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Research article

Organic White Corn (*Zea mays* L. IPB var. 6) Production through the Integration of Bio-fertilizer on Chicken Manure

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Abstract: White corn is the most important substitute staple in periods of rice shortage. Currently, there is an increasing global trend toward reducing dependence on synthetic fertilizers. The increasing demand for organic produce among health-conscious consumers is driving the adoption of sustainable agricultural practices, including the use of organic fertilizers and bio-fertilizers to meet plant nutrient needs. A field experiment was conducted to evaluate the effectiveness of bio-fertilizer added to chicken manure in terms of growth, yield, and physicochemical characteristics of corn. The study used a Randomized Complete Block Design (RCBD) consisting of five treatments with three replications each, and data were collected on the growth, yield, and physicochemical parameters of corn. Data were analyzed using Analysis of Variance (ANOVA) in RCBD, and Comparisons among means were performed using Duncan Multiple Range Test (DMRT) to determine the specific significant differences among treatments. One-half the recommended rate of *Azospirillum* combined with half the recommended rate of Mykovam® at half the amount of chicken manure was comparable to using the full-recommended inorganic fertilizer in terms of plant height, days to silking, ear height, and average length of ears. Moreover, the same treatment combination significantly affected all growth and yield parameters, except for plant stand and average number of ears, which were comparable to using the full-recommended rate of chicken manure. The overall results of this study suggest that combining bio-fertilizer with organic amendments, like chicken manure, using only half the recommended rate, can effectively enhance corn production.

Keywords: Bio-fertilizer; organic fertilizer; chemical fertilizer; sustainable agricultural practices, bio-enhancer

1. Introduction

Corn (*Zea mays* L.) ranks as the second most important crop in the Philippines after rice, with around 1.8 million Filipino farmers or one third of the farming population relying on it as their primary source of income. White corn serves as the main alternative staple during times of rice shortage, particularly for those living in rural communities [1]. It is known to be a rich source of vitamins A, B, and E, as well as various essential minerals. Corn production in the Philippines, harvest area, and yield per hectare increased by 11%, 7.2%, and 3.5%, respectively, in 2019 compared with 2018. In Central Visayas, Cebu had the widest area dedicated to corn cultivation, making up 55.2% of the region's total, and emerged as the top corn producer in 2018, contributing 54.63% to the region's overall corn production [2]. Chemical fertilizers have been used for decades to increase crop yield. However, the extensive use of chemical fertilizers has also led to environmental challenges, including water pollution and soil degradation [3]. Farmers employ alternative and economical techniques to make food production more sustainable, including crop rotation, biological pest management, composts, and organic fertilizers, which contribute to reducing negative environmental impacts. Currently, there is an increasing global trend toward reducing dependence on synthetic fertilizers, driven by environmental concerns, rising costs, and the pursuit of sustainable agriculture. Additionally, the growing demand from health-conscious consumers for organically produced crops has sparked greater interest in foliar feeding, the use of organic fertilizers, and the use of bio-fertilizers as effective alternatives to meet plants' nutritional needs during the growing season [4].

Bio-fertilizers (microbial inoculants) and organic materials such as chicken manure are cost-effective nutrient sources that can act as alternatives to chemical fertilizers and enhance crop production in low-input farming systems. Application of organic amendments like chicken manure increases soil organic carbon and stimulates microbial activity, which provides N and P to the soil [3]. Microbial inoculants, on the other hand, are agricultural enhancements that utilize beneficial microbes to improve both plant and soil health. These are used to enhance plant nutrition and can also support plant growth by stimulating the production of plant hormones. *Azospirillum* is a microbial-based fertilizer that makes use of nitrogen-fixing microbial inoculants, which have been shown to effectively improve root development and lead to higher crop yields [5]. *Azospirillum* forms an associative symbiotic relationship with many plants, especially those that utilize the C4 dicarboxylic acid pathway of photosynthesis (Hatch and Slack pathway), as it thrives and fixes nitrogen using organic acid salts like malic and aspartic acids [21]. On the other hand, Mykovam® is a soil-based bio-fertilizer containing spores. According to Dr. Jocelyn T. Zarate of UPLB BIOTECH, these fungi, when inoculated to seedlings, will infect the roots, help absorb water and nutrients, particularly phosphorus, and prevent root infection by pathogens. Moreover, they boost the plant's ability to handle stress, such as drought or soil diseases [16]. Furthermore, they are involved in interactions with plant roots, either symbiotically or as free-living, improving plant nutrient uptake, bolstering crop production, and improving soil quality [6].

