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The Effectiveness of *Trichoderma*-enriched Organic Fertiliser in Increasing the Production of Green Mustard in Typic Haplustepts Soil

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Fertilisation is important to support plant growth in the agricultural cultivation systems. Organic fertilisers can be used to reduce the excessive use of inorganic fertilisers in improving crop production. A study was carried out to evaluate the effectiveness of several fertilisation regimens using the organic fertiliser enriched with *Trichoderma* sp. in increasing the growth and production of green mustard (*Brassica juncea*) in the Typic Haplustepts soil. The experiment was carried out in the third planting season from June to September 2017 on mechanically irrigated rice fields in Rarang Village (East Lombok Regency, West Nusa Tenggara) using a randomised block design consisted of 8 treatments in triplicate. The treatments were as follows: P1 (control without fertilisation); P2 (standard fertilisation with 150 kg/ha urea + 50 kg/ha NPK); P3 (2000 kg/ha organic fertiliser); P4 (2500 kg/ha organic fertiliser); P5 (3000 kg/ha organic fertiliser); P6 (75 kg/ha urea + 25 kg/ha NPK + 2000 kg/ha organic fertiliser); P7 (75 kg/ha urea + 25 kg/ha NPK + 2500 kg/ha organic fertiliser); and P8 (75 kg/ha urea + 25 kg/ha NPK + 3000 kg/ha organic fertiliser). Treatments with combined application of organic and inorganic fertilisers (P6, P7 and P8) resulted in significantly higher growth and yield of mustard greens, compared to the standard fertilisation regimen using inorganic fertilisers (P2) and treatments only with organic fertiliser at different doses (P3, P4 and P5). The application of organic fertiliser in combination with half of the standard dose of inorganic fertilisers was recommended for improving the production of green mustard based on the higher agronomic efficiency obtained relative to standard inorganic fertilisation.

Keywords: fertilisation; organic fertiliser; *Trichoderma* sp.; green mustard

I. INTRODUCTION

Fertilisation is an important factor that affects plant growth in the agricultural cultivation systems. Nutrients contained in the soil alone are insufficient for optimal plant growth. Plants need additional nutritional supplementation in the form of fertilisers, including organic fertilisers which are eventually decomposed into stable organic matter in the soil (Simanungkalit *et al.*, 2006). Organic materials or organic fertilisers added to the soil will be gradually decomposed by soil microorganisms into stable organic matter known as humus. In addition to serving as a reservoir of nutrients and water in the soil, organic matter also improves the soil structure. In general, both paddy fields and dry lands used for farming in Indonesia are known to have low levels of organic matter (Kasno *et al.*, 2003), which may be caused by the weathering-induced leaching of water-soluble organic matter, and soil erosion that displaces organic matter from the upper layer of soil (Simanungkalit *et al.*, 2006).

Currently, there is an increasing trend in the utilisation of organic fertilisers as the farmers began to become aware of the importance of maintaining the health of the soil. The adoption of organic fertilisers is also driven by the high price of inorganic fertilisers. According to Darwis &

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Rachman (2013), the Indonesian Organic Agriculture Statistics in 2011 reported a positive development in the organic agriculture in the country, with an increase in the organic farming area from 40,970 ha in 2007 to 225,063 ha in 2011. The use of organic fertilisers could be a solution to reduce the excessive application of inorganic fertilisers because the presence of organic materials had been shown to improve the physical, chemical and biological properties of the soil as they decompose into organic matter over time. Apart from supplying the basic nutrients (N, P and K), organic fertilisers also contain complete nutrients and can prevent microelement deficiencies in plants (Amilia, 2011).

The application of organic fertilisers in combination with inorganic fertilisers is beneficial for increasing the agricultural production both in quality and quantity, reducing environmental pollution, and improving the quality of land in a sustainable manner (Omidire *et. al.*, 2015; Pathak & Godika, 2010). Long term use of organic fertilisers can increase land productivity and prevent land degradation. These prompted the production of organic fertiliser as a strategic means for the farmers to enhance their agricultural production. Organic fertilisers have been widely produced in the farms and are applied in the forms of granules and liquid (Chandini *et al.*, 2019). As various materials can be used as the source of organic fertilisers, the diverse physical characteristics and chemical or nutrient content of organic matter are responsible for the various effects on the land and plants following their application as organic fertilisers (Widnyana *et al.*, 2017).

