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Effect of Varying Levels of Fortified Bio-organic Fertilizer (Rabbit Manure + *Trichoderma* spp.) on the Growth and Yield of Taiwan Chili Pepper (*Capsicum capsici*)

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ABSTRACT

Purpose: *Agricultural wastes such as animal manure and dried leaves, when completely decomposed, is a great source of organic fertilizer for crops. This study demonstrated the potential of agricultural wastes as compost activated by the fungus Trichoderma spp, applied as bio-organic fertilizer in the growth and yield of Taiwan chili pepper.*

Research Method: *The experimental treatments were designed as fertilizer increments (negative, recommended inorganic fertilizer, 600g, 900g, 1200g) in Randomized Complete Block Design (RCBD). The fortified bio-organic fertilizer (FBOF) was a 180-day-old rabbit manure + Trichoderma spp. mixed with lactic acid bacteria solution, banana peels, and madre de cacao leaves (Gliricidia sepium). Growth and yield parameters were recorded. Preliminary changes in the physicochemical condition of the soil were also recorded.*

Findings: *The application of varying levels of FBOF resulted in a significant plant height increase from the day of transplanting until 80 days after transplanting (DAT). Overall, treatments with varying levels of FBOF obtained more branches than the recommended inorganic fertilizer treatment. Early flowering, early fruit development, and early fruit ripening were also exhibited by the Taiwan chili pepper applied with 600g of FBOF. The yields of the FBOF increments further provided significantly higher yields than the recommended inorganic fertilizer.*

Research Limitations: *The present study focused on the growth and yield of the Taiwan chili pepper. A preliminary test on the soil profile post-application was done and further analysis is needed to investigate the impact of the FBOF on soil characteristics.*

Originality/Value: *This is the first report on the synergistic influence of rabbit manure decomposed by Trichoderma spp. as a bio-organic fertilizer applied to the Taiwan chili pepper, considered a high-value crop in the Philippines.*

Keywords: *beneficial fungi, high-value crop, organic agriculture, soil fertility*

INTRODUCTION

The continuous popularity of red-hot pepper F1, or Taiwan chili pepper, among vegetable farmers in the Philippines is mainly due to its economic value and relatively stable and growing demand. According to the Food and Agriculture Organization (FAO, 2020), the Philippines is an emerging producer of pepper globally, producing around 15 MT/ha as of 2017. In the Philippines, several types of chili peppers are commonly grown and contribute to the spice palette of Filipino cuisine.

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One of these is the Taiwan chili pepper, locally known as *"Siling Tingala"* and often sold as *"Siling Labuyo"* due to their similar appearance. Taiwan chili pepper is a hybrid of *Capsicum frutescens* and *Capsicum annuum* (San Jose, 2021). It is a highly branched solanaceous plant with fruit reaching up to two centimeters in length. Nowadays, Taiwan chili pepper is one of the major sources of spices and ingredients for many food products. With the country becoming a leading global producer of chili, there is a growing need to sustain its production. However, reliance on inorganic fertilization has detrimental consequences for the environment. Organic farming practices, to a certain extent, may offer advantages in mitigating the declining health of the environment, particularly soil degradation.

While the agricultural sector in the Philippines has provided many services and opportunities—including livelihood and food production—the extensive use of chemical fertilizers has led to a decline in soil fertility.

Bio-organic fertilizers are becoming increasingly popular in many countries. A bio-fertilizer can either be utilized directly as a fertilizer or as a soil amendment, depending on its effect on plant nutrition. A fertilizer is a ready source of quickly available nutrients with immediate, short-term effects on plant growth, while a soil amendment indirectly influences plant growth by enhancing the physical and biological properties of the soil(Angelova *et al.*, 2013). Bio-organic fertilizer is an essential component of organic farming and plays a vital role in maintaining long-term soil fertility and sustainability. It is also crucial for environmental protection, serving as an eco-friendly and cost-effective input for farmers(Kumar, 2021). Additionally, *Trichoderma* spp. have been identified and well characterized as decomposer fungi with saprophytic nature. *Trichoderma* spp. provide free organic matter, especially in compost production(Badaluddin and Zin, 2020).

