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Effects of Vermicompost Levels on the Growth and Yield of HT152 Tomato Variety Grown Organically

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***Abstract* — The aim of this study is to investigate the appropriate vermicompost dose in tomato production following organic direction. The tomato variety, HT152, was cultivated in field at the Center for Organic Agriculture Promotion and Studies (COAPS), Vietnam National University of Agriculture in autumn-winter season 2012 and 2013. Both experiments arranged in a Randomized Complete Block Design-RCBD included six vermicompost levels (10, 15, 20, 25, 30, 35 ton ha^{-1}) with three replications.The results showed that vermicompost dose had significant effect on plant height, leaf number, and height and internode number from stump to the first flower cluster. When appling higher vermicompost levels, significant higher in individual fruit weight and yield of tomato were supported. The highest yield was obtained at 35 ton ha^{-1} vermicompost (in autumn-winter season 2013) and at 30 ton ha^{-1} vermicompost (in autumn-winter season 2012, but the difference was not significant as compared to level 35 ton ha^{-1}). Vermicompost had beneficial effects not only on yield but also on fruit quality. By regression way, the regression equation that presents depended relation between yield of HT152 tomato variety and vermicompost dose was established as following: $y = 0.0054x^2 + 0.3596x + 34.602$ with $R^2 = 0.4745$. The result of optimal calculation indicated that the highest yield of HT152 tomato variety at optimal vermicompost dose of 33.3 ton ha^{-1}. The knowledge gained from this study provided an important link about organic production, and could further improve product quality not only in tomato, but also in other plants.**

***Keywords* — HT152 Tomato Variety, Organic Agriculture, Vermicompost, Correlation, Optimal Dose.**

I. INTRODUCTION

Fresh produce, include tomato (*Lycopersicumesculentum*), is an essential component of human diet. It contains micro-nutrients, vitamins and certain phytochemicals which contribute significantly to human diet [1]. It has been strongly advocated by relevant global agencies that, consumption of approximately 400 g of fresh produce per day has a prophylactic capacity to stem the tide of certain maladies in humans such as carcinoma, diabetes and cardiovascular diseases [2]. Despite its veritable contribution to human diet, the quality of fresh produce consumption has been greatly challenged by the excessive application of chemical fertilizers and pesticides [3]. Heavy use of agrochemicals since the "green revolution" of the 1960s to get a better yield killed the beneficial soil organisms, destroyed their natural fertility, reduced the biological resistance ability in crops making them more susceptible to pests and diseases, further affected human health [4]. In this context, the application of organic agricultural production is crucial because they not only can promote plant growth and yield but also can increase product quality.

Organic agriculture is a production system that sustains the health of soils, ecosystems and people [5]. In 2014, Vietnam has 43,007 ha organic agricultural land (including in-conversion areas), accounting for 0.4 percent of total agricultural land [6]. In organic production, instead of chemical fertilizers with many adverse effects, organic manures were applied, in there, vermicompost has high porosity, drainage, water holding capacity and microbial activity. Vermicompost is produced by biodegradation of organic material such as farm wastes, kitchen wastes, market wastes etc. through interactions between earthworms and microorganisms [4,7]. Vermicompost contains an average of 1.5% - 2.2% N, 1.8% - 2.2% P and 1.0% - 1.5% K. The organic carbon is ranging from 9.15 to 17.98 and contains micronutrients like Sodium (Na), Calcium (Ca), Zinc (Zn), Sulphur (S), Magnesium (Mg), Iron (Fe) and growth hormones auxins, gibberlins, cytokinins [4]. Vemicompost is reported to affect positively to growth and productivity of plants and several studies had examnined the effects of vemicompost on numbers of plants such as: cereals, legumes, vegetables, ornamental and flowering plants and field crops [8]. Available nutrients in vemicompost such as nitrate, exchangeable phosphorus, potassium, calcium and magnesium as well as natural plant growth regulation that supplied and stimulate plant growth [9]. However, the application of vermicompost in Vietnam is not much and its effects on plant growth requires further research. Therefore, the main objectives of the present study were to investigate the effects of vermicompost on the growth, yield and quality of HT152 tomato cultivar and find out optimal dose for HT152 tomato cultivar under field conditions.

II. METHODOLOGY

A. Materials

Tomato variety: HT152 is a hybrid tomato variety which is stable and high yielding, resistant to heat and wilt disease. They ripen early, elongated fruit, flesh thickness and withstand to long-distance transport.

Vermicompost: Vermicompost was collected at Faculty of Veterinary Medicine, Vietnam National University of Agriculture.