However, under field conditions, studies are still very limited. A study on determining the comparative performance of *Azospirillum*, Mykovam® on Chicken manure in terms of plant growth, yield, and physicochemical characteristics is deemed necessary, especially towards full organic white corn production.

2. Methodology

2.1 Location

The study was conducted at Barangay Cagay, experimental area of Cebu Technological University-Barili Campus, from the months of November 2024 to February 2025, situated at approximately 10° 8' North, 123° 32' East in the island of Cebu and located approximately 8.5 kilometers away from the market proper. Elevation at these coordinates is estimated at 145.2 meters or 475.4 feet above mean sea level. The soils vary in color from dark brown to yellowish brown, becoming hard when dry but plastic and sticky when wet. They have a high clay content (46-70%) and a water-holding capacity greater than 40%. Chemically, these soils have an alkaline pH of 7.83.

2.2 Experimental Design and Treatment

A single-factor experiment having five treatments replicated three times, arranged in a Randomized Complete Block Design (RCBD) was used in the study. Since both *Azospirillum* and Mykovam® do not provide nutrients to plants but instead allow more efficient utilization of available nutrients, the sole application of both bio-inoculants was not considered, but instead used with chicken manure. The following were the treatments of the study.

T1- Full Recommended Rate Inorganic Fertilizer (120 N- 60 P_2O_5 – 60 K_2O)
T2- *Azospirillum* + Half-Recommended Rate (RR) Chicken Manure
T3- Mykovam® + Half- Recommended Rate Chicken Manure

T4- Half-Recommended Rate *Azospirillum* + Half-Recommended Rate Mykovam® +Half-Recommended Rate Chicken Manure
T5- Full Recommended Rate Chicken Manure (20 tons/ha)

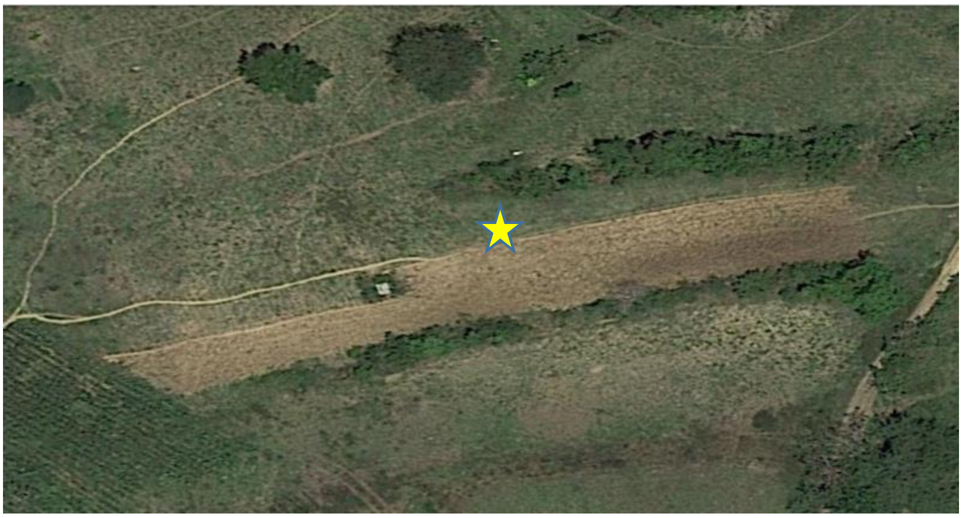

Figure 1. Location of the study within Cebu Technological University-Barili Campus

2.3 Land Preparation

The experiment was set up in a 100 m^2 land, which was divided into three major blocks. The area was plowed twice and harrowed once before furrowing. Rocks and residues were removed. Furrows were established 75 cm apart across the plots. Each treatment plot measured 5 meters in length and 3 meters in width, with a one-meter space allocated between blocks and replications to facilitate data collection and regular inspection.

