AGRIVITA Journal of Agricultural Science. 2018. 40(2): 338-349

AGRIVITA
Journal of Agricultural Science

The Influence of Mineral-Based Compound Fertilizer (CFC) on the Health and Production of Tea Plant Clone GMB 7

Eko Pranoto[1*], Ridwan Saleh[2] and Restu Wulansari[1]

[1] Research Institute for Tea and Cinchona (RITC), Gambung, West Java, Indonesia
[2] Center of Mineral and Coal Technology, Ministry of Energy and Mineral Resources, Indonesia

ARTICLE INFO

Keywords:
Plant healthy
Mineral-based compound fertilizer
Productivity
Tea plant

Article History:
Received: November 6, 2015
Accepted: April 4, 2018

*) Corresponding author:
E-mail: ekogambung@gmail.com

ABSTRACT

Tea is a commodity that has a significant contribution to Indonesia's foreign exchange, especially from non-oil and gas sectors. Fertilization is one of the important factors to produce high productivity and keep the plant healthy. The healthy plants are simply indicated by the ratio of pecco and banji more than 2.33. This research aimed to test the effect of Mineral-Based Compound Fertilizer (CFC) on a plant health and tea plant productivity. The research was carried out in April – October 2014 at the Gambung Experimental Station, Block B6, Research Institute for Tea and Chincona by using CFC with a composition of 80% Mineral Compound Fertilizer, 10% urea, and 10% KCl. The experiments used a Randomize Blocked Design with four replications and six treatments; i.e. 120% CFC tekMIRA; 100% CFC tekMIRA; 80% CFC tekMIRA; 60% CFC tekMIRA; NPK (25:7:12:3) as control compound fertilizer; and single standard fertilizer. The result showed that all of the treatments did not increase the plant health. However, the application of CFC produced a higher tea plant productivity compared to NPK (25:7:12:3) as control compound fertilizer and single standard fertilizer. Based on regression equation, the dose of CFC that produced the optimal tea productivity was 93.92%.

INTRODUCTION

Tea (*Camellia sinensis* (L) O. Kuntze) is the commodity that has a significant contribution to the gross national income of Indonesia. From the data, Indonesia is the sixth biggest tea exporter country after India (18.9 %), China (17.1 %), Kenya (7.9 %), the UK (7.9 %), and the United Arab Emirates (4 %). Market demand for tea products at both domestic and foreign is very high, but the need is still not fulfilled. The increasing market demand should be offset by an increase in the quantity, quality, and continuity of tea production by using plant cultivation technology.

Tea plants have several varieties. According to recent taxonomic classifications, cultivated tea are of three types named as *Camellia sinensis* (L.) O. Kuntze or China tea, *C. assamica* (Masters) Wight or Assam tea and *C. assamica* lasiocalyx (Planch ex Watt) Wight or Cambod tea (Hazra, Dasgupta, Sengupta, & Das, in press). The optimal conditions of tea cultivation are pH of soil at 4.5 to 5.6, temperature at 12-25 ºC, relative humidity at 70-80%, intensity of sunlight at 70-80%, solar radiation at 3-6 hours, rainfall at 2,000-4,000 mm per year with maximum two dry months, leaf temperature at <35 °C, and solar radiation at four hours per day (Santoso et al., 2006). Although a large amount of water demand is not entirely utilized for shoot growth, tea plants require high rainfall for evapotranspiration and maintain high humidity. The growth of pecco in tea plants was influenced by several factors such as the population that has covered the area (Sitienei, Kirui, Kamau, Kanyiri, & Langat, 2016).

Tea (*Camellia sinensis* L.) plantations typically use high-level of chemical fertilizers that greatly affect crops and soil (Qiao et al., 2018). Fertilization is one of the things that need to be considered to produce healthy tea plant and to reach the potential genetic of tea productivity. Fertilizer application is the second most expensive

ISSN: 0126-0537 Accredited by DIKTI Decree No: 60/E/KPT/2016

Cite this as: Pranoto, E., Saleh, R., & Wulansari, R. (2018). The influence of mineral-based compound fertilizer (CFC) on the health and production of tea plant clone GMB 7. *AGRIVITA Journal of Agricultural Science, 40*(2), 338–349. http://doi.org/10.17503/agrivita.v40i2.709

agronomic inputs in tea production after plucking/ harvesting (Qamar-uz-Zaman, Shams-ul-Islam, Hamid, Ahmad, & Sohail, 2016). Tea is a perennial crop requiring more nitrogen, preferably using NH_4^+ to NO_3^- when both are available in the soil (Han, Ma, Shi, Ruan, & Kemmitt, 2008). Plants obtain the nutrients from the soil (Omwoyo, Owuor, Ongeri, & Kamau, 2014). Fertilization has a major role in tea sector to increase production, growth and economic yield (L. H. M. G. Gunathilaka, Gunarathne, & Arachchi, 2016). Fertilizer is an element of the production costs which is quite high. Currently, it ranges between 15-25 % of the production cost and spends 40-45 % for the cost of plant maintenance. Production costs tend to continue increasing along with the increased price of fertilizer, so the cost of fertilizer is often reduced to cut the production costs. With these conditions, fertilization should be done efficiently and effectively in order the production targets can be achieved. According to Yang et al. (2018), an excessive nitrogen fertilization should be replaced by organic compound fertilizer or reduce the soil acidity. In addition, the risk of loss of N and P in the tea garden due to leaching can be caused by a result of the cultivation of tea and excessive fertilization (Bagyalakshmi, Ponmurugan, & Balamurugan, 2017). The organic fertilizer has a positive effect on the production of antioxidants. The effect of different dose of mineral fertilizers indicated significant changes in accumulated antioxidant (Koala et al., 2013).

TekMIRA Research Center is one of the competent institutions in research of mineral and coal. Based on the regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 20 year 2013 on Mineral Added Value through Mineral Processing and Purification Activities, states that there are minerals that could potentially be another added value. They are known in agriculture as sources of plant nutrients need, such as cassiterite, pyrolusite, psilomelane, braunite, manganite, feldspar, and zircon. In addition, Indonesia has other potential mineral wealth such as Kieserit agricultural fertilizer, rock phosphate and silicate minerals like muscovite, orthoclase, biotite, illite, mica, vermiculite, and smectite.

