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Growth and Yield of Onion (*Allium cepa L.*) by the Application of Plant Growth-Promoting Rhizobacteria

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Abstract

Aim: This study assessed the effects of vermicompost, the plant growth-promoting rhizobacteria (PGPR) *Azospirillum*, and the entomopathogenic fungus *Beauveria bassiana* on the growth and development of onion (*Allium cepa L.*).

Methodology: The field experiment was conducted in a farmer's field located in Guayabal, Cauayan City, Isabela. This site has a flat surface and is suitable for planting upland crops. The soil texture is loamy with good drainage and is irrigated. The study evaluated combinations of vermicompost (ranging from 1.5 to 3 tons/ha), with or without *Azospirillum* and *Beauveria bassiana*, and compared these treatments to a control using the recommended rate of inorganic fertilizer. Treatments were arranged in a randomized complete block design (RCBD) with three replications.

Results: Findings indicated that the combination of 3 tons/ha vermicompost, *Azospirillum*, and 3 liters of *Beauveria bassiana* significantly enhanced plant height, leaf length, and bulb diameter, outperforming the recommended rate of inorganic fertilizer. No significant differences were observed in leaf number and neck diameter across all treatments. The improved bulb yields were attributed to increased nutrient availability and biological activity resulting from the organic amendments, suggesting that this integrated approach could serve as a superior alternative to conventional fertilization practices.

Conclusion: Based on the results, an integrated approach utilizing 3 tons/ha vermicompost, *Azospirillum*, and 3 liters of *Beauveria bassiana* offers a promising and potentially superior alternative to the recommended rate of inorganic fertilizer for enhancing key growth parameters and bulb yield in onion.

Keywords: *Azospirillum*, *Beauveria bassiana,* plant growth-promoting rhizobacteria, vermicompost

INTRODUCTION

A highly significant vegetable worldwide, onion *(Allium cepa L.*) plays a vital role in numerous cuisines due to its versatility and high demand. The onion bulb offers a wealth of essential nutrients such as carbohydrates, protein, vitamin C, phosphorus (P), and calcium, and is also known for its medicinal attributes (Ramesh et al., 2017). Frequently employed to enhance flavor or consumed as a vegetable in stews and salads, mature onions contain substantial quantities of starch, sugar, protein, and vitamins A, B, and C. The nutritional makeup of onions, as reported by the National Onion Association, is approximately 89% moisture, 4% sugar, 1% protein, 2% fiber, and 1% fat (Adeyeye et al., 2017).

Globally, onion cultivation is on the rise due to its high profitability per unit area and relatively simple production process (FAO, 2011). In the Philippines during the quarter, the MIMAROPA Region led onion production with 46.94 thousand metric tons (55.3% of the total). Central Luzon (23.66 thousand metric tons) and the Ilocos Region (12.54 thousand metric tons) followed, with these three regions collectively producing 97.9 percent of the nation's total onion output (PSA, 2023).

However, onion cultivation frequently faces challenges from various biotic stress factors, including soil-borne pathogens and insect pests, which can markedly decrease both crop yield and quality. While chemical pesticides are widely employed to address these issues, their prolonged use often results in environmental harm, pest resistance, and adverse health effects. This underscores the urgent need for sustainable and alternative pest management approaches. One promising strategy involves the use of plant-beneficial microorganisms, especially rhizobacteria and

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entomopathogenic fungi, which have shown potential in improving plant health, controlling pests, and enhancing crop productivity.

Rhizobacteria are recognized for promoting plant growth by increasing nutrient availability, synthesizing growth hormones, and triggering systemic resistance against pathogens. Meanwhile, entomopathogenic fungi like *Beauveria bassiana* and *Metarhizium anisopliae* have proven effective as biological control agents in managing insect pests. Although rhizobacteria and entomopathogenic fungi have typically been studied independently, their combined use holds promise for synergistic effects, potentially providing a more holistic and effective approach to onion cultivation.