Innovation that can support optimal plant growth with the application of organic fertilisers is necessary, considering nutrients are released from organic fertilisers slowly. Microbial enrichment has been used to improve the efficiency of organic fertilisers as soil microorganisms inoculated to the organic matter used as fertilisers were capable of improving soil nutrient availability, in addition to suppressing the growth of plant pathogens in the rhizosphere. *Trichoderma* is a cellulolytic fungus that can degrade organic matter containing cellulose into simple sugars required for its growth (Haque *et. al.*, 2012; Singhania *et al.*, 2006). The fungus has also been used as a biological control agent. Application of *Trichoderma*-enriched organic fertiliser facilitates the decomposition of organic matter in the soil into nutrients that are released around the root area for easy uptake to support plant growth. Various studies had documented the successful application of biofertiliser enriched with the antagonistic biological agent *Trichoderma* in enhancing crop production (Ali *et. al.*, 2015; Barua *et. al.*, 2018; Hadiyal *et. al.*, 2017; Haque *et. al.*, 2010; Hardianus *et. al.*, 2017; Khattabi *et. al.*, 2004; Ong *et. al.*, 2014; Wolna-Maruwka *et al.*, 2017).

In view of the benefits of biofertilisers, a study was carried out to assess the application of several fertilisation regimens using a locally produced commercial *Trichoderma*-enriched organic fertiliser in increasing the production of green mustard (*Brassica juncea*) at Terara District of the Lombok Island. Terara District is included in the agricultural development zone dedicated for food crops and horticulture (Suparto *et al.*, 2013). The soil at the study site was classified as Typic Haplustepts which is commonly found in the southern part of central Lombok (Zulhaedar & Suriadi, 2017). This group of soil is relatively young; it has a texture that is generally rather rough to moderate. Physical characteristics of the land in the area had been considered to be suitable for growing mustard plants (Ritung *et al.*, 2011). Application of organic fertiliser had been reported to increase cation exchange capacity (CEC), or the ability of the soil to hold positively charged nutrients (Bot & Benites, 2005; Djajadi *et al.*, 2011). In other words, organic fertiliser can be used to enhance the nutrient availability in the soil for optimal plant growth. Therefore, the effectiveness of applying organic fertiliser at different doses within the recommended range, either singly or in combination with inorganic fertilisers, on the growth and yield of green mustard plants was evaluated and compared with that of standard fertilisation using inorganic fertilisers.

II. MATERIALS AND METHODS

The research was carried out on the mechanically irrigated rice fields in Rarang Village, Terara District, East Lombok Regency, West Nusa Tenggara. A uniform stretch of land that is flat, close to waterways and not prone to flooding was selected as the test location to ensure sufficient irrigation with proper drainage. Determination of the test location was based on the consideration for reducing the chances of introducing variabilities to the experimental design to ease monitoring of the experiment. The study site was representative of the agricultural land characterised by Typic Haplustepts soil commonly found in Lombok. The experiment was conducted in the third planting season from June to September 2017.

The materials used were green mustard (*Brassica juncea*) seeds; commercial organic fertiliser that came with a separately packed *Trichoderma* powder, both under the trademark Putri Sumber Sari Nadi Panca Kawi Agro (UD Sumber Sari, Badung-Bali); inorganic fertilisers (urea and NPK Phonska produced by PT Kaltim Indonesia and Petrokimia Gresik, respectively); and insecticide containing active thiamethoxam. The organic fertiliser took the form of granules, with an organic C content of 24.39%, C/N ratio of 19.20, total N of 1.27%, 0.88% P_2O_5, 1.93% K_2O, a moisture content of 20.00% and a pH of 7.10. The tools used were soil processing equipment such as ploughs, rakes, hoes, sickles; rope; hand sprayer; ruler; counter; scales; sack; and tarpaulin.