Soil fertility is the ability of soil for the plant to grow. This is the result of capability in physical, chemical and biological processes to provide nutrition, water, aeration and stability in plants (Peigné, Vian, Payet, & Saby, 2018). According to Crittenden, Poot, Heinen, van Balen, & Pulleman (2015), the impact of soil fertility for tea root and shoot development is one of the goals to study, especially in the long term. Mineral fertilizer technology with organic fertilizer is a better choice in increasing the efficiency of fertilizer used and providing a balanced nutrition. Besides, it returns the biomass to the field as fertilizer (Brännvall, Wolters, Sjöblom, & Kumpiene, 2015; Zhang et al., 2018) and can balance the input and loss of nutrients in the soil. It is very important for the sustainability of ecosystems (Freire, Lopes, & Tarelho, 2015) because it currently causes nutrient degradation in the soil.

Research on the technology of mineral-based compound fertilizer production has been done for 13 years from 2001-2012. The results of the R&D activities concluded that technically the manufacture of Compound Fertilizer laboratory scale has been controlled and can be done on a pilot scale. The flowchart of the process of making compound fertilizer, as it has been tested in previous study, is presented in Fig. 1. The rock phosphate and dolomite first crushed with a jaw crusher tool. If their conditions are wet, they need to be dried first with a rotary dryer (rotary dryer). The material is then milled with a hammer mill, and followed by sieving at 80 mesh size with the vibrating screen. The product passes sieve, transported to the mixer ribbon mixer or paddle mixer, while the crude product is returned to the grinding tool. In the mixer lasts stirring process that phosphate materials, dolomite, and sulfuric acid can be mixed evenly with the addition of a little water.

Based on the results of laboratory analysis, compound fertilizer (CF) tekMIRA contains the following nutrients: P_2O_5 = 10 %; CaO = 23.6 %; MgO = 6.0 %; S = 6.3 %; B = 79 ppm; Zn = 83 ppm; Cu = 76 ppm; and Mn = 72 ppm. (Purnomo, 2010). A complete compound fertilizer formulation (CFC) is a combination of compound fertilizer (CF) by 80 %, urea 10 %, and 10 % KCl. In this study, mineral-based compound fertilizers are expected to produce healthy plants and high shoots on tea plants at clones GMB 7. The healthy plant are simply indicated by the ratio of pecco shoots and banji shoots more than 2.33. Furthermore, If the mother leaves nutrient levels are at the threshold, it is indicated that the tea plant is experiencing a deficiency of nutrients or in other word, the plant is unhealthy.

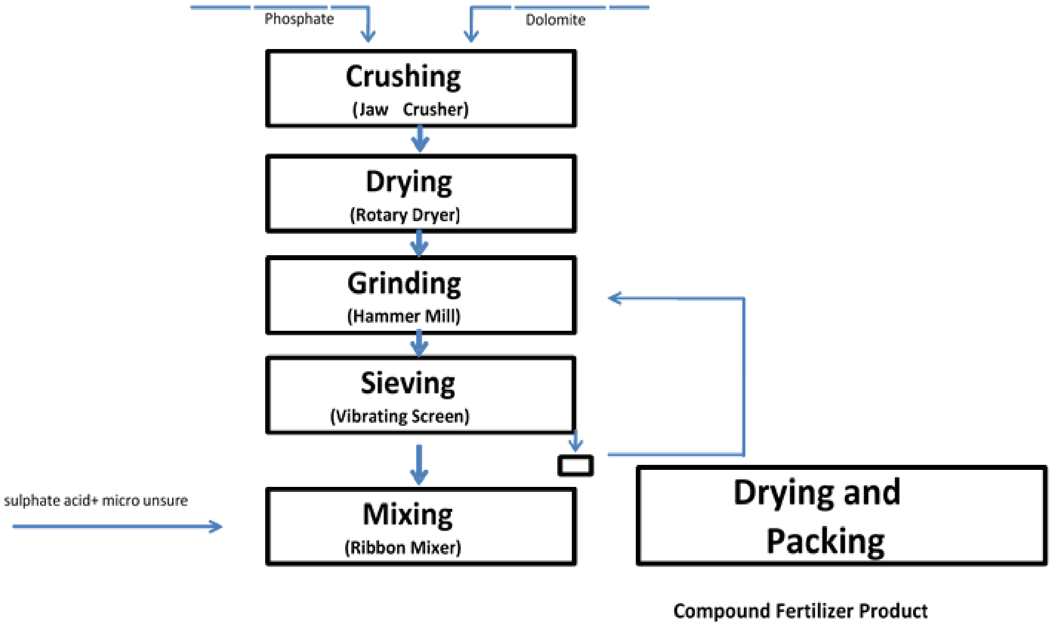

Fig.1. The flowchart of the process of making compound fertilizer

Table 1. Fertilizer dose for every treatment

No	Treatments	Fertilizers (kg per plot per aplication)	Plot Number in the Field
1	120 % of CFC Tekmira	3.6 kg (600 kg ha^{-1} year^{-1}) + Urea 2.6 kg (434 kg ha^{-1} year^{-1}) + KCl 0.96 kg (160 kg ha^{-1} year^{-1}) + Kieserit 0.42 kg (70 kg ha^{-1} year^{-1})	4; 7; 16; 22
2	100 % of CFC Tekmira	3.0 kg (500 kg ha^{-1} year^{-1}) + Urea 2.6 kg (434 kg ha^{-1} year^{-1}) + KCl 0.96 kg (160 kg ha^{-1} year^{-1}) + Kieserit 0.42 kg (70 kg ha^{-1} year^{-1})	3; 11; 18; 20
3	80 % of CFC F Tekmira	2.4 kg (400 kg ha^{-1} year^{-1}) + Urea 2.6 kg (434 kg ha^{-1} year^{-1}) + KCl 0.96 kg (160 kg ha^{-1} year^{-1}) + Kieserit 0.42 kg (70 kg ha^{-1} year^{-1})	2; 9; 15; 23
4	60 % of CFC Tekmira	1.8 kg (300 kg ha^{-1} year^{-1}) + Urea 2.6 kg (434 kg ha^{-1} year^{-1}) + KCl 0.96 kg (160 kg ha^{-1} year^{-1}) + Kieserit 0.42 kg (70 kg ha^{-1} year^{-1})	1; 10; 17; 19
5	NPK (25:7:12:3)	4 kg (667 kg ha^{-1} year^{-1})	5; 12; 14; 24
6	Single Standard Fertilizer	2.6 kg Urea (434 kg ha^{-1} year^{-1}); 0.79 kg SP-36 (132 kg ha^{-1} year-1); 0.96 kg KCl (160 kg ha-1 year-1); and 1.37 kg Kieserit (229 kg ha^{-1} year^{-1})	6; 8; 13; 21

MATERIALS AND METHODS

The experiment was conducted in April–October 2014 at Gambung experimental station of Research Institute for Tea and Cinchona (RITC), South Gambung sector in Block B6 with the type of soil was Andisols, at an altitude of ± 1,200–1,450 m above sea level (asl). Mineral-Based Compound Fertilizer (CFC) was applied to the tea plant at clones GMB 7 on three years after pruning. The experimental plot size was 20 m x 10 m or 200 plants per plot with boundaries around one plant. Plucking was done by manually plucking with the period of 15-25 days per plucking.