2.4 Inputs, Treatments, and Application

Farm supplies such as urea (46-0-0) and complete fertilizer (14-14-14) were acquired from an Agrivet supplier in Barili, Cebu City. White Corn IPB var. 6 used in the study was purchased from a reliable seed farmer in Barili, Cebu City. Chicken manure was sourced from the Department of Animal Science of the Cebu Technological University- Barili Campus, while *Azospirillum* and Mykovam® were purchased online. Basal application of chicken manure was done 1 week before sowing at 20 tons per hectare. The application of synthetic fertilizer was based on the recommended rate of 120kg N, 60kg P, and 60kg K per hectare. Mykovam® was applied at the rate of 10 g per hill, and *Azospirillum* was applied by coating 3 kilograms of corn seeds with a 200-gram pack of BIO-N. The amounts of fertilizers and bio-fertilizers were reduced by half the recommended rate, depending on the treatments of the study.

2.5 Seed Planting and Hilling-up

White Corn IPB var. 6 seeds were soaked in coconut water for twenty-four (24) hours to improve germination rate and were directly planted with a row spacing of 75cm and plant spacing of 25 cm. Hilling up, on the other hand, was performed at 30 DAP.

2.6 Care and Maintenance of Experimental Plants

Watering was done at three days interval, one week after germination. Weeding was done just before thinning and fertilizer application. Constant check-ups and regular monitoring were done to monitor pest and disease infestation.

2.7 Data Gathered

2.7.1 Agronomic Characteristics of Corn

- Plant height (cm) was determined by measuring from the base of the plant to the base of the tassel using a measuring tape.
- Days to silking were obtained by counting the number of days of silk emergence after planting.

- Ear height (cm) was measured at the maturity stage; it was measured from the ground to the base of the ear.
- The Plant Stand was done by counting the number of live plants in a row per treatment.
- The number of Ears was determined by counting the total number of ears of the plants within the row per treatment.
- Fresh Weight of Ears with Husk (kg) was measured by weighing the total ears taken from the plants within the row per treatment.
- Average Length of Ears (cm) was measured by getting the total length of ears without husks divided by ten.
- The average weight of unshelled ears (g) was measured by weighing all the total sample ears without husks, divided by ten per treatment.
- The average weight of shelled ears (g) was measured by weighing all the total sample grains divided by ten per treatment.
- Total yield (kg). The total yield with 18% moisture content was computed using this formula:

$$\text{Total } Yield\ (t/ha) = \frac{SW(g)\ x\ 55{,}000\ x\ (100-MC)}{(100-18)x\ (1{,}000{,}000)}$$

Where:

SW = shelled weight (g)
55,000 = assumed plant population per hectare (constant)
MC = actual harvest moisture
18 = standard moisture basis used
1,000,000 = conversion factor from grams to metric tons

2.7.2 Physicochemical characteristics of Corn

- Total Soluble Solid (TSS). Twenty (20) grams of kernels were blended and homogenized with 100 mL of distilled water. TSS in Brix% was measured using a hand-held refractometer (model HI-96801 manufactured by Hanna Instruments Ltd.) calibrated with distilled water by placing 1-3 drops of juice on the instrument's prism and taking the reading.
- Titratable Acidity (TA). Five mL of corn juice was taken, and homogenized samples prepared from TSS were diluted with 45 mL of distilled water. The 50 mL extract (aliquot) was measured and put into an Erlenmeyer flask and a beaker, and 2 drops of 1% phenolphthalein indicator were added. This was titrated with 0.1% NaOH until a pale pink color was achieved using a Cordial 1642TF Glass burette.