The soil was ploughed using a tractor and left for 1–2 weeks before use. The experimental plots were prepared as indicated in the regulation of the Minister of Agriculture number 70/Permentan/SR.140/10/2011. A total of 24 experimental plots were prepared for this study. Each treatment consisted of an experimental plot measuring 4 m × 5 m, with 4 raised beds measuring 0.8 m × 5 m, and was replicated three times in a randomised block design (Table 1). *Trichoderma* sp. was applied to the soil along with the organic fertiliser at a ratio of 1:500 according to the manufacturer's recommendation.

Irrigation for treatments and replicates was controlled to avoid infiltration of water from neighbouring plots. Seedlings of green mustard plants were grown in a separate nursery and transplanted into the experimental plots at a spacing of 20 × 20 cm at 15 days after planting (DAP) (Fuad, 2010), with one seedling planted in each planting hole. Fertilisation was carried out according to the treatments outlined in Table 1 one week before planting. Inorganic fertilisers (urea and NPK fertiliser) were sown and covered with soil for treatment P2. Organic fertilisers were spread evenly between the raised beds for treatments P3, P4 and P5. For treatments P6, P7 and P8, organic and inorganic fertilisers were applied as a mixture and evenly sown to each raised bed. Maintenance activities such as irrigation, weeding and pest control were synergised according to the circumstances and needs of the field conditions.

Soil samples collected at the site before application of fertilisers and postharvest were sent to the soil laboratory at the Assessment Institute for Agricultural Technology of West Nusa Tenggara Province, BPTP Balibangtan NTB for analysis of the physicochemical properties. The agronomic parameters for 10 randomly selected plants in each test plot, including plant height, number of leaves, leaf length, leaf width and canopy width, were collected at 21, 28 and 35 DAP. The green mustard plants were harvested at the age of 2 months by removing whole plant from the soil, and the weight of biomass was measured. Dry weight measurements were also carried out by drying the pre-weighed harvested biomass in an oven at 70°C for 5-6 days until the weight became constant. Moisture content of the produce was calculated from the fresh and dry weight.

Table 1. Treatments for testing the effectiveness of organic fertiliser enriched with *Trichoderma* sp. applied singly and in combination with inorganic fertilisers in improving the growth and productivity of mustard greens.

Treatments		**Urea (kg/ha)**	**NPK Phonska (kg/ha)**	**Organic fertiliser (kg/ha)**
P1	Control	0	0	0
P2	Standard (100% dosage of urea and NPK)	150	50	0
P3	2000 kg/ha organic fertiliser	0	0	2000
P4	2500 kg/ha organic fertiliser	0	0	2500
P5	3000 kg/ha organic fertiliser	0	0	3000
P6	½ dosage urea + ½ dosage NPK + 2000 kg/ha organic fertiliser	75	25	2000
P7	½ dosage urea + ½ dosage NPK + 2500 kg/ha organic fertiliser	75	25	2500
P8	½ dosage urea + ½ dosage NPK + 3000 kg/ha organic fertiliser	75	25	3000

P1: Control treatment without fertilisation.
P2: Standard treatment with inorganic fertilisers at the rate locally used for the tested plant.
P3, P4 and P5: Treatments with organic fertiliser enriched with *Trichoderma* sp. at the range of dosage recommended by the manufacturer.
P6, P7 and P8: Treatments with combined application of inorganic fertilisers at half of the standard dose and organic fertiliser enriched with *Trichoderma* sp. at different doses recommended by the manufacturer.

To find out the differences between treatments in this experiment, all agronomic data collected were analysed using ANOVA (analysis of variance) and LSD (least significant difference) test at 5% significance level using GenStat discovery. To compare the effectiveness of organic fertiliser tested at different doses in combination with inorganic fertilisers, the relative agronomic efficiency (RAE) was calculated using the following formula:

$$RAE = \frac{Yield\ of\ treatment - Yield\ of\ control}{Yield\ of\ standard - Yield\ of\ control} \times 100 \qquad (1)$$

Any treatment that results in an RAE exceeding 100% is considered effective compared with the standard treatment with inorganic fertiliser.