Plant growth-promoting rhizobacteria (PGPR) enhance plant development by facilitating the uptake of vital nutrients such as nitrogen and phosphorus, as well as by regulating plant hormones. They also serve as biocontrol agents, helping to minimize the effects of pathogens on vegetable crops including potatoes, tomatoes, peppers, and onions. These beneficial soil bacteria, which belong to genera like *Pseudomonas*, *Bacillus, Azotobacter, Enterobacter, and Azospirillum*, colonize plant roots, improve soil fertility, break down organic matter, and increase the availability of nutrients like phosphorus and potassium. Furthermore, PGPR suppress harmful pathogens by outcompeting them or producing antimicrobial substances, thereby reducing disease incidence in crops.

While numerous studies highlight the beneficial impact of plant growth-promoting rhizobacteria (PGPRs) on onion (Thangasamy & Lawande, 2015), their effectiveness can vary depending on the specific location and growing season. This inconsistency may stem from the competition that introduced bacteria face with indigenous soil microorganisms, which are often better adapted to the local environment (Bishnoi, 2015). Nevertheless, the positive contributions of PGPRs to vegetable growth and yield are well-documented (Dey et al., 2004), involving a range of mechanisms that are species-specific. These mechanisms include modulating volatile organic compounds and hormone levels, enhancing nutrient availability, and improving tolerance to abiotic stresses (Choudhary et al., 2011).

This study contributes to addressing the urgent need for sustainable agricultural practices by reducing chemical inputs and enhancing plant resilience and productivity in onion farming systems, thereby supporting sustainable consumption and production patterns in line with Sustainable Development Goal (SDG) 12. Additionally, it aligns with SDG 8, which focuses on promoting sustained, inclusive, and sustainable economic growth, fostering progress, improving living standards, and creating decent work for all. By encouraging the development of decent jobs within communities, equipping young people with essential skills, investing in education and training, and providing vulnerable populations with access to social protection, this approach supports broader social and economic development goals.

Objectives

This study aimed to determine the effects of rhizobacteria in combination to organic fertilizer and entomopathogenic fungi as foliar spray on the growth, and yield of onion (*Allium cepa L.*).

Specifically, it aimed to:

1. evaluate the effect of rhizobacteria inoculation on the growth parameters (root length, shoot height) and yield of onion.
2. assess the effects of entomopathogenic fungi as foliar spray and pest control in onion; and
3. compare the effects of inoculation of rhizobacteria and entomopathogenic fungi with the control group in terms of growth, pest resistance, and yield of onion.

METHODS

Securing of Planting Material, PGPR and Entomopathogenic Fungi`

A red onion variety was used for the study. Seeds for planting were obtained from a reliable source in Nueva Vizcaya. The plant growth-promoting rhizobacteria (PGPR), vesicular arbuscular mycorrhiza (VAM), was secured from Biotech, Los Baños, Laguna, while the entomopathogenic fungi (Beauveria bassiana) was secured from the Department of Agriculture, Ilagan, Isabela.

Soil Sampling and Analysis

Soil samples were randomly collected from the experimental site using a shovel. The samples were then spread out on newspaper and air-dried for approximately one week. One-kilogram portions of the dried soil were thoroughly pulverized and cleaned to remove any foreign materials. These prepared samples were sent to the Cagayan Valley Integrated Laboratory Division, Soils Laboratory Research Center in San Felipe, City of Ilagan, for

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analysis. The soil's NPK content determined the fertilizer recommendation for the study, which was set at 90-40-75 kg NPK per hectare.

Production of Seedlings

Seeds were sown in a nursery on well-prepared seedling trays. When seedlings attained the proper stage for transplanting—at the 3- or 4-leaf stage, estimated around 12 to 15 cm in height—they were transplanted to the experimental field. Seedlings were planted on fine soil, which was prepared following the recommended tillage practice for the crop.

Land Preparation

An area of 110 square meters was cleaned before plowing initially with animal-drawn plow. The area was left idle for two weeks for weeds to decay and weed seeds to germinate before the final plowing. Final harrowing was done before the construction of beds.

Application of Fertilizer

For the control treatment, urea (46% N), Triple Super Phosphate (TSP) (46% P_2O_5), and sulfur were the fertilizer sources. For the other treatments, organic fertilizer was applied before transplanting to supply nitrogen and phosphorus.

Planting and Replanting

Onion seedlings were planted in double rows. The spacing between rows was kept at 20 cm, and the spacing between hills was 20 centimeters. Replanting of missing hills was done to maintain the required plant population.