Recently, many studies have focused on the development of agro-waste-based bio-fertilizers. Bio-fertilizers are derivatives of agricultural waste such as manure, husks, leafy vegetables, and fruits residues, etc., broken down by bio-decomposers (microorganisms) and are also known as recycled products containing, basic and secondary nutrients (Thaha *et al.*, 2020). Rabbit manure is one agro-waste, produced at an increasing rate since rabbit production for food purposes is becoming popular in the country as an alternative to pork as promoted by the Philippines's Department of Agriculture (Celes-Bejarin, 2021).

Thus, the study aimed to measure the growth and yield response of the Taiwan chili pepper using bio fertilizers prepared from local agricultural wastes. Also, the foregoing study assessed the short-term influence of bio fertilizers on soil fertility.

MATERIALS AND METHODS

Collection of the Materials

The researchers gathered and purchased all the materials required for the experiment from a local agricultural supply store in San Ildefonso, Bulacan. Rabbit manure was collected from the rabbit production facility of the College of Agriculture, Bulacan Agricultural State College (BASC) at Poblacion, San Ildefonso, Bulacan. Partially decomposed banana peels were collected from banana vendors in Camias, San Miguel, Bulacan, while madre de cacao leaves were gathered from different barangays in San Ildefonso and San Miguel, Bulacan. The lactic acid bacteria solution (EM-1) was purchased locally, and the homogenous powder form of *Trichoderma* spp. (BioQuick) was sourced from the University of the Philippines Los Baños (UPLB-NIMBB).

Land Preparation

The study was conducted at Net House 6, College of Agriculture, Bulacan Agricultural State College (coordinates: 15° 4' 47.586", 120° 56' 53.8404"). The land was cultivated, and weeds were manually removed before laying black plastic mulch. Land preparation, crop establishment, maintenance, and all agronomic practices were done according to the chili manual production of Cultivation New Frontiers in Agriculture (CNFA, 2014). Deep tillage was performed to a depth of 30–45 cm, and large soil clods were crushed to facilitate better root growth. The area (132 m^2, 22 m × 6 m) was divided into three blocks with five plots each, making a total of 15 plots, each measuring 1 m × 3.5 m. Five (5) treatments namely: T1 negative control, T2 – positive control (synthetic fertilizer), T3 – 600 g of FBOF, T4 – 900 g of FBOF, and T5 –1200 g FBOF were established in the field with Randomized Complete Block Design (RCBD).

Seedling Preparation of Taiwan Chili Pepper

The seeds were germinated in seedling trays within 30 days based on farmers' practices, and the temperature ranged between 27–32 °C was maintained to ensure that the seedlings would be vigorous, and stems hardened enough. Vermicompost mixed with coco peat in a 1:1 ratio was used as the germination media as adopted from vegetable growers' practice. If some seeds did not grow, it was recorded as the data of mortality rate and replanted only within 7 days. Any incurred mortality 30 days after sowing (DAS) was recorded as the mortality rate. To compute the data on the mortality rate, the number of dead seeds will be divided into the number of seedlings multiplied by 100. One seedling per hill was transplanted 31 days after sowing (DAS) at a distance of 60 cm between rows and 50 cm between plants.

Soil Sampling and Analysis

Soil samples were collected from the net house 6 using the method of Imakumbili (2019) with some modifications. All the samples collected were mixed thoroughly until a bulk sample was produced. A 2kg soil sample was collected. This collected sample was air-dried and sieved before submission to the Department of Agriculture-Regional Soils Laboratory for analysis. The analysis was done before the establishment of the experiment and after the termination of the experiment. The tested soil parameters include total nitrogen, total phosphorus, organic carbon, organic matter, pH, and trace elements (Zn, Mg, Cu, Mn). Methods of testing followed the standards of the Association of Analytical Chemists (AOAC, 2005).

