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Examination of the Impact of Biofertilizers Alongside Mineral Enrichments on the Development, Harvest, and Virtues of Onion

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Abstract

The onion is an important crop because of its nutritional and economic benefits. The overuse of artificial fertilizers and the soil's deterioration make it challenging to increase onion output and quality sustainably. One potential strategy to improve crop yields and soil health is to combine biofertilizers with inorganic nutrients. The impact of mineral nutrients and biofertilizers on onion growth, yield, and quality parameters is investigated in this research. All five treatments recommended dosage of fertilizer (RDF), biofertilizer alone, and biofertilizer with RDF and foliar micronutrient spray—were evaluated in field experiments using a randomized block design. Measurements were taken on growth metrics, leaf count, bulb diameter, total soluble solids, and pyruvic acid content, among other yield and quality factors. When compared to the control group, treatments alone and the combination of biofertilizers and inorganic nutrients, plant development, yield, and quality were all markedly improved. Research shows that using biofertilizers and mineral nutrients together is the best way to grow onions eventually since it boosts crop yields, soil health, and nutrient absorption.

Keywords:
Onion cultivation, Biofertilizers, Mineral nutrients, Azospirillum, Phosphobacteria, Foliar spray, Yield enhancement, Growth parameters, Total soluble solids (TSS), Pyruvic acid, Nutrient uptake, Sustainable agriculture

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Introduction

Background

Among the many vegetable crops grown and eaten across the globe, the onion (Allium cepa L.) ranks high. Its high nutritional profile and bioactive components make it significant for medical and industrial purposes in addition to its culinary usage. India has a significant role in worldwide onion commerce and production, being one of the top onion growers. Soil nutrient depletion, environmental stress, and deteriorating soil fertility induced by intensive agricultural techniques make it difficult to achieve high yields and consistent quality, even though onions are economically and nutritionally important (Phanendra et al., 2024).

To get the most out of their crops, conventional farmers use chemical fertilizers. Soil deterioration, nutrient leaching, water contamination, and the loss of beneficial soil microbes are some of the

environmental difficulties caused by the excessive and continual application of these fertilizers, even though they give crops nutrients immediately (Ammar et al., 2023). Soil productivity drops and production costs rise because of this. Soil fertility and agricultural yields need to be sustained over the long run, which means farmers need to use sustainable techniques.

Role of Biofertilizers

Soil fertility and crop yields are both improved by biofertilizers, which are natural chemicals that include helpful microbes such as algae, fungi, and bacteria. These microbes increase plant metabolic activity and improve nutrient availability. Biofertilizers, in contrast to conventional fertilizers, can promote plant development by biological mechanisms such as nitrogen fixation, phosphate solubilization, and hormone synthesis (Cordeiro et al., 2022). Biofertilizers provide several benefits for agriculture, including better soil health, increased crop stress tolerance, and less environmental impact.

Combining biofertilizers with inorganic nutrients increases plant vigor, productivity, and nutrient absorption efficiency in several crops, including onion, according to recent research (Dineshkumar et al., 2020). Onion production with biofertilizers and artificial fertilizers has received little attention in the literature. The purpose of this field research is to assess the impact of biofertilizers and mineral nutrients on onion growth, yield, and quality traits when applied together.

Objective

The primary objectives of this study are:

1. To evaluate the impact of biofertilizers on the growth and development of onion.
2. To assess the yield performance of onions under different fertilization regimes.
3. To analyze the biochemical quality of onions influenced by combined biofertilizer and mineral nutrient treatments.
4. To identify the most practical combination of biofertilizers and inorganic nutrients for optimizing onion productivity.

Literature Review

Effect of Biofertilizers on Crop Growth

An increase in nutrient uptake, root development, and resilience to stress are just a few of the ways in which biofertilizers are known to boost plant growth. It is a widespread practice to use microbial inoculants like Azospirillum, Rhizobium, and phosphate-solubilizing bacteria (PSB) to boost plant health and soil fertility. Onions grown with biofertilizers derived from microalgae showed increased yield and growth due to better nutrient absorption and root stimulation (Cordeiro et al., 2022). Because the helpful microbes enhance nitrogen fixation and nutrient availability, plant height, leaf yield, and bulb size are enhanced.

Along similar lines, Dineshkumar et al. (2020) found that both the quantity and quality of onions were enhanced when microalgae biofertilizer was applied with nitrogen and phosphorus fertilizers. The research also saw an improvement in nitrogen cycling and an increase in root biomass.

