

Research Article

Application of foliar biofertilizers with and without NPK in cultivating white-glutinous corn

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Abstract

Organic farming used fermented fruit and plant juices as foliar fertilizers to enhance crop production. However, the usage is usually limited to sole fruit or plant fermentation with chemicals and other growth enhancers. The use of various fruits, plants, fish products, and *Cyanobacteria* with *Mycorrhizal* fungi combinations to enhance white-glutinous corn has not yet been explored. This trial investigated the different fermented fruits (FFJ), plants (FPJ), fishes (FAA), and commercial *Cyanobacteria* with *Mycorrhizal* fungi (Rhizocote) in single-use or combination with NPK to enhance the growth, yield, and Return on Investment (ROI) of cultivating white-glutinous corn. The application was 2 tbsp L⁻¹ water for single use of fermented biofertilizers while 1 tbsp L⁻¹ water for fermented foliar with NPK combinations. The results showed that the height of corn was not significant among treatments in 30 and 60 days after planting (DAP). However, corn treated with Rhizocote alone was the tallest in 45 DAP and had longer days to reach 50% corn tasseling. White-glutinous corn treated with Rhizocote + NPK had the highest number of ears. The rest of the treatments yielded a comparable number of ear sizes ranging from 1.27 to 1.37 cm. The highest yield of marketable green ears accounted for 7.45 t ha⁻¹ with Rhizocote + NPK, while the lowest was observed when the white-glutinous corn was fertilized alone with FFJ at 2.93 t-ha. The Rhizocote + NPK obtained the highest R.O.I. of 263.68% compared to other treatments. Thus, the recommendation is to use 1.00 tbsp L⁻¹ water commercial Rhizocote + recommended NPK for a productive and profitable white-glutinous corn. More investigation using different agri-fishery products fermentation at higher concentrations are needed in culture of white-glutinous corn for green ear production in various planting season.

Introduction

Corn is an essential crop in Southeast Asia and is considered a valuable vegetable in most

parts of India. Attention is now being paid to explore its potential in India for earning foreign exchange (Mohammadi et al., 2019). Thailand

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and China are the world leaders in baby corn production. In the Philippines, farmers recently have an interest in green corn production. Green corn is typically harvested 60 to 70 days after planting, resulting in three to four harvests each year and, as a result, as a means of income for farmers living in commercial food centers.

Waxy or glutinous corn (*Zea mays* L. var. *ceratina*), one type of natural genetic mutant of vegetable corns, was found in China in 1909. It is commercially grown for sticky taste green corn in Thailand and many countries in Asia (Lertrat & Thongnarin, 2008). It is popular with local people because of its stickiness due to the amylopectin content similar to sticky rice. Glutinous corn is consumed as food at the green corn stage or a feed for livestock (Salazar et al., 2009). Green corn products have long been popular sidewalk snacks like steamed corn, grilled corn, and "Binaki", a sweet delicacy made from corn in Bukidnon, Philippines (Medenilla, 2021). With this information on the varied uses of green corn by-products, there is a need to increase green corn production per unit area.

In optimizing corn yield, it is essential to apply the best practices and better site-specific technologies to achieve a maximum production. The appropriate kind and amount of nutrients and soil conditioning for optimum growth, development, and production is a viable solution. In fertilizer management, organic-based fertilizers are being encouraged due to their benefits on soil properties. The excessive mismanagement of synthetic chemicals such as chemical fertilizers and pesticides degraded the soil over time. The farmers, particularly those from Davao Region, usually provide these nutrients with inorganic fertilizers and insecticides. Philippine Republic Act 10068, otherwise known as the "Organic Agriculture Act of 2010", promotes natural farming technology. This entails all agricultural systems should promote ecologically sound, socially acceptable, economically viable, and technically feasible production. Biofertilizers contain living cells of different microorganisms (Bacteria, Fungi, Actinomycetes, and others), which can fix atmospheric nitrogen and mobilize phosphorous in

the soil from unavailable form to plant usable form (PCCARD 1998). Their mode of action differs and can be used alone or in combinations (Ritika & Utpal, 2014).