Preparation of Fortified Bio-Organic Fertilizer

To fortify, the pre-produced BOF (180 days old) was mixed with different types of agricultural wastes like banana peels (partially decomposed) and madre de cacao leaves with a ratio of 1:1:1. The procedures of Savala et al. (2003) were adopted with modifications. The materials such as banana peels and leaves of Madre de cacao were chopped into desirable sizes to break down quickly. The chopped banana peels and madre de cacao were mixed with the BOF thoroughly. Once completely mixed, the lactic acid bacteria solution (EM-1) was applied gradually while combining the materials to ensure effectiveness, and every 10mL of EMAS was added to 1 L of water. The moisture content of the FBOF was checked by molding the sample of FBOF and squeezing it by the hand; if there is no water left on the hand, it means the moisture content is around 30 to 40%. It was turned every week and allowed to fully decompose for 30 days before storing it in a sack and placed in a fully shaded room at ambient temperature.

Application of Fortified Bio-Organic Fertilizer

The fertilizer was applied in four splits. The first application was applied basal on the day after transplanting (DAT). The three applications were done at 20 DAT, 40 DAT, and 80 DAT, respectively by side dressing. The application rates for the FBOF treatments were 150g (T3), 225g (T4), and 300g (T5). Negative control (T1) was not applied with any fertilizer while positive control (T5) followed the recommended inorganic fertilizer of the soil analysis result.

Harvesting

Once the Taiwan chili pepper began to fruit, harvesting was carried out for each treatment, and recorded the number of harvests occurred in every plot. Harvesting was done up to 29 times with maturity indices of color red or at least 80 percent ripened using East-West Seed Company data.

Data Gathering

Data collected included plant height, days to flowering, fruit development, and fruit ripening. For the yield parameters, the total yield of the representative sample plants and root-to-shoot ratio were also measured. NPK concentration and chemical properties of the soil were also compared among the treatments.

Statistical Analysis of Data

All the gathered data were statistically analyzed using the analysis of variance (ANOVA) and Tukey HSD for Randomized Complete Block Design (RCBD) in Statistical Tool for Agricultural Research (STAR) version 2.0.1 (IRRI).

RESULTS AND DISCUSSION

Influence of Fortified Rabbit Manure +Trichoderma spp. Bio-organic Fertilizer on the Growth of Taiwan Chili Pepper

At 40 and 60 DAT, T3 with 600 g of FBOF showed significantly the highest plant height ($p<0.05$) of 83.80 cm and 137.30 cm respectively, while at 80 DAT, plant height in the different treatments was found to be comparable and not significantly different from each other (Figure 1). The initial number of lateral branches was counted in the second week after transplanting. During this time, T3 was the treatment in which branching was first observed. At this stage, T3 produced 20-22 leaves. Also, the branches of T3 increased in length after 20 days. T3 was still consistent in developing the highest number of lateral branches

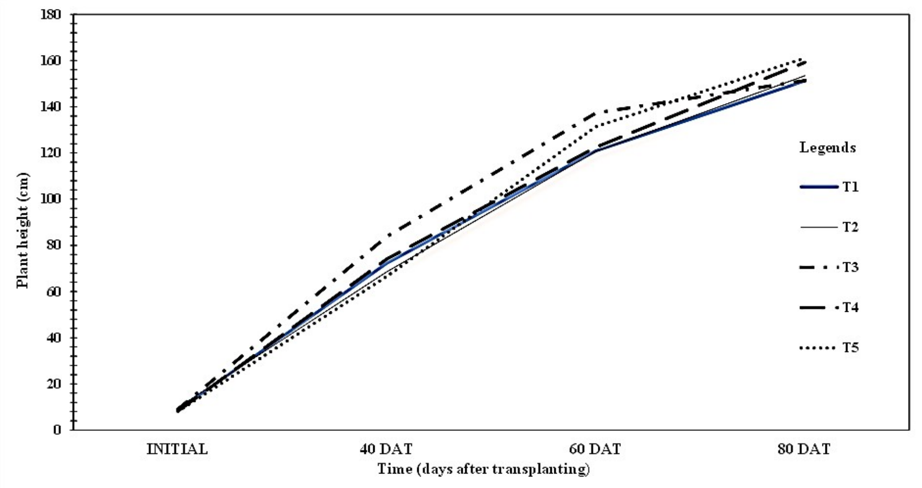

Figure 1: Effect of different treatments on plant height at 40, 60, and 80 DAT.

