EFFECTS OF SOME ORGANIC FERTILIZER COMBINATIONS TO GREEN TEA GROWTH, YIELD FOLLOWING THE ORGANIC PRODUCTION

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ABSTRACT

When transitioning from traditional cultivation to organic cultivation green tea yields and quality decrease significantly. There is a problem which green tea farmers is currently facing to. To minimize these disadvantages, this is needed to conduct researches to identify appropriate technical methods, practies and fertilization. In this study, we conducted research on four fertilizer combinations for green tea with the following quantities per hectare: 15 tons + 70 kg MgO, 25 tons + 70 kg MgO, 35 tons + 70 kg MgO and 7 tons of organic fertilizer + 180 N + 100 P_2O_5 + 120 K_2O + 70 kg MgO (control). The experiment was arranged in a completely randomized block design and criteria of growth, yield, quality and pests on green tea plants were monitored. The research results revealed that the combination of 35 tons of organic fertilizer + 70 kg MgO/ hectare had good results. With this amount of fertilizer, the green tea plants exhibited good growth, tree height, canopy width, and stem diameter were equivalent to the control formula. The components of yield such as bud density (202.5 buds/m^2), bud weight (0.82g/bud), and yield (1740.3 kg/ha) were high and equivalent to the control formula. While the tea quality decreased slightly (green yellow color of water, a slightly bitter, sweet aftertaste and a pleasant aroma). The rate of infestation by some harmful insects such as Chlorita flavescens Fabr. (3.3 individual/tray), Physothrips setiventris density *(0.22 individual/bud), Metatetranychus bioculatus density (0.35 individual/leaf), and Helopeltis theivora (20%), they were equivalent to the control formula.*

Keywords: *Green tea, organic fertilizer, growth , yield, LPD1.*

1. INTRODUCTION

Organic agriculture is a production system that protects land resources, ecosystems and human health, based on ecological cycles and biodiversity adapting to natural conditions.This production system is not used the factors that negatively impacts on the ecological environment. Organic agriculture is a combination of traditional techniques and scientific advances to benefit the environment, creating fair relationships and a balanced life in the ecosystem (Decree No. 109/2018/ND- CP dated August 29, 2018 of the Government on organic agriculture) [1].

Organic agriculture plays a huge role not only in the health of producers and consumers but also in the improving and protecting ecological environment and contributes in the sustainable development of agriculture. Specifically, organic agriculture has the following main roles: maintaining and preserving soil fertility; mitigating water pollution; ensuring high biodiversity; ensuring good product quality; improving economic efficiency and protecting the ecological environment.

According to FAO statistics (2020), Organic Agriculture was practiced in 187 countries and 72.3 million hectares of agricultural land which were managed organically by at least 3.1 million farmers. Global sales of organic food and drinks reached more than 106 billion euros in 2019.[2]

Thai Nguyen is a northern midland and mountainous province with a priority agricultural product of green tea. Thai Nguyen's tea output and area cultivation always lead on the top of our the country. In 2022, the whole agriculture product had over 22.2 thousand hectares, of which the area for tea products reached 20.9 thousand hectares; Fresh tea bud output reached over 260 thousand tons [3].

The production of tea according to organic standards is the right direction to gradually transition to sustainable organic agriculture (The Prime Minister's Decision No. 885/QD-TTg dated June 23, 2020 approved the Project on the Development of Organic Agriculture for the 2020-2030 period [4]. However, organic production involves strict processes, and the conversion from traditional tea production to organic tea faces certain difficulties. The main reasons include: 1) soil pollution with residues of fertilizers, plant protection chemicals in traditional tea cultivation models, and 2) both tea yield and quality decrease during the period of 18-36 months when transitioning from traditional to organic production.

Tea is one of the key crops in the province for many years, Thai Nguyen province has shown interest and focused on allocating resources for the investment and development of tea cultivation and tea products [5]. The

direction is to both expand the cultivation area, enhance processing and develop towards improving quality, inceasing added value, and enhancing product competitiveness.

With the goal of overcoming the difficulties faced by tea farmers when transitioning to organic production with high productivity and maintaining tea quality, we conducted experiments with various organic fertilizer levels to monitor the growth and yield of green tea plants.

2. MATERIALS AND METHODOLOGY

2.1. Materials

a) Research Materials

The organic fertilizer used in the experiment is the HDT-02 organic biological fertilizer, with the following composition: organic matter 30%, total nitrogen (N) 1.5%, effective phosphorus (P_2O_5) 1.5%, effective potassium (K_2O) 2%, humic acid 2%, moisture content 30%, C/N ratio 12, pH 5.