Liquid biofertilizers are suspension containing desired microorganisms and special cell protectants or chemicals that enhance the formation of latent spores or cysts for longer shelf life and tolerance to unfavorable environments that are easily handled and applied to seeds or soil (Herrmann & Lesueur, 2013). The advantages of liquid biofertilizers over powder-based are that microorganisms have a longer shelf life of up to 2 years. Generally, they circumvent the effect of high temperature, maintain a high colony-forming unit (CFU) for more than 10^9 ml⁻¹ up to 12 months, and better survive on seeds and soil. In addition, liquid biofertilizers are easy to use, handling, and storage for farmers. The dosage is ten times less than the powder form and can be packed in different volumes and save carrier materials (Verma et al., 2011; Borkar, 2015).

A study of an apple fruit fermentation plus *Bacillus licheniformis* reportedly has increased antioxidant enzyme activities in strawberry seedlings, optimize the status of rhizosphere microbial, and promote plant growth (Zhang et al., 2016). The fermented plant juice study in different durations and concentrations showed no significant effect of duration or concentrations on the weight of marketable plants or plant biomass of leaf mustard (*Brassica juncea* L.). However, a higher ROI and Benefit-Cost Ratio (BCR) noted at a lower concentration of FPJ at 1.5 tbsp L⁻¹ fermented over a 5-day duration (Denona et al., 2020). Moreover, Siti et al. (2017) suggested using both combinations as FPJ water spinach for enhancing the vegetative growth of tomato plants than FPJ bamboo shoots, while FFJ pineapple for better reproductive development of tomato plants rather than FFJ banana for sustainable, eco-friendly agriculture practices.

It has known that organic farming used fermented fruit and plant juices as foliar fertilizers to enhance crop productivity. However, the usage is usually limited to using a single fruit or plant juice fermentation or chemicals and other growth enhancers to combine the same. To our

knowledge, this is the first attempt of using various fruits, plants, fish products, and *Cyanobacteria* with Mycorrhizal fungi combinations to enhance white-glutinous corn for green ear purposes. This study was conducted to determine the effects on single-use of combined fermentation of various plant (FPJ), fruits (FFJ), fishes (FAA), and commercial Bluegreen Algae with Mycorrhizal fungi as foliar with and without NPK on the growth, yield, and profitability of white-glutinous corn under Davao del Norte, Southern Mindanao Region.

Materials and methods

Study site and soil sampling

The experiment was conducted at the University of Southeastern Philippines, Tagum Mabini Campus, Apokon Tagum City (7.4472° N, 125.8093° E), Davao del Norte, Philippines, from 2020 to 2021. Bulk sample from 0-30 cm layer of the soil was collected using soil auger at the experimental area in a zigzag method. The subsamples were air-dried, pulverized using a wooden mallet, and sieved in a 2-mm wire mesh to get the fine soil for nutrient analysis to determine the quantity of NPK, soil pH, and organic matter (OM) at the Department of Agriculture Regional Soils Laboratory, F. Bangoy St., Agdao, Davao City, Philippines.

Experimental design and treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with eight treatments and three replications. It included the combinations of fermented plant juice plus recommended rate of NPK fertilizer (FPJ + NPK), fish amino acid plus recommended rate of fertilizer (FAA + NPK), fermented fruit juice plus recommended rate of fertilizer (FFJ + NPK), commercial biofertilizer Rhizocote plus recommended rate of fertilizer (Rhizocote + NPK), and the four solo foliar biofertilizers FPJ, FAA, FFJ, and Rhizocote. The plot size was 2 m wide and 3 m long with a total area of 6 m². The one-meter alleyway was provided between treatment plots and replication to facilitate farm operations and data gathering.