Table 1: Comparison of the Number of Lateral Branches of Taiwan Chili Pepper at 40, 60, and 80 DAT in 5 Different Fertilizer Treatments

Treatment	Number of Lateral Branches		
	(40 DAT)	(60 DAT)	(80 DAT)
1 (Negative)	2.56 ± 0.40^{d}	4.00 ± 1.15^{c}	7.56 ± 0.37^{b}
2 (RIF)	5.40 ± 0.16^{bc}	11.70 ± 1.70^{a}	15.10 ± 0.54^{a}
3 (600g FBOF)	7.20 ± 0.44^{a}	12.90 ± 0.99^{a}	15.40 ± 0.31^{a}
4 (900g FBOF)	5.80 ± 0.25^{b}	12.30 ± 1.49^{a}	15.10 ± 0.47^{a}
5 (1200g FBOF)	4.30 ± 0.54^{c}	9.40 ± 1.17^{b}	14.10 ± 0.37^{a}

Means with different letters in the same column are significantly different (p<0.05).

even after 40, 60, and 80 DAT (Table 1).

Consistently, T3 with 600g of FBOF showed the highest number of lateral branches of Taiwan chili pepper during 40, 60, and 80 DAT and in all treatments and had been calculated to have significant differences. As mentioned by Wu (2016), bio-organic fertilizer from microorganisms (BFM) may promote the production of some beneficial secondary materials such as growth-stimulating hormones, indole acetic acid (IAA), gibberellic acid (GA), and other phytohormones and enzymes which then stimulate development and growth of plants. In several studies (Halifu *et al.*, 2019; López -Bucio *et al.*, 2015; Shoresh *et al.*, 2010),*Trichoderma* spp. is proposed and considered as major plant growth-promoting fungi and have a direct promotional effect on the growth of various seedlings. In addition, *Trichoderma* spp. has been reported by Halifu *et al.* (2019) to promote nutrient uptake by secreting organic acids to dissolve minerals and activate nutrients in the soil, leading to the circulation and utilization of macro and micronutrients in the soil thus, making it easily available for plants' absorption. This biological function of *Trichoderma* spp. may have caused a significant increase in the plant height of the Taiwan chili pepper throughout its vegetative stage.

Flower emergence, fruit development, and fruit ripening were measured when 50% of the population of the Taiwan chili pepper was observed to proceed with those mentioned reproductive developments. As shown in Table 2, T3 demonstrated the shortest number of days (20.5) for initial flowering. T5 shared the same statistical significance at 22.50 days. This was followed by T2 (23 days) and equaled statistically by T5 (22.5 days). Meanwhile, T4 had the second longest days to flowering at 28.50 while T1 had the longest days to flower emergence at 37 days.

T3 reported the shortest number of days for fruit setting as presented in Table 2. At 27 days, 50% of the plants under T3 (600g FBOF) application were able to bear their first fruit. Plants in T5 had similar findings wherein at day 28, 50% of the plant population also bore its first fruit. Plants on T2 followed and by day 30, half of the plant population bore their first fruit. On the other hand, T4 (900g FBOF application) was not able to gain comparable results with other FBOF treatments (T3 and T5) because it was observed to have significantly longer days before the plants in this treatment were able to produce their first pepper fruit at 35 days. The reason observed was the blockings in the

Table 2: Comparison of Days to Flowering, Fruit Development, and Fruit Ripening of Taiwan Chili Pepper in 5 Different Fertilizer Treatments

Treatment	Days to Flowering	Days to First Fruit Development	Days to Fruit Ripening
1 (Negative)	37.00 ± 0.82^{a}	44.50 ± 0.87^{a}	77.00 ± 0.91^{a}
2 (RIF)	23.00 ± 0.82^{c}	30.50 ± 0.87^{c}	77.00 ± 0.91^{a}
3 (600g FBOF)	20.50 ± 0.76^{d}	27.00 ± 0.82^{d}	68.77 ± 1.02^{c}
4 (900g FBOF)	28.50 ± 0.76^{b}	35.00 ± 0.91^{b}	76.00 ± 0.91^{ab}
5 (1200g FBOF)	22.50 ± 0.76^{cd}	28.50 ± 0.87^{cd}	74.00 ± 0.91^{b}

Means with different letters in the same column are significantly different (p<0.05).

net house in which the plot location for one replication in T2 was partially shaded by the shadow of adjacent net house.

