ARTICLE

Potential reduction of chemical fertilizer use by applying *Trichoderma* microbial inoculant (TMI) in UPLB Lagkitan variety native corn cropping

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Field trials were conducted for two seasons to evaluate the effects of *Trichoderma* microbial inoculant (TMI) as biofertilizer and biocontrol agent for fall armyworm (FAW- *Spodoptera frugiperda*) in corn. Six treatments with four replicates were arranged in a randomized complete block design. Mean yields during the wet season for T1 (full dose recommendation, chemical fertilizer (CF) and T2 (TMI + ½ recommended rate CF) did not differ significantly at 3.44 t ha^{-1} and 2.94 t ha^{-1}, respectively. Dry season mean yields of T1 and T2 plots were equal. During the wet season, T2 had significantly fewer larvae than T1 and was not significantly different from T5 (full dose CF, insecticide). The damaged hills in T2 were 41% lower than in T1, although this difference was not statistically significant. The chemical insecticide (T5) effectively lowered FAW damage but reduced damage did not increase corn yield. Yield from the dry season was severely reduced at 0.33 t ha^{-1} for T1 due to unfavorable weather conditions. Continuous rain resulted in an average of 4.5 sunshine hours and waterlogged soil conditions. Yield data from dry and wet seasons cropping suggest that TMI has the capability to reduce use of chemical fertilizers in corn. FAW incidence in dry season cropping showed no significant differences among the treatments probably due to extremely low grain yield. Control of FAW using TMI was not conclusively demonstrated although results of the wet season cropping showed TMI potential as a FAW biocontrol agent. These results merit further verification with trials in corn-producing provinces.

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INTRODUCTION

Corn (*Zea mays* L.) is second only to rice as the most valuable crop grown in the country. About 24 million Filipino families rely on corn as a primary source of income (Salvacion et al. 2015). White corn is an important substitute for rice as food, while yellow corn is used in industry and is a primary component of animal feeds for swine, poultry, and prawns. In 2022, the production volume of corn in the Philippines amounted to over eight million metric tons (PSA 2023).

Corn production is challenged by pests and diseases during growth stages affecting its yield. Fall armyworm (*Spodoptera frugiperda* Smith) originated in the Americas and is now a major corn-invasive pest. It is relatively new to the country, with the first report in the Philippines by Navasero et al. (2019) in different municipalities of at least ten provinces. The very first record of incidence was documented at Piat, Cagayan, and it was observed that the pest is damaging only to non-Bt corn. Caasi-Lit and Marmeto (2022) concluded that the Philippine traditional maize remains susceptible to Asian Corn Borer (ACB) and even more to FAW. Their conclusion was based on the results on screening of several traditional maize varieties for resistance to

KEYWORDS

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ACB and FAW through larval survival on laboratory leaf-feeding assay. In addition, FAW was also reported to damage rice seedlings in May 2021 in Gonzaga, Cagayan (Valdez et al. 2023).

Though most small-scale corn farmers in major corn growing areas of the country have adopted hybrid corn farming, they still utilize native or traditional open-pollinated varieties (OPV). Traditional varieties are mainly used as feed for backyard animals and personal consumption due to their good eating quality and low input requirements, such as fertilizer and irrigation (Caasi-Lit and Marmeto 2022). Thus, FAW incidence disproportionately affects small-scale traditional corn farmers.

This study employed an agro-ecological approach (Kenis et al. 2022) and hence, gives importance to sustainable soil fertility management to improve crop vigor and reduce susceptibility to pests and diseases. It also emphasizes using or enhancing populations of natural enemies and promotes biodiversity through non-use of chemical pesticides to provide living space to pest's natural enemies. Compost from corn residues was mixed with chemical fertilizers, and *Trichoderma* microbial inoculant (TMI) was used to replace chemical pesticide and as a biofertilizer.

Biofertilizers are formulations composed of living or latent cells, primarily bacteria or fungi, which are applied either to soil, seed, or seedlings to improve nutrient availability and uptake from soil and improve plant growth development and soil quality (Fasusi et al. 2022). TMI consists of three strains of *Trichoderma,* a naturally occurring soil inhabitant, mixed together in equal proportions. It is sold in 250-g pack; 1 g contains 1.6 x 10^8 colony-forming units (CFU) of *Trichoderma* spp. It is commercially produced by BIOSPARK Corp., UPLB Science Park, College, Laguna, a Filipino company that signed a licensing agreement with the University of the Philippines Los Baños (Cuevas et al., 2012). TMI has been documented as a biofertilizer for rice (Cuevas 2006), as control agent for a variety of soil-borne pathogens in vegetables (Cuevas et al, 2012), effective with salt (NaCl) for coconut rapid recovery from scale infestation and possible control agent of *Brontispa* (Cuevas et al, 2023) and a bioremediation agent (Cuevas and Banaay, 2022).

This study was conducted to test the capability of TMI to reduce the use of chemical fertilizers and to help manage FAW in UPLB Lagkitan corn native variety cropping.

MATERIALS AND METHODS

The wet season (27 April to 28 July 2023) and dry season (03 October 2023 to 04 January 2024) corn cropping were conducted in the Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños experimental field along Pili Drive. A 1000-m^2 corn field was divided into four blocks with 24 plots (2m×5m) at 3m×2m intervals. Each plot was interspaced by parcels of grasses dominated by *Rottboellia cochinchinensis* (itch grass), a possible alternate host of FAW. For each treatment replicate plot, soil cultivation practices were done, and three furrows were made. The test crop was an open-pollinated white glutinous maize variety, LB Lagkitan. DA-ATI CAR (2014) recommended May to June and October to November each year as the best time for planting corn for the wet and dry seasons, respectively. Following this recommendation, planting was done on 27 April 2023 for the wet season and 05 October 2023 for the dry season. Two seeds were sown at 10-cm intervals using a mechanical corn planter when the soil was water-saturated at field capacity. The seedlings per hill were thinned to one plant after 30 days.

TMI and *Trichoderma* activator were purchased from Biospark Corporation, the inoculant manufacturer. The chemical fertilizers used were urea (46-0-0 N) and complete (14-14-14 NPK). Six treatments were used, with different combinations and input rates (Table 1). Plots for the different treatments were arranged in a completely randomized block design (CRBD) with four replicates. Three 1-kg topsoil samples (20 cm deep) were taken at 10-m intervals from each of the imaginary diagonal lines across the experimental field for initial analysis of the fertility status of the area. Samples of corn residues from the previous cropping were analyzed for their nutrient contents. The samples were analyzed at the Agricultural Systems Institute, College of Agriculture and Food Science, UPLB.