Composition and preparation of fermented plant juice (FPJ)

The FPJ was composed of three fast-growing plants such as banana, camote, and swamp cabbage. One kilo each of banana pseudo-stem and shoots of camote and swamp cabbage (1:1:1 ratio) were chopped and mixed with 1.5 kg of molasses. The mixture was placed in a plastic container and let ferment. After seven (7) days, the mixture was squeezed and filtered to separate the sludge and put the juices in a clean vessel for future use.

Composition and preparation of fish amino acid (FAA)

Three (3) kilograms of three varied fresh fishes (1:1:1 ratio) were chopped into 1-inch long and mixed with molasses at the standard ratio of 1:0.5. Place the mixture in a plastic container and let it ferment for seven (7) days. Consequently, the mixture was squeezed and filtered to separate the sludge and packed in a clean pot.

Composition and preparation of fermented fruit juice (FFJ)

The fresh fruits of disease-free papaya, banana, and melon were utilized for FFJ. The collected three kilograms of ripe fruits at (1:1:1 ratio) were sliced into cubes then mixed with 1.5 kg of molasses. The mixture was fermented within seven days inside the plastic container, and the resulting mixture was squeezed and strained to separate the juices from sludge and kept in a vessel until used.

Commercial bluegreen algae and mycorrhizal fungi

A commercial biofertilizer (Rhizocote) sourced from a reliable farm supply in the community were utilized in this study. Per product labels, it contains exclusive organic vita-minerals that trigger the multiplication of beneficial native-to-the-soil bluegreen algae and mycorrhizal fungi.

Application of recommended rate of fertilizer and foliar biofertilizers

The recommended NPK fertilizers for T₁, T₂, T₃, and T₄ were based on the soil test results. The application was sidedressing during seven

(7) DAP at the rate of 0.5 – 1 bag ha⁻¹ Urea, 4-8 bags ha⁻¹ of Duofus, 0.75 – 1.5 bags ha⁻¹ of Muriate of Potash (MOP), and 5 kilograms ha⁻¹ zinc sulfate. And follow-up sidedressing of 0.5 – 1 bag ha⁻¹ of Urea was applied on 35 DAP of corn. All the foliar biofertilizers were used two (2) times weekly from 7 to 40 DAP at a rate of one (1) tbsp L⁻¹ water for treatments 1-4 while double doze at two (2) tbsp L⁻¹ water for treatments 5-8. The application was done early in the morning or late in the afternoon where the temperature was low.

Plant growth and yield experiment

Plant height was gathered from 10 representative plants in a plot and was measured from the base up to the flag leaf using a meter stick at 30, 45, and at harvest or 60 DAP. Ear height measurement was measured from the bottom of the nodes where the primary ear is attached using the representative plants from each block (10 plants). Days to tasseling counting started from planting up to 50% of the plants per plot produced the tassels, whereas the days silking were counted from planting to 50% of the plants produced silks. Ten plants per plot were randomly selected in determining the number of ears (green ear) per plot at harvest and consequently measured the ear length (green ear) using meter sticks and ear diameter (green ear) after de-husking using the vernier caliper. Yield traits were determined by weighing the harvested marketable and non-marketable fresh green ears per plot. Those damage-free and possessed a well-developed ear were considered as marketable and non-marketable, otherwise.

Cost and return analysis

The assessment of cost and return was done per treatment to determine the most promising and economically feasible treatment combinations that earned the highest net return. The determination was done by subtracting the total expenses from gross income using the following formula:

$$\text{Net Return} = \text{Gross Income} - \text{Total Expenses}$$

Where: Gross Income = yield that was computed per hectare basis x current price of the crop (PhP kg⁻¹) green ear

Statistical analysis

The data on the growth and yield were subjected to one-way analysis of variance (ANOVA) for a randomized complete block design (RCBD) and the post hoc Tukey HSD test to examine the significant differences between means. In all the tests, the difference between means was deemed significant at $P \leq 0.05$. The statistical analyses were run by SPSS ver 26 software for windows.