Based on the investigation of Yahya et al. (2022), plant height will have implications for the emergence of production branches. The taller the plant, the higher the tendency to have many branches. Similarly, the (more) increased number of branches that a plant produced indicates that it was able to absorb large amounts of nutrients from the treatment applied thereby having a great advantage in providing a high number of harvest and yield. These findings corresponded to the results of the present study as the FBOF treatments, shown to have the greatest number of lateral branches, were also the treatments with the highest yield (Table 3).

Moreover, the findings of this study are consistent with the investigation of Dema (2020) wherein the emergence and growth of lateral branches come out around the first flower shoot. This was true and evident in T3 where the first flower appearance occurred on day 20 followed by other FBOF treatments between days 22-28. T3 also showed the shortest day among all treatments in terms of fruit setting (27 DAT) and fruit ripening (69 DAT).

Influence of FBOF on the Yield Response of Taiwan Chili Pepper

The highest yield was obtained by T3 (901.27g) which was comparable with other FBOF treatments T4 (778.45g) and T5 (838.55g) respectively. All FBOF treatments recorded comparable yields. However, T3 and T5 showed significantly higher yields compared to T1 and T2. It clearly demonstrates that the plants applied with FBOF are able to produce higher yields of chili than the recommended inorganic fertilizer treatment (Table 3). Several studies were deemed consistent with this study's results on the yield of chili pepper from bio-organic fertilization (Yahya *et al.*, 2022; Zayed *et al.*, 2013). More so, the bio-organic fertilizer from microorganisms has been associated not just with improved fertility of the soil but with increased yield and promotion of good quality horticultural crops with reduced cost (Hafez *et al.*., 2022).

The statistically higher yields of Taiwan chili pepper in FBOF treatments may have been explained by the capabilities of the *Trichoderma* spp., to synthesize acid phosphatase that converts organic phosphorus into inorganic phosphorus, and makes it available for plant absorption which proved to be vital in the plant growth and fruit yield (Kapri and Tewari, 2010). Furthermore, Andraini *et al.* (2021), also elucidated the application of organic fertilizers that provided better growth and yield of chili varieties; hence, organic fertilizers containing microorganisms such as N-fixers and P solvents can reduce the use of inorganic fertilizers by up to 50%.

Another probable reason for the higher yield in terms of fruit weight was addressed by the increased potassium content of the FBOF due to the addition of banana peels to the 180-day-old BOF. It was observed that when the BOF was fortified, its potassium increased from 0.18 to 0.83 (361.11%). In some studies, bananas, when used as fertilizer, have been proven to increase flowering activity and yield production of many horticultural crops. Potassium is also important in pest and drought resistance (So and Tan, 2018; Akpan *et al.*, 2020).

The plant tissues were on the other hand assessed for macronutrient uptake. That being the case, the nitrogen uptake in T1 (5.11%) was found to have the highest concentration in whole plant parts. This was followed by T2(3.19%) and T4 (3.18%), and the lower percentages were found in T5 (2.83%) and T3 (2.17%) respectively. T1 had the highest statistical significance while T3 had the lowest significance. In addition, no significant difference was observed between T2 and T4 (Table 4).
As investigated by Munson (1998) via plant analysis, plants with higher than 4.50% nitrogen in their tissues could pose toxicity to plants that may result in poorly

Table 3: Comparison of Total Yield (grams) of Representative Sample Plants of Taiwan Chili Pepper in 5 Different Fertilizer Treatments

Treatment	Mean Total Yield (g)
1 (Negative)	478.27 ± 50.22^{c}
2 (RIF)	670.18 ± 36.61^{b}
3 (600g FBOF)	901.27 ± 59.89^{a}
4 (900g FBOF)	778.45 ± 47.71^{ab}
5 (1200g FBOF)	838.55 ± 39.72^{a}

Means with different letters in the same column are significantly different (p<0.05).