2.8 Statistical Analysis

Analysis of variance (ANOVA) for a randomized complete block design (RCBD) was used to analyze any significant difference in all the parameters gathered. Comparisons among means were done using Duncan Multiple Range Test (DMRT) to determine the specific significant differences among treatments.

3. Results and Discussion

3.1 Agronomic Characteristics

The agronomic characteristics of corn, such as plant height, days to silking, and ear height, as affected by *Azospirillum* and Mykovam® Biofertilizers and chicken manure, are shown in Table 1. Treatment applied with half the amount of *Azospirillum* combined with half the rate of Mykovam® at half the amount of chicken manure has a plant height mean of 218.93, which is statistically comparable with treatment applied with inorganic fertilizer (225.10 cm) and *Azospirillum* combined with half the amount of chicken manure (213.47 cm). These treatments showed to be significantly different compared to treatments with Mykovam® combined with half the amount of chicken manure and chicken manure alone. These results are similar to those obtained in [3] that the application of biofertilizer on poultry manure significantly produced taller plants compared to the control poultry manure alone. Furthermore, the inoculation of maize with biofertilizers had a beneficial effect on the plant growth due to the stimulation of root development and the supply of combined nitrogen. The symbiotic association of microorganisms with plant roots is one of the most enhanced biological activities in the soil. Soil microorganisms that colonize the rhizosphere assist plants in the uptake of phosphorus, potassium, and nitrogen from the soil [7]. Similar to the study of Rotor [14] that inoculation of maize with *Azospirillum* bacteria (Bio-N) contributed to an increase in plant vigour. Plants were taller with the inoculation of *Azospirillum*. Similarly, [15] found that biofertilizers have a positive effect on the plant height and other agronomic characteristics.

In mean differences of the days to silking, treatment applied with chicken manure alone has a significant difference among all the treatments. In mean differences of the ear height, treatment applied with inorganic fertilizer has the highest mean of 130.03 cm, which is statistically comparable with using half the recommended rate *of Azospirillum* combined with half the recommended rate of Mykovam® at half the amount of chicken manure (124.30 cm), but showed to be significantly different compared to other treatments. On the other hand, treatment applied with chicken manure alone has the significantly shortest mean ear height of 108.50 cm. The positive effects of bio-fertilizer and poultry manure on plant growth, as observed in this study, have also been reported by some workers (Abdullahi et al. 2013) using various organic amendments. They observed that inoculated plants grown with organic amendments produced plants with higher growth characteristics than uninoculated ones. Positive growth response of inoculated plants could be due to the provision of nutrients, especially nitrogen and growth-promoting hormones by *Azospirillum*, and enhanced uptake of phosphorus and other nutrients due to mycorrhizal colonization. Enhanced nutrient availability could also be attributed to the decomposition of organic manure or the transformation of inorganic substances to an available form by microorganisms [3]. Moreover, the study conducted by Chen et al. (2024) also supported this, highlighting that microorganisms such as bacteria, fungi, and actinomycetes help decompose complex organic substances into simpler forms that plants can readily absorb. For instance, studies have shown that greater microbial diversity is closely associated with increased rates of organic matter decomposition, resulting in quicker nutrient release and enhanced soil quality [8].

Table 1. Agronomic characteristics of corn as affected by the integration of biofertilizer on chicken manure application to corn.

Treatment	Plant Height (cm)	Days to Silking	Ear Height (cm)
Full RR Inorganic Fertilizer	225.10 a	51.63 b	130.03 a
Azospirillum + ½ RR Chicken Manure	213.47 b	51.63 b	118.73 bc
Mykovam® + ½ RR Chicken Manure	200.30 c	51.87 b	114.33 cd
½ RR *Azospirillum* + ½ RR Mykovam® + ½ RR Chicken Manure	218.93 ab	51.77 b	124.30 ab
Full RR Chicken Manure	187.97 d	52.40 a	108.50 d
CV (%)	2.32	0.33	2.74

