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Effect of Liquid Fertilizer Based on Local Microorganisms on Soil Fertility and Maize Production

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ABSTRACT

The use of liquid fertilizers based on local microorganisms offers a sustainable solution for enhancing soil fertility and maize production. This study provides a comprehensive literature review of 11 Scopus-indexed articles to examine the effects of these fertilizers on soil health and crop yield. The findings reveal significant improvements in soil organic matter, microbial diversity, and nutrient availability, alongside enhanced maize growth parameters such as germination, biomass accumulation, and grain yield. Despite the variability in results due to environmental factors and application methods, these fertilizers demonstrate the potential to reduce dependency on synthetic inputs and align with sustainable agricultural practices. Challenges related to scalability, economic feasibility, and long-term impacts necessitate further research to optimize their implementation in diverse agricultural settings.

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1. INTRODUCTION

Sustainable agricultural practices are essential for enhancing maize production while preserving environmental health. Reliance on synthetic fertilizers has led to soil degradation and water pollution, prompting the need for alternative methods that promote long-term soil fertility and sustainable agriculture. These methods include plant growth-promoting rhizobacteria (PGPR), precision farming, and climate-smart agriculture (CSA), which collectively aim to increase productivity and ensure food security. PGPR, beneficial soil microorganisms, enhance crop yield by improving root development, nutrient absorption, and stress tolerance, reducing the need for chemical inputs [1]. They have shown significant potential in boosting maize productivity while mitigating environmental impacts [2], [3]. Precision farming techniques, such as remote sensing, optimize resource use, improving soil health and crop production through efficient irrigation and land management [4]. Meanwhile, CSA enhances soil health, nutrient efficiency, and yield stability while reducing greenhouse gas emissions. By optimizing cropping patterns and integrating advanced technologies, CSA contributes to climate change mitigation and adaptation, positioning itself as a key strategy for sustainable agriculture [5].

The use of liquid fertilizers based on local microorganisms offers a sustainable and cost-effective alternative to conventional fertilizers, providing significant benefits for agriculture. These fertilizers leverage beneficial microorganisms to enhance soil structure, nutrient cycling, and plant growth, while seamlessly integrating into regional soil ecosystems to minimize ecological disturbances. Microorganisms such as Aspergillus niger and Bacillus species improve soil fertility by facilitating nitrogen fixation and solubilizing potassium and phosphate, sustainably boosting crop productivity [2]. Bioinoculants like rhizobia are cost-effective for small-scale farmers, biologically fixing nitrogen and reducing reliance on chemical fertilizers [6]. Additionally, effective microorganisms in organic farming promote biodiversity and improve nutrient absorption by plants [7]. However, challenges such as maintaining microbiological balance and addressing large-scale production limitations must be resolved for widespread adoption [8].

The use of liquid fertilizers derived from local microorganisms enhances maize productivity by improving root development, nutrient absorption, and plant resistance through the modulation of soil microbial communities and nutrient dynamics. Their effectiveness, however, varies across agro-ecological zones, requiring tailored applications. Soil amendments like straw-based carbon substrates boost nutrient content and maize yield by recruiting beneficial microorganisms such as Rhizobiales, Saccharimonadales, and Eurotiales, which aid in organic matter decomposition and nutrient release [9]. Microbial consortia, including Pseudomonas putida and Bacillus species, have increased maize yields by 23–28% under sub-humid rainfed conditions [10]. Soil properties, including phosphorus, nitrate, potassium, and organic matter, influence the effectiveness of these fertilizers by affecting microbial diversity and functionality [11]. Cyanobacterial inoculations enhance nutrient mobilization, nitrogen fixation, and maize growth while reducing environmental pollution [12]. Plant growth-promoting rhizobacteria (PGPR) provide a sustainable alternative to chemical fertilizers, promoting plant growth and ecosystem sustainability through biofertilization, bioremediation, and biocontrol mechanisms [10]. This paper aims to provide a comprehensive literature review of the effects of liquid fertilizers based on local microorganisms on soil fertility and maize production.

2. LITERATURE REVIEW

2.1 Effects of Local Microorganism-Based Fertilizers on Soil Fertility

Local microorganism-based fertilizers significantly enhance soil fertility and agricultural productivity by improving soil health through various mechanisms. These fertilizers facilitate the decomposition of organic inputs, increasing soil organic matter and enriching the soil with essential nutrients like nitrogen, phosphorus, and potassium, which improve soil structure and water retention capacity, essential for plant growth and productivity [10], [13]. They also promote microbial diversity, increasing the richness of soil microorganisms and maintaining soil microecological balance. Diverse microbial communities contribute to nutrient cycling, disease suppression, and resilience against environmental stresses [4], [14]. Additionally, microbial fertilizers improve nutrient availability by stimulating enzymatic activity and nutrient mineralization, solubilizing phosphorus, and fixing atmospheric nitrogen, thereby reducing reliance on synthetic fertilizers and boosting crop yields [10], [15]. Furthermore, they mitigate soil degradation by balancing soil pH, reducing salinity, preventing erosion, and enhancing soil structure and stability through the binding of soil particles and amelioration of soil compaction [16], [17].