The design of experiments in this research was a randomized block design (RBD) with six treatments and four replications. All variables were tested using ANOVA (Analyze of Variant) and further tested by different test Duncan. The composition of treatments can be seen in Table 1.

The observed variables are as follows:

1. The production of shoots (productivity) per plot for every plucking.

Shoots that were plucked with the plucking medium of pecco shoots + 3 leaves (p+3) or banji shoot + 3 leaves (b+3), then weighed and recorded for each treatment. Productivity was interpolated observational data which was adjusted by coefficient of data variance during the observation.

2. Analysis of plucking.

Plucking analysis was conducted to determine the healthy plant by taking into account the ratio between pecco shoots and banji shoots in each plucking. A hundred grams of shoots were taken randomly from the plucking in the item-1 observed variables (productivity), then calculated the number of pecco shoots and banji shoots in each treatment and after that they were weighed. The ratio number of pecco shoots and banji shoots were calculated with the following formula (1):

$$\text{Pecco - banji ratio} = \frac{\text{The number of pecco shoots}}{\text{The number of banji shoots}} \qquad (1)$$

While the weight per shoots (WS) of pecco and banji shoots was calculated by the following formula (2):

$$WS = \frac{\text{Pecco or banji shoots weight}}{\text{The number of pecco or banji shoots}} \times 100\% \qquad (2)$$

3. Relative Effectiveness of Agronomy (RAE)

Relative Agronomic effectiveness (RAE) is the ratio between the increased results due to the use of a fertilizer with the increased results and standard fertilizer use, and was multiplied by 100 as the following formula (3):

$$RAE = \frac{\text{Production of tested treatment – Production of control}}{\text{Production of standard treatment – Production of control)}} \times 100\% \qquad (3)$$

RESULTS AND DISCUSSIONS

The observations of production shoots variables and analysis of plucking were performed for eight times of plucking, namely, 1st plucking (April 23, 2014); 2nd (May 12, 2014); 3rd (May 28, 2014); 4th (June 16, 2014); 5th (July 7, 2014); 6th (July 25, 2014); 7th (August 22, 2014); and 8th (Sept 16, 2014). While, the productivity variable and RAE was based on interpolation data of production for a year.

Production and Estimated Productivity

The observation of shoots data production in each plucking was shown in Fig. 2. It seems that the production of shoots in each treatment fluctuated and had the same pattern with the average of the highest production found in the 5th plucking (July 7, 2014) and the average production during the eight plucking on the 3rd treatments (80% of CFC tekMIRA) around 10.09 kg per 200 m^2.

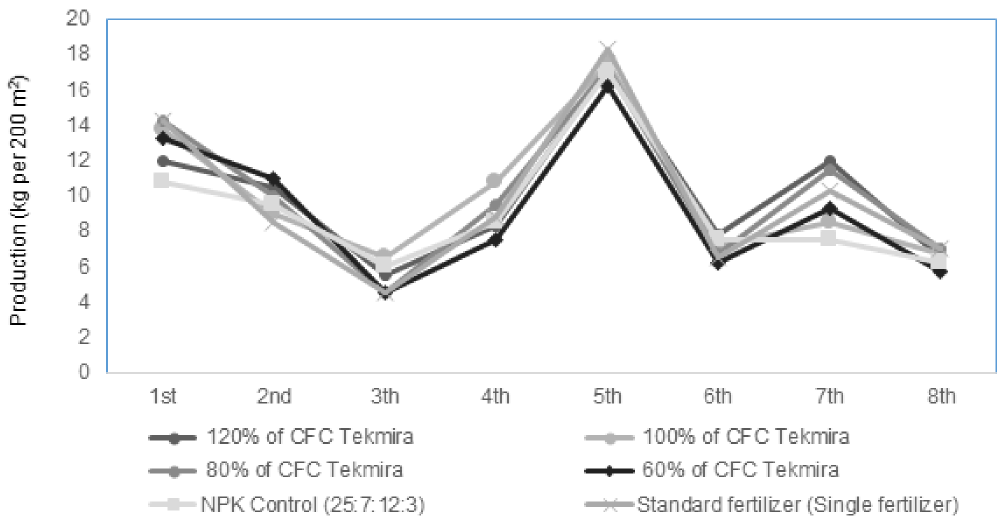

Fig. 2. Fluctuations in production (kg per 200 m^2) of every treatment during the observation

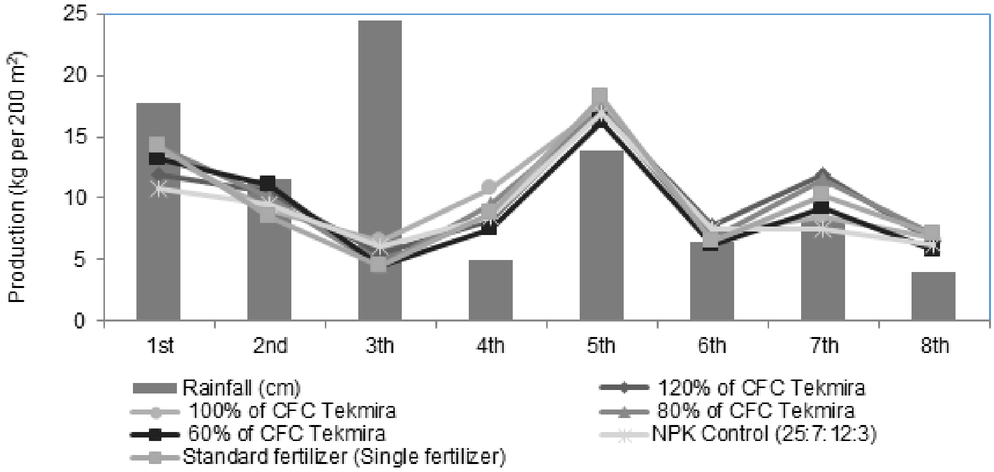

Fig. 3. Production data (kg per 200 m^2) of every treatment and rainfall (cm) during the observation period

