

# Effects of Tea-Pruned Mulches and Microbial Products on the Accumulation of Organic Matter and Micro Biota in Soils Grown Tea in Phu Ho, Phu Tho Province, Vietnam

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**Abstract** – Tea-pruned mulches is as considered effective measures to improve soil moisture and also contribute to the nutrient cycle to ensure the ecological balance and increasing the efficiency of tea production in the North mountainous region of Vietnam. However, due to tea-pruned residues contains many persistent substances, e.g., tannin, lignin, cellulose and hemicelluloses, adding microbial products to accelerate the decomposition of crop residues are expected methods to supply more humus substance to soils. To appreciate the role of tea-pruned mulches to soil improvement, field experiments have been done on soils growing tea in Phu Ho, Phu Tho province. The main purpose of the research is to evaluate the influences of tea-pruned mulches and addition of microbial products to properties, organic matter accumulation and micro biota in soils.

The results show the use of tea-pruned mulches have significant to improve soil moisture, reduce soil bulk density and increase the contents of organic matter in soils. Microbial products also change dramatically the composition and performance of micro biota to decompose organic matter in soils. When the tea-pruned mulches with addition of microbial products that accelerate the rate of organic matter decomposition and improve soil humus substances. However, the addition of microbial products has also increased mineralization processes. Consequently, the soil organic matter rapidly decline in a short time. Which uses EM, cellulose decomposition bacteria and Compost Maker have stronger effects than EMUNIV on organic decomposition process.

**Keywords** – Tea-Pruned Mulch, Microbial Products, Organic Matter, Micro Biota.

## I. INTRODUCTION

Tea plant is one the most important crops grown in the hilly and mountainous region of Northern Vietnam. Phu Ho (Phu Tho province) is where tea plantation with high intensive farming in the country [1]-[2]. Although tea is the perennial crop with the harvest cycle lasting about 30-40 years, but by the time of tea plantation here has undergone monoculture for hundreds of years, the nutrients have been removed from soils by tea harvested or lost due to erosion and runoff [1]-[3]. In order to maintain productivity, tea growers use chemical fertilizers increasing intensification in tea production. This also impacts negatively on the quality of tea and soil degradation [4]-[5].

Soil organic matter (SOM) is composed of plant, animal, and microbial residues at varying stages of decomposition and amorphous humic substances. The content of SOM has long been recognized as a key component of soil quality [6], and thus maintenance of soil organic carbon in cropland is a major determinant of the productivity and long-term stability of agricultural systems [7]. Natural organic mulch eventually breaks down and becomes a part of the soil and a source of plant nutrients [8]-[9]-[10]. But the influence of mulch on soil agrochemical properties and soil organic matter depend on the chemical composition of mulch [11]-[12].

Applying tea pruned to reimbursement for soil nutrients were also quite good results, increasing tea yields [4]. But tea residues with high contents of tannin, lignin and cellulose have high persistence and slowly decompose, often shattered on the surface, is dried and blown away in the wind or washed by rain. The use of microorganisms may effect shorten decay time of tea residues to increase soil humus substance and enrich the soil micro biota.

As a conventional management in the study region, tea-pruned mulches are widely used for tea production, but little known about their effects on soil properties functioning. To find solutions to increase the efficiency of tea residue use improving soil fertility, this study focused on evaluating the effects of tea-pruned mulches and in combination with microbial products to soil humus and micro biota in soils growing tea in Phu Ho, Phu Tho province, Vietnam.

## II. MATERIALS AND METHODS

Field experiments were carried out during period of 2009-2012 at a tea plantation area (tea plants about 10 years old) in Phu Ho, Phu Tho province, the Northern mountainous region of Vietnam. Phu Tho is located in the tropical monsoon climate, with cold winter. The average annual temperature is about 23°C and annual rainfall 1,600-1,800 mm. However approximately 70% of annual rainfall happened in rainy season, during April to October.