B. Methodology

Experimental design:

Both experiments were arranged in a Randomized Complete Block Design-RCBD included six treatments equivalent with six vermicompost levels (10, 15, 20, 25, 30, 35 ton ha^{-1}) with three replications in two years 2012 and 2013 in autumn-winter season. Tomato seeds were sown in plastic pots containing slob soil, vermicompost and Songgianh microorganism fertilizer with ratio 2:2:1. The pots were placed in a greenhouse until germination. Tomato seedlings were transplanted into the field 3 weeks after germination, when they had 4-5 leaves. Each plot area on field was 5m^2.

Plant nutrient:

Vermicompost with above levels and Songgianh microorganism fertilizer with level 2 ton ha^{-1} were supplied to soil before culturing.

After 10 days since cultivation, we sprayed organic nutrient solution once a week with 1% concentration. Organic nutrient solution was extracted following the method of Cho and Koyama (1997):

+ Fish, water spinach and mugwort were soaked separately with molasses at 1:1 ratio. After 30 days, filting to take each solution;
+ Animal bones soaked with vinegar at 1:10 ration. After 15 days, filting to take solution;
+ Mixing above solutions with equal in appropriate proportion obtained the organic nutrient solution.

Organic nutrient solution contains an average of 8.8 mg L^{-1} N, 32.3 mg L^{-1} P, 148.1 mg L^{-1} K and 81x10^8 CFU ml^{-1} aerobic bacteria.

***Pests and diseases control*:**

Pests and diseases were controlled by using organic solution which extracted from garlic, chili, cinnamon soaked with molasses with ratio 1:1 [10].

C. Measurements and data analysis

- Growth and yield parameters: Plant height, leaf number, the height and internode number from stump to the first flower cluster, number of fruits per plant, average fruit weight (g), individual yield (g plant^{-1}) (individual yield = average fruit weight * number of fruits per plant), total yield (ton ha^{-1}) (total yield was calculated as the sum of ripened fruits harvested until the end of the experiment)
- Fruit morphological parameters: Fruit pattern index (I) (I=L/C, L: Fruit length, C: Fruit circumference), fruit flesh thickness.
- Fruit quality parameters: Dry matter content (fruit after weighing fresh weight were put in paper bags and dried at 80^{0}C until constant weight reached. Dry matter content (%) = dry weight/fresh weight*100), Brix degree was measured by Brix REF107 meter, total sugar content was determined by Bertrand method, NO_3^- content was determined by Kjeldahl method.
- Economic effectiveness: Net income of each treatment was also calculated by following formulas:

Total variable cost = ∑ Cost of all variable inputs = Cost of land preparation + Cost of fertilizer + Cost of human labor + Cost of other inputs

Gross return = Returns from fruits

Net income = Gross return – Total variable cost

-Data processing and statistical analysis were done using Microsoft Excel and IRRISTAT Software (http://irristat.software.informer.com/). One-way analysis of variance (ANOVA) was used for analyzing each set of data. Differences between treatments were tested by Least-Significant Difference (LSD) value at significant level 0.05.

III. Results and Discussions

A. The effect of vermicompost levels on the growth of HT152

In autumn-winter season 2012, plant height was the highest when HT152 plants were growed with 30 ton ha^{-1} vermicompost (83.5) and 35 ton ha^{-1} level (82.4 cm).Meanwhile, in autumn-winter season 2013, the highest plant height was 85.7 cm which was observed for vermicompost dose 35 ton ha^{-1} and significant decrease with reduction of vemicompost levels (Table 3.1). A similar trend was published by Joshi and Vig (2010) [3]. Accordingly, the mean plant height of tomato in treatment VC15 (soil+15% vermicompost), VC30 (soil+30% vermicompost) and VC45 (soil+45% vermicompost) were found to be 63cm, 63.4 cm and 63.5cm, respectively, which were significantly greater than in soil (control).

Table 3.1. The effect of vermicompost levels on HT152 growth

Vermicompost levels (ton ha^{-1})	Plant height (cm)		Leaf number		The heightfrom stump to the first flower cluster (cm)		The internode number from stump to the first flower cluster	
	2012	2013	2012	2013	2012	2013	2012	2013
10	78.1^{c}*	74.5^{c}	14.7^{c}	17.9^{e}	37.8^{c}	30.1^{d}	9.3^{c}	7.6^{e}
15	79.7^{c}	76.9^{c}	14.6^{c}	18.4^{d}	40.4^{b}	31.3^{cd}	9.3^{c}	7.7^{de}
20	79.7^{c}	80.1^{b}	14.9^{bc}	19.6^{c}	41.8^{ab}	32.6^{bc}	9.4^{bc}	8.0^{cd}
25	81.6^{b}	81.1^{b}	15.1^{b}	20.4^{b}	43.0^{a}	33.5^{ab}	9.6^{ab}	8.2^{bc}
30	83.5^{a}	82.2^{b}	15.8^{a}	20.8^{ab}	43.9^{a}	34.2^{ab}	9.8^{a}	8.4^{b}
35	82.4^{ab}	85.7^{a}	15.9^{a}	21.2^{a}	42.6^{ab}	34.9^{a}	9.7^{a}	8.8^{a}

