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RESPONSE OF PEPPER (*Capsicum spp.*) TO ORGANIC FERTILIZERS: GROWTH, YIELD, AND SOIL HEALTH IMPLICATIONS

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Abstract

This article evaluates the response of pepper plants to various organic fertilizers, including compost, cow dung, poultry manure, sheep manure and farmyard manure. Literature and experimental findings showed that organic management and amendments especially when combined with beneficial microorganisms like AMF or Trichoderma can match conventional yield levels and enhance fruit quality while improving soil health indices such as enzyme activity and nutrient cycling. Pepper plants (Capsicum spp.) respond positively to organic fertilizers, which include compost, animal manure, green manure, bone meal, and other natural soil amendments. Studies and field trials have shown that organic fertilizers significantly improve soil fertility, plant growth, fruit yield, and quality in pepper cultivation. The key benefits of using organic fertilizers in pepper cultivation include: Enhanced soil structure and microbial activities by improving soil aeration and water retention, promoting healthy root systems. Gradual nutrient release by decomposes slowly, providing a steady supply of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). Increased yield and fruit quality with organic inputs often exhibit better flavor, firmness, and nutrient content. Reduced dependence on synthetic inputs which may supports sustainable and eco-friendly farming. It was recommended that farmers should use well decomposed organic fertilizers to avoid phytotoxicity and ensure nutrient availability, applies composted manure or properly cured organic matter. Combine different organic sources such as blending compost, poultry manure, and green manure which may provide a more balanced nutrient profile. Apply according to soil needs by conducting soil tests to tailor fertilizer application based on nutrient deficiencies. However, the effectiveness depends on the type, application rate, decomposition time, and soil conditions. Proper management is essential to avoid nutrient imbalances or delayed availability of nutrients.

Key Words: Response, Pepper, Organic, Fertilizer

Introduction

Pepper (*Capsicum spp.*) is an economically and nutritionally important vegetable worldwide. Pepper plants can thrive when cultivated with organic fertilizers. Utilizing organic matter like compost, well-rotted manure, and other natural amendments not only provide essential nutrients but also improves soil structure and fertility, creating a healthy environment for pepper growth and fruit production (George and Onwugbuta-Enyi, 2023).

Pepper scientifically known as *Capsicum spp.*, comprises 43 species, of which five are domesticated and widely cultivated. Pepper (*Capsicum annuum)* is the most extensively produced and consumed species globally. This review explores the growth responses of pepper plants to organic fertilizers, with particular emphasis on plant-based and animal-based organic fertilizers

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(Barboza et al., 2022). Being a high-value crop, pepper is a source of income for farmers, especially smallholder farmers in Asia and Africa. Africa contributes 1,008,574 tons (approximately 21% of global production) with a harvested area of 375,989 ha of global dry pepper production and 3,472,485 tons (approximately 10% of global production) for a harvested area of 331,064 ha of global green pepper production (FAOSTAT, 2022).

Globally, *C. annuum* is the most widely produced and consumed species, however, in Africa, significant production of *C. chinense* and to a lesser extent *C. frutescens* also occurs (Zohoungbogbo et al., 2024). Traditionally pepper fruits have been used as appetite stimulants, flavoring agents, and treatments for parasitic infections, rheumatism, toothache, muscle pain, coughs, sore throats, and wound healing. Their health benefits can be ascribed to their antioxidant properties. Pepper is rich in diverse bioactive components and mineral nutrients, such as vitamins (especially C and E) and colored pigments (β-carotene, zeaxanthin, violaxanthin, β-cryptoxanthin, lutein, capsanthin, and capsorubin), as well as phenolic substances, such as capsaicinoids and flavonoids.1 The concentration of these compounds in pepper can exhibit significant differences influenced by factors, such as pepper genotypes, and cultivation practices (George and Onwugbuta-Enyi, 2023).