The experimental object is the 8-year-old hybrid tea LDP1 at Thai Nguyen University of Agriculture and Forestry.

b) Experimental Design Method

The experiment includes 4 fertilizer formulas with 3 replications arranged in a Randomized Completely Block Design (RCBD). The area of each experimental plot is $60m_2$

CT1 (control): 7 tons of organic fertilizer + 180 N + 100 P_2O_5 + 120 K_2O + 70kg MgO per hectare

CT2: 15 tons of organic fertilizer + 70 kg MgO per hectare

CT3: 25 tons of organic fertilizer + 70 kg MgO per hectare

CT4: 35 tons of organic fertilizer + 70 kg MgO per hectare

Replication I	CT1	CT 3	CT 4	CT 2
Replication II	CT 2	CT 4	CT 3	CT 1
Replication III	CT 3	CT 2	CT 1	CT 4

Figure 1: Experimental layout diagram

2.2. Methodology

a) Soil Sample Collection and Analysis Method

Soil samples were collected before fertilizer application in the experimental plots according to TCVN 7538-2:2005 (ISO 10381-2:2002). Samples were taken using a cross-line method in the cultivated soil layer from 0-30 cm. The samples were collected at five points along the cross-line in each plot. At each point, a small hole was 30 cm deep, and a thin layer of soil was cut vertically from top to bottom (200g). The soil samples from the 5 points were mixed to create a 1kg sample for analysis.

Determination of total nitrogen content (%): According to TCVN 6645:2000

Determination of total phosphorus (P_2O_5) content (%): According to TCVN 8940–2011

Determination of total potassium (K_2O) content (%): According to TCVN 8660-2011

b) Determination the growth and yield criteria of green tea.

Five tea plants were selected in each experimental plot using a cross-line method for monitoring.

*Monitoring of morphological indicators:

- Plant height (cm): Measured from the root collar to the highest point of the canopy.
- Canopy width (cm): Measured at the widest point of the canopy.
- Root collar diameter (cm): Measured 2 cm above the root collar using calipers.

*Monitoring of yield and yield components:

- Buds density/m^2: Counted using a 25x25cm frame, considering only buds with 2 leaves.
- Weight of buds with 2 leaves: Harvested 30 buds with 2 leaves, weighed and then converted to the weight of 1 bud.

- Percentage of low quality buds: Randomly weighed 100g, counted the total number of buds, the number of low quality buds, and calculated the percentage of low quality buds.
- Yield (kg/ha): The actual average yield of fresh buds for each experimental formula, converted to hectares.

*Quality indicators: measured twice

- Main pest status: Monitoring of some main pests in the main tea harvests
- *Chlorita flavescens Fabr.* density: In each formula, 5 corner points were selected, each point investigated 5 trays. Aluminum trays sized 35x25 cm were coated with petroleum jelly, tilted at a 45° angle, shaken (3 shakes), then counted the number of *Chlorita flavescens Fabr.* in the tray and averaged per formula.

Chlorita flavescens Fabr. density (individual/tray) $= \frac{\text{Total number of } Chlorita\ flavescens\ Fabr. \text{ investigated}}{\text{Total number of trays investigated}}$

- Density of *Physothrips setiventris* : In each formula, 20 buds (1 shoot with 2-3 leaves) were randomly selected and placed in a nylon bag to count the number of *Physothrips setiventris*. *Physothrips setiventris* density was calculated according to the formula:

Physothrips setiventris density (individual/bud) $= \frac{\text{Total number of } Physothrips\ setiventris}{\text{Total number of buds investigated}}$

- Density of *Metatetranychus bioculatus*: In each formula, 5 points were selected, each point harvesting 20 buds to count *Metatetranychus bioculatus* under a magnifying glass. *Metatetranychus bioculatus* density was calculated according to the formula:

Metatetranychus bioculatus density (individual/leaf) $= \frac{\text{Total number of } Metatetranychus\ bioculatus}{\text{Total number of leaves investigated}}$

Investigation of *Helopeltis theivora*: In each formula, 5 points were investigated, each point harvesting 20 buds for transport to the research room, and the percentage of damaged buds was calculated according to the formula:

Percentage of damaged buds (%) $= \frac{\text{Number of buds damaged by } Helopeltis\ theivora}{\text{Total number of buds investigated}} \times 100$

2.3. Data analysis

Data calculation was performed using Excel software, and statistical analysis was carried out using SAS software.