Table 1: Treatments, descriptions, and concentration of inputs.

Treatments	Description	Inputs (rate and time of application)				
		TMI	Complete Fertilizer (14-14-14)	Urea (46-0-0)	Compost	Chemical Pesticide
T0	Control (no input)	0	0	0	0	0
T1	Farmer's Practice (full CF, no CP)	0	50 g/plot or 150kg ha^{-1} or 3 bags ha^{-1} at 0 DAP	50g/plot = 150 kg ha^{-1} or 3 bags at 30 DAP	0	0
T2	TMI + 1/2 CF	0.3 g TMI per 10m^2 as seed coating at 0 DAP + 0.3 g TMI per 10m^2 mixed with urea at 30 DAP	25 g/plot or 75 kg ha^{-1} or 1.5 bags ha^{-1} at 0 DAP	25g/plot = 75 kg ha^{-1} or 1.5 bags ha^{-1} at 0 DAP	0	0
T3	TMI + compost + reduced dose CF	0.3 g TMI per 10m^2 as seed coating at 0 DAP + 0.3 g TMI per 10m^2 mixed with urea at 30 DAP	12.5 g/ plot - 37.5 kg ha^{-1} or 0.75 bag ha^{-1} at 0 DAP	25 g/plot = 75 kg ha^{-1} or 1.5 bags ha^{-1} at 30 DAP	8.1 kg 10 m^{-2}	0
T4	TMI + ½ dose urea	0.3 g TMI per 10m^2 as seed coating at 0 DAP + 0.3 g TMI per 10m^2 mixed with urea at 30 DAP	0	25g/plot or 75 kg ha^{-1} or 1.5 bags ha^{-1} at 30 DAP	0	0
T5	Full dose CF + CP	0	50 g/ plot = 150 kg ha^{-1} or 3 bags ha^{-1} at 0 DAP	50 g/plot= 150 kg ha^{-1} or 3 bags at 30 DAP	0	25 mL Prevathon® / 16L water (spray tank), sprayed 7, 14, 21 DAP

Abbreviations: CF – Chemical fertilizer; CP – chemical pesticide; DAP – days after planting; TMI – *Trichoderma* microbial inoculant

The residues were shredded and inoculated with *Trichoderma* activator mixed with urea at the rate of 0.2 g per 1 g activator per 8.1 kg residues. They were placed along the furrows of T3 plots and allowed to decompose in situ for 30 days. This rate of application at 10 m^2 plot was estimated to be roughly 7-8 tons/ha. Thereafter, composite soil samples from T3 plots were taken and analyzed, just before seed sowing.

The number of fall armyworm egg masses, larvae, and damaged hills were observed at 19, 21, 26, 28, 33, 35, and 40 days after planting (DAP) during the wet season cropping. The frequency of monitoring during the dry season cropping was reduced to only 7, 14, and 21 DAP due to extreme weather conditions.

Yield and yield parameters monitored were percent seed germination, number of cobs with complete and incomplete ears and dry weights of kernels. All data collected for corn yield and yield parameters and FAW incidence were subjected to statistical analysis by Multivariate Analysis of Variance (MANOVA). The different parameters to measure FAW pest incidence were correlated with observations at seven monitoring dates DAP and with each other using Spearman's rank correlation.

Weather data such as sunshine hours (SSH) and rainfall for the two cropping periods were sourced from the National Agromet Station (NAS), Agrometeorology, Bio-Structures and Environment Engineering Division, Institute of Agricultural and Biosystems Engineering, College of Engineering and Agro-Industrial Technology, UPLB, located about 1 km from the experimental site.

RESULTS AND DISCUSSION

A. Soil chemical and corn tissue analyses

The soil in the study area had approximately 3% organic matter content at pH 6 (Table 2). The data indicated that the area was fertile. At pH 6-7, most of the essential macronutrients needed by crops are available. Available phosphorus was also sufficient at 14.77 mg-kg^{-1}. However, potassium was deficient, with only 1.32 cmol/kg. Phosphorus and potassium are considered deficient if soils have less than 7 mg-kg^{-1} (PCAARRD 2006). Data from Table 2 show that P is adequate but K is deficient in initial soil samples and that corn tissues contained minimal amounts of N, P and K. Soil analysis after corn compost application in T3 plots revealed that the soil had slightly improved available P from initial, up from 14.77 mg/kg to 29.08 mg/kg, but N and K contents registered minimal change. K addition from compost was not enough to satisfy the total K requirements of corn since the required 7 mg-kg^{-1} was not met. Soil after compost application was still at 2.4 cmol/kg a little higher from 1.32 cmol.kg from initial (Table 2).

Table 2: Soil chemical properties and corn residues nutrient contents.

Type of samples	Parameters analyzed				
	pH	Organic Matter	Nitrogen, N	Phosphorus, P	Potassium, K
Initial soil samples	6.0	2.98%	0.16%	14.77 mg/kg	1.32 cmol/kg
T3 - soil samples after application of corn compost**	6.4	Not analyzed	0.18%	29.08 mg/kg	2.4 cmol/kg
corn tissue samples*	-	Not analyzed	1.087%	0.187%	1.43%

**Mean of 3 replicates; **mean of 2 replicates*

B.1. Corn yield, and yield parameters – wet season and dry season cropping

Productivity was assessed based on per cent seed germination, number of cobs with complete and incomplete ears and dry weights of corn kernels. The data for these parameters for wet and dry seasons cropping are presented in Table 3. Percent germination for wet season was lowest in T5 significantly lower than other treatments but not significantly different from T3. The soil condition where T5 plots were located seemed not conducive to seed germination. But in the dry season cropping treatments did not have significant effect on seed germination since percent germination for all treatments were not significantly different from each other. The average germination of this corn variety for both seasons was about 73%.