Experimental Design and Treatments

The treatments consisted of six levels of fertilizer supplemented with PGPR. The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications. Each treatment was assigned to the plots randomly as follows:

T_1 – 90-40-75 kg NPK ha^{-1}
T_2 – 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*
T_3- 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_4- 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_5- 7.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*
T_6 - 3 Tons Vermicompost ha^{-1}

Data Gathered

Data on growth, yield, and yield components of onion were recorded from the central double rows of plants, which were randomly selected in each plot as specified for each plant character.

Growth Parameters

1. **Plant Height (cm)**. This was measured from the ground to the tip of the leaves from 10 randomly selected plants at maturity.
2. **Leaf Number per Plant**. The total number of leaves per plant was counted from 10 randomly selected plants at maturity.
3. **Leaf Length (cm).** This was measured at physiological maturity from the sheath to the tip of the **leaf** from the ten leaves of the representative plants that were used to count the number of leaves per plant, using a ruler.

Yield and Yield Components

1. **Bulb Diameter (cm).** The bulb diameter of ten sample bulbs was measured at the widest portion of matured bulbs using a caliper.
2. **Neck Diameter (cm).** The neck diameters of ten randomly selected mature bulbs were measured using a vernier caliper and expressed in centimeters after harvest.

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3. **Average Bulb Weight (g)**. The fresh weight of ten randomly selected mature bulbs was measured using a sensitive weighing balance and then expressed in grams.
4. **Marketable Bulb Yield**. These bulbs were weighed using a weighing scale.

Statistical Analysis

The collected data were analyzed using ANOVA for a Randomized Complete Block Design with the Statistical Tool for Agricultural Research (STAR) software. Differences among treatment means were evaluated using Tukey's Honestly Significant Difference (HSD) test.

RESULTS and DISCUSSION

Table 1 shows the growth parameters of onion such as plant height (cm), leaf length (cm) and number of leaves.

Table 1. Growth Parameters as Affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Plant Height (cm)	Leaf Length (cm)	Number of Leaves
T_1 - 90-40-75 kg NPK ha^{-1}	57.30^{bc}	51.70^{c}	7.10
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	54.83^{c}	47.33^{d}	6.63
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	64.40^{a}	63.10^{a}	7.83
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	59.67^{b}	59.53^{a}	7.10
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	56.13^{bc}	55.67^{b}	7.13
T_6 - 3 Tons Vermicompost ha^{-1}	55.90^{bc}	55.47^{bc}	7.20
F- RESULTS	**	**	ns
C. V. (%)	2.55	2.44	5.35

Means with the same letter are not significantly different using HSD Test
ns-not significant
***- significant at 1% level*

Plant Height (cm). The effect of combining vermicompost, *Azospirillum*, and *Beauveria bassiana* effectively enhanced onion plant height as shown in Table 1. The application of 3 Tons Vermicompost ha^1 combined with *Azospirillum* and 3 liters *Beauveria bassiana* were the tallest plants among all treatments with 64.40 centimeters. Lowering the levels of vermicompost into 1.5 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *B. bassiana* registered an average height of 59.67 cm. Treatments that included the recommended fertilizer rate (90-40-75 kg NPK ha^{-1}), in combination with 3 tons vermicompost ha^{-1} or 0.75 ton vermicompost ha^{-1} + *Azospirillum* + 3 liters *B. bassiana*, showed comparable plant heights to T_4. The treatment comprising 3 tons vermicompost ha^{-1} + 3 liters *B. bassiana* without Azospirillum recorded a lower average height of 54.83 cm. It shows that the combination of vermicompost), Azospirillum), and Beauveria bassiana as biocontrol agent had a t positive effect on the height of onion plants.

The observed increase in plant height resulting from the combined treatments is consistent with the findings of Wani and Khan (2010), who reported that Bacillus strains improved nutrient uptake, leading to taller tomato plants and greater fresh weight in both nutrient-deficient soils and those supplemented with nitrogen fertilizer. This suggests that the synergistic effect of the treatment combination can be attributed to the plant growth-promoting properties of the organic fertilizer, *Azospirillum*, and *Beauveria bassiana*, which collectively enhance nutrient absorption and overall plant vigor.

