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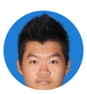

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COMPARATIVE STUDY OF TRICHODERMA-INFUSED COMPOST ON GROWTH AND YIELD OF CHILI PLANTS

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Abstract – Chili Kulai (*Capsicum annuum*) is an important agricultural crop in many countries due to its economic importance, nutritional and medicinal value. The aim of this study was to determine the effect of *Trichoderma* infused compost on the growth and yield of chili plants. Two treatments were carried out, which were chemical fertilizer (CF) and *Trichoderma*-infused compost (TC). Plants without any treatment were included as controls in this study. Three replicates were carried out for each treatment. The growth parameters including plant height and the number of branches were measured. The yield parameters observed were in terms of number of chilies produced, weight of chilies, length of chilies, percentage of ripened chilies and fungal-infected chilies. TC and CF showed comparable results in relation to all the parameters observed. The plants treated with TC grew as well as CF treated plants. The plants in TC treated group could also produce comparable yield of chilies as CF treated plants. The results from this study indicate that *Trichoderma* infused compost is a suitable and effective replacement for chemical fertilizers for the growth and production of chilies.

INTRODUCTION

Chili Kulai (*Capsicum annuum*) is a common and extremely popular type of chili that people use as spices in their daily food. *C. annuum* is also an important agricultural crop in many countries due to its economic importance, nutritional and medicinal value (Emmanuel-Ikpeme *et al.*, 2014). Farmers have been using inorganic fertilizers such as NPK blue or NPK green for decades because these fertilizers could offer them a promising harvest. In current practice, there is an increased in the usage of fertilizers in agriculture although the side effect of it causes quality degradation in soil. According to recent findings in China fields, soil organic carbon decreases as the usage of inorganic fertilizer become excessive (Yang *et al.*, 2015). Another sighting of this incident happens in India as well (Srinivasarao *et al.*, 2014). However, the usage of organic compost (*Trichoderma*-infused compost) which was more environmental friendly and cheaper compared was rarely used by farmers because they are afraid to try new things.

Trichoderma harzianum is one of the many types of fungus that plays an important role in degrading the organic compounds in soil which then helps the plants to grow well (Augé *et al.*, 2015). Currently, it is developed and marketed as a plant growth stimulator (with stimulation and protection properties). In addition to promote growth, *Trichoderma* spp. has also been reported to contain bio-control properties and ability to combat plant diseases (Cornejo *et al.*, 2014; Emmanuel-Ikpeme *et al.*, 2014). The mixture of *Trichoderma* inoculants and vermicompost mixed homogenously can harbor organic compost which is useful for agricultural fields. This is because it can help to fight against plant pathogens and yet environmentally friendly. It is also a good alternative to chemical fertilizers which leach away organic carbon (Mehta *et al.*, 2014).

In agriculture field, the increase usage of chemical fertilizers wills subsequently increases the agricultural cost. Hence, it is importance to reduce the usage of fertilizers or pesticides in chilies cultivation and control the quality of chilies

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harvested to serve the public with organic based chilies. The aim of this study was to determine the effect of *Trichoderma*-infused compost on the vegetative growth of chili plants which included plant height, number of branches and plant girth as well as the quality of chilies in relation to the number of chili fruits, the weight of chilies per plant produced, the length of chilies, percentage of unripe versus ripen fruits, percentage of insects infested or spoilt fruits, the percentage of fungal-infected fruits.

MATERIALS AND METHODS

Nursery

This experiment was conducted at University Agriculture Park, UPM. The chili seeds of variety *kulai* (*Capsicum annuum*) were planted in seed trays and placed in a nursery with an automated water sprinkler to irrigate the seeds every morning at 10 am. After three weeks, the seedlings were transferred into small black polythene bags (one seedling per polythene bag) to allow better growth. The seedlings were subsequently transferred to the beds after two months. Only healthy seedlings were selected and planted in the beds and this was counted as week 0.The beds were covered with silver screen plastic (11 m x 1.5 m) to prevent insects from attacking the chili plants.

Experimental Design

Two treatments were carried out namely chemical fertilizer (CF) and *Trichoderma* infused compost (TC). Plants without any treatment were included as controls (C). Distribution of the beds were determined using the randomized completely block design (RCBD). For each treatment, fifteen seedlings were planted.

