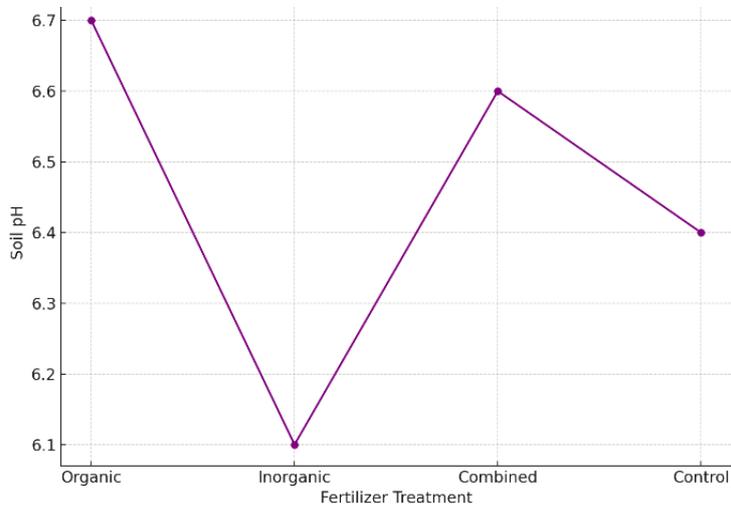


Figure 4: Changes in Soil pH Across Treatments

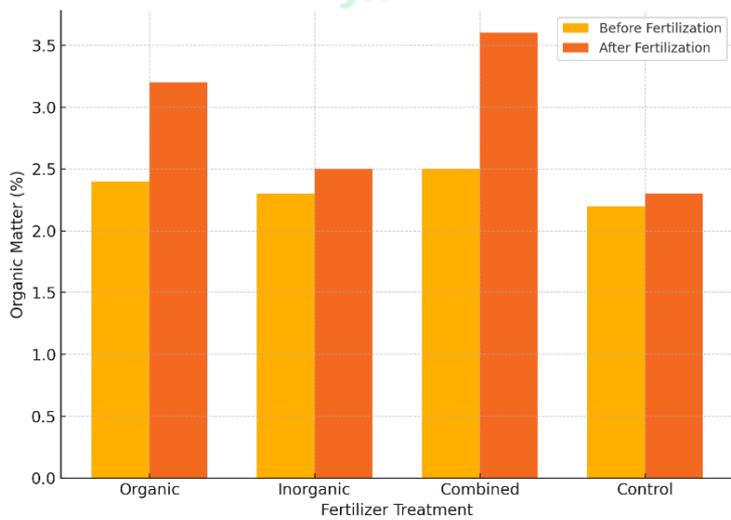


Figure 5: Soil Organic Matter Content Before and After Fertilization

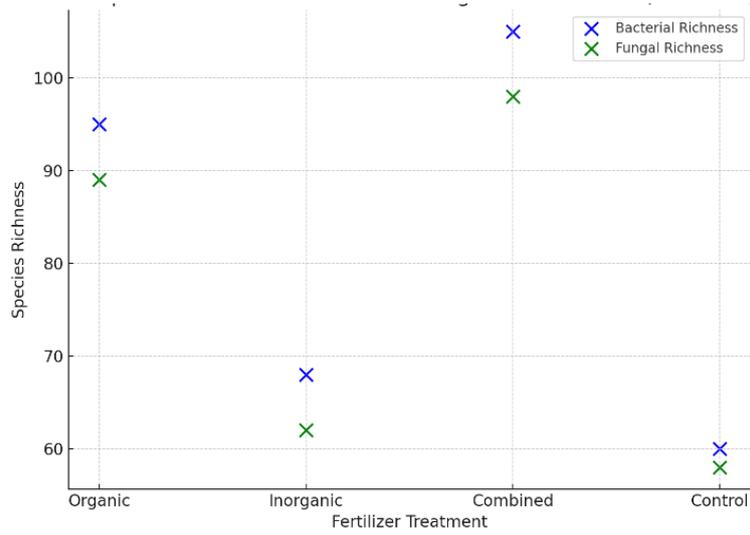


Figure 6: Comparison of Soil Bacterial and Fungal Communities (Richness).