The ornamental and esthetic value of pepper fruit is greatly influenced by its color. In modern *C. annuum* cultivars, the fruit color at biological ripeness is mostly limited to red, yellow, or orange, but the color of unripe fruits (technical ripeness) varies considerably from light green to purple, chocolate, brown, and nearly black. This variation reflects combinations of three groups of pigments: chlorophylls, carotenoids, and anthocyanins (Tian et al., 2015). Chlorophyll gives the fruit a green color, whereas the red color is mainly due to carotenoid pigments, such as capsanthin and capsorubin. In contrast, the purple color of unripe fruit results from an accumulation of anthcyanidins, particularly delphinidin derivatives, in the fruit exocarp. Pepper fruit color development is also linked to chlorophyll metabolism and chloroplast development (Jung et al., 2019).

Organic fertilizers are organic materials that are cheaper, affordable and environmentally friendly compare to synthetic or chemical fertilizers. Organic fertilizer materials are naturally present in nature. In most times, organic fertilizers are typically made of mono ingredients. However, it could be from plant, animal, or other natural sources which will in turn enriched the soil nutrients depending on the actual target. Plant-based fertilizers for example will help in improving drainage and moisture retention to poor soils while the animal-based fertilizers will give great effect for leafy plants and strong growth in the early stage of gardening. The mineral-based fertilizers on the other hand, help in raising or lowering the pH level when needed for healthy plant growth. Organic farming provides several benefits to the growers. It reduces production cost and it is an environmentally friendly method of cultivation. Addition of organic fertilizers improves soil structure and enhances activities of useful soil organisms (Wang et al., 2025). In recent times, consumers are demanding higher quality and safer food and highly interested in organic products. Consuming commodities planted and produced from organic cultivation are good for human health.

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Statement of the Problem

Pepper (Capsicum spp.) is a global important horticultural crop valued for food, nutritional, and economic benefits. However, yield and productivity remain constrained by declining soil fertility, especially in tropical and subtropical regions where nutrient depletion and poor soil health are common. Conventional use of inorganic fertilizers can improve initial growth but often leads to soil degradation, reduced microbial activity, and increased environmental risks such as nutrient leaching and soil acidification over time. In contrast, organic fertilizers such as compost, vermicompost, and animal manures are proposed as sustainable alternatives that enhance soil organic matter, microbial activity, nutrient availability, and long-term soil health.

Objectives of the Study

The general objective is to evaluate the response of organic fertilizers on the growth performance, yield components, and soil health status of pepper (Capsicum spp.).

The specific objectives include:

1. To assess the impact of different organic fertilizer sources on pepper growth.
2. To determine the effects of organic fertilizers on yield components.
3. To evaluate changes in soil chemical and physical properties.
4. To compare soil health implications of organic fertilizers with conventional fertilization regimes in pepper production system**s.**

Methodology

Data from related studies were collected and reviewed. Results from related studies were also reviewed.

Botanical Origin and Classification of Pepper Plants

The pepper plant (*Piper nigrum)* is a flowering vine in the *Piperaceae* family, native to the Malabar Coast of India, particularly in the present-day state of Kerala. It produces small fruits called peppercorns, which are dried and used as the spice known as black pepper (Guertal and Green, 2012). Black pepper has been cultivated in India for over 4,000 years, making it one of the oldest known spices in human history. Peppers belong to the genus Capsicum, with the most common cultivated species being Capsicum annuum, C. chinense, C. frutescens, C. baccatum, and C. pubescens. Capsicum annuum is the most economically important, including bell-peppers, jalapenos, and cayenne peppers. Species like C. chinense include habaneros and scotch bonnets, while C. frutescens include tabasco peppers. Capsicum pubescens is unique, with violet flowers, black seeds, and hairy leaves (Barboza et al., 2022).

Peppers can be broadly classified into two main groups: Sweet peppers and Chili peppers and with other groups beyond sweet and chili peppers (Castellanos et al., 2017).

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Sweet peppers, like bell peppers, are known for their mild flavor, while chili peppers, such as jalapenos and habaneros, are known for their varying degrees of spiciness. With these groups, there are numerous varieties, each with unique characteristics in terms of size, shape, color, and heat level, which is measured using the **SCOVILLE SCALE (**Castellanos et al., 2017).

Common Types of Sweet Pepper

Common types of sweet peppers include, **Bell Peppers** which are large, bell-shaped, and come in various colors (green, red, yellow, and orange) with a mild, slightly sweet flavor; **Pimiento peppers** with heart-shaped, sweet, and often used in pimento cheese or Stuffed olives and **Banana peppers** which are mild, tangy, and yellow, resembling a banana in shape and color (Salma et al., 2022).