3.1 Plant Stand, number of ears, and fresh weight of ears with husk

Table 2a presents the yield and yield components of corn as affected by the application of biofertilizers and chicken manure. Table 2a shows that there is a significant difference in the fresh weight of ears with husk among all the treatments. Treatment applied with inorganic fertilizer had the highest mean fresh weight of ears with husk of 4.96 kg, followed by half the recommended rate *of Azospirillum* and Mykovam® at half the amount of chicken manure, with the mean of 4.14 kg. On the other hand, treatment applied with chicken manure alone has the significantly lowest mean of fresh weight of ears with husk of 2.90 kg. The results are consistent with those of Cleyet-Marel [9], who found that inoculation of plants with plant growth-promoting rhizobacteria at the early stage of development made a positive impact on biomass through direct effect on root growth, production, and production of phytohormones by bacteria, mineral enhancement uptake, and transfer of nitrogen to the plant. Similar findings were reported in [10], stating that nitrogen-fixing microorganisms such as *Azospirillum* and beneficial fungi like Mykovam®, commonly found in biofertilizers, can enhance plant growth and yield. They achieve this by capturing atmospheric nitrogen and solubilizing soil phosphate, making it more accessible to plants. Additionally, they produce growth-promoting hormones like IAA (Indole-3-acetic acid), cytokinins, gibberellins, and auxins, which significantly contribute to improved plant development and productivity. Moreover, numerous studies, including Fadlalla [11], have demonstrated that combining biofertilizers with organic amendments can enhance the availability and uptake of plant nutrients, leading to improved crop yields.

Table 2a. Yield and yield components of corn as affected by the integration of biofertilizer on chicken manure application to corn.

Treatment	Plant Stand	Number of Ears	Fresh Weight of Ears with Husk (kg)
Full RR Inorganic Fertilizer	24.67	23.67	4.96 [a]
Azospirillum + ½ RR Chicken Manure	24.00	23.33	3.63 [c]
Mykovam®+ ½ RR Chicken Manure	24.00	23.33	3.44 [d]
½ RR *Azospirillum* + ½ RR Mykovam® + ½ RR Chicken Manure	24.33	24.00	4.14 [b]
Full RR Chicken Manure	24.67	23.00	2.90 [e]
CV (%)	1.50	2.19	2.26

3.2 Average weight of unshelled ears, average weight of shelled ears, average length of ears, and total yield

Table 2b shows that there is a significant difference in the average weight of unshelled ears and the average weight of shelled ears, among all the treatments. Treatment applied with half the amount of *Azospirillum* combined with half of the recommended rate of Mykovam® at half the amount of chicken manure has the average weight of unshelled ears mean of 179.30 g, and inorganic fertilizer has the highest mean of 203.06 g. On the other hand, treatment applied with chicken manure alone has the lowest mean of average weight of unshelled ears with 118.98 g. In the mean differences of the average of shelled ears, the highest average of shelled ears was recorded on corn in inorganic fertilizer with 170.64 g, followed by *Azospirillum* combined with Mykovam® at half the amount of chicken manure with 148.42 g. On the other hand, according to Pascual [5], the combined application of BIO-N and VAMRI with only half of the recommended fertilizer rate consistently produced optimal outcomes in ear dry weight without husk, average ear diameter, and kernel dry weight—showing results comparable to the full-recommended rate of inorganic fertilizer. Moreover, the study by Haserirad [12] and Rokhzadi [13] showed that inoculation of biofertilizers containing Azotobacter and *Azospirillum* increased plant height, number of leaves per plant, and corn weight compared to those without biofertilizer. Furthermore, Amba [6] stated that the mixed application of Mykovam® and inorganic fertilizer gave the heaviest corncobs. The increase in the average weight of both unshelled and shelled ears was attributed to enhanced traits like the number of leaves, ear length, and plant height, which ultimately led to greater assimilate production.