III. RESULTS

A. Soil Conditions

Soil analysis was carried out on the pre-planting and postharvest soil samples to determine whether different doses of organic fertiliser enriched with *Trichoderma* sp. applied singly and in combination with inorganic fertilisers would affect the soil conditions. Table 2 showed the results of both initial and final soil analysis for each treatment outlined in Table 1. There was no significant difference in the nutrient content, CEC, organic carbon content, pH, and composition of the soil at the study site before and after the experiment ($p > 0.05$).

The total N and organic C contents were low in the pre-planting and postharvest soil, but fertilisation appeared to have slightly increased the contents of N and C in the soil. Similarly, the content of P in the soil showed an increase after experiment, especially when inorganic and organic fertilisers were applied singly in treatments P2, P3, P4 and P5, probably because not all P supplied from the inorganic fertilisers was taken up for plant growth and the element was slowly released from organic fertiliser. Despite the relatively high levels of K available measured in the soil before and after treatments, the K content in the soil was reduced following the production of green mustard plants (Table 2).

The soil at the experimental site was classified as neutral with an initial pH of 7.30. The soil texture was classified as loam that contained 44% sand, 32% silt, and 24% clay (Table 2). The decline in soil pH after the cultivation process and treatment with organic and inorganic fertilisers was not statistically significant, where the soil was still considered neutral with the lowest and highest pH recorded at 6.76 and 7.23 for treatments P5 and P4, respectively. The soil texture was also not significantly altered after the application of fertiliser, probably because the change in soil texture is a natural process that occurs gradually over a long period of time.

B. Agronomic Parameters of Green Mustard Plants

The agronomic parameters (plant height, leaf number and width, and canopy width) were measured for plants at the age of 21, 28 and 35 DAP of each treatment. In general, treatments with the combined application of inorganic

Table 2. Soil analysis at the study site before and after experiment

Treatment	Parameter								
	N (%)	P (ppm)	K (ppm)	CEC (cmol/kg)	Org-C (%)	pH	Sand (%)	Silt (%)	Clay (%)
Before experiment	0.16	15.24	303.54	18.32	0.91	7.30	44	32	24
After experiment									
P 1	0.17	17.18	207.33	16.36	0.97	7.05	44	31	25
P 2	0.17	25.43	218.39	16.36	1.48	7.12	44	32	24
P 3	0.19	22.05	227.26	16.36	1.63	6.90	46	30	24
P 4	0.20	25.68	227.35	16.36	1.89	7.23	44	32	24
P 5	0.22	25.78	233.02	15.94	1.98	6.76	46	30	24
P 6	0.18	18.37	186.75	16.36	1.63	6.97	44	32	24
P 7	0.20	18.40	195.11	16.36	1.70	7.02	46	30	24
P 8	0.21	19.33	215.01	16.04	1.79	6.99	44	32	24

Treatments follow annotations in Table 1.

fertilisers and organic fertiliser at different doses (P6, P7 and P8) showed significant improvement in all agronomic parameters over time (p < 0.05), compared with the control without fertilisation (P1), standard application of inorganic fertilisers (P2), and treatments with only organic fertiliser at different doses (P3, P4 and P5).

Sole application of organic fertiliser at different doses (P3, P4 and P5) did not improve the plant height compared to the control (P1). The plant height was significantly different between treatments with the sole application of inorganic fertilisers (P2) and with organic fertiliser at different doses (P3, P4 and P5) (Table 3). The combined application of organic fertiliser and inorganic fertilisers (treatments P6, P7 and P8) significantly increased the plant height compared to the treatments solely with organic fertilisers at different doses (P3, P4 and P5) and inorganic fertilisers at standard dose (P2), as well as the control (P1). The plant height was not significantly different when treated with organic fertiliser applied at different doses in combination with inorganic fertilisers, with the exception that the plants grown under treatment P8 were significantly shorter than those under treatments P6 and P7 at 28 DAP. Application of organic fertiliser at the highest dose of 3 t/ha in combination with inorganic fertilisers resulted in tallest mustard greens at 35 DAP.