3. Results and Discussion

3.1. Results of Soil Analysis

Soil plays a crucial role in the development of crops, particularly in tea plants. It serves as a medium and a source of nutrients for plant growth. The organic, inorganic compounds and microorganisms present in the soil are absorbed by plant roots to participate in metabolic processes and photosynthesis, thereby influencing the quality of the products. Nitrogen (N), phosphorus (P), and potassium (K) are three essential elements that significantly impact the growth of tea plants. To accurately assess the effectiveness of fertilizer levels in the experiment, analyzing the soil before planting is essential to determine the baseline factors. The results of the analysis are as follows:

Nitrogen (N): The total nitrogen content is 0.14%. It showed that the total nitrogen amount in the soil lie in medium level. This indicates that the soil contains a moderate amount of nitrogen, suitable for various types of crops.

Phosphorus (P_2O_5): The phosphorus content is 0.35%, indicating at high level. Phosphorus is crucial for the development of roots and fruits of plants, so this concetration will be sufficient for many types of crops.

Potassium (K_2O): The potassium content is 0.20%, also at medium level. Potassium is important for overall plant development and resistance to pests and diseases.

Conclusion, the soil used in the experiment with amount of 0.14% total nitrogen, 0.35% total phophorus, 0.20% total potassium is nutrient-rich soil.

3.2. Influence of Some Organic Fertilizer Combinations on Morphological Characteristics of Tea Plants

Plant height is a significant indicator for evaluating the quality of tea cultivation, reflecting the genuine growth process of the plant. Plant height varies depending on the tea variety, cultivation techniques, fertilization practices, climatic conditions, soil type, and topography. Additionally, It directly affects the harvesting process, if plants with big high can make difficult to harvest. To assess the impact of some organic fertilizer combinations on plant height growth, the results are presented in Table 1:

Fomular	Plant height before experiment (cm)	Plant height after 6 months (cm)	Increasing the canopy width (cm)	Stem diameter (cm)
CT1 (control)	80.4	86.7^{a}	11.5^{a}	4.3
CT2	78.2	82.2^{b}	5.2^{c}	4.1
CT3	82.2	85.4^{ab}	6.9^{bc}	4.1
CT4	79.6	84.8^{ab}	8.4^{b}	4.2
p	> 0.05	< 0.05	<0.05	>0.05
CV	3.04	1.52	9.1	4.6

Table 1: Effect of organic fertilizer amount on morphological criteria in green tea

The table 1 show that the plant height of four experiment fomular (78.2 cm- 80.4cm) was not significant difference (p>0.05) before applying the organic fertilizer. After 6 months, the plant height was significant differrence (p< 0.05) and ranged from 82.2cm- 86.7cm. In which, the height of green tea in CT1 had 86.7 cm higher than this of CT2 (82.2cm). and equivalent with plant height of CT3 (85.4 cm), CT4 (84.8cm).

The stem diameter in four experiment fomular was not significant difference (p>0.05). It ranged from 4.1-4.3cm. This is explain that green tea is perennial plant so it is slow growth. The experiment was conducted in short time (6 months) so there was not visisible effect on tree diameter.

3.3. Effect of organic fertilizer amount on green tea yield components and yield

Tea buds are raw materials for processing dry tea products. Beside this, tea buds are directly related to the yield and quality of green tea. Bud density and bud weight are two important indicators that need to be monitored to evaluate the productivity of green tea plants.

Fomular	Bud density (bud/m^2)	Bud weight (g/ bud)	Yield (kg/ha)
CT 1 (Control)	223.9^{a}	0.91^{a}	1791.3^{a}
CT 2	161.9^{b}	0.64^{c}	1647.7^{b}
CT 3	170.4^{b}	0.72^{bc}	1689.0^{ab}
CT 4	202.5^{a}	0.82^{ab}	1740.3^{ab}
p	<0.05	<0.05	<0.05
CV	4.9	4.5	2.4

Table 2: The effect of amount organic fertilizer on bud density, bud weight and yield of exprimental green tea.