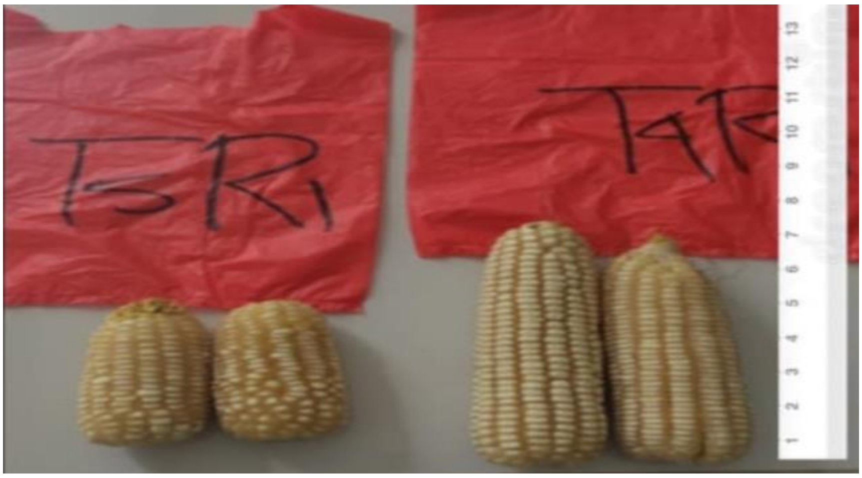

Figure 2. Comparing the corn yield using full chicken manure with the yield from a combination of *Azospirillum* and Mykovam® applied alongside half the usual amount of chicken manure.

Table 2b. Yield and yield components of corn as affected by biofertilizer on chicken manure application to corn.

Treatment	Ave. weight of unshelled ears (g)	Ave. weight of shelled ears (g)	Ave. Length of Ears (cm)	Total yield (kg)
Full RR Inorganic Fertilizer	203.06 a	170.64 a	14.05 a	8.04 a
Azospirillum + ½ RR Chicken Manure	145.82 c	118.93 c	12.25 bc	5.83 c
Mykovam® + ½ RR Chicken Manure	138.68 c	116.47 c	11.62 cd	5.52 c
½ RR *Azospirillum* + ½ RR Mykovam® + ½ RR Chicken Manure	179.30 b	148.42 b	13.10 ab	7.10 b
Full RR Chicken Manure	118.98 d	94.98 d	10.80 d	4.71 d
CV (%)	3.94	4.19	4.78	3.94

In terms of average ear length, the treatment using half the recommended rate of *Azospirillum* combined with 50% of the recommended rate of Mykovam® and half the amount of chicken manure recorded a mean ear length of 13.10 cm. This result was statistically comparable to the treatment with inorganic fertilizer (14.05 cm) and the treatment combining *Azospirillum* with half the amount of chicken manure (12.25 cm). On the other hand, treatment applied with chicken manure alone has the significantly lowest ear height mean of 10.80 cm. Pascual [5] observed similar results, which showed that using BIO-N and VAMRI together with just half of the recommended fertilizer rate was comparable with treatment applied with the full-recommended rate of inorganic fertilizer in terms of average length of ears. Bakry [17] stated that triple treatment of combinations of Micronutrients, Chicken Manure, and Rhizobium Inoculation achieved a considerably greater increase, which reached 53.80, 29.10, 29.93, 31.14, and 42.27 % for length, ear diameter, ear weight, raw number/ear, and grain number/raw over the control treatment, respectively. The improvements in the examined ear characteristics resulting from the applied treatments may be attributed to their ability to release plant growth-promoting substances, which likely enhanced plant growth and increased the uptake of water and nutrients from the soil. Differences in treatment means of total yield showed significant differences at α0.05. The highest total yield was recorded on corn in inorganic fertilizer with 8.04 kg, followed by *Azospirillum* combined with Mykovam® at half the amount of chicken manure with 7.10 kg. However, treatment applied with chicken manure alone has the significantly lowest total yield of 4.71 kg. These findings are consistent with those reported by Purwani [18] that the treatment using 50% of the recommended NPK rate combined with bio-fertilizer resulted in a higher maize yield compared to the treatment with 100% of the recommended NPK rate. Mahato and Neupane [19] reported similar results, demonstrating that the combined use of chemical fertilizers and biofertilizers produced higher corn yields compared to using chemical fertilizers alone, thereby lowering the required amount of chemical fertilizers during cultivation. Zarabi [20] stated that the application of organic fertilizer enhances water use efficiency, improves photosynthesis, and promotes plant growth and development. Furthermore, Rattin [22] reported that the improvement in growth parameters was linked to the activity of arbuscular mycorrhizal fungi and other microorganisms, which enhanced plant biomass and phosphorus content. Additionally, Javier [23] noted that the microorganisms in biofertilizers help develop a strong root system, enhancing the plant's ability to absorb nutrients, which in turn promotes better plant growth and higher biomass production.