Common Types of Chili Peppers

Below are the common types of Chili peppers which includes, **Jalapeno Peppers** which are widely used, have medium-sized and moderately spicy. **Cayenne Peppers** they are long, thin, and very hot, often dried and ground into a powder form. **Serrano Peppers** which are smaller than jalapenos, but hotter, with a bright, fresh flavor. **Habanero Peppers** they are Small, lantern-shaped, and intensely hot, with fruity and floral notes. **Scotch Bonnet Peppers** which are similar to habaneros, but with a slightly different shape and flavor. **Ghost Peppers (Bhut jolokia)** they are extremely hot, with a fruity, earthy flavor. **Poblano Peppers** which are large, heart-shaped, and mild to moderately hot, often use for stuffing. **Anaheim Peppers t**hey are long, slender, and mild to moderately hot, often use in Mexican cuisine **(**Baenas et al., 2019).

Other Pepper Types beyond Sweet and Chili Peppers

Black Peppers are often grouped with chili peppers; black pepper (*piper nigrum*) is from a different plant genus and family (*Piperaceae*). It is a spice derived from the dried berries of the pepper vine. **White Pepper** they are milder than black pepper, made from the dried seeds of the black pepper fruit. Other Varieties includes many other types of peppers, including some with unique flavors and uses, like alligator pepper (Aframomum melegueta) **(**Li, 2020).

How to Grow Pepper

General Description: Peppers are heat-loving vegetables that require a long frost-free season and full sun. Peppers originated in Central and South America, and they were one of the first plants cultivated there up to 5,000 years ago (Castellanos et al., 2017).

Planting: Start seeds from March-April, Transplanting from May-June, and Harvest from July-September.

Timeline: Pepper seeds are started indoors and transplanted outdoors. Start pepper seeds about 8 weeks before transplant. Reduce fertilizer and water a few days before transplanting to harden the plants off, and the gradually expose them to sun. Harvesting days range from 65- 85 days (South Dakota State University Extension, 2024).

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Spacing: Peppers plants should be spaced 12-18 inches apart.

Site Selection: Peppers need 8 hours of sun per day. Windbreaks can provide better plant growth and yield. Do not plant where related crops, such as tomatoes, eggplant, or potatoes were planted the previous year.

Transplants: If you purchase transplants, examine them carefully to make sure they are free of insects and diseases (healthy looking with brown or yellow spots on stems or leaves). Plant transplants outside after the chance of frost has passed and nighttime temperatures stay above 45^0F. Protective structures, such as row covers, wall-of-waters, hot caps etc., can be used to protect against cooler temperatures.

Organic Fertilizers

Organic fertilizers are materials derived from natural sources, plant or animal matter, minerals, or microorganisms used to enrich soils naturally. They supply essential macro and micronutrients (N-P-K, calcium, magnesium, sulfur, etc.) and support soil ecology and long-term fertility. Organic fertilizers are fertilizers that are naturally produced. Typically organic fertilizers include all animal waste, including meat processing waste, manure, slurry, and guono, plus plant based fertilizers such as compost and bio solids (IASHK, 2024).

Types and Sources of Organic Fertilizers

Organic fertilizers can be broadly categorized into plant-based, animal-based, mineral-based, and other types and sources. Examples include compost, manure, blood meal, bone meal, fish emulsion, seaweed, and rock phosphate. They offer various benefits like improving soil health, providing a slow-release source of nutrients, and promoting beneficial microbial activity (Baenas et al., 2019).

Plant-Based Organic Fertilizers

Compost comprised decomposed organic matter such as food, scraps, yard waste and agricultural residues that improves soil structure and fertility. **Alfalfa Meal a** nitrogen-rich fertilizer derived from alfalfa plant. **Seaweed** provides a range of micronutrients and growth stimulants. **Green Manure** they are crops grown specifically to be incorporated into the soil, enriching it with nutrients. **Cottonseed Meal** a slow-release nitrogen source with soil conditioning properties. **Crop Residues** they are Stems, leaves, and other parts of plants left over from harvests. **Plant Extracts:** Seaweed and kelp extracts can be used as liquid fertilizers (Mughunth et al., 2024). **Sewage Sludge:** Treated human waste that can be a source of nutrients after processing.

