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Integrated Effect of Kitchen Waste Compost and Chemical Fertiliser on Growth and Yield of Vegetable Crops

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Abstract: *Sustainable crop production requires achieving good yields without harming the environment. Overreliance on chemical fertilizers has disturbed soil nutrient balance, reduced organic matter, and weakened microbial activity, resulting in declining soil health. At the same time, increasing urbanization has led to a rise in domestic waste, especially kitchen waste, which is usually discarded instead of being reused. Transforming this biodegradable waste into compost offers a practical way to manage household waste while enriching the soil.This study investigates how combining kitchen-waste compost with chemical fertilizers influences vegetable growth, yield, and soil characteristics. Kitchen compost supplies essential nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and trace minerals, and also improves soil structure, moisture-holding capacity, and microbial activity. However, because compost releases nutrients slowly, it may not fully satisfy the immediate nutrient needs of fast-growing vegetables. Chemical fertilizers, on the other hand, provide quick nutrient availability but can cause leaching, acidity, and environmental pollution when misused. Using both together can increase nutrient-use efficiency, maintain soil fertility, and promote long-term sustainable production.*

The integrated nutrient management (INM) concept was examined through both pot and field experiments using different compost–fertilizer combinations (25:75, 50:50, and 75:25), along with treatments containing only compost and only fertilizer. The selected vegetable crops included lettuce (Lactuca sativa), cucumber (Cucumis sativus), tomato (Solanum lycopersicum), and spinach (Spinacia oleracea).

Keywords: Kitchen waste, tomato juice patches, cucumber seeds, straw, rice husk, waste management

I. INTRODUCTION

The increasing pace of urbanization and the rising demand for environmentally responsible waste management have intensified interest in the productive reuse of kitchen waste (KW). Composting this waste stream has become one of the most practical and cost-effective strategies for recycling biodegradable materials. Despite these advantages, KW often contains naturally high concentrations of soluble salts, which cannot be completely removed with current processing technologies. This poses a challenge for its direct use in dryland agriculture. Recent studies indicate that incorporating kitchen waste compost (KWC) with other organic materials to prepare vegetable seedling substrates (SS) offers a promising route for resource utilization. Such blending not only supports secondary use of composted KW but also helps reduce salt-related risks.

Traditionally, peat has been the primary constituent of commercial seedling substrates. However, peat is a non-renewable resource and its continued extraction conflicts with modern goals of ecological sustainability. Consequently, researchers worldwide have been exploring renewable alternatives, especially substrates derived from agricultural residues. Evidence shows that plant-based wastes such as straw can serve as effective substrate components, while among livestock manures, only composted cow manure has demonstrated consistent suitability. Compared with many agricultural wastes, KW contains higher nutrient levels, and when properly composted, its nutrient profile allows partial replacement of peat while meeting environmental and agronomic requirements.

Our earlier investigations revealed that substituting a portion of peat with KWC can enhance several growth parameters of cucumber seedlings. However, KWC alone does not fully meet the standards required for high-quality seedling media. Its physical texture may be overly compact, limiting aeration and water infiltration. The pH of KWC is often unstable and may fall outside the optimal range for seedling development. Nutrient composition can also vary considerably due to differences in household waste sources, potentially causing imbalances in the growth medium. Additionally, if the composting process is incomplete, pathogens and weed seeds may persist. For these reasons, simple one-to-one replacement of peat with KWC is inadequate for producing standard vegetable seedling substrates.

While several studies have examined the use of KWC in substrate formulation, research remains limited regarding the most effective mixing ratios between KWC and agricultural wastes for crops sensitive to salinity, such as cucumber. High salt levels and fluctuating pH continue to be major constraints that have not been sufficiently addressed. The present study focuses on evaluating different mixtures of KWC with rice husks, straw, peat, and other organic materials to determine their effects on cucumber seedling growth. The central hypothesis is that an appropriate combination of KWC with other renewable components can enhance nutrient availability, dilute excess salts, improve physical structure, and ultimately support stronger seedling development. Conversely, higher proportions of KWC are expected to raise salinity to levels that negatively influence root elongation and overall seedling vigor.