Table 2. Estimated production of shoots (kg ha^{-1}) for each treatment

No	Treatment	Total of 8 plucking times (kg per plot)	Estimated production of shoots every year (kg ha^{-1} year^{-1})	Estimated productivity (kg ha^{-1} year^{-1})
1	120 % of CFC Tekmira	79.75	11,487	2,412
2	100 % of CFC Tekmira	80.00	11,523	2,420
3	80 % of CFC Tekmira	80.75	11,631	2,443
4	60 % of CFC Tekmira	73.75	10,623	2,231
5	NPK control (25:7:12:3)	73.00	10,515	2,208
6	Single Fertilizer (standard fertilizer)	78.00	11,235	2,359

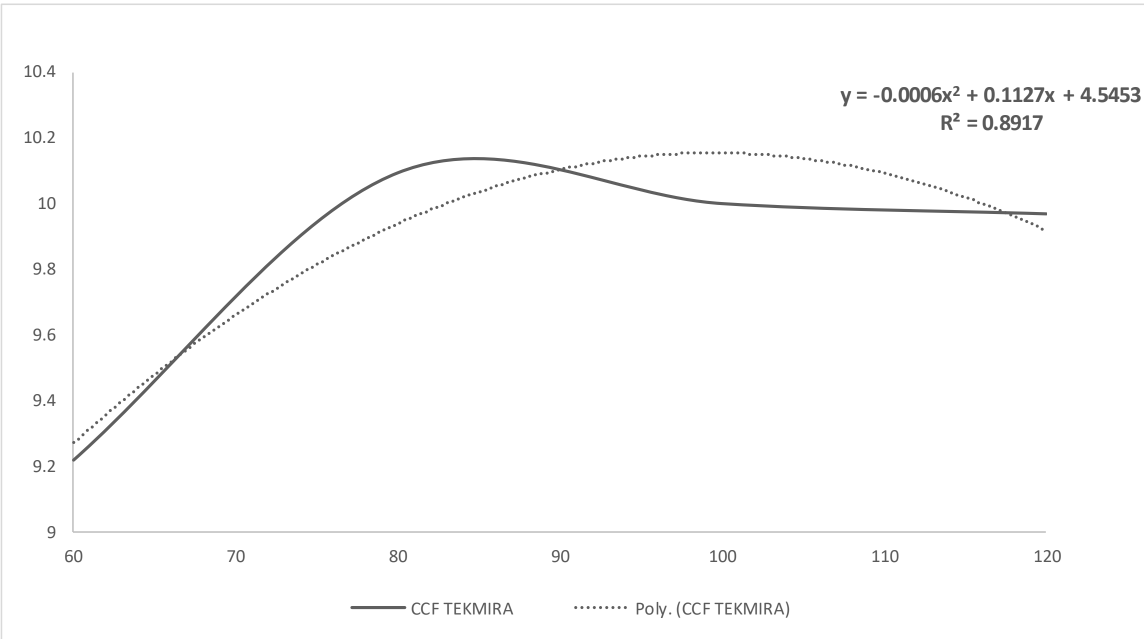

Fig. 4. Data regression of production with a dose of mineral-based compound fertilizer

Based on the statistical calculations using ANOVA, the production of shoots on each plucking showed no significant difference between each treatment with a coefficient of diversity 12-36 %. The tea plant is a plant that needs a lot of water to grow, therefore it is very resistant to the long dry season (Dalimoenthe, Apriana, & June, 2016). The tea production depends on weather stability (Cheserek, Elbehri, & Bore, 2015). The occurrence of temperature changes, rainfall, and extreme weather will affect tea plantations (R. P. D. Gunathilaka, Smart, & Fleming, 2017). Based on the rainfall data, some pluckings were observed in the period with rainfall <100 mm or called the dry period. Drought is one of the main causes of productivity declining issues of tea plant following an excessive rainfall. An increase in average temperature by global warming will reduce the productivity of tea plantations (Duncan, Saikia, Gupta, & Biggs, 2016). Periods of drought can lead to reduce yield and increase susceptibility to pest attacks (Dikshit & Dikshit, 2014). Adequate rainfall will affect the intensity of sunlight received by the leaves and activate the process of photosynthesis (Setiawati, Wulansari, & Pranoto, 2014). The results study in Sri Lanka revealed that the optimal rainfall for tea varied from 223–417 mm per month and decreased the productivity to 29-81 kg ha^{-1} per month due to the decreased of monthly rainfall of 100 mm (Abeysinghe, 2014). Based on Ashardiono & Cassim (2014) study, the selection of appropriate cultivars and cultivation for the quality production of tea can be applied for these indicators, and became a powerful tool for monitoring the effects of climate change and maintained the production of tea. Future climate impacts are projected to affect tea production through the rising temperatures, where cultivation management needs to adapt to this temperature change (Dutta, 2014). The production data for each treatment at each plucking is correlated with rainfall (RF) as shown in Fig. 3.

Fig. 3 showed the average production during the dry period (RF < 100 mm) was 5.81 kg and the average production during the wet period (RF > 100 mm) was 14.8 kg, it means that production decreased to 60.74 % on dry period. The mean of the highest production during dry periods was found in the 3rd treatments (80 % of CFC tekMIRA) around 8.69 kg per 200 m^2 and the mean of the highest production during wet periods was found in the 2nd treatment (100 % of CFC tekMIRA) around 11.69 kg per 200 m^2. On the 3rd plucking, the production decreased because of the excessive rainfall. A productive tea tree plant needs from 1.34 to 2.66 mm rainfall water at 10-28 ºC per day (Chang & Wu, 1971). Water availability also acts as a nutrient solvent from the soil, therefore nutrients can be absorbed by plants and maintain turgidity (Dalimoenthe & Rachmiati, 2009). According to Wang et al. (2016), soil water deficit affects the number of important growth processes of tea yield and highly sensitive to soil moisture conditions.