Table 3: Corn yield and yield parameters in different treatments in wet (April 27-July 25, 2023) and dry (03 October 2023 - 04 January 2024) seasons cropping

	(%) Germination		Mean number of ears harvested				Mean dry wt of kernels (kg^{-1} $10m^2$)	
			wet		dry			
Treatments	Wet	Dry	Complete	Incomplete	Complete	Incomplete	wet	dry
T0	76.5 a	74.2 a	24.5 bc	29.75 a	1.0 a	7.50 ab	1.05 c	0.188 a
T1	78.0 a	80.1 a	45.75 a	21.5 a	15.5 a	19.75 a	3.44 a	0.338 a
T2	81.0 a	81.6 a	42.75 a	18.75 a	16.0 a	22.50 a	2.94 ab	0.350 a
T3	75.5 a	64.9 a	42.75 abc	20.75 a	8.3 a	5.00 b	2.81 ab	0.087 b
T4	69.5 ab	83.3 a	35.25 bc	16.75 a	10.0 a	8.25 a	2.39 ab	0.100 a
T5	49.8 b	66.8 a	20.5 c	19.75 a	10.0 a	12.00 ab	1.76 bc	0.163 a

*In a column, means followed by a common letter are not significantly different at 5% by Tukey's test. Mean of 4 replicates.

The wet season mean yield (Table 3) measured as corn kernels' dry weight (kg/$10m^2$) in T1 (full dose CF and T2 (TMI, ½ dose CF) plots were not significantly different from each other at 3.44 kg/$10m^2$ and 2.94 kg/$10m^2$, respectively. There was no significant difference also in the number of complete ears between the T1 and T2 treatments. These treatments had the highest yields and significantly higher than those of T3 and T4. Mean yields of T3 (TMI + compost + 25% CF) plots were 2.81 kg/10 m^2, and T4 (TMI + ½ dose urea) 2.39 kg/10 m^2. T4 also had a significantly lower number of cobs with complete ears than T1 and T2. The lower yield in T3 and T4 may be due to inadequate potassium, phosphorus, and nitrogen availability. It was already pointed out in the soil chemical analysis that the soil in the area is deficient in potassium. T4 had only urea as an added chemical fertilizer and, therefore, was deficient in phosphorus. T3 had a 75% reduction in the full dose complete (tri-14) fertilizer application at 0 DAP and, therefore, was also deficient in N. The compost applied in T3 did not completely supply the full amount of nitrogen and potassium elements needed. Although both T3 and T4 had TMI application, *Trichoderma* can enhance nutrient uptake but cannot increase nutrient supply. T0 (control) had the lowest yield, as expected. T5 and T0 had the lowest dry weight of corn kernels. They had the lowest number of cobs with complete ears. T5 had full dose CF and with chemical pesticide and therefore was expected to have yield even higher than T1. The low seed germination in this treatment may have affected the low productivity in the plots since there was a lower number of plants that bore fruits. No investigation was done to explain the low seed germination rate.

T1 yield at 3.44 kg 10 m^2 (3.44 t ha^{-1}) was within the range for the LB Lagkitan variety as affected by the prevailing climatic factors during the growing period, as reported by Anuada et al. (2021). There were no significant differences among treatments on the number of cobs with incomplete ears. It seems that the production of cobs with incomplete ears may be due to some other factors not covered in this study.

Yield from the dry season cropping was extremely low. T1 yield at 0. 337 kg/10 m^2 was only 10% of the yield from 1st season cropping at 3.44 kg/10 m^2 shown in Table 2. Yield of T2 at 0. 350 kg/10 m^2 was equal to that of T1. Similar to the data during the wet season, the mean number of cobs with complete and incomplete ears for the two treatments were not significantly different from each other. These set of data for wet and dry seasons cropping on yield and yield parameters seemed to indicate that TMI may have the capability to lower the use of chemical fertilizers in native corn cropping without sacrificing yield. In all treatments the number of cobs produced was also severely reduced. There were more cobs with incomplete ears than cobs with complete ears. Such low yield was due to the prevailing weather conditions during the crop's vegetative growth, flowering, and grain-filling stages.

B.2 Weather conditions during the wet and dry seasons cropping and its impact on corn grain yields

Simon et al. (2023) stated that the yield potential and quality of corn are correlated and strongly influenced by environmental factors such as solar radiation, total rainfall, and water storage in the soil. These are then highly influenced by weather effects. The impacts of these environmental factors are related to the different stages of the crop's growth. Thus, to clearly explain the corn yields attained in two cropping seasons, the number of minutes of sunshine duration and the average sunshine hours (SSH) and rainfall during the cropping periods are presented in Figures 1-4.