This research contributes beyond previous studies by examining not only the nutrient characteristics of KWC-based mixtures but also their structural, chemical, and functional properties, along with detailed assessments of plant morphological responses. The findings aim to provide practical guidance for developing environmentally sound substrate formulations that reduce dependency on non-renewable peat resources while promoting sustainable management of organic household waste.

In addition to addressing KW utilization, this study recognizes its broader relationship with global food waste challenges. Worldwide, more than one-third of all food produced is lost or wasted, generating significant greenhouse gas emissions, squandering water and land resources, and overwhelming waste management systems. Differences in waste patterns across countries—ranging from production losses in low-income regions to retail and consumer-level waste in higher-income nations—further amplify economic and environmental impacts. These realities underscore the importance of transforming organic waste into valuable agricultural inputs wherever possible.

Finally, the integrated use of organic and inorganic nutrient sources underpins the long-term sustainability of agricultural soils. Organic amendments such as KWC improve soil structure, enhance biological activity, and provide slow-release nutrients, while inorganic fertilizers supply immediately available nutrients but may degrade soil quality when used excessively. Combining the two can balance nutrient availability, protect soil health, and align with circular-economy principles by converting household waste into productive resources.

Principles of Kitchen Waste Composting

1. Aerobic Breakdown: Composting operates through the action of aerobic microorganisms—mainly bacteria, fungi, and actinomycetes—that use oxygen to decompose organic materials. Through their activity, the waste is transformed into a stable, humus-like product.

2. Carbon–Nitrogen Balance: Maintaining an appropriate C/N ratio is essential for efficient compost formation. Carbon-rich components such as dried leaves or paper supply energy, while nitrogen-rich inputs like vegetable and fruit residues support microbial protein synthesis. A suitable balance speeds up decomposition and helps prevent unpleasant odors.

3. Moisture and Oxygen Supply: Microbial activity requires proper moisture content, generally between 40% and 60%. Turning or mixing the compost pile introduces oxygen and prevents anaerobic zones that can cause slow breakdown and bad smells.

4. Temperature Control: As microorganisms work, the compost pile heats up. Managing and tracking these temperature changes helps accelerate the process and ensures the destruction of harmful pathogens.

5. Final Stabilization: In the last stage of composting, the material undergoes curing, during which it becomes fully stabilized and safe to apply to soil. This phase ensures the compost no longer contains viable pathogens or weed seeds.

Benefits of Kitchen Waste Composting

- **Waste Reduction**: Composting significantly reduces the volume of organic waste sent to landfills, mitigating methane emissions—a potent greenhouse gas.
- **Soil Enrichment**: The resulting compost enhances soil structure, water retention, and nutrient content, promoting healthier plant growth.
- **Sustainable Agriculture**: Utilizing compost in agriculture reduces the need for chemical fertilizers, supporting sustainable farming practices.
- Considerations for Effective Composting
- **Material Selection**: Avoid composting meat, dairy, and oily foods, as they can attract pests and slow down the composting process.
- **Bin Design**: Using a compost bin can help maintain temperature and moisture levels, and prevent pests.
- **Monitoring**: Regularly check the compost for moisture content, temperature, and aeration to ensure optimal conditions for decomposition.

Integration of Organic and Inorganic Fertilizers in Vegetable Production

The combined use of organic and inorganic fertilizers offers a balanced method of nutrient management that pairs the quick nutrient availability of chemical fertilizers with the long-term soil enhancement provided by organic inputs. Organic sources—such as compost, vermicompost, and kitchen waste compost—supply organic matter and essential micronutrients that improve soil texture, boost microbial activity, and increase moisture retention. However, because nutrients from organic amendments are released slowly, they may not satisfy the immediate demands of rapidly growing vegetables. Chemical fertilizers, on the other hand, provide instantly available nitrogen, phosphorus, and potassium, resulting in rapid crop growth and improved yield. When used together, these inputs help maintain soil quality while ensuring an adequate and timely nutrient supply.Studies consistently show that integrating organic materials with chemical fertilizers increases nutrient-use efficiency compared to applying chemical fertilizers alone. Organic matter serves as a slow-release nutrient pool, reducing losses from leaching and lowering the risk of environmental contamination. For example, nitrogen from chemical fertilizers can be partially conserved in the soil when organic components are present, while the organic fraction gradually supplies nutrients throughout the crop cycle. The combined system also stimulates beneficial soil microorganisms, improving nutrient cycling and soil fertility. This complementary interaction not only raises crop productivity but also strengthens soil health over the long term, which is vital for sustainable vegetable cultivation.