For the CF treatment, Green Compound Fertilizer (N: 12; P: 15; K: 15) and Blue Compound Fertilizer (N: 12; P: 12; K: 17) were obtained from Advanced Agricultural Micro-organism Sdn. Bhd., Kepong KL. When the seedlings were transplanted from polythene bags to beds, 30 g of Green Compound Fertilizer was applied around the seedlings. After two weeks, 40 g of Blue Compound Fertilizers was applied per seedling and 50 g of Blue Compound Fertilizers were applied again per seedling after another two weeks.

The TC treatment was prepared by mixing *Trichoderma* inoculants and sterilized vermicompost in a ratio of 1:1. The *Trichoderma* infused compost was mixed into the soil of the beds for three weeks before the seedlings were transferred to the beds. Second application of TC was applied to the seedlings on the fifth week after the first application of TC. Each seedling was given 100 g of TC for each application.

Growth and Yield of Chili Plants

The growth parameters were measured and recorded every three weeks. For each treatment, only five random plants were selected. The plant height was measured from the ground soil to the uppermost leaves using a steel measuring tape. The numbers of branches were counted as the number of smaller branches that grew out from the main stem.

The harvest was performed at week fourteen when there were at least 70 % of red chilies observed. At harvest, number of chilies produced per plant was noted. The percentage of ripe versus unripe fruits at time of harvest was noted. The red chilies were counted as ripe fruit while the green chilies and partially red chilies were counted as the unripe fruit. All the fruits were graded as A-longest size (more than 13 cm), B-medium size (11-13 cm) and C-shortest size (less than 11 cm) by measuring the length. The chilies that were infected by fungus were observed by the shrunken body texture on the chilies.

Statistical Analysis

The analysis of variance (ANOVA) was applied by using SPSS software version 17.0 for Windows to find the difference in growth and yield parameter for different treatments (Zar, 1996).

RESULTS AND DISCUSSION

Growth Parameter

For plant height, there were no significant differences for all treatments at week 0and week three. At week six, the plant height from TC plants showed the highest mean plant height (36.80 ± 3.91 cm) followed by the CF (31.80 ± 6.33 cm) and C plants (31.80 ± 6.33 cm). The plant height showed no significant for CF and TC at week nine and twelve but was significantly higher than control (Table 1).

The chili plants only began to produce branches in the sixth week. There was no significant difference for the mean number of branches for chili plants at week six. At week nine and twelve, the mean number of branches of CF chilies was higher compared to the TC chilies but there was no statistical significant difference. Both treatments

Table 1. Plant height (mean ± SD, cm) from week 0 to 12 for different treatments (N=5)

Week (th)	Treatment		
	C	CF	TC
0	19.18 ± 1.73[a]	19.08 ± 1.38[a]	20.00 ± 1.81[a]
3	20.06 ± 3.94[a]	24.20 ± 2.84[a]	24.06 ± 1.28[a]
6	28.56 ± 3.27[b]	31.80 ± 6.33[ab]	36.80 ± 3.91[a]
9	39.60 ± 1.99[b]	46.28 ± 2.62[a]	54.68 ± 6.66[a]
12	45.64 ± 5.47[b]	61.38 ± 8.25[a]	60.26 ± 6.48[a]

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

showed significantly more branches than C (Table 2).

With reference to the growth parameters in terms of plant height and branching, the plants treated with TC grew as well as CF treated plants (Table 1 and Table 2). This was because TC treatment has evolved numerous mechanisms for enhancing plant and root growth that enable the plant to uptake sufficient nutrients. This is supported by a study by Ranasingh *et al*. (2006) which showed efficacy of *T. harzianum* in enhancing nutrient uptake and controlling red rot in sugarcane. *Trichoderma* spp. was shown to have ability to promote plant growth in normal and stress conditions, which was related to the induction of lateral roots and root hairs through auxin signaling (Contreras-Cornejo *et al.* 2014). Furthermore, *Trichoderma* isolates are known to influence the phytohormonal network of their host plant, thus leading to an improvement of plant growth and stress tolerance (Martínez-Medina *et al.* 2014).

Table 2. Number of branches (mean ± SD) from week 6 to 12 for different treatments (N=5)

Treatments	Week		
	6	9	12
C	2.40 ± 0.89[a]	4.60 ± 0.54[b]	4.80 ± 0.83[b]
CF	6.40 ± 3.43[a]	8.60 ± 3.43[ab]	9.80 ± 1.78[a]
TC	5.00 ± 3.53[a]	7.20 ± 0.44[a]	7.40 ± 1.81[ab]

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

The plant-growth promoting fungus, *Trichoderma* spp. has the ability to solubilize many plant nutrients for the usage of plant. In this study, more root hairs were observed in TC treated plants when compared to CF and C treated plants. The most noticeable effect of application of *Trichoderma* was an increase of quantitative and qualitative characteristics of the root system with a consistent development of root hairs. This is concurrent with the findings of Di Marco and Osti (2008). The benefit of using the fungi has been proven to increase the rate of plant growth and robust roots development due to increase of nutrient and water uptake by the plant (Harman, 2014).