Results and discussion

Results

Table 1 presents the plant height of white-glutinous corn applied with different foliar biofertilizers at different growth interval. The result showed no significant difference between treatments at 30 and 60 DAP. At 45 DAP, the tallest plant height was observed in corn fertilized alone with Rhizocote. Days to tasseling of white-glutinous maize plants increased significantly on Rhizocote fertilizer compared with the rest of treatment combination. The rest of the treatments followed with the height ranged from 190.40 cm to 193.87 cm (**Table 2**). White-glutinous corn that was fertilized with Rhizocote + NPK had the most number of ears (1.53). The rest of the treatments yielded comparable number of ear sizes ranging from 1.27 to 1.37 cm (**Table 3**).

There were significant differences among treatment means for harvested green ears (**Table 4**). The highest yield of marketable green ears accounted for 7.45 t ha⁻¹ with Rhizocote + NPK. The lowest yield was observed when the glutinous corn was fertilized alone with FFJ at 2.93 t ha⁻¹. The cost and return analysis of using the different foliar biofertilizers with and without combination with inorganic fertilizer. Rhizocote + NPK obtained the highest R.O.I. of 263.68% compared to FFJ + NPK with 214.25% (**Table 5**).

Discussion

The taller heights of Rhizocote fertilized corn at 45 DAP signified N₂-fixing microorganisms, including *Cyanobacteria* and Mycorrhizal fungi, in the product (Rhizocote). Nitrogen availability plays a vital role during plant growth stages. It is a primary component of many composites necessary for plant growth processes such as chlorophyll formation and cell division. It is also a component of ATP as energy-transfer composites (Asaduzzaman et al., 2014). Additionally, mycorrhizal fungi improve plant growth through increased uptake of relatively immobile nutrients such as P, Zn, Cu, etc. (Tarafdar & Rao, 1997). In general, the glutinous corn fertilized with Rhizocote + NPK was taller than the rest of the fertilizer treatments at 60 DAP (during harvest). The result is likely attributed to the second application of the recommended NPK during 35 DAP of corn. Balanced fertilization improved the assimilation of essential nutrients needed for the food resources allocated to growth, maintenance, and reproduction. The nitrogen that plays an integral component in protein production and chlorophyll influences the plant's ability to produce carbohydrates needed in fruit development, several essential plant structure compounds, and numerous biochemical reactions (Taiz & Zeiger, 2010).

The number of days to tasseling of white-glutinous maize plants was increased significantly on Rhizocote fertilized corn compared to others. The result indicates Rhizocote fertilizer has delayed the corn tassel developments. According to Olowoboko et al. (2017) phosphorus application enhanced the crop to reach 50% tasseling and silking earlier. Phosphorous is an essential component of nucleic acid, phosphorylated sugar, lipids, and protein. It forms phosphate bonds with adenine, guanine, and uridine, which act as carriers for biological processes (Olusegun, 2015). Based on the guaranteed nutrient analysis for the Rhizocote product, it has no P element and probably the reason for the delayed development of corn tassels.

The grain per ear is an essential yield-determining factor in maize (Cheema et al., 2010). Results showed that plants applied with

Rhizocote + NPK and FFJ + NPK contributed to the significant increase in the numbers of ears per plant with a mean average of 1.53 and 1.50 compared with the other treatments (Table 3). The result was expected as the latter (Rhizocote + NPK and FFJ + NPK) treatments generally the taller in plant heights (Table 1). An indication that fruit combination for FFJ or Rhizocote as foliar in association with recommended NPK had sufficient nutrients that can optimize the yield of corn. An adequate amount of N absorbed being a primary constituent of chlorophyll, amino acids, and protein could have promoted satisfactory plant growth, photosynthetic surface, and yield structures. In addition, combination with organic fertilizers has many advantages (Kumar & Bohra, 2014). Significant increase in the corn yield due to the adequate and balanced supply of nutrition at a higher fertility level. Organic fertilizer management also affects the enzymatic activities (Gałazka et al., 2017) and the physical condition of the soil by lowering bulk density, as well as increasing porosity and buffering capacities (Reeve et al., 2016).