The number of leaves in mustard greens treated with organic fertiliser in combination with inorganic fertilisers (P6, P7 and P8) was significantly higher compared with the control (P1) and sole application of inorganic fertilisers (P2) and organic fertilisers at different doses (P3, P4 and P5) for plants at all ages, with the highest number of leaves achieved at 35 DAP (Table 4). The application of standard inorganic fertilisation (P2) produced more leaves in the plants compared to the control (P1) as well as the sole application of organic fertiliser (P3, P4 and P5) at 28 and 35 DAP, except that the number of leaves produced in plants under treatment P2 and P4 was the same at 28 DAP. Application of organic fertiliser alone did not increase the leaf number of mustard greens over time relative to the control.

The leaf width of mustard greens treated only with organic fertiliser at different doses (P3, P4 and P5) was not significantly different from that of the control (P1), but the combined application of organic and inorganic fertilisers (P6, P7 and P8) significantly improved the leaf width of green mustard plants compared with fertilisation regimens with either inorganic or organic fertilisers (Table 5). Fertilisation regimen with inorganic fertilisers applied singly (P2) and in combination with organic fertiliser at different doses (P6, P7 and P8) resulted in leaf width that was not significantly different at 21 and 28 DAP. However, there was a decrease in the leaf width of mustard greens treated with organic fertilisers, either singly or in combination with inorganic fertilisers, from 28 DAP to 35 DAP.

The canopy width of mustard greens was also not significantly different between treatments with only organic fertiliser applied at different doses (P3, P4 and P5)

Table 3. The effect of *Trichoderma*-enriched organic fertiliser applied at different doses, both singly and in combination with inorganic fertilisers, on the height of green mustard plants at 21, 28 and 35 days after planting (DAP).

Treatment	Plant height (cm)		
	21 DAP	28 DAP	35 DAP
P1	19.81 ± 3.09 a	26.85 ± 1.94 a	28.03 ± 0.90 ab
P2	23.63 ± 3.54 b	38.07 ± 0.89 b	44.63 ± 0.97 c
P3	20.19 ± 3.96 a	27.08 ±0.88 a	28.47 ± 0.40 ab
P4	19.67 ± 2.72 a	27.31 ± 1.45 a	27.00 ± 2.12 a
P5	19.93 ± 3.25 a	27.06 ± 1.29 a	28.03 ± 0.80 ab
P6	25.78 ± 4.34 c	40.51 ± 2.49 c	46.07 ± 1.72 cd
P7	25.31 ± 3.40 bc	40.11 ± 0.70 c	47.40 ± 2.04 d
P8	26.41 ± 2.68 c	39.45 ± 1.11 b	48.03 ± 2.48 d

Treatments follow annotations in Table 1. Plant height expressed as mean ± standard error. Different letters in the same column indicate difference among treatments according to the LSD test at 5% significance level.

and the control (P1) over time (Table 6). However, treatments with the combined application of organic and inorganic fertilisers (P6, P7 and P8) produced significantly wider canopies, although the canopy width was not significantly different from those grown under standard treatment only with inorganic fertiliser (P2) at 21 and 28 DAP. The application of organic fertiliser at different doses in combination with inorganic fertilisers resulted in mustard greens with the largest canopy at 35 DAP.

C. Quality of Mustard Greens and Efficiency of Tested Fertilisation Regimens

Table 7 showed that treatments with combined application of organic fertiliser at different doses and inorganic fertilisers (P6, P7 and P8) yielded significantly higher fresh weight per unit area for the harvested green mustard, compared with the treatments only with organic fertiliser (P3, P4 and P5) and the control (P1). The highest yield recorded at 4.21 kg/m^2 was obtained from treatment with inorganic fertilisers in combination with organic fertiliser at the highest dose of 3 t/ha (P8), and the effect of treatment P8 was significantly different from that of other treatments on the fresh yield of mustard greens. The fresh yield was not significantly different between treatments with inorganic fertilisers, applied singly (P2) or in combination with organic fertiliser at lower doses (P6 and P7). A similar trend was observed for the effect of

Table 4. The effect of *Trichoderma*-enriched organic fertiliser applied at different doses, both singly and in combination with inorganic fertilisers, on the number of leaves per green mustard plant at 21, 28 and 35 days after planting (DAP).