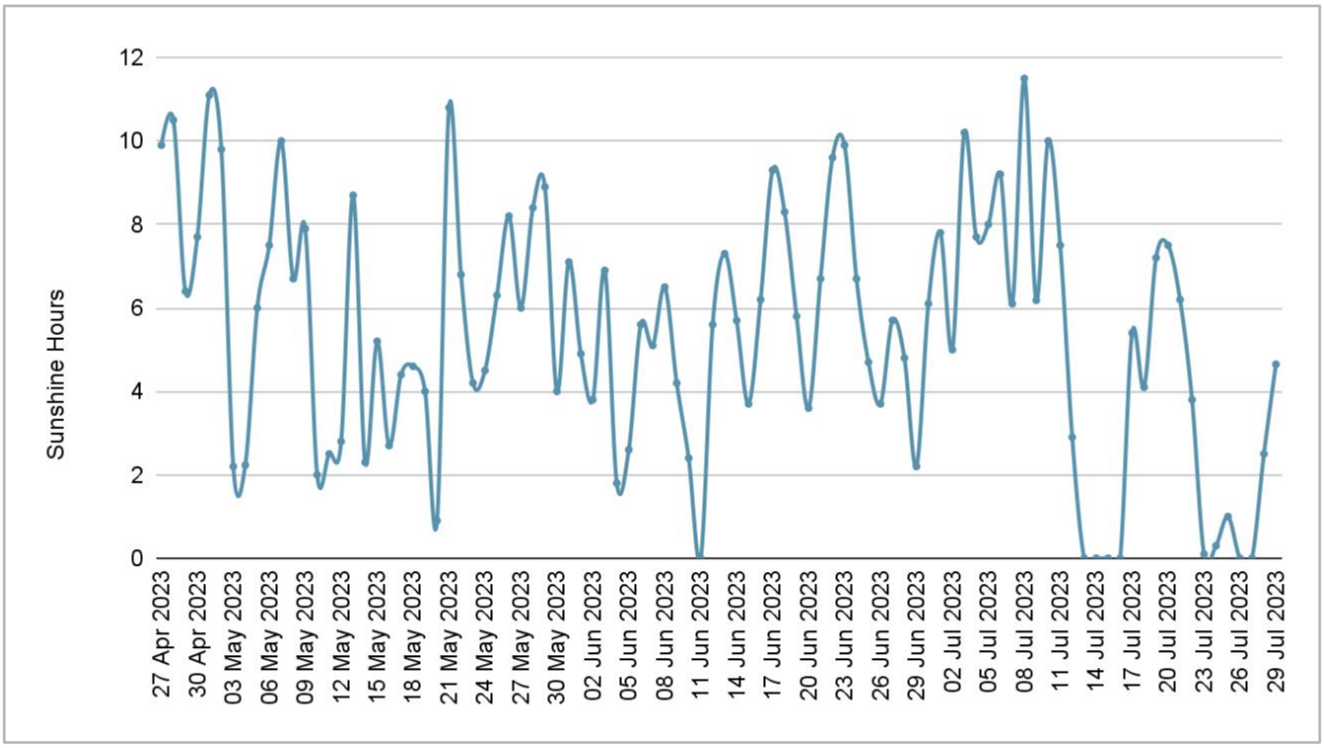

Figure 1: Daily sunshine hours during the wet season trial (April to July 2023).

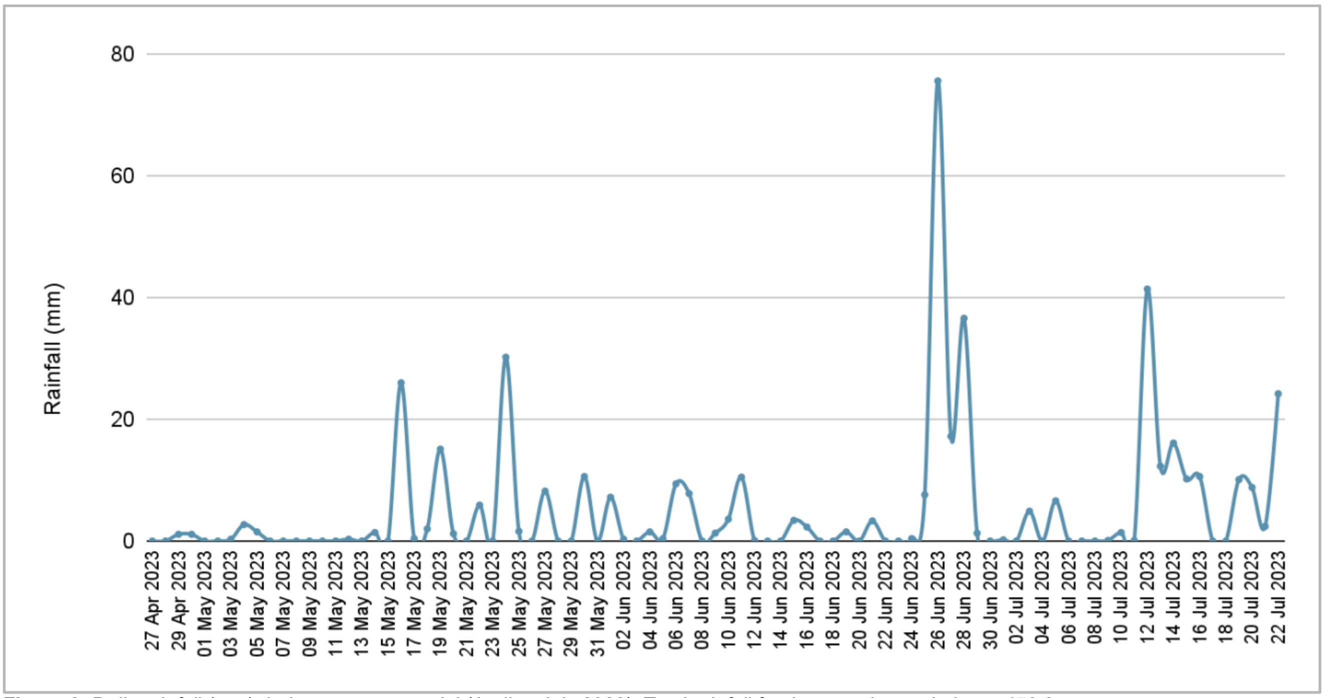

Figure 2: Daily rainfall (mm) during wet season trial (April to July 2023). Total rainfall for the cropping period was 450.3 mm.