The experiments were arranged in a randomized block design, six treatments with three replications. The area of each plot is 45m<sup>2</sup> (10m x 4.5m). These treatments includes tea-pruned mulches of 135 kg residues per plot (equivalent to 30 tones/ha) and additional different microbial products

(Table 1). Microbial products are added by mixing in water and irrigation once immediately after mulches, equivalent to 3 kg of product per ton of tea residues (or 405 g products for each plot 45 m<sup>2</sup>). The density of microorganisms in these products was 10<sup>9</sup> CFU/g. The basal chemical fertilizers were applied every year according to local recommendations at the rates of 300 kg N, 100 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O per ha.

Table 1: The treatments design in the experiment

Treatment	Amendment
Trt.1	Without tea residue mulches and microbial products (Control)
Trt.2	Tea residue mulches only
Trt.3	Tea residue mulches with additional EMUNIV
Trt.4	Tea residue mulches with additional Compost Maker
Trt.5	Tea residue mulches with additional EM
Trt.6	Tea residue mulches with additional cellulose decomposition bacteria

EM product is a mixed groups of beneficial microorganisms for cellulose, starch and protein decompose, e.g., *Bacillus*, *Lactobacillus*, *Streptomyces*, *Saccharomyces*, *Aspergillus* and other deodorization microorganisms.

EMUNIV product is a collection of effective microorganisms used as fertilizer to soil improvement and rapid resolution of cattle dung, agricultural waste into nutrients for plants; including *Bacillus subtilis*, *Lactobacillus plantarum* and *Lactobacillus acidophilus*, *Saccharomyces cerevisiae*, etc.

Compost Maker is a product with a high density of microorganisms, utilizing to handle many types of agricultural by-products. This product contain mainly cellulose decomposition, proteolysis and deodorant bacteria.

Cellulose decomposition bacteria is capable of fast decomposition of cellulose, including local strains of microorganisms isolated from soils growing tea in Phu Ho, Phu Tho province.

The studied soil is classified as Acrisols with the texture of silty clay loam and the following properties: pH(KCl) 3.95; total SOM 2.73%; total P<sub>2</sub>O<sub>5</sub> 0.16, total K<sub>2</sub>O 0.22, total bacteria 6.3x10<sup>5</sup> CFU/g soil, total actinomyces 3.5x10<sup>2</sup> CFU/g soil and total fungi 5.1x10<sup>3</sup> CFU/g soil.

The soil samples were taken before experiment, one year (in 2010) and three year (in 2012) after application, in December each year (dry season) at each plot to a depth of 0-30 cm to analyze the soil properties, soil humus fractions and soil microbiota.

### III. RESULTS AND DISCUSSION

#### 1. Effects of tea-pruned mulches and microbial products on selected soil physical and chemical properties

##### A. Effects of tea-pruned mulches and microbial products on physical properties of soils

The effects of tea-pruned mulches and microbial products on soil moisture and bulk density are presented in Table 2. After a year (in 2010) of tea-pruned mulches and addition of microbial products, the soil moisture increases and significant difference from the control as well as between different treatments, ranging from 25% in the control to 35.87% in the treatment mulched tea residues with additional EM. The high moisture contents in the treatment of tea residues mulches with supplemented EM (Trt.5) due to the tea residues have decomposed and created a thick layer of organic litter on the soil surface and that also increase the content of SOM. Therefore, soil moisture is protected and holding by SOM to reduce evaporation processes. These are the main reason for soil moisture increase.

Table 2: Effects of tea-pruned mulches and microbial products on moisture and bulk density of soils in the experiment

Treatment	Soil moisture (%)		Bulk density (g/cm <sup>3</sup> )	
	2010	2012	2010	2012
Trt.1	25.00	23.56	1.32	1.35
Trt.2	33.65	30.65	1.31	1.21
Trt.3	30.28	25.73	1.17	1.23
Trt.4	32.19	25.82	1.13	1.21
Trt.5	35.87	25.54	1.15	1.25
Trt.6	32.21	25.78	1.11	1.23

After three years of the experiment, in 2012, the soil moistures in all treatments were dropped significantly to compare with the values in 2010, a year after application; except the treatment with tea-pruned mulches only (Trt.2). The contents of soil moisture closely relate to decomposition processes of tea-pruned mulches. In the treatments with adding microbial products, tea residues decompose quickly and almost turnover during the first two years after utilization. However at this time, the highest contents of soil moisture is observed in the treatment with tea-pruned mulches only. This may be explained due to tea residues have high contents of lignin, cellulose and hemicelluloses and should decay slowly in the natural conditions. The results of tea residues still left on the soil surface and help to retain moisture better than other treatments for a long time.