Treatment	Number of leaves per plant		
	21 DAP	28 DAP	35 DAP
P1	5.98 ± 0.07 b	7.10 ± 0.16 c	8.68 ± 0.52 c
P2	5.98 ± 0.07 b	8.04 ± 0.77 b	9.93 ± 0.33 b
P3	5.98 ±0.07 b	7.08 ± 0.36 c	8.62 ± 0.51 c
P4	6.37 ± 0.48 ab	7.60 ± 0.46 bc	8.70 ± 0.46 c
P5	6.18 ± 0.32 ab	7.31 ± 0.10 c	8.67 ± 0.44 c
P6	6.68 ± 0.48 a	9.65 ± 0.49 a	11.73 ± 0.43 a
P7	6.59 ± 0.50 a	9.14 ± 0.57 a	11.39 ± 0.53 a
P8	6.68 ± 0.46 a	9.32 ± 0.45 a	11.38 ± 0.57 a

Treatments follow annotations in Table 1. Number of leaves per plant expressed as mean ± standard error. Different letters in the same column indicate difference among treatments according to the LSD test at 5% significance level.

Table 5. The effect of *Trichoderma*-enriched organic fertiliser applied at different doses, both singly and in combination with inorganic fertilisers, on the leaf width of green mustard plants at 21, 28 and 35 days after planting (DAP).

Treatment	Leaf width (cm)		
	21 DAP	28 DAP	35 DAP
P1	7.50 ± 0.73 a	9.81 ± 0.57 a	10.23 ± 0.06 a
P2	9.74 ± 0.72 c	14.01 ± 1.74 b	14.50 ± 0.70 c
P3	7.94 ± 1.06 ab	10.43 ± 0.61 a	9.97± 0.29 a
P4	7.39 ± 0.96 a	10.20 ± 0.26 a	10.17 ± 0.31 a
P5	8.24 ± 0.91 b	10.59 ± 0.07 a	10.17 ± 0.21 a
P6	10.30 ± 0.46 c	13.88 ± 0.55 b	13.03 ± 0.49 b
P7	9.54 ± 1.03 c	13.19 ± 1.08 b	12.77± 0.42 b
P8	10.30 ± 0.67 c	13.93 ± 1.86 b	13.50± 0.66 b

Treatments follow annotations in Table 1. Leaf width expressed as mean ± standard error. Mean values followed by the same letter in the same column were not significantly different in the LSD test at 5% significance level.

Table 6. The effect of *Trichoderma*-enriched organic fertiliser applied at different doses, both singly and in combination with inorganic fertilisers, on the canopy width of green mustard plants at 21, 28 and 35 days after planting (DAP).

Treatment	Canopy width (cm)		
	21 DAP	28 DAP	35 DAP
P1	23.15 ± 3.64 a	26.04 ± 1.12 a	29.53 ± 1.55 a
P2	27.22 ± 2.30 b	38.18 ± 1.95 bc	39.70 ± 1.37 b
P3	22.11 ± 2.51 a	27.27 ± 2.57 a	29.03 ± 1.02 a
P4	22.19 ± 1.98 a	25.20 ± 1.61 a	28.17 ± 1.18 a
P5	22.33 ± 3.37 a	25.43 ± 1.54 a	28.67 ± 1.00 a
P6	28.81 ± 3.68 b	38.33 ± 2.39 c	44.17 ± 1.31 c
P7	26.93 ± 3.91 b	37.03 ± 3.20 bc	42.8 ± 1.25 c
P8	27.59 ± 3.48 b	35.34 ± 3.36 b	43.03 ± 3.71 c

Treatment follow annotations in Table 1. Canopy width expressed as mean ± standard error. Different letters in the same column indicate difference among treatments according to the LSD test at 5% significance level.

different fertilisation regimens on the dry yield and moisture content of the harvest (Table 7). Plants treated with inorganic fertiliser, either applied singly or in combination with organic fertilisers showed higher dry yield and moisture content compared with the control and those treated only with organic fertilisers, although the difference was not significant.