Table 4: The NPK Concentrations in the Plant Tissue of Taiwan Chili Pepper in 5 Fertilizer Treatments

Treatment	Mean Nitrogen (%)	Mean Phosphorous (%)	Mean Potassium (%)
1 (Negative)	5.11 ± 0.14^{a}	0.25 ± 0.003^{c}	2.83 ± 0.019^{c}
2 (RIF)	3.19 ± 0.14^{b}	0.25 ± 0.006^{c}	2.68 ± 0.059^{d}
3 (600g FBOF)	2.17 ± 0.03^{d}	0.25 ± 0.001^{c}	3.10 ± 0.006^{b}
4 (900g FBOF)	3.18 ± 0.003^{b}	0.33 ± 0.001^{a}	3.20 ± 0.011^{a}
5 (1200g FBOF)	2.83 ± 0.09^{c}	0.30 ± 0.003^{b}	3.19 ± 0.020^{ab}

Means with different letters in the same column are significantly different (p<0.05).

elongated roots and stems. In addition, when plants have too much nitrogen (N), they become more attractive and susceptible to different insect pests and diseases.

The highest mean of P was found in T4 (0.33%), followed by T5 (0.30%), T2 (0.25%) and T3 (0.25%), and lastly, T1 (0.245%). The data presented indicated that T4 (900g of FBOF) and T5 (1200g of FBOF) have significant differences among other treatments when it comes to the concentration level of phosphorous. It is opposite to the P concentration in T1 (negative control), T2 (positive control), and T3 (600g of FBOF), which shows no significant differences from each other.

The level of P in the plant tissues of the Taiwan chili pepper was found to be within a normal range as Munson (1998) suggested that 0.20-0.75% is the sufficient and normal level concentration of P elements in plant tissues. These findings were supported by the plant tissue analysis and interpretation for vegetable crops performed by Hochmuth *et al.* (2018) when they established that deficient leaves will have only about 0.1% P in the dry matter while the normal level, most recently matured leaves of most vegetables will contain 0.25% to 0.6% P on a dry weight basis.

For the K uptake, levels of K in all treatments were considered sufficient or normal. This result was supported by the plant analysis conducted by Hochmuth *et al.* (2018), which revealed that the normal and sufficient level of nutrient element K is around 1.50%-5.50%. In contrast, lower than 1.5% K is considered deficient while, higher than 6.00% will result in toxicity or excessiveness which can lower the leaf concentration of elements such as N, P, Mg, Ca, Cu, In, Mn, B, and Na. K is an activator of dozens of important enzymes and cellular activities, such as protein synthesis, sugar transport, N and C metabolism, and photosynthesis. It plays an important role in the formation of yield and quality improvement (Oosterhuis *et al.*, 2014). K is also very important for cell growth, which is an important process for the function and development of plants (Hepler *et al.*, 2001).

The root-to-shoot ratio of Taiwan chili pepper was recorded during the termination day of the study (120DAT). As shown in Table 5, from T2 to T5, R:S were not significantly different from one another implicating that these treatments resulted in similar root-to-shoot ratios as affected by the different levels of FBOF (T3-T5) and recommended inorganic fertilizer (T2). Meanwhile, the negative control (T1) had the lowest R:S (1:5) which differed significantly from the other four treatments.

As for the root-to-shoot ratio, it is important to note that it was recorded during the maturity stage of the plants, and according to Blaha (2019), root proportion and growth are larger than the above-ground (shoot) part of the plant during the vegetative phase of the plant. As the plant matures, growth-related parts comprise the larger proportion, though this may not be the case all the time because other factors may affect the root-shoot ratio such as plant stress including disease, nutrient deficiency, over-fertilization, and water availability in the soil (Koike *et al.*, 2003). Other cited factors that

Table 5: Comparison of Root-Shoot Ratio (Dry Weight Basis) of Taiwan Chili Pepper in 5 Different Treatments