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Furthermore, as noted by Ardakani and Mafakheri (2011), while the nitrogen-fixing ability of *Azospirillum* is its most widely recognized benefit, a growing number of studies highlight additional growth-promoting properties. These include the production of phytohormones that significantly stimulate root development, thereby improving the plant's capacity to absorb water and nutrients.

Leaf Length (cm). Leaf length was measured from the base of the pseudo-stem to the tip of the leaf. The ANOVA results indicated significant variation across all treatments. The longest leaves were recorded in treatments with 3 tons and 1.5 tons of vermicompost per hectare combined with *Azospirillum* and a constant rate of *Beauveria bassiana*, measuring 63.10 cm and 59.53 cm, respectively (T_3 and T_4). This suggests a synergistic effect among vermicompost, *Azospirillum*, and *Beauveria bassiana*, where even a reduced organic input (T_4), when paired with appropriate microbial support, can effectively promote vertical growth in onion plants.

On the same manner, the plants treated with 0.75 tons of vermicompost in combination with *Azospirillum* and *Beauveria bassiana* exhibited a mean leaf length of 55.67 cm, comparable to those treated with vermicompost alone (55.47 cm). The leaf length in T_1 (51.70 cm) and T_6 (55.47) both resulted in similar lengths despite of the variation in nutrient sources. In contrast, the shortest leaf length was observed in the treatment applied with 3 tons of vermicompost per hectare combined with 3 liters of *Beauveria bassiana* with 47.33 centimeters.

Number of Leaves. Results listed in Table 1 revealed that the number of leaves of onion was not affected by the tested treatments. This shows that regardless of treatment employed did not increase leaf number (6.63 to 7.83) which might be attributed to onion plant that has a specific potential in producing number of leaves mostly governed by genetics factor. In addition, although environmental and nutrient management factors influence the growth of the plants, they have minimal effect on surpassing the genetic limit of the plant in terms of the total number of leaves.

Table 2 shows the yield parameters of onion such as neck diameter (cm), bulb diameter (mm), bulb weight per plant (g), and bulb weight per sampling area (kg/6m^2).

Table 2. Yield Parameters as Affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Neck diameter (cm)	Bulb diameter (mm)	Bulb weight per plant (g)	Bulb weight per sampling area (kg)
T_1 - 90-40-75 kg NPK ha^{-1}	1.19	68.43^c	68.43c	13.06^c
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	1.03	72.37^c	72.37c	14.03^c
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.12	90.27^a	90.27a	18.20^a
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.10	86.83^{ab}	86.83ab	16.99^{ab}
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	1.18	84.00^b	84.00b	16.87^b
T_6 - 3 Tons Vermicompost ha^{-1}	0.99	83.07^b	83.07b	15.38^b
F- RESULTS	ns	**	**	**
C. V. (%)	10.14	6.61	2.46	2.38

Means with the same letter are not significantly different using HSD Test
*** - significant at 1% level*
Ns - not significant

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Neck Diameter (cm). Table 2 shows the average neck diameter of onion at harvest. Results revealed that all treated plants, regardless of fertilizer sources (either organic or inorganic) and irrespective of the application of *Azospirillum* and *Beauveria bassiana*, recorded comparable neck diameters, with mean values ranging from 0.99 cm to 1.19 centimeters. This shows that the treatments did not influence the neck diameter of the onion due to the inherent genetic characteristics and the stability of the variety used in the study.

Bulb Diameter (mm). Average bulb diameters of onion plants as affected by fertilization and bacterial inoculation are also presented in Table 2. The results indicate that mineral fertilization, bio-fertilization, and inoculation had a significant impact on bulb diameter. The treatments that produced the largest bulb diameters were T3 (86.83 mm) and T4 (86.83 mm), which showed similar results, followed by T6 and T5 with diameters of 93.07 mm and 84.00 mm, respectively. The smallest bulb diameters were observed in plants under T2 (72.37 mm) and T1 (68.43 mm).