From the shoots production data obtained in each plot (200 m^2), interpolation by a correction factor of 7.815 % were taken from the diversity coefficient tabulated for 8 times plucking and assumptions were 25 times of the manual plucking. The data estimation of crop productivity during the year was shown in Table 2.

Table 2 showed that the highest plant productivity were on the 3rd treatments (80 % of CFC tekMIRA) which was 2,443 kg ha^{-1}. The production estimation to all treatments was under the potential productivity of clones GMB 7 in three years after pruning, in the amount of 5,391 kg ha^{-1} with a weight of pecco shoots on medium plucking was 2.083 g (Santoso et al., 2006). The relationship between the dose of CFC and the production of processed banji produced a regression as shown in Fig. 4. From the regression equation, application doses of complete compound fertilizer (CFC) mineral-based that produced the optimal productivity of tea clone GMB 7 on three years after pruning was 93.92 %.

Analysis of Shoots

Analysis of shoots is one indicator of healthy plant. Shoot observation analysis consists of the number and weight of pecco and banji shoots. The number of shoots produced will describe the productivity of a tea plant (Ayu, Indradewa, & Ambarwati, 2012). These data were calculated by the ratio of the number of pecco with banji shoots, weight average of pecco shoots (g per shoots), and weight average of banji shoots (g per shoots). The normal ratio value is 2.33 (Pranoto, 2010), which means there is a plucking every number of pecco shoots 70 % and banji shoots 30 %.The proportion of the energy needed for the process of growing pecco shoots and banji shoots is greater than the energy needed for the process of the growth of other plant parts (Setiawati, Wulansari, & Pranoto, 2014). Climate change occurring in the area around the tea bush directly affects the quality of the leaves picked during harvest (Jones & Webb, 2010). Shoots analysis calculation results were shown in Fig. 5- Fig. 7.

From Fig. 5, it can be seen that overall treatment and the ratio fluctuated from pecco and banji shoots which was under 2.33. This means that the whole treatment did not increase the health of the tea plant. Similarly, the ratio of pecco shoots with banji shoot, in Fig. 6 and Fig. 7 showed that pecco shoots weight of each unit and banji shoots weight of each unit fluctuated. The mean of pecco shoots weight of each unit for 8 times of plucking was the highest plucking and was found in the 2nd treatments (100 % of CFC tekMIRA) which was 1.98 g per shoots. Whereas, the weight average of banji shoots of each unit for the 8 times was the highest plucking in the 4th treatments (60 % of CFC tekMIRA) which was 1.86 g per shoots. This showed that in carrying out their metabolism as a function of production, the need for macro and micro nutrients was critical. If there is a deficiency of one nutrient, it will affect productivity. This is in accorance with the Liebig's Law of the Minimum.

Table 3. The dose of fertilizer (kg ha^{-1} year^{-1}) for mature tea with a minimum productivity target of 2,000 kg tea ha per year

Fertilizer	Nutrient	Optimal Dose (kg ha^{-1} year^{-1})
Urea, Za	N	250 – 350
TSP, PARP	P_2O_5	60 – 120
MOP, ZK	K_2O	60 – 180
Kieserit	MgO	30 – 75
Seng sulfat	ZnO	5 – 10

Source : Santoso et al. (2006)