3.3 Total Soluble Solid and Titratable Acidity

Table 3 indicates that the total soluble solids of corn in *Azospirillum* combined with Mykovam® at half the amount of chicken manure showed significantly different results compared to other treatments, especially in the treatment applied with chicken manure alone. Treatment applied with inorganic fertilizer had the highest total soluble solids (2.13), followed by *Azospirillum* combined with Mykovam® at half the amount of chicken manure (1.93). In contrast, the chicken manure treatment has the significantly lowest total soluble solids (1.67). Mahdi [24] also reported similar findings, indicating that the application of mixed bio-fertilizer significantly enhanced the levels of starch, protein, and dry matter. Whereas, Azotobacter spp. T2 fertilizer was most effective in enhancing potassium availability (339 mg/kg) and total sugar content (0.507%), showing clear differences from other biofertilizers. Meanwhile, *Azospirillum* spp. T1 treatment led to the highest increase in total soluble solids (6.763%), significantly outperforming the other treatments. This is consistent with other studies showing that mineral nutrients—particularly sulfur and nitrogen from ammonium sulfate—enhance the photosynthetic activity of chloroplasts, facilitate the transport of photosynthates through the phloem to sink tissues, and ultimately improve fruit quality and yield, which is linked to higher sugar content [25].

Table 3. Physicochemical characteristics of corn as affected by the integration of biofertilizer on chicken manure application to corn.

Treatment	Total Soluble Solid (TSS)	Titratable Acidity (TA).
Full RR Inorganic Fertilizer	2.13 a	1.01 a
Azospirillum + ½ RR Chicken Manure	1.83 c	0.73 c
Mykovam® + ½ RR Chicken Manure	1.80 c	0.75 c
½ RR *Azospirillum* + ½ RR Mykovam® + ½ RR Chicken Manure	1.93 b	0.86 b
Full RR Chicken Manure	1.67 d	0.69 c
CV (%)	1.82	4.99

In titratable acidity, differences in treatment means showed significant differences at α0.05. Treatment applied with inorganic fertilizer has the highest titratable acidity with 1.01, followed by *Azospirillum* combined with Mykovam® at half the amount of chicken manure with 0.86. On the other hand, treatment applied with chicken manure alone has the lowest titratable acidity with 0.69. According to Bhattacharjee [26], bio-fertilizers such as plant growth-promoting rhizobacteria (PGPR) promote plant growth through various mechanisms, typically by solubilizing phosphorus, enhancing nutrient uptake, or producing plant growth hormones. Moreover, Di-ammonium Phosphate (DAP) often leads to higher acid accumulation, which can influence the flavor and shelf life of corn varieties. The phosphorus supplied by DAP fertilizers can stimulate the synthesis of organic acids in plants, potentially increasing acidity in specific tissues, including fruits or kernels like corn [27].

4. Conclusions

Based on the results, the use of integration of biofertilizers on chicken manure significantly improved the growth, yield, and physicochemical characteristics of corn. Under the CTU-Barili Cebu Condition, the application of *Azospirillum* and Mykovam® singly or in combination with chicken manure at half the recommended rate is generally more effective than using chicken manure alone at the full recommended rate for the production of corn. This also indicates that using a combination of biofertilizer on chicken manure has greater potential to reduce reliance on inorganic fertilizers in corn production.

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