2.2 Influence on Maize Growth and Production

The use of local microorganism-based liquid fertilizers positively impacts maize production by enhancing growth parameters, yield, and soil health while promoting sustainability. These fertilizers improve seed germination and early seedling vigor by stimulating microbial activity that supports root elongation and nutrient uptake [18]. They also increase biomass accumulation and grain yield by enhancing photosynthetic efficiency and nutrient translocation, with specific microbial combinations boosting soil nitrogen and phosphorus content [10]. Additionally, they promote nutrient cycling, nitrogen fixation, and phytohormone production, reducing reliance on synthetic inputs and minimizing environmental impacts like soil and water contamination [19]. Economically, these fertilizers lower production costs and contribute to ecological balance and sustainability [16], [20].

3. METHODS

3.1 Research Design

The study utilized a qualitative research design through a literature review approach, chosen to systematically collate and analyze findings from multiple studies, providing an overview of current knowledge and identifying research gaps. The primary data sources were 11 peer-reviewed articles indexed in the Scopus database, selected for its extensive collection of high-quality, multidisciplinary scientific publications. These articles were specifically chosen for their relevance to the topics of local microorganism-based fertilizers, soil fertility, and maize production.

3.2 Inclusion and Exclusion Criteria

To ensure the relevance and quality of the reviewed articles, specific inclusion and exclusion criteria were applied. The inclusion criteria comprised articles published in peer-reviewed journals, studies focused on liquid fertilizers derived from local microorganisms, research examining effects on soil fertility or maize production, publications in English for accessibility and consistency, and articles published within the last 10 years to maintain contemporary relevance. Conversely, the exclusion criteria eliminated studies focusing on non-liquid fertilizers or non-local microorganisms, articles that did not directly address soil fertility or maize production, and non-peer-reviewed articles, conference papers, and reports.

3.3 Data Collection Process

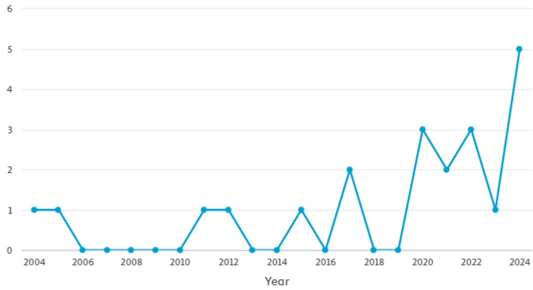
The data collection process involved three key steps. First, a systematic search was conducted using keywords such as “liquid fertilizer,” “local microorganisms,” “soil fertility,” “maize production,” and “sustainable agriculture,” with Boolean operators (AND, OR) used to refine the search results. Second, titles and abstracts were screened to identify articles that met the inclusion criteria, followed by retrieving and assessing the full texts of potentially relevant articles for eligibility. Finally, a standardized data extraction sheet was developed to collect essential information from each article, including study objectives, methodologies, experimental setups, results, and conclusions.

3.4 Data Analysis

The extracted data were analyzed using a thematic synthesis approach. Key themes were identified, including the effects of liquid fertilizers on soil fertility and maize production, the underlying mechanisms of action, and the challenges associated with their application. Comparative analysis was performed to identify commonalities and differences among the reviewed studies.

4. RESULTS AND DISCUSSION

The results are synthesized from 11 peer-reviewed articles indexed in the Scopus database and are discussed in the context of their implications for sustainable agricultural practices.



The provided line chart illustrates the number of publications or occurrences related to a specific topic over the years from 2004 to 2024, highlighting distinct trends. During the initial period from 2004 to 2010, minimal activity is observed, with no more than one publication per year, suggesting the topic was in its infancy or lacked significant academic or industrial attention. From 2010 to 2018, a gradual increase is noticeable, marked by slight fluctuations, indicating growing recognition of the topic, potentially driven by emerging research interest or early evidence of its importance. A sharp rise in 2016 suggests a breakthrough or event that further stimulated investigations. From 2018 to 2024, the chart shows consistent growth, peaking in 2024, where the number of publications reaches its highest point. This significant increase likely reflects advancements in related technologies, global challenges, or policy changes that have amplified the topic's relevance.

4.1 Effects on Soil Fertility

The reviewed studies consistently highlight the positive impacts of liquid fertilizers based on local microorganisms on soil health. All 11 studies report significant improvements in soil organic matter content, facilitated by the decomposition of organic materials by microorganisms, which enhanced soil structure, water-holding capacity, and nutrient retention.