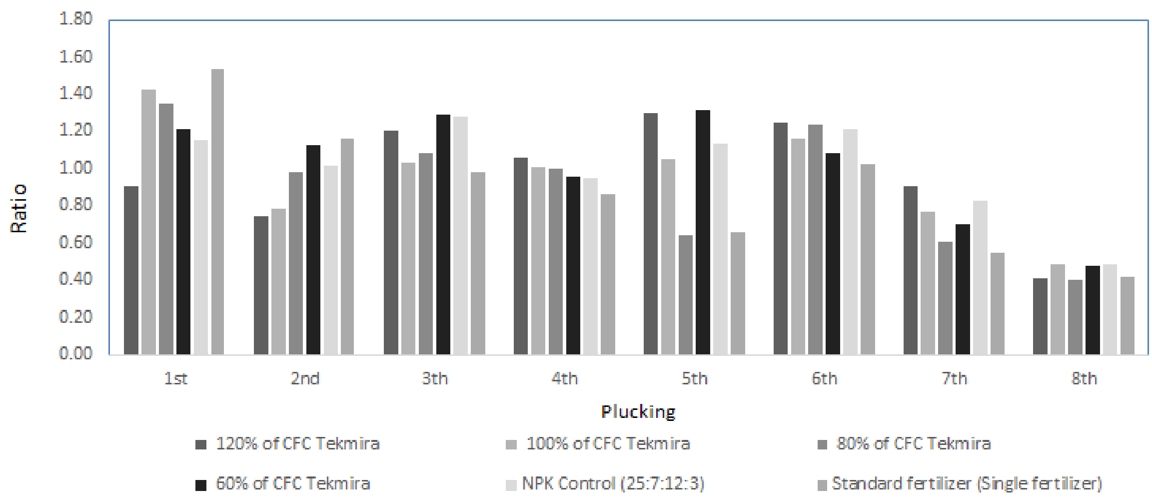

Fig. 5. Pecco and banji shoots ratio

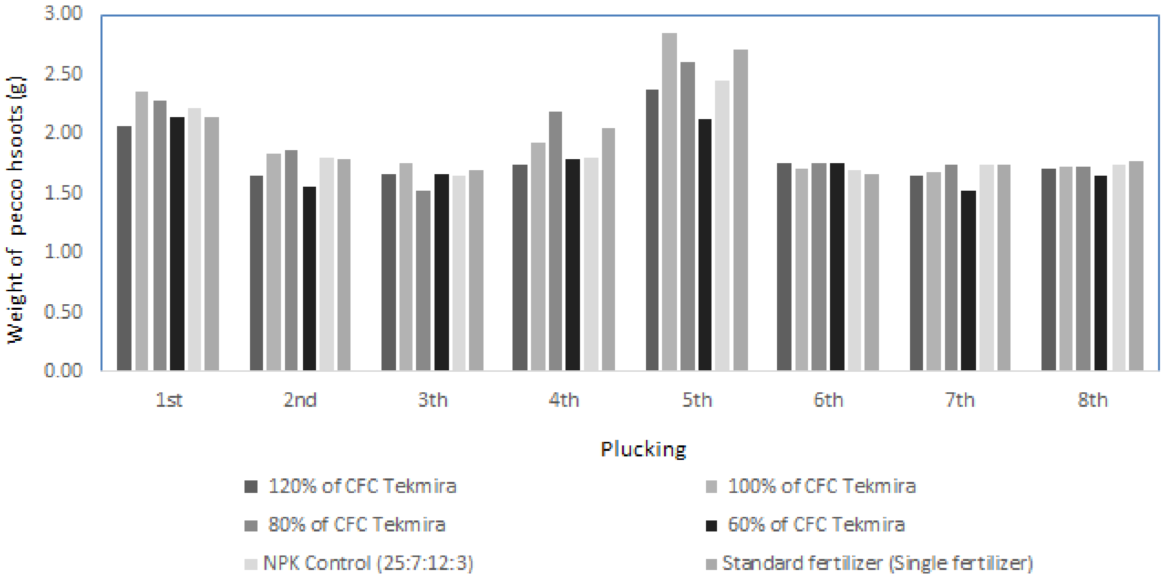

Fig. 6. Pecco shoots weight of each shoots unit

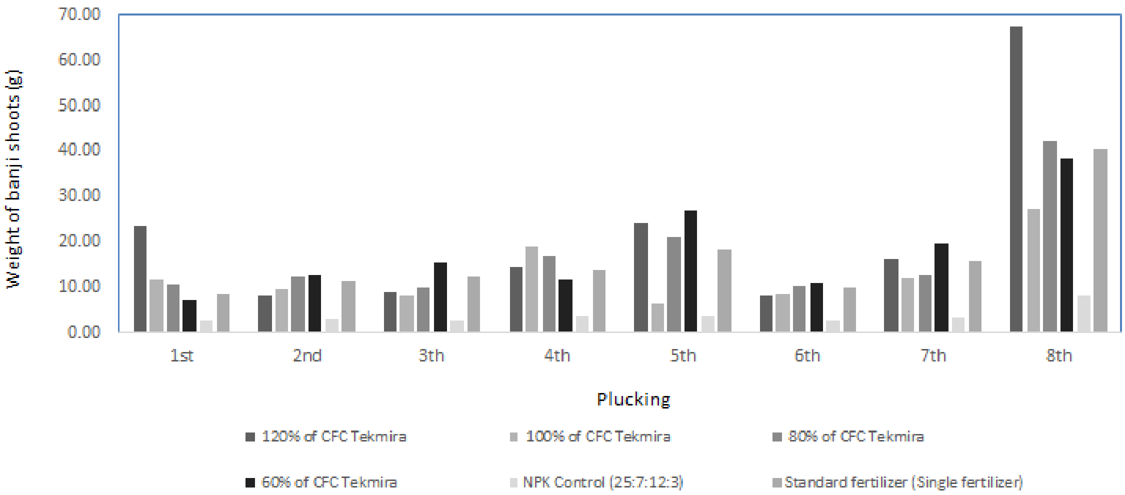

Fig. 7. Banji shoots weight of each shoots unit

The application of fertilizer required macronutrient to be delivered effectively by soil, while the micronutrient needs is obtained more effectively through leaves (Haq, Rachmiati, & Karyudi, 2014). These findings are in line with Qamar-uz-Zaman, Shams-ul-Islam, Hamid, Ahmad, & Sohail (2016) who observed a significant increase in shoot length and number of roots of tea plant with the application of ammonium sulphate. Nutrient management plays an important role in land use, weather, and NPK fertilization (Miao, Stewart, & Zhang, 2011) by directly or indirectly assisting the optimization of nutrient use, improving crop quality and soil health (Bhattacharyya, Goswami, & Bhattacharyya, 2016). In accordance with the standard dose of fertilizer for mature tea, it can be seen that macro and micro nutrients needs to achieve minimal productivity of 2,000 kg ha^{-1} year^{-1} (Table 3).

Nitrogen (N) is the major nutrient affecting tea growth, yield, and quality. The application of nitrogenous fertilizer substantially increases the production of new shoots and the content of functional compounds, such as amino acids (Kamau, Spiertz, & Oenema, 2008). Phosphorus and potassium are also major nutrients for tea production. Tea soils are highly weathered and have Kaolinite clay minerals, where there is hardly any binding site for K, which necessitated a frequent application of K fertilizers. Therefore, a balanced fertilizer application including K is important for getting high-quality products (Singh & Pathak, 2018), not only K but also all nutrient which is needed for tea plant. Based on research (Karak et al., 2015), a balanced fertilizer application would be needed as a part of tea improvement program.

Table 4. Estimated of RAE Value (%) each treatment

No	Treatment	RAE value (%)
1	120 % of CFC Tekmira	135
2	100 % of CFC Tekmira	140
3	80 % of CFC F Tekmira	155
4	60 % of CFC Tekmira	15
5	NPK control (25:7:12:3)	Control treatment
6	Single Fertilizer (standard fertilizer)	Standard treatment

Source : Santoso et al. (2006)

RAE index

Relative Agronomic Effectiveness (RAE) value is calculated based on a formula that has been determined, and shown in Table 4, by 5th treatment (NPK control) as a control treatment and the 6th treatment (standard fertilizer) as the standard treatment. Table 3 showed that the value of the highest RAE contained in the 3rd treatment (80 % of CFC tekMIRA) of 155 %. This means that the full mineral-based compound fertilizer (CFC) with a composition of 80 % is a formula that has the highest agronomical effectiveness. In relation to this factor, soil texture influences some soil properties such as organic matter retention, microbial biomass and distribution of minerals. Soil aggregates or soil structure with different particle sizes had a variation of total N concentrations and organic C in all tea plantations (Wang, Li, & Zheng, 2018). The identification of alternative sources of fertilization that reduce impacts on soils is necessary for the development of sustainable agriculture and sustainable soil management practices.

CONCLUSION AND SUGGESTION

The result showed that the highest production and plant productivity estimated during the dry season was in 80% of CFC TEKMIRA application or around 8.69 kg per 200 m^2 and the highest production during the rainy season was in 100% of CFC TEKMIRA application or around 11.69 kg per 200 m^2. All treatments did not increase the health of tea plant. However, the application of CFC produced a higher tea productivity compared to NPK control and Single Fertilizer (standard fertilizer). The dose of CFC that produce the optimal productivity of tea clone GMB 7 on three years after pruning was 93.92 %. The application of CFC resulted in the highest production in the rainy season and the highest pecco weight indicating that the health of tea plant is better than some other treatments.