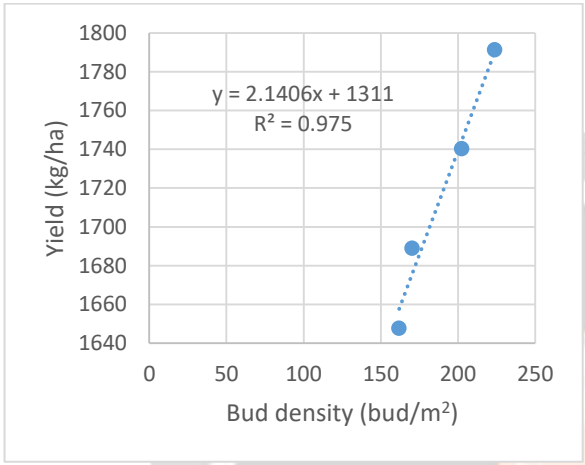
Table 2 show that the bud density of the experimental formulas had significant differences ($p < 0.05$), with values ranging from 161.9 buds/m^2 to 223.9 buds/m^2. CT4 and CT1 (control) had the highest bud density of 202.5 buds/m^2 and 223.9 buds/m^2, respectively, higher than CT2 (161.9 buds/m^2) and CT3 (170.4 buds/m^2). There is a strong correlation between bud density and yield, R2= 0.975. The more density increases, the more tea yield increase. (Figure 2a.)

The statistical data showed that there was the different bud weights at the different fertilizer doses ($p < 0.05$), experimental formulas had bud weights ranging from 0.64 g/bud to 0.91 g/bud. CT1 (control) had a weight of 0.91

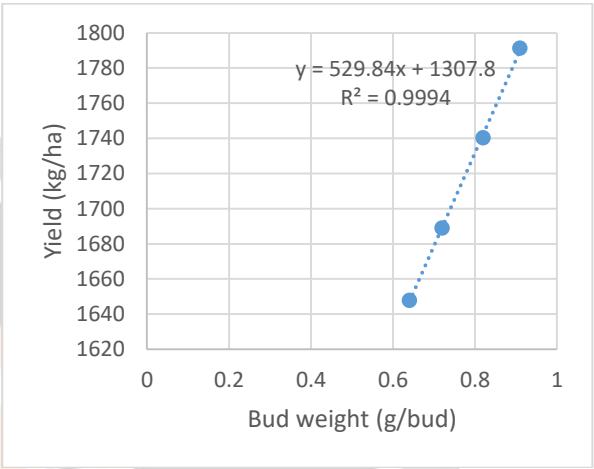
g/bud and CT4 had a bud weight of 0.82 g/bud, which were higher than two formulas CT2 and CT3. With $R^2 = 0.9994$, it shows that bud weight and yield have a very strong correlation. (Figure 2b.)

The actual yield of the experimental formulas was significant differences ($p < 0.05$), with values ranging from 1647.7 kg/ha - 1791.3 kg/ha. In which, yield of CT1 (control) (1791.3 kg/ha) is higher than CT2 (1647.7 kg/ha) and equivalent to CT3 (1689.0 kg/ha).), CT4 (1740.3 kg/ha).

Thus, using organic fertilizer in the right dosage and manner will not reduce the yield and quality of green tea. This research result is consistent with the results published by Nguyen Thi Mai et al (2020) [10], Hoang Mai Thao et al (2020) [9], Dang Thi Thai Ha et al (2019) [10].



a) Correlation between bud density and yield



b) Correlation between bud weight and yield

Figure 2: Corelation between bud density, bud weight and yield of green tea.

3.4. Effect of organic fertilizer dosage on experimental tea quality

The percentage of low quality buds is an important indicator, it affects not only productivity but also the quality of raw tea and the quality of dry tea products. Under inappropriate care, harvesting, pest control, the rate of low quality buds will increase. Low quality buds are abnormally developed buds. The results in Table 3 show that the experimental formulas had no difference in the ratio of low quality buds ($p > 0.05$), with the value range from 4.0-6.9%.

The quality of tea is expressed in water color and flavor. The dry tea products had blue water color will have a higher selling price than yellow water color. Experimental results show that all organic fertilizer formulas give water a yellow-green color while CT1 (control) gives green color. Thus, the water color of the control formulas is more beautiful than the experimental formulas.

In terms of flavor, CT2 had the lowest quality tea with an bitter taste, light aftertaste, medium aroma, followed by CT3 with bitter taste, light aftertaste and good aroma. The better quality CT4 had bitter taste, a sweet aftertaste, and a good aroma, equivalent with control treatment (CT1).