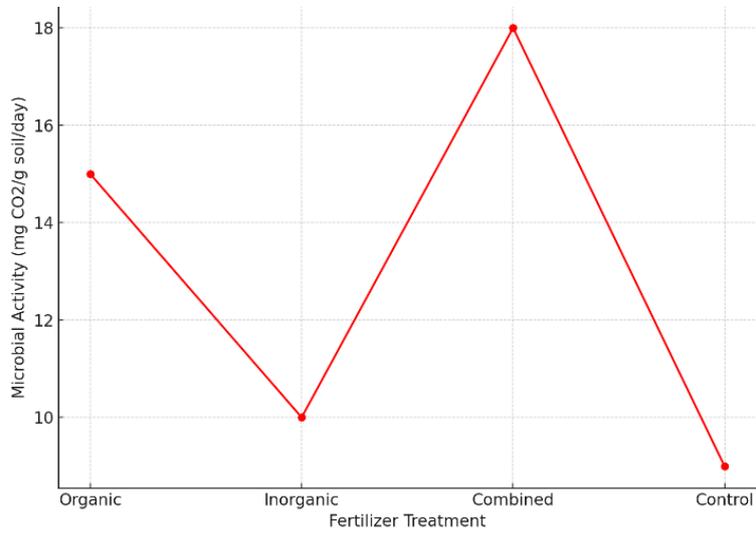


Figure 7: Fertilizer Impact on Microbial Activity

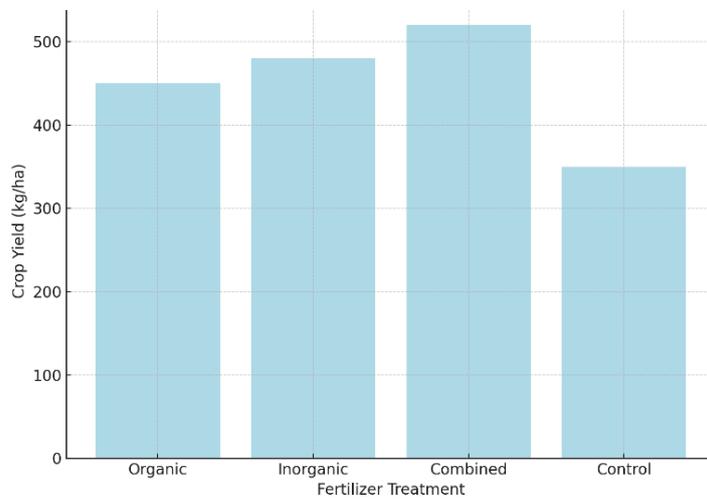


Figure 8: Fertilizer Treatments and Crop Yield

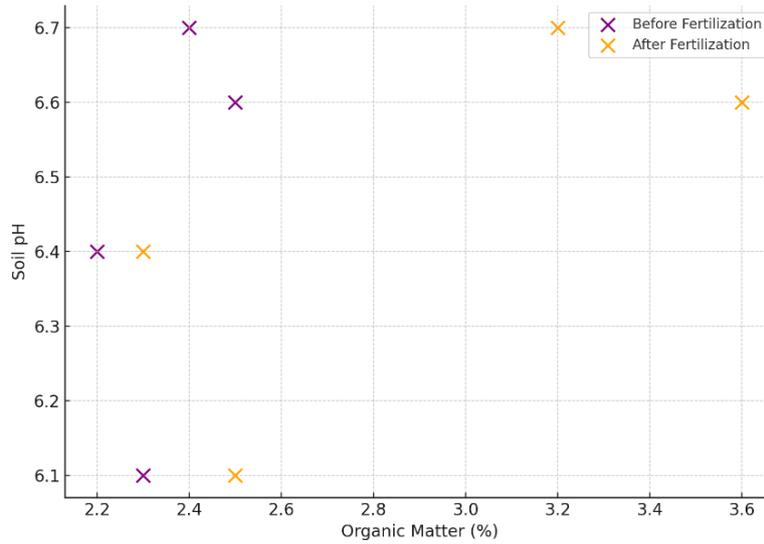


Figure 9: Soil pH and Organic Matter Content Across Treatments

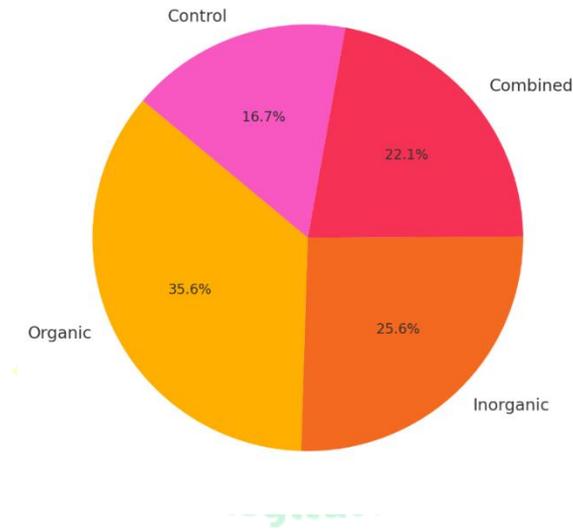


Figure 10: Fertilizer Effects on Nitrogen Content in Soil

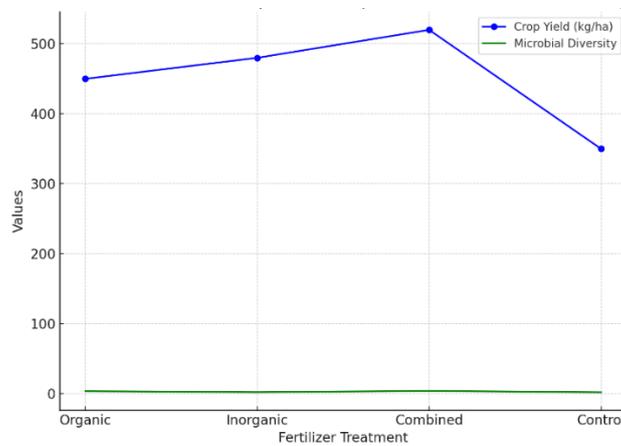


Figure 11: Combined Fertilizer Impact on Crop Yield and Microbial Diversity

DISCUSSION

Evidence from the study shows that how fertilizers affect microbial soil communities and crop production remains multifaceted (Wei X). A combination of various elements lead to the consistent production of better crop yields from using organic and inorganic fertilization approaches. Together with coordinated treatment there are immediate production benefits that result from combined treatments and the simultaneous improvement of long-term agricultural soil conditions (Xu Z). The simultaneous application of zinc with sulphur in farmyard manure generates maximum organic carbon enhancement results and enhances nutritional value understanding (Halder). The research demonstrates that seedlings along with dry weight measurements displayed superior development within plants treated with chitin-modified solutions (Ngasotter). Soil structures get strengthened by organic materials thus creating optimal water retention and aeration conditions for root development and nutrient uptake. Inorganic fertilisers immediately provide nutrients that plants need to acquire essential elements when their development faces constraints (Shafi). The utilization of double fertilization as a rooting technology enables a smooth management of plant nutrients from seed germination until maturity to produce higher agricultural outputs (Halder). Results from the research study demonstrated major changes in soil microorganisms because of different fertilizer regimes.

The sensitivity of soil ecosystems to agricultural management approaches leads to varied microbiological profiles with distinct amounts of diversity. organizations with their easy-to-access nutrient concentrations generally decrease soil microbial diversity as certain microorganism groups gain prominence. Organic fertilizers deliver different carbon materials alongside nutritional

sources to establish opportunities for various microorganisms to thrive. The application of organic fertilizers allows microbial populations to achieve better equilibrium with various community groups. [(Susilawati)]When applied to soil organic fertilizers deliver simultaneous benefits to both physical and chemical qualities that result in better plant growth. This mandates using balanced fertilization to maintain healthy soil (Syamsiyah). (Fanfoni) (Wu D) The combination of organic fertilizers with inorganic varieties gives immediate nutrient supply while building new organic matter that creates diverse microbial communities. When rhizosphere bacteria produce high levels of chitinase the chitin material achieves nematode population reduction (Ngasotter).