REFERENCES

Abeysinghe, I. S. B. (2014). *Keynote address*. Paper presented at Proceedings of the 228th Experiments and Extension Forum: Adaptation Strategies for Climate Change and Carbon Friendly Tea Cultivation, Talawakelle, 31st January. Talawakelle, LK: Tea Research Institute.

Ashardiono, F., & Cassim, M. (2014). Climate change adaptation for agro-forestry industries: Sustainability challenges in uji tea cultivation. *Procedia Environmental Sciences*, *20*, 823–831. http://doi.org/10.1016/j.proenv.2014.03.100

Ayu, L., Indradewa, D., & Ambarwati, E. (2012). Pertumbuhan, hasil dan kualitas pucuk teh (*Camellia sinensis* (L.) Kuntze) di berbagai tinggi tempat [The growth, yield and quality of tea tip (*Camellia sinensis* (L.) Kuntze) in various elevations]. *Vegetalika*, *1*(4), 21–32. Retrieved from https://journal.ugm.ac.id/index.php/jbp/article/view/1598

Bagyalakshmi, B., Ponmurugan, P., & Balamurugan, A. (2017). Potassium solubilization, plant growth promoting substances by potassium solubilizing bacteria (KSB) from Southern Indian tea plantation soil. *Biocatalysis and Agricultural Biotechnology*, *12*, 116–124. http://doi.org/10.1016/j.bcab.2017.09.011

Bhattacharyya, P. N., Goswami, M. P., & Bhattacharyya, L. H. (2016). Perspective of beneficial microbes in agriculture under changing climatic scenario: A review. *Journal of Phytology*, *8*, 26. http://doi.org/10.19071/jp.2016.v8.3022

Brännvall, E., Wolters, M., Sjöblom, R., & Kumpiene, J. (2015). Elements availability in soil fertilized with pelletized fly ash and biosolids. *Journal of Environmental Management*, *159*, 27–36. http://doi.org/10.1016/j.jenvman.2015.05.032

Chang, P. C. M., & Wu, C. T. (1971). Studies on the effect of soil moisture control and irigation of tea plant. Water and the tea plant. *Tea Research Institute of East Africa Proceedings of Symposia*, 139-144.

Cheserek, B. C., Elbehri, A., & Bore, J. (2015). Analysis of links between climate variables and tea production in the recent past in Kenya. *Donnish Journal of Research in Environmental Studies*, *2*(2), 5–17. Retrieved from http://www.donnishjournals.org/djres/content/2015/march/march-content.php

Crittenden, S. J., Poot, N., Heinen, M., van Balen, D. J. M., & Pulleman, M. M. (2015). Soil physical quality in contrasting tillage systems in organic and conventional farming. *Soil and Tillage Research*, *154*, 136–144. http://doi.org/10.1016/j.still.2015.06.018

Dalimoenthe, S. L., & Rachmiati, Y. (2009). Dampak perubahan iklim terhadap kadar air tanah di perkebunan teh [Impact of climate change on groundwater content in tea plantations]. *Jurnal Penelitian Teh dan Kina*, *12*(3), 59-66.

Dalimoenthe, S. L., Apriana, Y., & June, T. (2016). Dampak perubahan iklim terhadap pola curah hujan dan defisit air di perkebunan teh [The effect of climate change on rainfall pattern and deficit of water in tea plantation]. *Jurnal Penelitian Teh Dan Kina*, *19*(2), 157–168. Retrieved from https://tcrjournal.com/index.php/tcrj/article/download/104/101

Dikshit, K. R., & Dikshit, J. K. (2014). *North-East India: Land, people and economy*. Dordrecht: Springer Netherlands. http://doi.org/10.1007/978-94-007-7055-3

Duncan, J. M. A., Saikia, S. D., Gupta, N., & Biggs, E. M. (2016). Observing climate impacts on tea yield in Assam, India. *Applied Geography*, *77*, 64–71. http://doi.org/10.1016/j.apgeog.2016.10.004

Dutta, R. (2014). Climate change and its impact on tea in Northeast India. *Journal of Water and Climate Change*, *5*(4), 625. http://doi.org/10.2166/wcc.2014.143

Freire, M., Lopes, H., & Tarelho, L. A. C. (2015). Critical aspects of biomass ashes utilization in soils: Composition, leachability, PAH and PCDD/F. *Waste Management*, *46*, 304–315. http://doi.org/10.1016/j.wasman.2015.08.036

Gunathilaka, L. H. M. G., Gunarathne, G. P., & Arachchi, L. P. V. (2016). Manurial effect of wood ash and refuse tea on nutrient status and yield of tea (*Camellia sinensis* L.). *Procedia Food Science*, *6*, 261–266. http://doi.org/10.1016/J.PROFOO.2016.02.042

Gunathilaka, R. P. D., Smart, J. C. R., & Fleming, C. M. (2017). The impact of changing climate on perennial crops: The case of tea production in Sri Lanka. *Climatic Change*, *140*(3–4), 577–592. http://doi.org/10.1007/s10584-016-1882-z

Han, W. Y., Ma, L. F., Shi, Y. Z., Ruan, J. Y., & Kemmitt, S. J. (2008). Nitrogen release dynamics and transformation of slow release fertiliser products and their effects on tea yield and quality. *Journal of the Science of Food and Agriculture*, *88*(5), 839–846. http://doi.org/10.1002/jsfa.3160

Haq, M. S., Rachmiati, Y., & Karyudi. (2014). Pengaruh pupuk daun terhadap hasil dan komponen hasil pucuk tanaman teh (*Camellia sinensis* (L.) O. Kuntze var. Assamica (Mast.) Kitamura) [Effect of foliar fertilizer application on yield, and yield components of tea (*Camellia sinensis* O. Kuntze var. Assamica (Mast.) Kitamura] *Jurnal Penelitian Teh dan Kina*, *17*(2), 47–56. Retrieved from https://www.researchgate.net/publication/303879546_Pengaruh_pupuk_daun_terhdap_hasil_dan_komponen_hasil_pucukMuthia

Hazra, A., Dasgupta, N., Sengupta, C., & Das, S. (in press). Next generation crop improvement program: Progress and prospect in tea (*Camellia sinensis* (L.) O. Kuntze). *Annals of Agrarian Science*. http://doi.org/10.1016/j.aasci.2018.02.002