Overall, CT1 has the best quality when assessment about flavor and water color.

Fomular	Percentage of low quality bud (%)	Water color	Taste
CT 1 (Control)	4.0	Green	Bitter taste, light aftertaste and good aroma
CT 2	6.9	Yellow- Green	Bitter taste, light aftertaste, medium aroma
CT 3	5.9	Yellow- Green	Bitter taste, light aftertaste and good aroma
CT 4	5.0	Yellow- Green	Bitter taste, a sweet aftertaste and good aroma

p	>0.05		
CV	20.9		

Table 3: Effect of organic fertilizer amount on green tea quality

3.5. Effect of organic fertilizer dosage on the situation of main pests on experimental tea plants.

Pests and diseases are the main cause of reduced yield and quality of green tea. Our country is located in a hot and humid tropical climate which are very favorable conditions for pests and diseases to develop and cause damage on tea plants.

The experimental results showed that the density of *Chlorita flavescens Fabr.* of the different experimental treatments was significant difference ($p < 0.05$), with values ranging from 3.0-3.9 individuals/tray. In particular, the density of *Chlorita flavescens Fabr.* of experimental formulas CT1 (control), CT3, CT4 are equivalent. The density of *Chlorita flavescens Fabr.* in CT1 is higher than the density of *Chlorita flavescens Fabr.* in CT2. The density of *Physothrips setiventris* appearing on the experimental tea plants was not significant differences ($p> 0.05$). Regarding *Metatetranychus bioculatus density*, the experimental formulas had significant different density ($p < 0.05$). The density of *Metatetranychus bioculatus* appearing in the treatments ranged from 0.15 to 0.35 individuals/leaf, in which CT1 (0.30 individuals/leaf), CT3 (0.20 individuals /leaf), and CT4 (0.35 individuals /leaf) are equivalent density. Formula CT4 had a higher density (0.53 individuals /leaf) than CT2 (0.15 individuals /leaf). Percentage of *Helopeltis theivora* that harm tea plants on experimental formulas are also different ($p<0.05$). The harm rate ranged from 8.3% - 20%, in which three experimental formulas had the same harm rate as the control. But CT4 (20%) had a higher percentage of *Helopeltis theivora* damaged than CT2 (8.3%). Thus, 4 pest species that appeared and were measured in the experiment, the experimental formulas were equivalent to the control.

Fomular	*Chlorita flavescens Fabr.* (individual/tray)	*Physothrips setiventris* (individual/bud)	*Metatetranychus bioculatus* (individual/leaf)	*Helopeltis theivora* (%)
CT 1 (Control)	3.9^{a}	0.13	0.30^{ab}	16.7^{ab}
CT 2	3.0^{b}	0.17	0.15^{b}	8.3^{b}
CT 3	3.3^{ab}	0.17	0.20^{ab}	11.7^{ab}
CT 4	3.3^{ab}	0.22	0.35^{a}	20.0^{a}
p	<0.05	>0.05	<0.05	<0.05
CV	7.1	16.9	22.4	24.5

Table 4: Effect of organic fertilizer amount on pests and diseases on green tea

4. Conclusion

The most difficult problem tea farmers are currently faced is sharply decreasing the productivity and quality of tea when transition from traditional cultivation to organic cultivation. To attract the farmers cultivating towards sustainable organic tea production, there need the researches to find out solutions to help tea farmers enhancing yield and tea quality. This research results had selected one formular for good results (organic fertilizer combination of 35 tons of organic fertilizer + 70kg MgO per hectare). With the above amount of fertilizer, green tea has good growth ability and growth criteria (such as plant height, canopy width and root diameter) were good (equivalent to the control formula). Regarding the indicators that yield component such as: Bud density (202.5 buds/m^2), bud weight (0.82g/bud) and yield (1740.3 kg/ha) were as high as the control. Although the quality of the tea had decreased, it was not much. The water color was yellow-green, the taste was light bitter, sweet aftertaste, and the aroma is quite good. The rate of infestation by some harmful insects such as *Chlorita flavescens Fabr*. (3.3 individual/tray), *Physothrips setiventris*

density (0.22 individual/bud), *Metatetranychus bioculatus density* (0.35 individual/leaf), and *Helopeltis theivora* (20%) were equivalent to the control formula. However, the scale of this experiment was conducted on a small area and short period of time, experiments on a larger scale and longer period of time are needed to conducting in the continuing time to point out recommendation for green tea farmers.

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