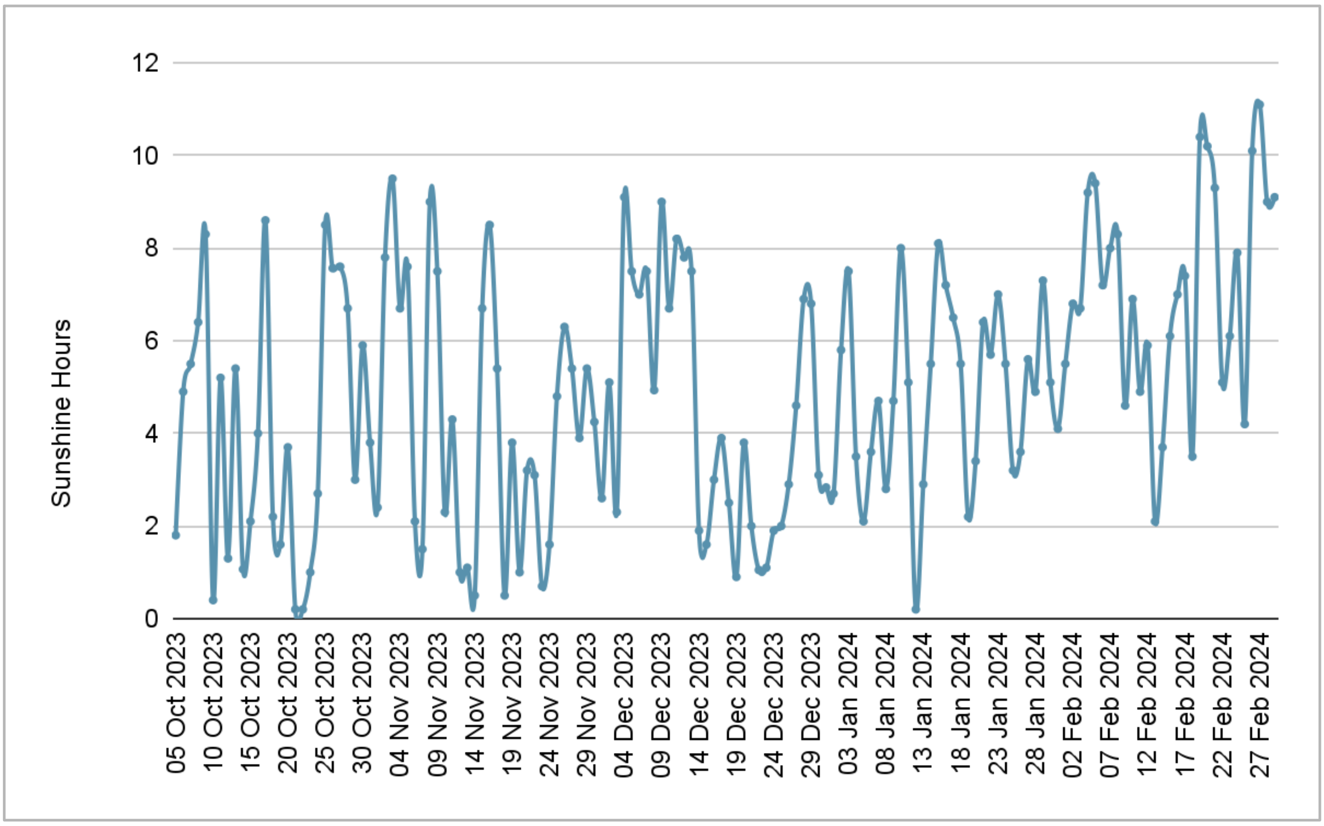

Figure 3: Daily sunshine hours during the dry season trial (October 2023 to January 2024).

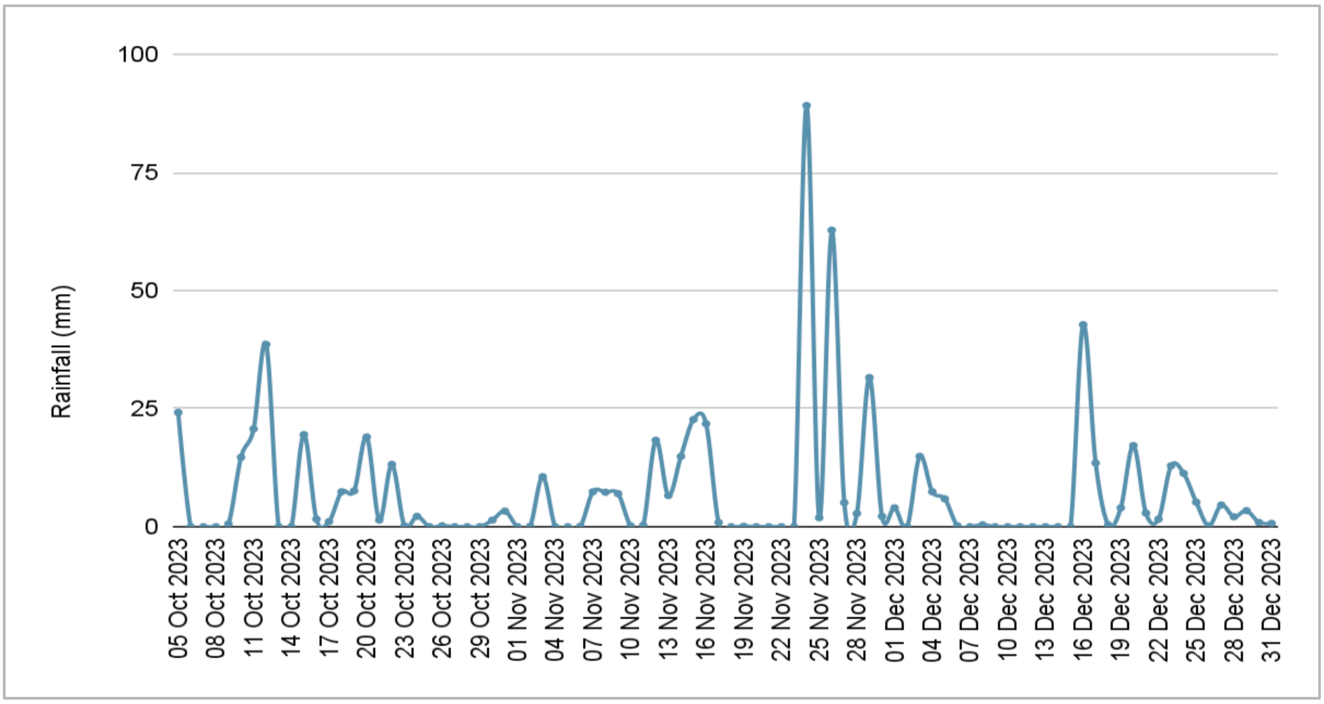

Figure 4: Daily rainfall (mm) during dry season trial (October 2023 to January 2024). Total rainfall for the cropping period was 649.2 mm.

B.3. Sunshine hours

EOS Data Analytics (2024) stated that corn plants require a minimum of 6–8 hours of sunlight (SSH) daily. The corn crops did not meet the light requirement (Figures 1 & 3). It was only on April 27-30, 2023, four days germination period for wet season cropping, and on Jan 1-4, 2024, four days grain filling stage, that crop had an average of 8.6 SSH and 7.8 SSH, respectively. For all the rest of the cropping periods, the crop received below minimum SSH. During the wet season cropping, the average SSH was 5.23 (May- July 2023), while the average SSH was 4.09 during the dry season. Los Baños belongs to the Type IV climate (UPLB National Agromet Station), where rainfall is more or less evenly distributed throughout the year. Anuada et al. (2021) stated that the effect of the environment on the grain yield of the LB Lagkitan variety was apparent under Type IV climate. The best yield for LB Lagkitan was attained in Maria Aurora, Aurora in Luzon (Type IV climate) at 4.6 t ha^{-1} where the variety is specifically adapted. However, in Zamboanga del Norte, Mindanao (Type IV climate), this variety had only 2.8 t ha^{-1}. Thus, T1 at 3.4 t ha^{-1} yield during the wet season was within the yield range registered for this variety.