Jones, G. V., & Webb, L. B. (2010). Climate change, viticulture, and wine: Challenges and opportunities. *Journal of Wine Research*, *21*(2), 103–106. http://doi.org/10.1080/09571264.2010.530091

Kamau, D. M., Spiertz, J. H. J., & Oenema, O. (2008). Carbon and nutrient stocks of tea plantations differing in age, genotype and plant population density. *Plant and Soil*, *307*(1–2), 29–39. http://doi.org/10.1007/s11104-008-9576-6

Karak, T., Paul, R. K., Boruah, R. K., Sonar, I., Bordoloi, B., Dutta, A. K., & Borkotoky, B. (2015). Major soil chemical properties of the major tea-growing areas in India. *Pedosphere*, *25*(2), 316–0328. http://doi.org/10.1016/S1002-0160(15)60016-9

Koala, M., Hema, A., Somé, K., Palé, E., Sérémé, A., Belem, J., & Nacro, M. (2013). Effects of organic and mineral fertilizers on total antioxidant, polyphenolic and carotenoid contents of orange fleshed sweetpotato tubers. *Journal of Natural Sciences Research*, *3*(6), 2225–921. Retrieved from http://www.sweetpotatoknowledge.org/wp-content/uploads/2016/02/5700-7829-1-PB.pdf

Miao, Y., Stewart, B. A., & Zhang, F. (2011). Long-term experiments for sustainable nutrient management in China: A review. *Agronomy for Sustainable Development*, *31*(2), 397–414. http://doi.org/10.1051/agro/2010034

Omwoyo, W. N., Owuor, P. O., Ongeri, D. M., & Kamau, D. M. (2014). Effect of genotypes in different environments on micronutrient content of black tea. *Journal of Tea Science Research*, *4*(2), 17–26. http://doi.org/10.5376/jtsr.2014.04.0002

Peigné, J., Vian, J.-F., Payet, V., & Saby, N. P. A. (2018). Soil fertility after 10 years of conservation tillage in organic farming. *Soil and Tillage Research*, *175*, 194–204. http://doi.org/10.1016/j.still.2017.09.008

Pranoto, E. (2010). Pengaruh aplikasi kombinasi berbagai dosis pupuk anorganik dan pupuk hayati terhadap kesehatan tanaman teh produktif [The effect of application of combination of various doses of inorganic fertilizers and biological fertilizers on the health of productive]. *Jurnal Penelitian Teh Dan Kina*, *13*(3), 61–68.

Purnomo, H. (2010). *Pembuatan pupuk majemuk dengan bahan baku mineral skala pilot plant* [Compound fertilizer production with mineral raw materials pilot plant scale], Internal Report Puslitbang tekMIRA. Bandung, ID: Pusat Pengembangan Teknologi Mineral.

Qamar-uz-Zaman, Shams-ul-Islam, Hamid, F. S., Ahmad, F., & Sohail, A. (2016). nitrogenous fertilizer on growth and yield of tea (*Camelia sinensis* L.). *Journal of Agricultural Research*, *54*(2), 185–194. Retrieved from http://apply.jar.punjab.gov.pk/upload/1480907159_122_5._203.pdf

Qiao, C., Xu, B., Han, Y., Wang, J., Wang, X., Liu, L., … Zhao, X. (2018). Synthetic nitrogen fertilizers alter the soil chemistry, production and quality of tea: A meta-analysis. *Agronomy for Sustainable Development*, *38*(1), 10. http://doi.org/10.1007/s13593-017-0485-z

Santoso, J., Suprihatini, R., Widayat, W., Johan, E., Rayati, D. J., & Dharmadi, A. (2006). *Petunjuk kultur teknis tanaman teh* [Technical guidelines of tea plant culture] (3rd ed.). Bandung, ID: Pusat Penelitian Teh dan Kina.

Setiawati, M. R., Wulansari, R., & Pranoto, E. (2014). Perbandingan efektivitas pupuk hayati konsorsium dan pupuk hayati endofitik terhadap produktivitas dan kesehatan tanaman teh menghasilkan klon GMB 7 [The comparison of effectivity from consortium bio fertilizer and endophytic bio fertilizer on productivity and health of clone mature GMB 7 tea crop]. *Jurnal Penelitian Teh Dan Kina*, *17*(2), 71–82. Retrieved from https://tcrjournal.com/index.php/tcrj/article/download/48/29

Singh, A. K., & Pathak, S. K. (2018). Potassium in tea (*Camellia sinensis* (L) O. Kuntze) cultivation from soil to cup quality - A review. *Agricultural Reviews*, *39*(1), 40-47. http://doi.org/10.18805/ag.R-1731

Sitienei, K., Kirui, K., Kamau, D., Kanyiri, W., & Langat, K. (2016). Effect of plant density, nitrogen fertilizer application rates and soil depth on clonal tea soil nutrient content. *Journal of Tea Science Research*, *6*(7), 1–5. http://doi.org/10.5376/jtsr.2016.06.0007

Wang, S., Li, T., & Zheng, Z. (2018). Tea plantation age effects on soil aggregate-associated carbon and nitrogen in the hilly region of western Sichuan, China. *Soil and Tillage Research*, *180*, 91–98. http://doi.org/10.1016/j.still.2018.02.016

Wang, Y.-C., Hao, X.-Y., Wang, L., Bin, X., Wang, X.-C., & Yang, Y.-J. (2016). Diverse *Colletotrichum* species cause anthracnose of tea plants (*Camellia sinensis* (L.) O. Kuntze) in China. *Scientific Reports*, *6*, 35287. http://doi.org/10.1038/srep35287

Yang, X. de, Ni, K., Shi, Y. zhi, Yi, X. yun, Zhang, Q. feng, Fang, L., … Ruan, J. (2018). Effects of long-term nitrogen application on soil acidification and solution chemistry of a tea plantation in China. Agriculture, *Ecosystems and Environment*, *252*, 74–82. http://doi.org/10.1016/j.agee.2017.10.004

Zhang, Z., He, F., Zhang, Y., Yu, R., Li, Y., Zheng, Z., & Gao, Z. (2018). Experiments and modelling of potassium release behavior from tablet biomass ash for better recycling of ash as eco-friendly fertilizer. *Journal of Cleaner Production*, *170*, 379–387. http://doi.org/10.1016/j.jclepro.2017.09.150