In addition, the presence of vermicompost can also enhance the potential of *Trichoderma* to induce the growth of chili plants. According to Bi *et al.* (2009), organic amendments can improve yield trends and profitability in intensive rice systems. The study showed that organic amendments increased the availability of nitrogen (N), phosphorus (P) and potassium (K) by 27, 65 and 44 %, respectively. Availability of some of the micronutrients such as Cu, Fe, Mn and Zn were also enhanced respectively by 6, 100, 79 and 66 %. In addition, the organic carbon content (55 %) also increased with a concurrent decrease in soil pH (6 %). The application of organic manure can greatly increase crop yields, soil pH, organic carbon, total NPK and available NPK content (Zhong *et al.* 2010). The TC treatment was prepared by mixing *Trichoderma* inoculants and sterilized vermicompost. Therefore, the growth parameter of TC treated plants able to show the comparable results to CF treated plant in the absent of chemical fertilizer.

Yield Parameter

The total number of fruits obtained during the harvest in week fourteen was as follow: 101 chilies for control plants, 263 chilies from CF plants and 241 chilies from TC plants. From the statistical analysis, there was no significance difference for the mean number of chilies between different treatments at week nine (Table 3). At week twelve, the mean number of CF chilies (37.00 ± 11.51) and TC chilies (32.60 ± 8.29) were significantly higher than C (15.60

Table 3. Number of chilies produced (mean ± SD) per plant per treatment from week 9 to 14 (N=5)

Treatments	Week (th)		
	9	12	14
C	4.67 ± 3.05[a]	15.60 ± 4.03[b]	20.20 ± 8.13[b]
CF	5.60 ± 3.36[a]	37.00 ± 11.51[a]	52.60 ± 17.03[a]
TC	7.60 ± 3.05[a]	32.60 ± 8.29[a]	48.20 ± 6.38[a]

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

± 4.03). At week fourteen, the CF treated plants (52.60 ± 17.03) still gave the best performance followed by the TC plants (48.20 ± 6.38) but this was not statistically significance. The least numbers of fruits produced were by the control plants (20.20 ± 8.13).

At week fourteen, the CF plants (0.47 ± 0.11) showed comparable results with TC (0.32 ± 0.07) in term of weight of fruits produced but both were significantly higher than C (0.15 ± 0.08) (Table 4). In terms of number of chilies and of weight of chilies produced, the plants in TC treated group could produce comparable yield of chilies as CF treated plants. This is supported by the study by Virginia (2006) on tomato plants which showed that the presence of *T. pseudokoningii* subspecies *Rifai* increased the levels macronutrients (P, K and Ca) and micronutrients (Zn and Fe) which were vigorously absorbed by the tomato plants. Absorbed nutrients influenced dry matter production of tomato which in turn resulted in the plants early flowering and better fruit production (Virginia, 2006). This was also supported by Rini *et al.*, (2006) who showed that incorporation of *Trichoderma* into the soil can enhance the chilies crop yields. The good growth parameters as shown in Table 1 and Table 2, indicate that TC treated plants were able to absorb sufficient nutrients from the soil and were able to grow healthy and produce a high yield of chilies. Therefore, the quality and quantity of chilies produced from TC treatment in this study showed comparable results with those from the CF treatment.

Table 4. Weight of chilies produced (mean ± SD, kg) per plant per treatment at week 14 (N=5)

Treatments	Weight (kg)
C	0.15 ± 0.08[b]
CF	0.47 ± 0.11[a]
TC	0.32 ± 0.07[a]

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

Based on Table 5, the length of chilies in category A was only slightly higher in TC (36.51%) than CF (27.38 %) but significantly higher than control (24.75 %). For Category B (medium length chilies), the TC plants produced the highest percentage (46.89%), followed by the control plants (44.55 %) and the CF produced the lowest percentage (40.30%). The Category C chilies (shortest length), TC plants produced the least with a percentage of 16.60 % and the CF applied plants produced the most number of shortest chilies with 32.32 %.

The TC plants showed the highest percentage (69.30 %) of ripe fruits compared to the CF applied plants (61.22 %) and the lowest percentage (50.50 %) is the control plants (Table 6). When comparing the unripe chilies, the number of TC treated unripe chilies were comparably higher than CF. As for the ripe chilies, CF and TC showed no significant difference.