T1 yield during the dry season cropping (October to January 2024) was extremely low at 0.344 t ha^{-1}. Very low radiation inputs due to thick cloud cover, high rainfall, and water-logged conditions severely affected grain production. Total rainfall for the dry cropping period at 649.2 mm was 30% higher than the wet season cropping at 450.3 mm (Figures 2 and 4). Anuada et al. (2021) indicated that undependable weather in terms of the onset of the rainy season and the amount of rainfall and its distribution during the corn growing period limits the yield of corn below the potential.

Solar radiation is an important climatic factor for crop growth as it is the main energy source for photosynthesis, producing carbohydrates used for plant development and grain production. Solar radiation inputs in agriculture are expressed as sunshine hours (SSH), as its duration per day directly affects crop production. Corn is a sun-loving plant that grows well without shade and needs at least 6-8 SSH. Sufficient solar radiation is critical during the early vegetative phase (about three weeks after seed sowing) since maize develops roots in the early seedling stage, and growth of maize roots is very sensitive to the external environment. During this period, less photosynthesis leads to a decrease in root mass, hindering the development of aboveground biomass during the later growth period due to weaker water and nutrient absorption. The increase in cloud cover was most likely a strong reason for the SSH decline. On average, the decline in SSH reduced the maize yield by 8% (Song & Jin, 2020). During the wet season, the average SSH was only 5.23. This could explain the lower T1 yield of 3.44 t ha^{-1} than the potential yield of 4.6 tons ha^{-1} (Anuada et al. 2021).

Simon et al. (2023) stated that the decrease in the hours of sunshine is an important problem because during the pre-blooming period of corn, 7-8 weeks after seed sowing, insufficient light can lead to disturbances in the formation of its reproductive organs. Low solar radiation affects yield most during silking, 9-10 weeks after seed sowing, and grain-fill periods (Golden Harvest Technical Bulletin 2019). Liu & Tollenaar (2009) found that shading of corn during silking stage that removes 50% solar radiation reduced yield by 12-20% and by 19-21% when shaded during grain fill.

As shown in Figure 3, there was cloud cover on most days of the dry season cropping period in the study site. The average SSH for the whole cropping period is only about 4 hours. As stated above, the minimum SSH is 6 hours for vegetative and reproductive growth to have a good crop yield. Thus, reduced solar radiation is one factor that caused the low yield observed.

B.4. Rainfall and waterlogging

Water logging results from successive rain events, and the soil becomes supersaturated with water. The total rainfall of 649.2 mm was monitored for the whole dry season 2 - 3 month cropping period, with the highest rainfall in November 2023 (Figure 4). As shown in the Figure, there were more rainy days than no rainy days during this period. Most of the time, thick cloud cover decreased SSH (Figure 3). Thus, with more rainy than sunny days, the soil in the study area was waterlogged.

Chao et al. (2022) explained that under this condition, excess water saturates the soil pores, so there is a rapid decrease in oxygen levels in the root zone, resulting in an anaerobic situation. Such an event could lead to the inhibition of root respiration and the activities of aerobic soil microorganisms. This may result in stomatal closure, transpiration and photosynthetic rates, and crop yield reduction. They observed that both leaf area index

(LAI) and chlorophyll content index (CCI) were significantly decreased after waterlogging, of which reduction induced by waterlogging resulted in the decrease of leaf effective photosynthetic area, which led to the disturbance of dry matter accumulation, and ultimately led to decreased yields.

These researchers also observed that waterlogging lasting seven days markedly limited stomatal conductance and intercellular CO2 concentration in maize leaves, decreased photosynthetic rate by 15.4% compared with the non-stress treatment, and reduced crop grain yields. Their study showed that when waterlogging at the vegetative stage was over four days, the grain number per ear began to decrease, and a loss of 67.1% of grain dry weights was observed. They concluded that 6^{th} leaf stage (5 weeks after seed sowing) had the greatest effect on maize growth. With rainfall events (Figure 4), there was a high probability of a waterlogged situation in the study area, which heavily affected pollination and grain filling of the kernels.

Walne and Reddy (2021) observed that when waterlogging days were imposed at different intervals during the vegetative period, especially at V2 (two-leaf stage), whole-plant dry weight declined as waterlogging duration increased by as much as 27-44%. Leaf area and root volume also showed exponential decay. Root forks were the most sensitive parameter, declining by 83% and 80% in both experiments after 14 days of waterlogging.

B.5. Pollination effects

Kruger seeds communication post (2023) stated that pollination impacts corn yield potential most. Pollination requires dry conditions. Taylor (2013) reported that the tassels do not release pollen as long as they remain wet. Pollen is produced daily when the tassel is dry and can continue for 10 – 14 days with a peak pollen drop on the 3^{rd} day. Cloudy and humid conditions delay pollen shed and will not occur during rainy conditions. Prolonged periods of moisture will delay pollen drop and lead to excessive silk growth, making it difficult for pollen to reach each silk. Thus, prolonged wet conditions during the silking and pollination period result in the non-formation of grains, producing ears with no kernels. Thus, it was concluded that VT – tassel-producing stage is a critical period where successful pollination is required to convert potential kernels into viable seeds. This VT stage occurred in the study from approximately November 25 – December 5, 2023. Heavy rains (Figure 3) in the study area severely affect pollination. This phenomenon was the primary contributor to the lower number of cobs produced and many cobs with incomplete ears that did not develop grains. Correspondingly, a very low yield was observed.

B.6. Combined climatic effects

The observed very low grain yield at season dry season cropping resulted from several climatic factors. One important factor was the low SSH throughout the vegetative and reproductive phases of growth. The required SSH was attained only three days before harvest time. Low solar radiation inputs resulted in a low photosynthesis rate and poor crop growth. Heavy rainfall during this period was 30% higher than wet season cropping. The wet conditions, especially during the silking and pollination periods, severely inhibited grain formation due to non-pollination. The soil in the study site was observed to be waterlogged due to heavy rains, which affected root growth and development as well as root respiration. Combining all these three factors affected the critical stages of corn growth and development and resulted in very low grain yield. All these factors contributed to a 90% yield reduction compared to wet season cropping.