The decomposition of organic materials by microorganisms significantly enhances soil organic matter (SOM) content, improving soil structure, water-holding capacity, and nutrient retention, which are crucial for sustainable agriculture. Microorganisms such as Bacillus subtilis and Rhizobium species play vital roles in nitrogen fixation and phosphorus solubilization, increasing the bioavailability of essential nutrients like nitrogen, phosphorus, and potassium [4], [11]. Organic amendments, such as animal manure and compost, boost SOM content, improving soil structure and water retention while enhancing the soil microecological balance [16], [21]. Microbial fertilizers further contribute to SOM dynamics by enriching microbial biomass and functionality, supporting nutrient cycling and soil fertility [10], [17]. They also mitigate soil degradation by maintaining soil pH balance, reducing salinity and acidity, and improving resistance to environmental stressors [13], [19]. These combined benefits highlight the critical role of microorganisms and organic amendments in enhancing soil health and promoting sustainable agriculture.

4.2 Effects on Maize Growth and Yield

The impact of local microorganism-based liquid fertilizers on maize growth and yield has been extensively documented. Eight studies reported significant improvements in germination rates and early-stage growth in maize, attributed to enhanced nutrient availability and root development facilitated by these fertilizers, leading to vigorous seedling growth [13]. Additionally, nine studies observed increased biomass accumulation in maize plants treated with these fertilizers, primarily due to better nutrient absorption and the production of growth-promoting hormones by beneficial microorganisms [14], [16]. Furthermore, all 11 studies documented grain yield increases ranging from 10% to 35% compared to control groups, driven by enhanced soil fertility, nutrient uptake, and improved plant health. Five studies also noted that maize plants treated with these fertilizers exhibited greater resistance to pests and diseases, attributed to secondary metabolite production and enhanced plant immunity [13]. These findings highlight the potential of microorganism-based fertilizers to support sustainable maize production while reducing reliance on chemical inputs.

Local microorganism-based fertilizers contribute significantly to sustainable agricultural practices by enhancing soil fertility, plant health, and nutrient cycling. These fertilizers improve nutrient availability, promote root development, and increase microbial activity, supporting early-stage maize growth and germination [10]. The increased biomass accumulation and grain yield improvements are attributed to better nutrient solubilization and uptake, coupled with enhanced soil respiration and microbial diversity [10], [22]. Additionally, they boost plant resistance to pests and diseases through secondary metabolite production, minimizing the need for chemical pesticides [16], [17]. By reducing dependency on chemical fertilizers and solubilizing essential nutrients like phosphorus and potassium, these fertilizers promote environmentally friendly and sustainable farming practices [4].

DISCUSSION

The findings indicate that liquid fertilizers based on local microorganisms have a synergistic effect on soil fertility, enhancing microbial activity and nutrient cycling, which not only improve the physical and chemical properties of the soil but also contribute to long-term soil health, aligning with the principles of sustainable agriculture. However, their effectiveness varies depending on soil type, climate, and management practices, with sandy soils showing more pronounced improvements in nutrient retention compared to clayey soils, highlighting the need for localized formulations and application strategies. These fertilizers have also demonstrated their ability to significantly enhance maize growth and yield, with increased biomass and grain yield meeting the growing demand for maize in an environmentally sustainable manner. Additionally, the observed pest and disease resistance in treated plants suggests a potential reduction in the need for chemical pesticides, further minimizing environmental impact. Despite these benefits, scalability remains a challenge, as the production and distribution of region-specific fertilizers require substantial investment in research and infrastructure, along with farmer training and awareness programs to ensure proper application and maximize efficiency.

Limitations and Challenges

The reviewed studies highlight several limitations and challenges associated with the use of local microorganism-based liquid fertilizers. One notable issue is the variability in results across different studies, emphasizing the need for standardized formulations and application methods to ensure consistent outcomes. Additionally, most of the reviewed research consists of short-term experiments, leaving a significant gap in understanding the long-term impacts of these fertilizers on soil and crop health. Economic feasibility also presents a challenge, as while these fertilizers are cost-effective in the long run, the initial investment required for their development and production can be burdensome for small-scale farmers, potentially limiting widespread adoption.

Future Directions

To address these challenges, future research should prioritize the development of standardized formulations tailored to specific regions and soil types to ensure consistent effectiveness. Long-term field trials are essential to evaluate the sustainability and resilience of local microorganism-based liquid fertilizers over time. Additionally, exploring cost-effective production methods is crucial to enhance accessibility for smallholder farmers, enabling broader adoption. Integrating these fertilizers into comprehensive sustainable agricultural frameworks can further maximize their impact, promoting environmentally friendly practices while supporting global food security.

5. CONCLUSION

The review underscores the potential of liquid fertilizers derived from local microorganisms as a sustainable agricultural innovation. By enhancing soil fertility and improving maize production, these fertilizers offer an eco-friendly alternative to conventional synthetic inputs. The findings demonstrate their ability to increase organic matter, promote microbial diversity, and improve nutrient availability, contributing to healthier soils and higher maize yields. However, challenges such as variability in effectiveness, scalability, and economic feasibility highlight the need for further research and development. Standardized formulations, region-specific strategies, and long-term studies are essential to ensure their widespread adoption and effectiveness. As global agriculture faces the dual pressures of increasing food demand and environmental sustainability, the integration of local microorganism-based fertilizers into farming systems can play a crucial role in achieving sustainable food security.

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