Animal-Based Organic Fertilizers

Manure: Manure from various animals (Cows, Horses, Chickens, Rabbits, Sheep, etc), offering a range of nutrients and improving soil structure. **Bone Meal:** Provides phosphorus and calcium, beneficial for root and flower development. **Blood Meal:** A high-nitrogen fertilizer derived from animal's blood. **Fish Emulsion:** A liquid fertilizer derived from fish, rich in nitrogen and other nutrients. **Fish Meal:** These are other fish-derived fertilizer, providing nitrogen and phosphorus.

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Bat Guano: A nutrient-rich fertilizer from Seabirds and Bats droppings rich in nitrogen, phosphorus and potassium. **Slaughter House By-products**: Bone meal, blood meal and feather meal are also sources of specific nutrients. **Slurry:** A liquid form of animal waste, often from cattle, which can be used as fertilizer (U. S. Environmental Protection Agency, 2025).

Mineral-Based Organic Fertilizers

Rock Powders: Mineral like rock phosphate and greensand, which can be ground into a powder and used as a fertilizer. **Greensand:** A natural mineral source of potassium and other trace elements. **Neem Cake: B**otanical by-product rich in NPK and micro-nutrients, also acts as nitrification inhibitor, extending nitrogen availability. **Epsom Salt: p**rovides magnesium and sulfur, which are important for preventing deficiencies and promoting healthy green leaves (Biology Insight, 2025).

Other Types of Organic Fertilizers

Peat: Partially decomposed plant matter, used as a soil amendment and source of nutrients. **Wood Ash:** Wood ash from burning wood contains potassium, calcium, and other minerals. **Sewage Sludge:** Sewage can be treated and used as a fertilizer, but may require careful handling (Kumar and Cardenas-Talero, 2025).

Benefits of Organic Fertilizers

Nutrient Availability: Organic fertilizers release nutrients slowly providing a consistent and long-lasting source of nourishment for plants. **Improved Soil Health:** Organic fertilizers enhance soil structure, drainage, aeration, and water retention, creating a thriving environment for roots and beneficial soil microorganisms. **Reduced Environmental Impact**: Organic fertilizers are sustainable and reduce the reliance on synthetic fertilizers, which can have negative impacts on the environment. **Enhanced Pest and Disease Resistance:** Healthy plants with strong root systems are better equipped to withstand pests and diseases. **Support Biodiversity: O**rganic fertilizers contribute to a more diverse soil ecosystem, supporting a wide range of beneficial organisms that contributes to soil health and plant resilience. **Reduced Risk of Over-fertilization:** Organic fertilizers release nutrients slowly, reducing the risk of over-fertilization and plant burn, which can be a problem with synthetic fertilizers. **Sustainable Agriculture**: Organic fertilizers promote a more sustainable agricultural system by reducing reliance on synthetic inputs and supporting natural process **(**Baenas et al., 2019.

Cost-Effectiveness: While the initial cost of organic fertilizers may be comparable to synthetic options, their long-term benefits, such as improved soil health and reduced need for other inputs, can lead to cost saving. **Environmentally Friendly**: **O**rganic fertilizers are less concentrated than synthetic fertilizers and are therefore much safer to use (Kumari, 2024). **Reduce Degradation of water and Soil**: **D**ue to their high solubility, synthetic fertilizers have the ability to readily drain out of the soil and pollute water and the soil. **O**rganic fertilizers help in boosting plant and soil health naturally. **Plant Damage Threat Avoided**: Some synthetic fertilizers can cause plant damage to leaves, stem and roots. This is less likely with organic fertilizers. **Soil Structure:** Due to organic matter present in organic fertilizers, soil structure is improved and as a result the soil

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ability to hold onto water and nutrients increases. **Microbes Thrive**: Synthetic fertilizer consists of chemical molecules without carbon. These molecules can sometimes be disruptive and not accessible to microbes. On the other hand, organic fertilizers contains carbon as part of its chemical constituent, and it is the carbon, along with nitrogen, phosphorus and potassium that feeds microbes and enables them to make nutrients available for plants in a naturally occurring biological process ((Sreeja et al., 2024).