Treatment	Root Dry Weight (g)	Shoot Dry Weight (g)	Rdw/Sdw (g)	R-S Ratio
1 (Negative)	17.68 ± 1.50^{b}	84.88 ± 8.70^{b}	0.22 ± 0.03^{a}	1:5
2 (RIF)	20.60 ± 1.93^{ab}	159.00 ± 10.74^{a}	0.13 ± 0.01^{b}	1:8
3 (600g FBOF)	19.60 ± 1.57^{b}	143.38 ± 13.72^{a}	0.14 ± 0.01^{b}	1:7
4 (900g FBOF)	26.40 ± 1.29^{a}	161.08 ± 5.83^{a}	0.16 ± 0.01^{b}	1:6
5 (1200g FBOF)	17.60 ± 0.68^{b}	137.24 ± 3.66^{a}	0.13 ± 0.01^{b}	1:8

Means with different letters in the same column are significantly different (p<0.05).

may influence root-shoot ratio include inherent species characteristics, variety, site moisture and nutrient availability, regeneration strategies, and competition for light (Mokany *et al.*, 2006).

However, in the study of Berova and Karanatsidis (2008), they found that nutrition with bio-fertilizer increases plant growth and influences the growth rate of the roots and stem of the plant, as well as the leaf formation. Both T2 and T5 possessed the higher ratio of R: S with 1:8, as the normal condition of root-shoot ratio is 1:5 to 1:6; the top is 5 to 6 times heavier than the roots for sufficient nutrient uptake. The importance of the root-to-shoot ratio during vegetation is indisputable. This ratio is strongly associated with plant integrity during the growth and development of all vegetation period and it's important because the root system plays a fundamental role in taking nutrients and water, and as the absorption at the root level is more intense, the higher the biomass, hence the higher the agricultural production.

Improvement in Soil Composition Post Application of Fertilizer Treatments

The use of FBOF had positive influences both on the soil and on the yield of Taiwan chili pepper (Table 6). While there is a limitation to this study because of the inability to determine the presence of the colony of *Trichoderma* spp. and rhizobacteria in the soil samples, the researchers believe that the balanced soil parameters and improved macro and micronutrient contents of the soil in this study presented strong evidence that the FBOF effectively improved the soil properties and its composition.

The FBOF Treatments were reported to have higher concentrations of micronutrients, organic matter, organic carbon, trace elements, and pH. The distinct increase in total NPK implied that the application of fortified bio-organic fertilizer could improve soil fertility if constantly practiced in agricultural production.

As shown in Table 6, FBOF treatments were reported to have a higher concentration of micronutrients, organic matter, organic carbon, trace elements, and pH. The soil pH in the five treatments was classified as normal ranging between 6.5 to 7.5 (Neina, 2019; Stiles, 2004), and is considered a normal level of pH and most favorable for plant growth because most plant nutrients are readily available in this pH range.

From the results of OC, it was evident that FBOF treatment had a higher OC concentration. As Corning *et al.* (2016) claimed in their investigation, the higher soil organic carbon promotes soil structure or tilth meaning there is greater physical stability. This improves soil aeration (oxygen in the soil) and water drainage and retention and reduces the risk of erosion and nutrient leaching. On the other hand, soil analysis experiments of Abbasi and Yousra (2012) revealed that bio-organic fertilizers usually have higher OM content, which supported the results of the present study. In addition, as Fenton *et al.* (2008) stated, the most productive agricultural soils have between 3 and 6% organic matter. Similarly, in this study, higher yield production and optimum growth of Taiwan chili pepper were reported in T3, T4, and T5 that had OM levels of 3.40 to 5.70%.

Total NP was also found to have increased concentrations and this was related to higher OM (Abbasi and Yousra, 2012) since OM contains minerals and nutrients that are not yet released in its plant-available forms. Total K however decreased when compared with the pre-application of FBOF. The decrease in K element in soil may be due to different factors. One explanation could be that the potassium in the soil solution may be taken up by the plant or lost from the soil by leaching, especially on sandy, coarse-textured soils (Han and Lee, 2006). Likewise, Morgan and Connolly (2013) state that plants contain several different transport systems to acquire potassium from the soil and distribute it within the plants which can increase disease resistance, help stalks and shoots to grow upright and sturdy, and improve drought tolerance.