This clearly demonstrates the role of biofertilization in increasing average bulb diameter, which may be attributed to the application of the recommended rate of vermicompost enhancing mineralization. As stated by Arisha et al. (2003), the increase is likely due to the organic matter in vermicompost, which contains many species of living organisms that release phytohormones, stimulating plant growth and improving nutrient absorption. Similarly, these results align with the findings of (Nagaraju et al., 2000), who reported that onion bulb diameter significantly increased with the application of vesicular-arbuscular mycorrhizae (VAM) - a beneficial fungus that forms a symbiotic relationship with plant roots-especially when combined with 50% to 100% inorganic fertilizer. Their observation that treatments without inoculation also performed well is consistent with the results of this study.

Bulb Weight per Plant (g). The data recorded on bulb yield per plant by different treatments are presented in Table 2. The results showed that combined application of vermicompost, *Azospirillum* and *Beauveria bassiana* significantly influences bulb yield per plant. The heaviest onions was recorded in the plants applied with 3 tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* (T_3) and lower level of vermicompost (T_4) with constant application of *Azospirillum* *Beauveria bassiana* indicating better results than the application of chemical fertilizer. This was followed by the plants treated with 0.75 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* and the plot without beneficial microbes (T_6) which were less effective in increasing bulb weight with mean values of 84.00 and 83.07 grams. The significant difference in bulb yield per plant under the combined application of vermicompost, *Azospirillum*, and *Beauveria bassiana* suggests that the treatment combinations are potentially beneficial in enhancing bulb yield.

Table 3. Bulb Weight per 1000 Square Meters (tons) as affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Bulb weight per 1000 square meters (tons)
T_1 - 90-40-75 kg NPK ha^{-1}	2.18^c
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	2.34^c
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	3.04^a
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.83^b
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.81^b
T_6 - 3 Tons Vermicompost ha^{-1}	2.56^b
F- RESULTS	**
C. V. (%)	2.39

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*** - significant at 1% level*

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Bulb Weight per 1000 Square Meters (tons). Calculating the yield per 1000 square meters, a similar trend of significant differences was observed. Effect of different treatments showed that the application of vermicompost *Azospirillum* and *Beauveria bassiana* (T_3) led to increase blub yield of onion compared to other treatments. Followed by T4, T5 and T6, while the least was noted in the plots fertilized with 90-40-75 kg NPK ha^{-1} and 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana.*

Table 4. Number of Infected Bulb per Plot as affected by the Application of Plant Growth-Promoting Rhizobacteria

TREATMENTS	Number of Infected Bulb per Plot
T_1 - 90-40-75 kg NPK ha^{-1}	11.33^a
T_2 - 3 Tons Vermicompost ha^{-1} + 3 liters *Beauveria bassiana*	8.00^b
T_3 - 3 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.00^d
T_4 - 1.5 Tons Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	7.33^b
T_5 – 0.75 Ton Vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana*	2.67^c
T_6 - 3 Tons Vermicompost ha^{-1}	3.33^c
F- RESULTS	**
C. V. (%)	2.39

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The number of infected bulbs per plot due to insect infestation is shown in Table 4. This reflects that the plants treated with the recommended rate of inorganic fertilizer produced the highest number of infected bulbs (11.33). The plants in both T2 and T4, which included Beauveria bassiana, had a moderate number of infected bulbs (8.00 and 7.33, respectively), followed by the plants in T6 and T5 (vermicompost only or with a reduced rate of vermicompost and microbes), which showed lower values (3.33 and 2.67). It is interesting to note that the plants treated with 3 tons vermicompost ha^{-1} + *Azospirillum* + 3 liters *Beauveria bassiana* (T3), despite receiving the full rate of vermicompost and bio-agents, had the lowest number of infected bulbs (2.00). This suggests that this combination is the most effective in minimizing bulb losses due to insect pests.

Conclusion

The study's results demonstrated that the combined application of 3 tons of vermicompost, *Azospirillum* , and 3 liters of *Beauveria bassiana* significantly enhanced growth parameters and yield in onions, outperforming traditional chemical fertilizer treatments.

Recommendations

Based on the results of the study, to enhance the growth and yield of onions, it is recommended to apply 3 tons of vermicompost, Azospirillum, and 3 liters of *Beauveria bassiana* per hectare. The combined benefits of organic nutrients from vermicompost, nitrogen fixation by *Azospirillum*, and biological pest control provided by *Beauveria bassiana* offer a sustainable and eco-friendly alternative to conventional inorganic fertilizers. Therefore, this integrated approach is strongly recommended for improved onion production.

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