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) is the government's National Meteorological and Hydrological Services agency. Its El Niño Advisory stated that El Niño was ongoing from June 2023 and predicted to continue through January-February 2024. November and December 2023 assessments reported way below to below normal rainfall conditions experienced in most parts of Northern and Central Luzon, Metro Manila, Cavite, Rizal, Occidental Mindoro, Palawan, and a few provinces in Visayas and Mindanao (NDRRMC 2024). Despite this prediction, Los Baños received heavy rainfall during the stated period which was contrary to PAGASA's prediction. Our study showed that considerable variability exists and local weather stations should be the farmers' information source.

Wet season yields in T1 (full dose CF) and T2 (TMI, ½ dose CF) plots were not significantly different, showing that TMI can help reduce the use of chemical fertilizer without sacrificing yield. T1 and T2 yields during the dry season cropping were almost equal. Harman et al. (2004) stated that *Trichoderma* spp. increase crop uptake and concentration of micronutrients and phosphorus, resulting in increased growth. In corn these researchers observed that *Trichoderma harzianum* T22 treated seeds have maximum yield with as much as 40% less nitrogen-containing fertilizer than similar plants not treated with the fungus. Cuevas (2006) reported that rice inoculated by *Trichoderma pseudokoningii* had higher yield than untreated plants and greater uptake of P and Zn. Tomato plants treated with the fungus had higher uptake of P, K, Ca, Zn, and Fe, which resulted in higher dry matter production, early flowering, and better fruit production. Our data therefore show that TMI has the potential to reduce the use of chemical fertilizers in Lagkitan native corn variety cropping.

C. Incidence of fall armyworm pest (FAW) – wet and dry seasons cropping

Fall armyworm causes serious leaf-feeding damage, reducing photosynthetic area and causing direct injury to the ear, which directly affects grain formation and, consequently, yield. The incidence of FAW was assessed in terms of the number of egg masses, number of larvae, and number of damaged hills observed at the different treatment plots at 19, 21, 26, 28. 33, 35, 40 days after planting. The observation period corresponded to the stages of heavy damage to the crop. In as much as the number of egg masses, number of larvae, and number of damaged hills were not correlated with sampling dates, the average larval densities for the seven sampling dates was statistically analyzed by MANOVA (Table 4).

Table 4: Fall armyworm densities by treatment (mean of seven sampling dates) – wet season cropping.

Treatment	Egg masses	Larvae	Damaged hills
T0	2.43 a	24 ab	74 bc
T1	3.29 a	54 c	112 c
T2	2.14 a	21 ab	66 bc
T3	5.29 a	28 b	82 bc
T4	1.71 a	19 ab	60 bc
T5	1.43 a	11 a	29 a
F(5,30)=	1.26	11	20
p-value=	0.309	<.001	<.001

*In a column, means followed by a common letter are not significantly different at 5% by Tukey's test. Mean of 4 replicates.

The mean number of egg masses observed at different treatments was not significantly different from each treatment. However, T1 (FP- full dose CF, 0 CP) had the highest number of larvae and damaged hills observed, which is significantly the highest compared to the other treatments. T1 also registered the highest number of damaged hills, but not significantly different from T0, T2, T3, and T4. T5 (full dose CF and pesticide Prevathon®) registered the least number of larvae and number of damaged hills, significantly lower than those from other treatments. The number of larvae in T5, though significantly lower than T1 was not significantly different from all TMI treatments (T2, T3 and T4). These data tended to indicate that TMI has similar control effect as that of chemical insecticide Prevathon® (in T5).

The data tend to show that the chemical pesticide, Prevathon®, effectively manages the FAW population (Table 5). Though the difference is not statistically significant, T5 registered the lowest number of egg masses among the treatments. Similarly, T5 registered the least number of larvae and number of damaged hills. The number of larvae, damaged hill, and DAP are significantly and positively correlated by Spearman's rank correlation (α = 0.05). The number of larvae was highly correlated to the number of damaged hills (α = 0.01), which means that the more larvae present, the more hills were damaged. Thus, with a low number of egg masses, fewer larvae were observed, resulting in lesser number of damaged hills (Figures 5a-b).

Table 5: Spearman's Correlations (rho) among different yield parameters monitored during dry season cropping and FAW damaged at 7, 14, 21 days after planting.

Variable	%Germination	Ears_Complete	Ears_Incomplete	Dry_wt	7DAP_dmg_hills	14DAP_dmg_hills	21DAP_dmg_hills	14DAP_FAW_larvae
Ears_Complete	0.359	—						
Ears_Incomplete	0.402	0.552 **	—					
Dry_wt	0.311	0.486 *	0.907 ***	—				
7DAP_dmg_hills	0.193	0.093	0.2	0.149	—			
14DAP_dmg_hills	0.121	0.298	0.436 *	0.388	0.327	—		
21DAP_dmg_hills	0.533 **	0.533 **	0.586 **	0.492 *	0.268	0.574 **	—	
14DAP_FAW_larvae	0.037	-0.169	-0.015	-0.111	0.167	0.141	0.366	—
21DAP_FAW_larvae	-0.208	-0.308	-0.045	-0.028	-0.083	0.142	0.242	0.508 *

* p < .05, ** p < .01, *** p < .001

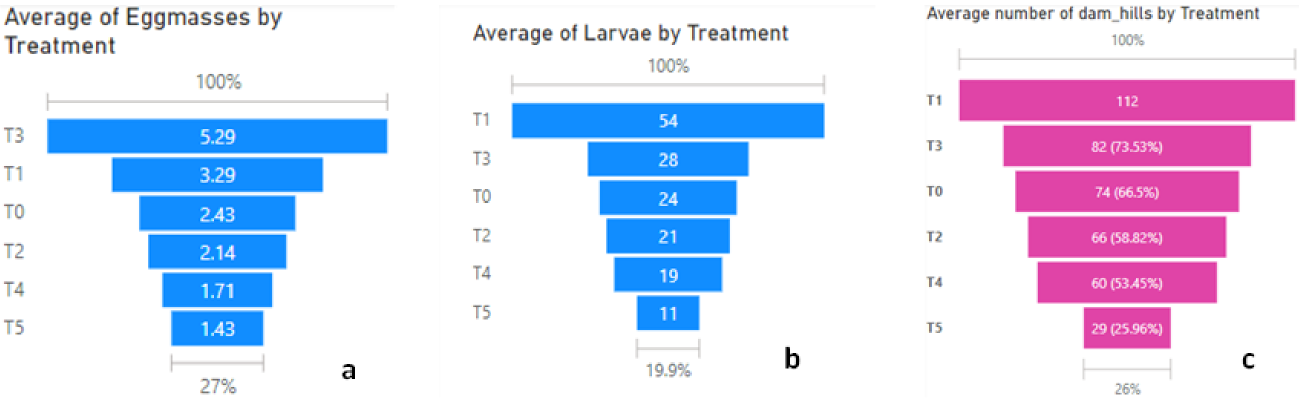

Figure 5: Average number of fall armyworm (a) egg masses, (b) larvae, and (c) damaged hills of corn plant per treatment in seven observation periods.