How Organic Fertilizers Work

Microbial Decomposition: Organic matter is broken down by soil microbes, releasing nutrients slowly in plant-available forms. **Improve Soil Physical Properties:** Organic inputs improve porosity, water-holding capacity, and root penetration. **Feeding Soil Biology:** Microbial activity and soil organisms flourish, enhancing nutrient cycling and plant health. **Building long-term Fertility:** Continuous organic additions result in stable humus and nutrient reservoirs (Salma et al., 2022)

Disadvantages of Organic Fertilizers

Slow Results: Because organic fertilizers must break down first, they release nutrients slowly. This can be a drawback for plants that need a quick nutrient boost. **Inconsistent Nutrient Level:** Nutrient content can vary depending on the source, making it challenging to apply precise doses. **Application Challenges:** Organic fertilizers can be bulkier and messier, requiring a bit more effort to apply evenly. Fortunately, Green Wing Handles the Application for you to ensure optimal results. **Quality and Contamination Risk:** Raw manure may contain pathogens or weed seeds, composting or curing prior to application is essential. **Inconsistent consistency:** Composition and nutrient availability may vary across batches; soil testing can help with dosage planning (University of Massachusetts, 2025).

Important Considerations in the Use of Organic Fertilizers on Pepper Plants

The type and amount of organic fertilizer used can influence the results of pepper production. The interaction between organic fertilizers and other factors like soil solarization or mycorrhizal inoculation can further enhance pepper growth and yield. Soil type and other environmental conditions can also play a role in the effectiveness of organic fertilization. Local soil condition varies significantly, so it is important to assess the specific soil characteristics of your farm to determine the most appropriate organic fertilizer application **(**Ghimirey et al., 2025). Pepper plants need specific nutrients like nitrogen, phosphorus and potassium for optimal growth and yield. Understanding these requirements will help you choose the right organic fertilizer and application rate (Zhao et al., 2025).

Consider the cost and availability of different organic fertilizers in your area when making your choice. Organic fertilizers provide a wide range of nutrients, it is essential to ensure a balanced nutrient supply for optimal growth. Consider supplementing with specific organic amendments to address any nutrient deficiencies. Organic matter needs time to decompose and release nutrients. Ensure that organic fertilizers are properly composed or aged before application to avoid potential nutrient imbalances. Peppers prefer a slightly acidic to neutral soil pH. Monitor the soil pH and

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adjust it accordingly using appropriate soil amendments. Follow recommended application rates for different organic fertilizers to avoid over-fertilization, which can be detrimental to pepper plants (FAO, 2020).

By utilizing organic fertilizers and following best practices, you can cultivate healthy and productive pepper plants, yielding abundant and flavorful harvest (Castellanos et al., 2017).

Response of Pepper Plants to Organic Fertilizers

Pepper plants can thrive when cultivated with organic fertilizers. Utilizing organic matter like compost, well-rotted manure, and other natural amendments not only provide essential nutrients but also improves soil structure and fertility, creating a healthy environment for pepper growth and fruit production. Organic fertilizers positively impact pepper plant growth and yield by improving soil health and nutrient availability. They enhance fruit size, length, and overall yield, while also contributing to better soil structure and microbial activity. Different types of organic fertilizers, such as compost, poultry manure, and tithonia compost, have been shown to be effective in promoting pepper growth and productivity (Akinfasoye et al., 2019).

Examples of Response of Pepper Plants to Specific Organic Fertilizer Types

Tithonia Compost: Studies have shown that tithonia compost can significantly increase plant height, number of leaves, leaf area, and fruit yield in pepper plants. **Poultry Manure:** This is a rich source of nutrient and can be beneficial for pepper growth, through its important to manage its application to avoid excessive vegetative growth. **Compost:** Compost, when used alone or in combination with other organic fertilizers, can positively influence various yield parameters and improve fruit quality in pepper plants. **Vermicompost:** Studies have shown that vermicompost can significantly enhance plant growth and yield in pepper plant. **Sheep Manure:** Application of sheep manure have been shown to increase the number of branches, fruits and fresh fruit yield in pepper plants. (Valenzuela-Garcia et al., 2019).