** Mean values sharing the same letter(s) in a column do not differ significantly according to Least-Significant Difference (LSD) value (P=0.05)*

A significant increase in leaf number of tomato plant was observed by the increasing of levels of vermicompost. Vermicompost has high microbial activity due to presence of fungi, bacteria and actinomycetes [11]. They can produce plant growth regulators (PGRs) such as auxins, gibberellins, cytokinins, ethylene and abscisic acid [12], then affected positively to the plant growth.

According to KieuThi Thu (1998) [13], the internode number from stump to the first flower cluster correlated with the growth period. The internode number is less, the flowering and ripening time is shorter, could further shorten harvest time. This has significant in increasing the cultivated season per year. The internode number from stump to the first flower cluster was significantly affected by genotype, nutrient status and environmental conditions. The results showed that, increasing vermicompost levels enhanced significantly the internode number. However, in autumn-winter season 2012, the difference between levels 25, 30 and 35 ton ha^{-1} was not significant (Table 3.1).

Table 3.2. The effect of vermicompost levels on yield components and yield of HT152

Vermicompost levels (ton ha^{-1})	Number of fruits per plant		Average fruit weight (g)		Individual yield (g plant^{-1})		Yield (ton ha^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013
10	24.8^{b*}	23.6^{f}	70.6^{d}	66.2^{f}	1747.7^{d}	1563.0^{f}	37.8^{b}	40.0^{f}
15	25.1^{b}	25.2^{e}	72.6^{c}	68.1^{e}	1818.2^{cd}	1711.6^{e}	38.4^{b}	43.8^{e}
20	25.3^{b}	26.9^{d}	75.6^{b}	69.4^{d}	1908.8^{bcd}	1866.6^{d}	39.6^{b}	47.8^{d}
25	26.4^{b}	28.4^{c}	76.5^{b}	71.3^{c}	2016.4^{abc}	2028.0^{c}	41.6^{ab}	51.9^{c}
30	26.7^{b}	30.5^{b}	79.6^{a}	73.4^{b}	2121.5^{ab}	2239.2^{b}	44.8^{a}	57.3^{b}
35	29.8^{a}	32.4^{a}	80.2^{a}	75.6^{a}	2150.3^{a}	2446.9^{a}	44.2^{a}	62.6^{a}

** Mean values sharing the same letter(s) in a column do not differ significantly according to Least-Significant Difference (LSD) value (P=0.05)*

The heightfrom stump to the first flower cluster is determined by the number and height of internode. It affects the first fruit cluster location as well as disease infection. If the heightfrom stump to the first flower cluster too short, the plants more susceptible to disease. In contrast, if too high, plants easily to collapse and affect the development of next flower clusters [13]. The effect of vermicompost levels on the height from stump to the first flower cluster same as on the internode number. Nevertheless, the difference between high levels of vermicompost was not significant in both seasons. It proved that the high vermicompost dose did not affect tomato structure.

B. The effect of vermicompost levels on yield components and yield of HT152

Vermicompost level of 35 ton ha^{-1} showed the significantly highest number of fruits per plant (29.8 in 2012 and 32.4 in 2013); average fruit weight (80.2 g in 2012 and 75.6 g in 2013) and individual yield (2150.3 g plant^{-1} in 2012 and 2446.9 g plant^{-1} in 2013) (Table 3.2). According to Adhikary (2012) [4], vermicompost is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes as well as nitrogen-fixing, phosphate plants.

In autumn-winter season 2012, the highest total yield of HT152 was 44.8 ton ha^{-1} at level 30 ton ha-1 vermicompost, but was not significant as compared to level 35 ton ha^{-1} vermicompost (44.8 ton ha^{-1} total yield).solubilizing bacteria, actinomycets and growth hormones. Both vermicompost and its body liquid (vermiwash) areproven as both growth promoters and protectors for crop

In autumn-winter season 2013, total yield was highest (62.6 ton ha^{-1}) under level 35 ton ha^{-1}vermicompost, significantly higher than other treatments. The result of our experiment showed addition of vermicompost had significant positive effect on yield of tomato. The similar trend also observed in study of Azarmi et al. (2008) [14].