Unfortunately, the effective control of FAW by Prevathon® in T5 was not reflected on the yield data on this treatment. The mean dry weight of corn kernels in this treatment was not significantly different from that of T0- 0 inputs). T5 also had the 2nd lowest mean dry weight of corn ears among the treatments, with T0 having the lowest weight. There seemed to be some factors affecting the germination and growth of the crop in the particular site of T5 plots, which were not noticed during the study.

It seems that the inoculation of *Trichoderma* can exert some degree of control over FAW. T2 (TMI, ½ dose CF) has a significantly lower number of larvae than T1- (FP- full dose CF) and is not significantly different from T5 (full dose CF, CP), as shown in Table 4. This observation is significant since T5 has chemical insecticide treatment, while T2 has TMI as control agent. However, in terms of the number of damaged hills, T2 was not significantly different from T1, though the number of damaged hills in T2 was 41% lower than T1. T3 had highest number of egg masses (5.29 – considered as 100%) while T5 has the least (1.43) which is only 27% of T3. These differences are not statistically significant (Table 4). The trend of parameters measured to assess FAW incidence is best depicted by Powell's B_i, as shown in Figures 5a-c.

The trend of damaged hills by treatment closely follows the pattern of the larvae. T5 resulted in significantly the fewest larvae and damaged hills (20% and 26% of T1, for larvae and damaged hills, respectively). In all parameters monitored for FAW incidence, T1 has a higher magnitude than T2, indicating that TMI can control FAW incidence.

Unfavorable weather conditions prevailed in dry season cropping, making sampling difficult. Thus, FAW was monitored only for the number of larvae and the number of damaged hills at 7, 14, and 21 days after planting (DAP). These data were already sufficient to assess the extent of pest damage affected by the different treatments. The data on the mean number of pest larvae and the number of damaged hills in the different treatments on these three sampling dates showed no significant differences among treatments by ANOVA by Tukey's test. However, FAW damage hills at 21 DAP was significantly and positively correlated with % germination, number of ears (complete and incomplete), and dry weight of kernels. FAW larvae at 14 and 21 DAP were positively correlated. Dry weight was positively correlated with number of ears. The more ears (complete or incomplete), the heavier the dry weight and the more FAW damage at 21 DAP. Spearman's correlation was used as a test parameter. Data on correlation is presented in Table 5. Therefore, it was observed that despite unfavorable weather conditions, FAW is still a serious threat.

Wet season data tend to show that *Trichoderma* inoculation can possibly control FAW. T2 had a significantly lower number of larval pests than T1, but was not significantly different from T5 -with chemical control (Table 5). The number of damaged hills in T2 was also 41% lower than in T1, though the difference was insignificant. Figure 5 shows that in all parameters monitored, T1 has a higher magnitude of FAW incidence than T2, indicating that TMI can exert some degree of control on FAW. Data for dry season cropping did not show the control effect of TMI on FAW probably because of abnormal weather conditions heavily affecting growth and development of the corn plants.

TMI with salt combination was reported to be a possible control agent of *Brontispa longissima,* a beetle feeding on young coconut leaves. The combination also assisted in the early recovery of coconut trees from the rigid coconut scale insect (*Aspidiotus rigidus*) infestation (Cuevas et al, 2023). Though the molecular mechanisms of the biocontrol was not explored in this study in coconut, the possibility that it is similar to the biocontrol of another leaf-eating insect is high. Silva et al, (2019) has shown that *Trichoderma* inoculation was able to protect lanzones (*Lansium domesticum*) seedlings from damaging levels of lanzones scale insect (*Unaspis mabilis)* infestation in the leaves even if it was inoculated only in the roots. Their study showed that the concentrations of jasmonic acid (JA) and salicylic acid (SA) in scale-insect-infested lanzones seedlings were found to be influenced by the inoculation of the plants with *Trichoderma*. TMI was able to fine tune the levels of Jasmonic and salicyclic acid in the leaves to make it more effective in overcoming the decoy defense of the scale insect. JA and SA are known defense chemicals of plants against herbivores whose production is enhanced by *Trichoderma* through a process known as induced systemic resistance (Contreras-Cornejo et al., 2018). In this present study, corn's poor growth and development during the dry season cropping probably hindered TMI from inducing defense mechanism against FAW similar to what was observed during the wet season, thus no control of FAW by TMI was observed.

Researchers from other countries reported that *Trichoderma* species is a potential biocontrol agent of FAW. Afandhi et al. (2022) reported that in Indonesia *Trichoderma asperellum* caused 81% mortality at a 10-day post-treatment assay on FAW larvae. Contreras-Cornejo et al. (2018) stated that *T. atroviride*, increases the parasitism rate of the FAW by its natural enemy, *Campoletis sonorensis.* They recommended using a combination of *T. atroviride* and *C. sonorensis* for the biocontrol of *S. frugiperda* as an alternative to using chemical insecticides. Macias-Rodriguez (2022) described *Trichoderma* spp. interact at multi-trophic levels, although they are universal saprotrophic fungi in terrestrial ecosystems.

CONCLUSION

Field trials on the effect of *Trichoderma* microbial inoculum (TMI) on corn yield and FAW incidence were conducted for wet and dry seasons 2023-2024. Traditional corn variety LB Lagkitan was used as a test crop. The study results indicated that TMI has the potential to reduce the use of chemical fertilizer by as much as 50% without sacrificing yield. Compost application did not reduce the use of chemical fertilizers, probably because compost nutrient contents were low. Wet season cropping data tend to show that TMI may have the potential to control FAW infestation. These results warrant further validation in the country's top corn-producing provinces.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

VCCuevas, MTCaasi-Lit, and ILLitJr. conceptualized and designed the experiment and wrote the manuscript. AMDMamerto, BBPanabang, and WJCMarasigan assisted with experimental site preparation, FAW data collection, and wrote parts of the manuscript.

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