The combined application of inorganic and organic fertilisers, but not the sole treatment with organic fertiliser at different doses, resulted in higher yield compared to the standard treatment with inorganic fertilisers. Therefore, the relative agronomic efficiency was only calculated for treatments with combined application of inorganic and organic fertilisers (P6, P7 and P8) and shown in Table 8. The results showed that the lowest dose of organic fertiliser at 2 t/ha when used in combination with a halved standard dose of inorganic fertilisers was good enough to result in a productivity higher than the standard fertilisation regimen using only inorganic fertilisers.

IV. DISCUSSION

The growth of mustard greens was characterised by an increase in plant height, leaf number and width, and canopy width. Fertilisation provides extra nutrients to support the growth and productivity of plants cultivated on nutrient poor soil. In particular, provision of N is important for plant growth. A lack of N will hamper plant growth and produce short plants with limited root system development (Fageria & Moreira, 2011; Soepardi, 1983). The deficiency in N would also cause the leaves to turn yellow and die. Provision of N in sufficient amount

Table 7. The effect of *Trichoderma*-enriched organic fertiliser applied at different doses, both singly and in combination with inorganic fertilisers, on the fresh yield, dry yield and moisture content of mustard green harvest.

Treatment	Fresh yield (kg/m^2)	Dry yield (kg/m^2)	Moisture content (%)
P1	1.12 a	0.13	88.39
P2	3.01 b	0.27	91.03
P3	1.17 a	0.13	88.89
P4	1.14 a	0.14	87.72
P5	1.29 a	0.14	89.15
P6	3.28 b	0.27	91.77
P7	3.24 b	0.26	91.98
P8	4.21 c	0.32	92.40

Treatments follow annotations in Table 1.

Table 8. Relative agronomic effectiveness (RAE) value for treatments with combined application of *Trichoderma*-enriched organic and inorganic fertilisers.

Treatment	Production (kg/m^2)	RAE value (%)
P1	1.12	-
P2	3.01	100
P6	3.28	114
P7	3.24	112
P8	4.21	163

Treatments follow annotations in Table 1.

by fertilisation would support plant growth through the development of leaves with the readily available N that promotes chlorophyll formation and cell division. An increased number of cells eventually results in the increase in the number and size (width) of leaves with enriched chlorophyll. This would increase sunlight interception for photosynthesis, and thus the production of carbohydrates and metabolites to support optimal plant growth.

The increase in plant growth is influenced by the fertilisation regimen. Inorganic fertilisers supply N directly to the soil, while nutrients are slowly released from the organic material in the soil for root uptake. The lower performance of sole application of *Trichoderma*-enriched organic fertiliser (treatments P3, P4 and P5) was not unexpected. According to Lingga and Marsono (2003), organic fertilisers have low macro- and micronutrients content, it follows that nutrients supplemented with organic fertiliser can be insufficient to support optimal plant growth. The uncontrolled rate, pattern and duration of release of nutrients from organic fertiliser which is dependent on the microbial activity driven by soil moisture and temperature condition (Liu *et al.*, 2017) also explained the inability of organic fertiliser to increase plant growth and production in our study. Nevertheless, Yunita *et al.* (2017) found the addition of rice husk compost and liquid organic fertiliser to the planting medium can increase the growth and production of sweet mustard plants. Although inorganic fertilisers supply only macro-elements, the nutrients were directly made available to the soil and can be taken up immediately for plant growth. As such, treatment with the standard application of inorganic fertilisers (P2) was more effective in promoting plant growth.

Compared to plants without fertilisation (control), or treated only with inorganic (treatment P2) or *Trichoderma*-enriched organic fertilisers (treatments P3, P4 and P5), the application of inorganic fertilisers at half of the standard dose in combination with organic fertiliser (treatments P6, P7 and P8) further improved plant growth because the fertilisation regimen provided macro- and micronutrients needed for optimum plant growth. This is in agreement with various studies that found a combined application of N fertiliser and organic fertiliser would provide high enough nutrients to support optimum plant growth (Moe *et. al.*, 2017; Nyakpa *et. al.*, 1988; Olowoboko *et. al.*, 2017; Roba, 2018; Sugito & Tugeno, 1999). According to Hakim (1986), the provision of N at a high dosage favours the conversion of carbohydrates into proteins, which in turn promotes the formation of protoplasm and results in an increase in the width, length and number of leaves. The application of high N inorganic fertilisers and high dose of organic fertiliser would supply more nutrients to the soil for the vegetative growth of plants, therefore the application rate of fertiliser also affects the harvest weight (Rakhmiati *et al.*, 2003).