Research on various vegetable crops—including lettuce, tomato, and cucumber—shows that plants treated with a blend of compost and chemical fertilizers demonstrate higher growth rates, better chlorophyll levels, and increased yields compared to those receiving only one type of nutrient source. Moreover, the nutritional qualities of vegetables, such as vitamin concentration, antioxidant potential, and storage life, often improve under integrated fertilization practices. These improvements stem from enhanced nutrient availability combined with better soil physical and biological conditions created by mixed nutrient sources.

Environmentally, integrated fertilization reduces reliance on excessive amounts of chemical fertilizers, which are linked to soil acidification, nutrient leaching, and greenhouse gas emissions. By partially replacing chemical inputs with organic materials, farmers can lessen these negative impacts without compromising productivity. This approach aligns with sustainable agriculture principles that prioritize resource conservation, soil protection, and reduced chemical dependency. Additionally, integrated nutrient management is flexible and can be adjusted according to soil type, crop needs, and the availability of organic resources, making it a practical and adaptable strategy for modern vegetable production.

Mechanism of synergy between compost and fertiliser

1. Nutrient Supply Complementation

Chemical fertilizers give quick-acting nutrients like nitrogen, phosphorus, and potassium that plants can absorb immediately. Compost, on the other hand, releases nutrients slowly as microbes break it down. When both are used together, chemical fertilizers meet the plant's instant needs, while compost maintains a steady nutrient supply and reduces leaching.

2. Soil Structure & Water Retention

Compost improves soil texture, increases pore spaces, and enhances its ability to hold water. With better moisture retention, chemical fertilizers are used more efficiently because fewer nutrients are washed away. This combination ensures plants get consistent moisture and nutrients for healthy growth.

3. Boost in Microbial Activity

Compost contains high organic matter and supports beneficial microbes like bacteria and fungi. Chemical fertilizers alone may reduce microbial diversity due to salts. When combined, compost balances the fertilizer effect and encourages microbes that help release plant nutrients through processes like mineralization.

4. Better Nutrient Uptake

Compost produces humic substances and organic acids that help unlock micronutrients such as iron, zinc, and manganese and promote root growth. Chemical fertilizers supply essential macronutrients quickly. Together, plants absorb both macro- and micronutrients more efficiently, improving overall yield.

5. Reduced Nutrient Loss

Compost helps hold nutrients in the soil, preventing nitrogen and phosphorus loss through runoff or volatilization. This increases fertilizer efficiency and lowers environmental pollution.

6. Soil pH Stabilization

Compost acts as a natural buffer and reduces soil acidity caused by ammonium-based chemical fertilizers. This maintains stable nutrient availability and protects helpful soil microorganisms.

Effects on growth and yield of Vegetable crops

1. Fertilizer Types and Their Effects on Broccoli Growth: Inorganic fertilizers provide quick nutrients such as nitrogen for green growth, phosphorus for strong roots, and potassium for plant health. Research shows that different NPK levels can significantly improve broccoli development, with higher rates giving better quality. Organic materials like compost, manure, and chicken manure tea help improve soil moisture, structure, and microbial activity.

2. Integrated Fertilizer Use: Using both organic and inorganic fertilizers together often improves results. For example, applying organic manure along with chemical fertilizer has been shown to increase broccoli yield. This method gives fast nutrients from fertilizers and long-term nutrient release from organic matter.

3. Micronutrient Requirements: Micronutrients such as boron and molybdenum are important for broccoli. Boron helps in cell wall formation, while molybdenum supports nitrogen metabolism. Applying them with fertilizers improves crop quality and yield.