Based on the results, TC treated plants produce higher length of chilies and the higher percentage of ripen chilies. These findings are supported by Lü *et al.* (2006) whose study showed that arbuscular mycorrhizal fungal inoculation could significantly promote seedling growth of *Cucumis sativus* L. and improve its fruit quality. Another study conducted by Hortencia *et al*., (2014) on chile ancho (*Capsicum annuum* L. cv San Luis) also showed arbuscular mycorrhizal fungal produced chilies that were 13 % wider and 15 % longer than the non arbuscular mycorrhizal fungal treatment. Application of *Trichoderma* strain with the plant or a plant seed under conditions in an agricultural setting was a method for enhancing growth of plants as *Trichoderma* strain was able to colonize the roots of the plant or a plant grown from the plant seed, thereby creating a plant *Trichoderma* system (Harman, 2014). Therefore TC treated plants were able to absorb sufficient water and nutrients to produce good quality chilies.

Table 5. Length of chilies produced (mean ± SD, cm) per plant per treatment at week 14 of harvest (N=5)

Treatments	Length categories (cm)					
	A		B		C	
	Mean	Percentage (%)	Mean	Percentage (%)	Mean	Percentage (%)
C	5.00±1.87[b]	24.75	9.00±1.61[a]	44.55	6.20±2.45[b]	30.69
CF	14.40±5.33[ab]	27.38	21.20±2.35[b]	40.30	17.00±2.23[a]	32.32
TC	18.80±3.44[a]	36.51	19.20±1.39[a]	46.89	12.40±1.69[ab]	16.60

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

Table 6. Ripe and unripe fruits produced (mean ± SD) per plant per treatment at week 14 (N=5)

Treatments	Mean	Percentage of unripe fruits (%)	Mean	Percentage of ripe fruits
C	10.00±2.7019[b]	49.50	10.2000±1.8547[b]	50.50
CF	21.20±2.9900[a]	41.06	31.0000±4.8683[a]	58.94
TC	28.20±2.9566[a]	30.70	20.0000±1.6125[ab]	69.30

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

Table 7. Fungal infected chilies produced (mean ± SD) per plant per treatment at week 14 (N=5)

Treatment	Mean	Number of fungal infected chilies	Percentage of fungal infected chilies (%)
C	5.2000±0.3742[b]	5	5.00
CF	3.8000±0.8000[a]	18	6.90
TC	2.0000±1.5811[b]	13	4.70

Note: a,b: different alphabets in each column show the different significant means (Tukey HSD test, P<0.05)

At week 14, the highest percentage (6.90 %) of fungal infected chilies was the CF treated plants; followed by the TC plants (5.39 %) and the lowest percentage (5.00 %) of fungal infected chilies were in the control plant (Table 7). Statistically, the CF showed no significance difference when compared to the C chilies but significantly lower when compared to the TC chilies.

Based on the quality of chilies obtained, the chilies from CF showed the significant lower percentage of fungal-infected chilies when compared to TC-treated and C-treated plant. In addition, the *Trichoderma* species also protected the plant from harmful pathogens by directly attacking and controlling the growth of disease-causing fungi (Woo *et al.* 2014). This mechanism of action is by growing tropically towards hyphae of other fungi, coiling around them in a lectin-mediated reaction, and degrading cell walls of the target fungi by the secretion of various lytic enzymes. This process of mycoparasitis limits growth and activity of pathogenic plant fungi (Sarma *et al.* 2014). Based on the study conducted by Shahid *et al.*, (2014), *T. harzianum* and *T. viride* are an effective fungicide and a biological control agent too that protects the plants and seeds from other pathogenic fungi. *Similar results were reported by* Martínez-Medina *et al.* (2014), *that Trichoderma* isolates could directly affect plant. Hence, the least fungal infected chilies were obtained from TC treated plants in this study.

CONCLUSION

In conclusion, *Trichoderma* infused compost treated plants showed comparable results as chemical fertilizers in relation to the growth and yield of chilies. This study creates a platform to encourage the agricultural industry to use *Trichoderma* infused compost as a substitute to the commercial chemical fertilizer, as TC is more economical and environmental friendly. Furthermore, the usage of this organic soil amendment has prolonged effects compared to chemical fertilizers. In line with the market demand of organic food which is chemically free and safe to consume, planting crops using *Trichoderma* enhanced soil will provide the assurance of high quality and quantity of food crops produced, as well as benefiting the environment.

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