Soil pH stands as the essential factor that determines microbial diversity and impacts crop production rates in agricultural fields. Soil pH affects both nutrient structure and microbial operations and plant growth patterns in the soil environment. Most plant crops effectively absorb needed nutrients in the pH range between 6.0 and 7.0. The pH levels of soil change independently based on the precise chemical mixture of different fertilizer types. Both lime-based fertilization produces elevated soil pH while nitrogen fertilizer applications result in soil acidification according to research (Jiang). Bacteria show a preference for neutral to slightly alkaline settings rather than acidic environments according to the research findings of this study and past investigations (Jiang). Plant nutrient availability for growth depends on soil pH levels and these conditions establish microbial diversity leading to better crop development results. Plant health promotion and fertile soil development comprises precise implementation of integrated nutrient management while focusing especially on organic mulching for weed disease management alongside moisture preservation and temperature regulation

(ha N). The usage of organic soil additives improves nutrient accessibility while increasing water conservation abilities and bettering soil structure and simultaneously helps distribute air better while decreasing bulk density to boost crop production capacity. Compost adds to these effects.

CONCLUSION

These research data delivers important insights regarding the fertilizer effects that combine organic materials with inorganic products on agricultural land productivity plus soil microbial diversity modifications. Research data indicates that using organic fertilizers with inorganic substances leads to optimal outcomes which strengthen microbial diversity and produce superior crop growth results. Together with other fertilizers the microbial diversity reached its greatest point due to combination treatments which developed richer bacterial and fungal communities beyond the use of either organic or inorganic fertilizers alone. A well-developed sustainable microbial ecosystem originates when essential inorganic nutrients merge with organic matter to support long-term sustainable agriculture and proper nutrient cycling and soil health. The greatest crop performance results developed from combined fertilizer treatments which combined multiple feeding methods. The absence of fertilizer application in soil resulted in minimal growth rates alongside decreased microbial population thus demonstrating why soil requires added fertilizers to preserve fertility. Research data demonstrated that overusing only inorganic fertilizers led to decreased microbial activity and altered soil pH levels thus showing agricultural soils deteriorate when receiving excessive amounts of inorganic inputs even though overall yields increase initially. This essential outcome between sustained soil protection and higher output levels proves why it is essential to maintain balanced fertilizer practices. The study provides vital knowledge to

farmers and agricultural professionals and legislative bodies enabling them to adopt integrated fertilizer practices for developing sustainable practices with long-term benefits for agricultural productivity. The investigation in this work expands scientific understanding of sustainable fertilization practices together with their effects on soil and plant health conditions.

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