4. Factors Affecting Vegetable Crop Yield: Climate, sunlight, soil fertility, pest control, and irrigation all influence vegetable productivity. Maintaining proper nutrients and water supply is necessary for good crop performance.

Soil Fertility and Microbial Health

1. Complementary Nutrient Supply: Chemical fertilizers provide immediate nutrients, while compost releases nutrients slowly. Using both improves nutrient efficiency and reduces losses from the soil.

2. Improvement of Soil Physical Properties: Compost increases organic matter and improves soil structure, porosity, and moisture retention. This reduces nutrient loss and supports healthy root growth.
3. Enhancement of Microbial Activity: Compost adds beneficial microbes that help release nutrients for plants. It also helps reduce the negative effects of excessive fertilizer use on soil organisms.
4. Improved Nutrient Uptake and Root Development: Humic substances in compost make micronutrients more available and promote root expansion. Combined with fertilizers, nutrient absorption becomes more effective.
5. Reduction in Nutrient Losses: Compost holds nutrients in the soil and prevents nitrogen loss and phosphorus runoff. This increases fertilizer efficiency and reduces pollution.
6. Soil pH Stabilization: Compost helps maintain balanced soil pH, reducing acidity caused by fertilizers. Stable pH improves nutrient availability and supports microbial activity.

Methods and measurements Seedling growth

Ten days after sowing, the number of emerged cucumber seedlings was counted to calculate the seedling emergence rate and cotyledon emergence rate. Additionally, the leaf area of cucumber seedlings was determined using the leaf area coefficient method [20]. Fifteen days after sowing, fifteen healthy cucumber seedlings per tray were selected for morphological measurements. The height of seedlings was measured using a ruler, while stem diameter was measured using a vernier caliper. Chlorophyll content was determined using a chlorophyll meter, expressed as SPAD values, on fully expanded leaves. The leaf area of cucumber seedlings was also measured.

Furthermore, the substrate adhered to the roots of the selected cucumber seedlings was collected using a brush, sealed, and stored at 4ºC for subsequent analysis.

The root length and root surface area of cucumber seedlings were determined using a root scanner. The fresh weight of both aboveground and belowground parts of cucumber seedlings was measured using an electronic balance. Subsequently, samples were dried at 60ºC to a constant weight, and dry weights were recorded to calculate the seedling vigor index.

Treatment	Kitchen waste	Peat	Fermented straw	Fermented rice husk
T1	15	45	40	0
T2	15	45	0	40
T3	15	45	20	20
T4	30	30	40	0
T5	30	30	0	40
T6	30	30	20	20

Economic and environmental perspective

1. Reduced Fertilizer Costs

Compost supplies a portion of essential nutrients, particularly N, P, and K, which allows farmers to reduce the quantity of chemical fertilizers applied. Over time, this can lower input costs significantly, especially in small-scale and resource-limited farming systems.

2. Improved Crop Yields

Synergy between compost and fertilizers often leads to higher crop productivity due to better nutrient use efficiency, soil fertility, and plant health. Higher yields translate to greater market income, making the investment in compost cost-effective.

3. Long-Term Soil Fertility Benefits

Compost improves organic matter and soil structure, enhancing nutrient retention. This reduces the need for frequent fertilizer application, offering long-term economic savings.

4. Utilization of Waste

Kitchen, agricultural, and municipal waste can be converted into compost, reducing disposal costs and generating a value-added product. Farmers and communities can profit from selling or using compost locally.

5. Labor and Management Considerations

Initial compost production may require labor, but the reduced dependence on chemical inputs balances the cost over time. Integration with fertilizers can optimize labor efficiency by reducing the number of applications.

6. Reduced Chemical Runoff and Pollution

Compost binds nutrients in the soil, reducing leaching of nitrogen and phosphorus into water bodies. This mitigates eutrophication and groundwater contamination associated with excessive chemical fertilizer use.

7. Carbon Sequestration

Adding organic matter in the form of compost increases soil carbon content, helping to sequester CO_2 and mitigate climate change.