Table 6: The Soil Properties Before and After Application of Fortified Bio-Organic Fertilizer

Parameter	Soil without Application	T1 – Negative	T2 – RIF	T3 – 600g FBOF	T4 – 900g FBOF	T5 – 1200g FBOF
Texture	Medium	Medium	Medium	Medium	Medium	Medium
pH	6.75	7.03	6.92	7.05	7.03	7.15
Organic Carbon (%)	1.23	1.23	1.51	1.98	2.07	3.33
Organic Matter (%)	2.44	2.11	2.60	3.40	3.57	5.73
Total Nitrogen (%)	0.11	0.11	0.14	0.19	0.21	0.31
Phosphorus (ppm)	126.40	168.39	191.79	273.26	292.65	392.95
Potassium (cmol/kg)	0.75	0.19	0.37	0.45	0.36	0.61
Zinc (ppm)	16.62	23.02	24.89	29.28	28.29	40.24
Copper (ppm)	10.13	10.23	10.12	8.53	12.46	12.79
Manganese (ppm)	80.86	35.72	143.97	154.68	122.42	114.96
Iron (ppm)	118.97	138.09	117.78	115.68	100.89	108.06

In the case of the Taiwan chili pepper, the researchers theorized that the potassium available in the soil and in the FBOF applied was absorbed by the plant favorably for its fruit development and increased yield as evidently shown in the weight of yield harvested in the FBOF treatments (Table 3). In addition, it should be noted that the study was conducted during summer and to make the plants withstand drought conditions, it needs to uptake a higher amount of potassium from the soil (Dyer, 2021). These findings are also consistent with the findings of Rather *et al.* (2019).

In terms of trace elements, Zn and Mn were observed to have a drastic increase in the FBOF treatments; this may have been related to the solubilization of the mineral deposits from the organic matter when the pH was lowered which the effective microorganism (EM) potentially played a role by releasing organic acids to help in the breakdown of OM and release of plant available Zn and Mn (Iriti *et al.*, 2019).

For the copper concentrations in the soil, of all the 3 treatments of FBOF, T4 (8.53ppm) which was the 600g application of FBOF was the only treatment that decreased the copper level in the soil compared to the untreated 10.13ppm. Subsequently, T5 (12.79 ppm) and T4 (12.46 ppm) had higher copper contents because these two treatments have a higher value of P. In terms of copper concentration, this was believed to be connected to the observed synergistic relationship of copper and phosphorus which was also observed in the investigation of Rahman and Schoenau (2022). The increased fertilization of P also increased the concentration of Cu availability in the soil logically following that T1 (10.23 ppm) and T2 (10.12 ppm) had almost the same value as the untreated soil because these treatments had no application of FBOF. Consistent with the proposition of Stiles (2004), copper availability is strongly influenced by soil pH, organic matter content of the soil, and levels of phosphates in the soil in manners like zinc. In addition, the availability of iron decreases as soil pH increases. Excessive levels of phosphates or carbonates reduce iron availability through the formation of insoluble iron compounds.

CONCLUSION

The findings of the study showed that fortification of bio-organic fertilizer from rabbit manure + *Trichoderma* spp. and its use in the cultivation of Taiwan chili pepper significantly provided better plant development and higher yield, based on the data gathered and results generated. The fortified bio-organic fertilizer was able to deliver positive effects on both plant growth and yield production.

Moreover, the application of varying levels of the fortified bio-organic fertilizer to the soil in the net house improved the soil fertility as implicated by the post-treatment analyses. The nutrient uptake of the plants under FBOF treatments was also regarded as optimum based on the plants' growth response, thereby providing a significant increase in yield. Likewise, the fortification through the integration of EM, madre de cacao leaves, and banana peels further improved the growth promotion quality of the FBOF's various chemical parameters which are primary indicators of the quality of the fertilizer material.

In addition, it should be taken into account that further studies are required to validate the effectiveness of the FBOF material in enhancing the growth response and fruit yield of the Taiwan chili pepper. At the same time, the relevance of FBOF to the increased soil fertility should also be further investigated through soil microbial analysis and other soil physicochemical parameters indicative of the soil enrichment properties. Further, it should be taken into account that further studies are required to validate the effectiveness of the FBOF material in enhancing the growth response and fruit yield of the Taiwan chili pepper.

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