The highest yield of marketable green ears reached 7.45 t ha⁻¹ with the application of Rhizocote + NPK. Lowest yield was observed when the glutinous corn was fertilized with FFJ alone at 2.93 t ha⁻¹. In terms of non-marketable yield, an inverse relationship with marketable yield was also observed. All the treatments without the recommended rate of NPK fertilizers had the higher non-marketable green ear yield ranging from 1.03 t ha⁻¹ to 1.08 t ha⁻¹. An adequate quantity of nitrogen is vital for the good growth and development of maize plants. Applying organic fertilizer along with NPK fertilizer was beneficial because it supplemented P and K, added some secondary and micronutrients, and improved the physical and biological characteristics of the soil organic fertilizer. Organic fertilizers offer the biological process necessities of plants and conjointly suppress the plant pests' populations (Farneselli et al., 2018). They increase the rate of microorganism activity in the soil, anion exchange capability, organic matter, and carbon content of the soil (Hosseinzadeh et al., 2016). The high marketable yield of corn caused by the combination of foliar biofertilizer

with inorganic fertilizer could be attributed to the living cells of different types of microorganisms (Vejan et al., 2016). Analysis showed that organic foliar fertilizer alone exerted significant influences on non-marketable yield. As based on the other yield parameters, organic foliar fertilizer alone is not enough to sustain the plant's nutritional status. This implies that crops may suffer initial starvation from nutrient immobilization due to slow reaction organic fertilizer. Consistent with the previous study by the Rohman and Safitri, (2017), the application of organic fertilizer is also a problem due to the slow reaction of organic fertilizer to become available nutrients for the crop to be absorbed. They are also required in large quantities which may not be readily available only in foliar feeding of organic fertilizer (Bhatt et al., 2019).

The results for the cost and return analysis indicate that higher marketable yield and lower non-marketable yield influence the percentage rate of the ROI of each treatment. The increases in yields and yield components due to foliar spraying in maize plants with the highest levels of blue-green algae extract as a new technique in maize fertilization might have been due to its vital effect on increasing the process of cell membrane permeability. The absorption of organic fertilizer was strongly affected by temperature and soil moisture thus nutrients may be released when the plant does not need them. Since it consists only of a limited amount of nutrients, and only a limited amount of organic material is available in many regions and it's generally difficult to meet crop nutrient demands through organic fertilizer alone.

Table 1. Height of white-glutinous corn treated with different foliar biofertilizers

Treatments	Plant height (cm)		
	30 DAP	45 DAP	60 DAP
T ₁ – FPJ + NPK	102.90	193.45 ^b	213.13
T ₂ – FAA + NPK	101.97	193.5 ^b	216.19
T ₃ – FFJ + NPK	101.40	193.87 ^b	216.70
T ₄ – Rhizocote + NPK	101.70	202.43 ^{ab}	219.95
T ₅ – FPJ	109.47	191.37 ^b	206.66
T ₆ – FAA	104.80	191.33 ^b	207.75
T ₇ – FFJ	107.90	190.94 ^b	208.96
T ₈ – Rhizocote	102.97	209.32 ^a	214.83
CV (%)	4.09	3.05	5.72

DAP – days after planting, FPJ – fermented plant juice, FAA – fish amino acid, FFJ – ferment fruit juice. Column means with the same letter are not significant

Table 2. Tasseling and silking of white-glutinous corn treated with different foliar biofertilizers