8. Enhanced Soil Microbial Biodiversity

Compost supports diverse microbial populations that contribute to nutrient cycling, disease suppression, and soil health. This reduces dependence on chemical pesticides and enhances the resilience of agroecosystems.

9. Waste Management and Resource Recycling

Composting organic waste reduces landfill burden and methane emissions, providing an environmentally sustainable solution. Nutrients are recycled back into the soil, closing the nutrient loop.

10. Mitigation of Soil Degradation

Continuous use of chemical fertilizers alone can lead to soil acidification, salinity, and structure deterioration. Compost addition buffers pH, improves aggregation, and enhances water retention, promoting long-term sustainability.

Challenges and future prospects

1. Lower Fertilizer Costs: Since compost provides a portion of key nutrients like nitrogen, phosphorus, and potassium, farmers can reduce their dependence on chemical fertilizers. This leads to noticeable cost savings, especially for small and resource-limited growers.

2. Enhanced Crop Growth and Yield**:** Using compost alongside chemical fertilizers improves soil conditions and nutrient delivery. This combination often boosts plant performance, resulting in higher yields and better economic returns from the same land area.

3. Sustained Soil Fertility**:** The organic matter in compost improves soil structure and increases its ability to retain nutrients. As a result, the soil remains fertile for a longer period, reducing the need for repeated fertilizer applications.

4. Productive Use of Organic Waste: Household, farm, and municipal organic wastes can be transformed into compost. This not only reduces disposal challenges but also produces a useful soil additive that can be applied in the field or sold.

5. Efficient Labor and Field Management: Although preparing compost may initially require some effort, combining it with fertilizers decreases the number of fertilizer applications needed. This helps streamline field operations and improves labor efficiency over time.

6. Lower Environmental Pollution:Compost increases the soil's nutrient-holding capacity, which helps minimize nutrient losses through runoff or leaching. This leads to reduced water pollution and helps prevent problems such as eutrophication.
7. Soil Carbon Enrichment: Adding compost enriches soils with organic carbon, which helps capture and store atmospheric CO_2. This contributes positively to climate change mitigation efforts.
8. Improved Soil Microbial Activity: Compost stimulates beneficial soil microbes responsible for nutrient transformation and disease suppression. This improves soil health and reduces reliance on agricultural chemicals.
9. Improved Waste Recycling and Nutrient Cycling: Composting organic materials reduces landfill loads and methane emissions while returning valuable nutrients to the soil. This supports a circular nutrient system.
10. Prevention of Soil Degradation: Continuous use of chemical fertilizers alone can lead to soil problems such as acidity, salinity, and poor structure. Compost helps counter these effects by stabilizing soil pH, improving aggregation, and enhancing moisture retention, ensuring long-term soil productivity.

II. CONCLUSION

The study concludes that a substrate mixture containing 15% kitchen waste compost (KWC), 45% peat, and 40% fermented rice husk is the most effective for cucumber seedling development. Despite this, the elevated salinity and alkaline nature of KWC continue to limit seedling performance, making them major issues that need further attention. Future work should focus on combining this study's results with existing knowledge of cucumber salt tolerance to refine the substrate composition, particularly when incorporating KWC.Beyond agriculture, recycling kitchen waste for seedling substrates offers advantages across multiple sectors. The agricultural industry can lessen its dependence on non-renewable materials such as peat, helping reduce environmental damage. Waste management organizations can turn organic waste into marketable compost products, supporting a circular economy model. Similarly, horticulture and landscaping sectors could adopt these substrates to promote eco-friendly cultivation practices, expanding the use of compost-based materials.To strengthen these opportunities, investment in advanced waste treatment facilities is necessary to produce high-quality compost from kitchen waste. This includes supporting research that enhances composting technologies, lowers salinity levels, and improves nutrient composition. Collaboration between government bodies and private stakeholders is also important for building systems that collect, process, and utilize kitchen waste efficiently. Through such efforts, kitchen waste recycling can significantly improve waste management practices and promote sustainable agriculture, delivering both environmental and economic benefits.

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