The combined application of organic fertiliser enriched with *Trichoderma* sp. and inorganic fertilisers used in this study improved the growth of green mustard plants (plant height, number of leaves per plant, and leaf and canopy width), as well as the biomass and moisture content of crop. The highest plant growth and production was observed in treatment with 3 t/ha organic fertiliser in combination with half of the standard dose of inorganic fertilisers. The ready availability of all essential nutrients supplied by fertilisers in the soil enables the formation of more proteins required for better plant growth (Harlina, 2003). Plants would grow well and produce good yield when sufficient nutrients were provided with the application of fertilisers at dosage that takes into consideration the nutritional needs of plants, nutritional status of the soil, and also nutrient content of fertilisers to be applied (Hardjowigeno, 2003). Although the use of organic fertiliser did not show apparent improvement in the soil properties and plant production in this study, probably because the study period was too brief, the results showed that organic fertiliser can be used in combination with inorganic fertilisers to increase crop production while reducing the use of inorganic fertilisers.

The higher biomass and moisture content of mustard greens obtained with combined treatments of organic and inorganic fertilisers is especially relevant in the production of mustard greens because the leafy vegetable is harvested before the generative growth phase. Products with greener and higher number of leaves are desirable, and can be obtained by providing sufficient N to the plants to improve the growth and development of leaves. Organic fertiliser functions as an additional source of nutrients, while it also plays a role in improving the physical, chemical and biological properties of the soil, thereby promoting increased nutrient uptake by the roots. The application of *Trichoderma*-enriched organic fertiliser in improving the quality of harvest had been documented (Ali *et. al.*, 2015; Barua *et. al.*, 2018; Haque *et. al.*, 2010; Hardianus *et. al.*, 2017; Wolna-Maruwka *et al.*, 2017). Although similar improvement by treating plants only with *Trichoderma*-enriched organic fertiliser was not seen in this study, supplementing inorganic fertilisation with organic fertiliser resulted in increased moisture content of the harvested mustard greens. This can be attributed to the larger surface area of organic fertiliser that increases its CEC and water holding capacity to retain nutrients and water in the soil, thereby stimulating microbial activity and improving soil aggregate and structure to enable better nutrient mobilisation and water use by the plants (Afa, 2016; Ahmad *et. al.*, 2017; Kalbani *et al.*, 2016). In addition, the C3 plants had been shown to be more amenable to the benefits of soil amendment using biochar and polyacrylamide compared to C4 plants which are already well-adapted with efficient photosynthesis and production (Lee *et al.*, 2013). The improved plant growth and productivity of green mustard which is one of the C3 plants following fertilisation regimen involving both organic and inorganic fertilisers is thus not unexpected given the well-established functions of organic fertiliser in ameliorating the soil properties.

V. CONCLUSION

The organic fertiliser enriched with *Trichoderma* sp. when applied singly at different doses (P3, P4 and P5) did not improve plant growth. However, significantly improved growth and harvest quality in terms of plant height, leaf number and width, harvest biomass and moisture content were observed when the mustard greens were treated with organic fertiliser in combination with inorganic fertilisers (P6, P7 and P8) compared to the standard fertilisation regimen using only inorganic fertilisers (P2). Based on the results from this study, we recommended the combined application of organic and inorganic fertilisers as an effective fertilisation regimen for improving the productivity of mustard greens with reduced use of inorganic fertilisers. Further research is expected to be carried out to establish the minimum effective dose of the organic and inorganic fertilisers to improve the productivity of not only the green mustard, but also other horticultural crops according to the soil condition and the specific nutritional needs of each type of crop.

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