Treatments	No. of days to tasseling	No. of days to silking
T ₁ – FPJ + NPK	45.67 ^b	47.33
T ₂ – FAA + NPK	45.33 ^b	47.33
T ₃ – FFJ + NPK	46.00 ^b	48.00
T ₄ – Rhizocote + NPK	46.00 ^b	48.00
T ₅ – FPJ	45.33 ^b	47.33
T ₆ – FAA	45.33 ^b	47.33
T ₇ – FFJ	46.00 ^b	48.00
T ₈ – Rhizocote	47.33 ^a	48.00
CV (%)	1.46	1.17

Column means with the same letter are not significant

Table 3. Green ear characteristics of white-glutinous corn treated with different foliar biofertilizers

Treatments	Number of ears	Ear length (cm)	Diameter (cm)
T ₁ – FPJ + NPK	1.33 ^b	16.47	4.13
T ₂ – FAA + NPK	1.27 ^b	17.37	4.20
T ₃ – FFJ + NPK	1.50 ^a	15.80	4.00
T ₄ – Rhizocote + NPK	1.53 ^a	17.07	4.40
T ₅ – FPJ	1.33 ^b	16.40	4.00
T ₆ – FAA	1.27 ^b	15.93	4.07
T ₇ – FFJ	1.37 ^b	16.30	4.20
T ₈ – Rhizocote	1.37 ^b	16.30	4.37
CV (%)	4.80	3.89	5.01

Column means with the same letter are not significant

Table 4. Marketable and non-marketable yield of white-glutinous corn treated with different foliar biofertilizers

Treatments	Yield (t ha ⁻¹)		
	Marketable	Non-marketable	Total yield
T ₁ – FPJ + NPK	6.11 ^b	0.72 ^b	6.83 ^b
T ₂ – FAA + NPK	6.17 ^b	0.69 ^b	6.86 ^b
T ₃ – FFJ + NPK	6.47 ^b	0.73 ^b	7.20 ^b
T ₄ – Rhizocote + NPK	7.45 ^a	0.59 ^c	8.03 ^a
T ₅ – FPJ	3.04 ^d	1.07 ^a	4.11 ^{cd}
T ₆ – FAA	3.27 ^{cd}	1.08 ^a	4.35 ^d
T ₇ – FFJ	2.93 ^d	1.08 ^a	4.01 ^d
T ₈ – Rhizocote	3.86 ^c	1.03 ^a	4.89 ^c
CV (%)	7.32	5.87	7.21

Column means with the same letter are not significant

Table 5. Cost and return analysis of white-glutinous green corn applied alone with foliar biofertilizers alone and with NPK combination (Philippine Peso, PhP)

Treatments	Cost and return analysis			
	Cost of production	Gross income	Net income	ROI (%)
T ₁ – FPJ + NPK	41,184.00	122,311.00	81,127.03	66.32
T ₂ – FAA + NPK	41,184.00	123,377.70	82,193.70	66.61
T ₃ – FFJ + NPK	41,184.00	129,422.10	88,238.14	68.17
T ₄ – Rhizocote + NPK	40,964.00	148,977.70	108,013.70	72.50
T ₅ – FPJ	25,234.00	60,799.96	35,565.96	58.49
T ₆ – FAA	25,234.00	65,422.18	40,188.18	61.42
T ₇ – FFJ	25,234.00	58,666.63	33,432.63	56.98
T ₈ – Rhizocote	25,014.00	77,155.51	52,141.51	67.57

Conclusion

Among the four organic foliar fertilizers tested, the agronomic and yield components of glutinous green corn improved by the

commercial Rhizocote foliar application. The Rhizocote + NPK combination significantly affects the growth and development of green corn, enhancing the agronomic and yield

characteristics and the highest R.O.I. compared with organic foliar fertilizers alone and the rest of the fertilizer combinations in areas of Davao del Norte, Southern Mindanao Philippines.

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Author's declaration and contribution

Authors declared no competing interests. RRA: Conceptualization, design, data gathering, analysis and interpretation of data. ECT: Corresponding author, drafting, and revising the article.

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