Cow Dung Manure: Research indicates that cow dung manure, when applied at a certain rate, can significantly affect the number of primary branches and plant height of pepper plants. **Novel Organic Liquid Fertilizers:** These fertilizers have also demonstrated positive effects on various growth and yield parameters in pepper plants. **Organic and Microbial Treatments:** These elevated phenolic and vitamin C content in peppers. **Vermitea:** At moderate doses increases plant height, marketable fruit yield and ROI. **Vermicompost/Vermitea:** Improved plant height, fruit yield, return on investment in Capsicum annuum (Remolleno & Radores, 2020).

Compost (rice husk + cow dung): At high rate (2.5 t/ha) produced comparable dry-pepper yield to NPK. **Biofertilizers (AMF, PGPR):** Arbuscular Mycorrhiza Fungi (AMF) boosted greenhouse bell-pepper yield by 18% over control; bacterial inoculants enhanced nutritional uptake (e.g., N, Fe, Zn, P, K, antioxidants). **Trichoderma-based Organic Fertilizers:** Improved soil enzyme activity (urease, phosphatase), nutrient availability (organic C, N, P, K) and pepper growth (Liu et al., 2020).

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Plant height, Stem girth, Leaf, Branches: Across various trials, compost, poultry waste and vermicompost treatments significantly increased these metrics over controls and in some cases even over NPK alone.

In Nigeria, household waste and poultry manure yield tallest plants and highest fruit numbers compared to NPK and control in pepper plants (Ozioko et al., 2024).

In Bangladash, vermicompost and mineral fertilizers gave highest yield, fruit number, size and nutrient uptake (Salma et al., 2022).

In Ethiopia, combining farmyard (FYM) with blended fertilizer maximized fresh yield, fruit number, branch number, outperforming unfertilized treatment (Obsi et al., 2022).

Effect of Organic Fertilizers on the Soil and Pepper Plants

Improved Soil Health: Organic fertilizers, like compost and manure, improve soil structure, water retention, and aeration, creating a more favorable environment for roots development in pepper plants. **Nutrient Release:** Organic matter decomposes gradually, releasing essential nutrients like nitrogen, phosphorus, and potassium slowly and steady, providing a consistent nutrient supply for pepper plants. **Enhanced Fruit Quality:** Organic fertilizers can improve the quality of pepper fruits, potentially increasing their total soluble solids (TSS) content. **Increased Yield:** Studies have shown that organic fertilizers have significantly increase fruit yield, fruit size, and frit length in pepper plants (Khandaker et al., 2017).

Combined Effects: The interaction of organic fertilizers with other soil amendments, like soil solarization and mycorrhizal inoculation, can further enhance pepper plant productivity.

Nutrient Uptake: Organic fertilizers can improve the uptake of essential nutrients like nitrogen, phosphorus, and potassium by pepper plants. **Overall Plant Health:** Organic fertilizers contribute to healthier pepper plants with increased vigor and disease resistance (Liu et al., 2025).

Conclusion

Organic fertilizers are a valuable tool for farmers looking to improve pepper production. By careful selecting and applying the appropriate organic fertilizers, farmers can enhance both the growth and yield of their pepper crops, while also contributing to the long-term health of the soil. By utilizing organic fertilizers and following best practices, you can cultivate healthy and productive pepper plants, yielding abundant and flavorful harvest.

Organic fertilizers like compost, vermicompost, green manure, biochar and biofertilizers can match or approach conventional yields while enhancing fruit quality and soil health. Optimally, combining organic amendments with microorganisms (e.g., AMF or PGPRs) delivers superior nutrient uptake, plant growth, and antioxidant content. Adoption requires balancing efficacy, economics, and context-based suitability (soil type, pepper genotype, resource availability).

Recommendation

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1. Use well decomposed organic fertilizers to avoid phytotoxicity and ensure nutrient availability, applies composted manure or properly cured organic matter. Combine different organic sources such as blending compost, poultry manure, and green manure which may provide a more balanced nutrient profile.
2. Apply according to soil needs by conducting soil tests to tailor fertilizer application based on nutrient deficiencies. Integrate with organic mulching to retain moisture and suppress weeds, apply mulch along with fertilizers.
3. Adopt proper timing and rate by applying organic fertilizers during land preparation or early growth stages for best results. Monitor and adjust by observing plants response and adjust application practices accordingly.

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