Synergistic Effect of Biofertilizers and Mineral Nutrients

Crop yield and nutrient-use efficiency are both enhanced when chemical fertilizers and biofertilizers are used together. When inorganic nutrients and biofertilizers were applied together, Phanendra et al. (2024) found that onion production was 20% higher than when chemical fertilizers were used alone. The more excellent root-shoot ratio and increased nutrient absorption efficiency, both made possible by beneficial microbes, were thought to be responsible for the improved performance.

Ammar et al. (2023) presented an extensive analysis of environmentally friendly biofertilizers and their function in enhancing soil fertility and agricultural yields. The research showed that biofertilizers make more micronutrients, like iron and zinc, available, in addition to macronutrients, like potassium, phosphorus, and nitrogen. The increased nutrient availability boosts plant development, production, and quality.

Impact on Biochemical and Nutritional Quality

The size of the bulb, amount of total soluble solids (TSS), amount of pyruvic acid, and amount of sulfur are some of the characteristics that define the quality of onions. Biofertilizers boost crop biochemical quality, according to Sharma et al. (2022), by increasing nutrient absorption and secondary metabolite synthesis. Improved taste, longer storage life, and disease resistance have all been associated with onions with higher levels of total soluble solids (TSS) and pyruvic acid (pyruvic acid).

Pokluda et al. (2023) showed that beneficial microbe consortia enhanced onion seedling performance by enhancing root development and nutrient absorption. The altered root structure influenced both bulb development and nutritional content, making it easier to absorb water and minerals.

Materials and Methods

Experimental Site and Design

Researchers used sandy loam soil for the field experiment, which drains well and holds modest amounts of nutrients. Onions do best in well-drained, slightly acidic to neutral soils, and the soil's pH of 7.1 was just right for growing onions.

The experiment adhered to a randomized block design (RBD) to guarantee accurate statistical analysis and reduce the impact of environmental unpredictability. Fifteen experimental plots were created from five different treatments, each of which had three replications. To ensure that treatments were not cross-contaminated, a 0.5 m buffer zone was established between each plot, which had dimensions of 3 m × 2 m. We created these experiments to see how different biofertilizers and inorganic nutrients affected onion output and growth on their own and in combination.

The five treatment combinations were as follows:

1. **T1:** Control (No fertilizers)—This treatment served as a reference point for evaluating the effects of fertilization by comparing plant growth and yield without nutrient supplementation.
2. **T2:** Recommended Dose of Fertilizer (RDF) – This involved applying the standard NPK fertilizer at the recommended rate of **120:60:60 kg/ha** (Nitrogen, Phosphorus, Potassium).
3. **T3:** Biofertilizer application – Biofertilizers used were a mixture of **Azospirillum** (nitrogen-fixing bacteria) and **Phosphobacteria** (phosphate-solubilizing bacteria) applied as a root dip and soil drench at specific growth stages.
4. **T4:** RDF + Biofertilizer application – Combined application of RDF and biofertilizer to evaluate the synergistic effect on nutrient uptake and plant metabolism.
5. **T5:** RDF + Biofertilizer + Foliar Spray of Micronutrients—This treatment included applying RDF and biofertilizer and foliar spraying of micronutrients such as **zinc (Zn), iron (Fe), and manganese (Mn)** at 30 and 45 days after transplanting (DAT).

Planting and Crop Management

Onion seedlings (variety: **Bhima Shakti**) were raised in a nursery for **30 days** before transplanting into the experimental plots. The seedlings were transplanted at a uniform spacing of **15 cm × 10 cm** to provide adequate room for root development and light penetration.

Biofertilizer Application:

- Root dipping was done before transplanting by immersing the seedlings in a biofertilizer solution (containing Azospirillum and Phosphobacteria at **2 g/L**) for **30 minutes**.
- Soil drenching with the same biofertilizer solution was performed at **30 and 45 DAT** to enhance root colonization and nutrient absorption.

Mineral Fertilizer Application:

- The recommended NPK fertilizer was applied in three splits:
  - **50% of nitrogen, whole phosphorus, and complete potassium** were applied at the time of planting.
  - **25% of nitrogen** was applied at **30 DAT**.
  - **The remaining 25% nitrogen** was applied at **45 DAT**.