C. The effect of vermicompost levels on morphological and quality parameters of HT152

We studied some parameters according to the typologies of tomato, including the pattern index of the unit in autumn-winter season 2012. The results showed that, HT152 tomato variety had elongated fruit shape (pattern index ranged from 1.17 to 1.23) (Table 3.3). The fruit firmness is one of the important morphological characteristics because of relationship with its storage and transferred capacity. The fruit firmness is determined by the peel firmness as well as the fruit flesh thickness (Nguyen Hong Minh and KieuThi Thu, 2006).In our research, the fruit flesh thickness of HT152 variety fluctuated form 0.72 cm to 0.79 cm (in autumn-winter season 2012).and from 0.60 cm to 0.76 cm (in autumn-winter season 2013), corresponding with the fruit flesh thickness of HT21, VF10 and HT7 cultivars has been rated as the varieties had good fruit firmness according to research of Nguyen Hong Minh and KieuThi Thu (2006) [15]. In both seasons, level 35 ton ha^{-1} showed the highest fruit flesh thickness (0.79 cm and 0.76 cm) however, the difference between levels 35, 30 and 20 ton ha^{-1} was not significant in autumn-winter season 2012 (Table 3.3).

Table 3.3. The effect of vermicompost levels on morphological and quality parameters of HT152

Year	Vermicompost levels (ton ha^{-1})	Fruit pattern index (I)	Fruit flesh thickness (cm)	Dry matter content (%)	Brix degree	Total sugar content (%)	Nitrate content (mg kg^{-1})
2012	10	1.21	0.72^{c*}	5.64	4.43	4.06	25.76
	15	1.22	0.77^{b}	5.58	4.55	4.57	34.68
	20	1.23	0.78^{ab}	5.81	4.40	3.58	25.40
	25	1.20	0.77^{b}	5.74	4.45	4.01	23.07
	30	1.19	0.78^{ab}	5.88	4.58	4.26	26.56
	35	1.17	0.79^{a}	5.95	4.53	4.18	23.88
2013	10	-	0.60^{d}	5.13	4.17	-	12.8
	15	-	0.62^{cd}	5.21	4.28	-	-
	20	-	0.65^{c}	5.24	4.48	-	19.5
	25	-	0.69^{b}	5.39	4.63	-	-
	30	-	0.71^{b}	5.62	4.71	-	-
	35	-	0.76^{a}	5.90	4.73	-	16.6

** Mean values sharing the same letter(s) in a column do not differ significantly according to Least-Significant Difference (LSD) value (P=0.05)*

One of the main objectives of these experiments was to test whether producing organic tomato has acquired some predisposition that affected fruit quality. Tomato fruit quality has been assessed by the the content of chemical compounds such as dry matter, Brix degree, acidity, single sugars, citric acids and volatile components [16]. Fruit dry matter content of HT152 ranged from 5.58 to 5.95 and 5.13 to 5.90 in autumn-winter season 2012 and 2013, respectively. Our results were slightly lower than values reported by Zaller (2007)[9] yet in acceptable range.

The Brix degree is expressed a unit of total soluble solids (TSS) content [17]. Suarez et al. (2008) [18] demonstrated the mean values of Brix degree varied according to variety, cultivation method and harvest period for the same group of tomatoes. The data showed that the average content Brix degree was 4.6 ± 0.9. In our research, the Brix degree of HT152 fluctuated from 4.17 to 4.73, corresponding with previous finding. These data also similar to values published by Nguyen Hong Minh et al. (2013) [19] when assessed some new combinations of hybrid tomato in 2011 autumn-winter and 2012 spring-summer cropping season and these new hybrid combinations indicated were tasty.

Sugar concentrations of tomato fruits have been shown to be affected by plant nutrition, water supply and light intensity. Especially, contents of sugars are also directly linked to tomato flavour attributes [9]. In our study, under effect of vermicompost, total sugar content in tomato fruits planted in autumn-winter season 2012 fluctuated from 3.58% to 4.57% (Table 3.3). According to research of Nguyen Hong Minh anhKieuThi Thu (2006) [15], a hybrid tomato variety, HT21, had high sugar content was 3.46%. It proved that, using vermicompost not only increased yield but also enhanced fruit quality. Impact on fruit quality of vermicompost could also be shown in comparison to hydroponic substrates[20] or when applied as foliar spray [21].