Micronutrient Foliar Spray:

- Micronutrients, including $ZnSO_4$ (0.5%), $FeSO_4$ (0.5%), and $MnSO_4$ (0.1%), were dissolved in water and applied using a hand sprayer at **30 and 45 DAT**.

Irrigation and Weed Control:

- Drip irrigation was provided twice a week to maintain optimum soil moisture levels without waterlogging.

- Manual weeding was carried out at **15-day intervals** to prevent weed competition and improve nutrient availability.
- Pesticides were applied only when necessary to control significant pests such as thrips and onion maggots.

Data Collection

Data on growth, yield, and quality parameters were recorded at regular intervals. The key parameters recorded include:

1. **Plant Height:**
   - Measured from the base to the tip of the tallest leaf using a measuring scale at **30, 60, and 90 DAT**.
2. **Number of Leaves:**
   - Counted manually at **30, 60, and 90 DAT** to evaluate leaf production under different treatments.
3. **Bulb Diameter and Weight:**
   - Diameter was measured using a vernier caliper, and bulb weight was recorded using an electronic balance at harvest.
4. **Total Yield:**
   - Recorded based on the total weight of bulbs harvested from each plot and converted to yield per hectare.
5. **Quality Parameters:**
   - **Total Soluble Solids (TSS):** Measured using a refractometer and expressed in °Brix.
   - **Pyruvic Acid Content:** Determined by colorimetric analysis to estimate pungency levels.

Results and Discussion

Growth Parameters

The data on plant growth characteristics, such as plant height and leaf number, showed a great deal of treatment-specific heterogeneity.

1. **Plant Height:**
   - The highest plant height was recorded in **T4** (RDF + Biofertilizer), followed closely by **T5** (RDF + Biofertilizer + Foliar Spray).
   - T1 (control) showed the lowest plant height, indicating poor growth due to nutrient deficiency.
   - The enhanced height in T4 and T5 is attributed to the increased availability of nitrogen and phosphorus from the combined effect of biofertilizers and mineral nutrients.
2. **Number of Leaves:**
   - T4 recorded the highest number of leaves at all growth stages, indicating better vegetative growth.
   - The improved leaf count reflects the enhanced nutrient uptake and root development supported by beneficial microbial activity.

Yield Parameters

1. **Bulb Diameter and Weight:**
    - The highest bulb diameter (7.4 cm) and weight (110 g) were observed in T5, followed by T4.
    - The increased bulb size and weight in combined treatments reflect the positive effect of improved nutrient availability and enhanced root growth.
2. **Total Yield:**
    - The highest yield (22.4 t/ha) was recorded in T5, followed by T4 (21.7 t/ha).
    - T1 recorded the lowest yield (12.1 t/ha) due to nutrient deficiency.
    - The increase in yield in T4 and T5 highlights the synergistic effect of biofertilizers and mineral nutrients in enhancing nutrient uptake and metabolic activity.

Quality Parameters

1. **Total Soluble Solids (TSS):**
    - TSS values ranged from **9.2°Brix** in T1 to **12.8°Brix** in T5.
    - The increased TSS in T5 reflects enhanced sugar synthesis due to improved nutrient availability.
2. **Pyruvic Acid Content:**
    - Pyruvic acid content, indicating onion pungency, was highest in T5 (3.5 µmol/g) and lowest in T1 (2.1 µmol/g).
    - The increase in pungency in T5 suggests enhanced sulfur uptake facilitated by biofertilizers and micronutrients.

Conclusion

This study demonstrates that the integrated use of biofertilizers and mineral nutrients significantly improves onion growth, yield, and quality compared to individual treatments or controls. The highest growth parameters, yield, and quality attributes were recorded in T5 (RDF + Biofertilizer + Foliar Spray), indicating that combining biofertilizers with micronutrients and inorganic fertilizers provides the most balanced nutrient availability and uptake efficiency.

The findings highlight the following key benefits of biofertilizer and mineral nutrient integration:

- Enhanced root development and nutrient uptake efficiency.
- Increased bulb size, weight, and total yield.
- Improved biochemical quality, including higher TSS and pyruvic acid content.
- Reduced dependence on chemical fertilizers, contributing to sustainable agriculture and improved soil health.

The study recommends the combined application of RDF, biofertilizers, and foliar micronutrient spray as an optimal strategy for improving onion productivity and quality under similar agro-climatic conditions. Further research can focus on optimizing the biofertilizer strains and nutrient formulations for different soil types and environmental conditions.

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