In organic production, one of the quality standards is nitratecontent in products. Nitrate content of vegetables depends on a number of external and internal factors. External factors should be mentioned such as supply of substrate with nitrate, light, temperature, relative humidity, carbon dioxide concentration in the air, the influence of the accompanying cations, heavy metals, herbicides, chemical properties of the soil, location, time of sowing, time and method of harvest, storage conditions, etc. Among the internal factors, the most important are the genetic specificity in the accumulation of nitrate (differences between species and differences within genotypes), the distribution of nitrate in certain parts of the plant, and the age of the plants. The tomato belongs to the vegetable plants, which accumulate fewer nitrates than other vegetables (100 to 150 mg kg^{-1}) [22]. In our research, nitrate contents in all treatments were far lower than safe level (12.8 to 34.68 mg kg^{-1} as compared to 150 mg kg^{-1}). A comparable study conducted in Austria on 17 vegetables found lower nitrate contents (-40% to -86%) in organic vegetables, except spinach [23]. In Germany, a comparison on carrots also showed 61% fewer nitrates in organic ones[24].

D. The economic effectiveness of different vemicompost treatments

We also estimated the economic effectiveness of different vemicompost treatments in autumn-winter season 2013 which is presented in Table 3.4. The data showed that using higher vermicompost level had higher total variable cost but with higher yield led to higher gross return as well as net income. It increased from 400 million VND per ha to 626 million VND (gross return) and from 258.57 million VND to 422.07 million VND (net income). Therefore, the addition of vermicompost had significant positive effect not only on yield but also on net income.

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Table 3.4. Economic effectiveness* of organic HT152 tomato production

Vermicompost dose (ton ha^{-1})	Vermicompost cost (1000 VND ha^{-1})	General cost** (1000 VND ha^{-1})	Total variable cost (1000 VND ha^{-1})	Yield (ton ha^{-1})	Price (1000 VND kg^{-1})	Gross return (1000 VND ha^{-1})	Net income (1000 VND ha^{-1})
10	25,000	116,430	141,430	40.0	10	400,000	258,570
15	37,500	116,430	153,930	43.8	10	438,000	284,070
20	50,000	116,430	166,430	47.8	10	478,000	311,570
25	62,500	116,430	178,930	51.9	10	519,000	340,070
30	75,000	116,430	191,430	57.3	10	573,000	381,570
35	87,500	116,430	203,930	62.6	10	626,000	422,070

** Economical effectiveness calculated at the price in 2013*

*** General cost includes the cost of seed, Songgianh microorganism fertilizer, plant nutrient, pests and diseases controlled solution.*

By regression analysis, the regression equation that presents a close relationship between yield of HT152 tomato variety and vermicompost level with $R^2 = 0.6443$. The result of optimal calculation indicated that the highest yield of HT152 tomato variety at optimal vermicompost dose of 33.3 ton ha^{-1}.

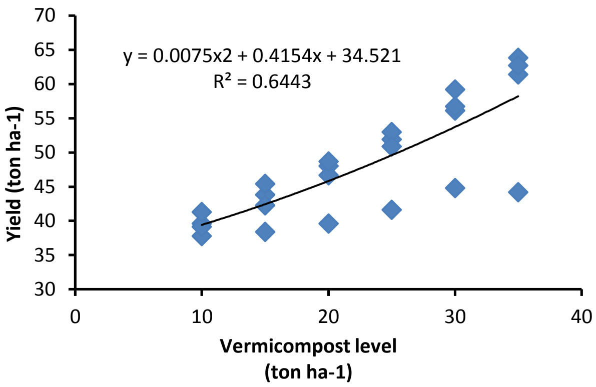

Figure 3.1. The correlation between vermicompost levels and yield of HT152

IV. Conclusion

1. Vermicompost affected significantly the growth and yield of HT152 tomato variety. Increased vermicompost dose enhanced plant height, leaf number, height and internode number from stump to the first flower cluster as well as individual fruit weight and yield of tomato. The highest yield was obtained at 35 ton ha^{-1} vermicompost (in autumn-winter season 2013) and at 30 and 35 ton ha^{-1} vermicompost (in autumn-winter season 2012). Level of 35 ton ha^{-1} also gained the highest net income with 422.07 million VND per ha.
2. Vermicompost had beneficial effects not only on yield but also on fruit quality. Tomato fruit produced organically indicated were tasty with high flesh thickness, total sugar content and Brix degree. The use of vermicompost obtained low nitrate accumulation in products.
3. By regression way, we indicated the highest yield of HT152 tomato variety obtained at optimal vermicompost dose of 33.3 ton ha^{-1}.

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