The effects of tea-pruned mulches and addition of microbial products on soil bulk density are presented in Table 2. These data shows that soil bulk density was improved significantly compared to the control, especially after the first year of application. After one year of tea-pruned mulches, in 2010, soil bulk densities in all treatments with adding microbial products have the values ranging from 1.11 to 1.17 (g/cm<sup>3</sup>) compared to 1.32 g/cm<sup>3</sup> in the control. However in the treatment with tea-pruned mulches only (Trt.2), the soil bulk density only reduce slightly compared to the control. According to Mulumba and Lal, 2008 [13], the mulch rates significantly increased available water capacity by 18–35%, total porosity by 35–46% and soil moisture retention at low suctions from 29 to 70%. At high suctions, no differences in soil moisture content were observed between mulch levels.

The mentioned here is that after three years of the experiment in 2012, the bulk densities of soils increase in all treatments compared to that after a year in 2010, ranged from 1.21 to 1.35 g/cm<sup>3</sup> due to the contents of soil organic matter decline, except the treatment with tea-pruned mulches only (Trt.2). In the Trt.2, the bulk density of soil continues to decrease from 1.31 to 1.21 g/cm<sup>3</sup> during period 2010 to 2012.

The reasons of bulk densities change sharply after three years of the experiment related to decline organic matter content in soils due to mineralization processes, and biological activity also reduced. Besides, due to the mechanical impact on the surface of harvesting activities may also have influence the soil structure and causing soil bulk density increase.

### B. Effects of tea-pruned mulches and microbial products on chemical properties of soils

The effects of tea-pruned mulches and microbial products on chemical properties of soils are presented in Table 3. The soil acidity in the treatments with tea-pruned mulches with addition of micro-products tends to decrease slightly over time. These change consistently with the concentration of exchangeable cations of Ca<sup>2+</sup>, Mg<sup>2+</sup> and Al<sup>3+</sup>. Due to the earth nutrients released from tea residues through mineralization processes, the contents of Ca<sup>2+</sup> and Mg<sup>2+</sup> increase that contribute to increase the values of pH (KCl) and causing decline of the contents of Al<sup>3+</sup>.

The effects of mulches on physical, chemical and biological properties of soil was reported by Antonio Jordan et al. (2010) [14] indicated that mulching application significantly improved physical and chemical properties of the studied soil with respect to control, and the intensity of changes was related to mulching rate. The organic matter content was generally increased, although no benefit was found beyond 10 Mg ha<sup>-1</sup> year<sup>-1</sup>. Bulk density, porosity and aggregate stability were also improved with increasing mulching rates, which confirmed the interactions of these properties.

Table 3: Effects of tea-pruned mulches and microbial products on acidity and exchangeable cations in soils of the experiment

Treatment	pH (KCl)		Exchangeable cations (me/100 g)					
			Ca <sup>2+</sup>		Mg <sup>2+</sup>		Al <sup>3+</sup>	
	20 10	20 12	20 10	20 12	20 10	20 12	20 10	20 12
Trt.1	3.9	3.4	2.1	2.0	0.2	0.2	6.5	6.6
Trt.2	4.2	4.5	2.1	2.6	0.2	0.5	5.3	4.9
Trt.3	3.7	3.9	2.3	3.6	0.8	0.7	6.4	4.6
Trt.4	3.5	4.0	2.1	2.5	0.6	0.6	6.7	5.5
Trt.5	3.6	4.1	2.2	3.2	0.3	0.5	7.5	5.9
Trt.6	3.7	3.8	2.5	3.0	1.0	0.4	8.8	7.6

## 2. Effects of tea-pruned mulches and microbial products on organic matter accumulation in soils

### A. Effects of tea-pruned mulches and microbial products on total contents of soil organic matter

The contents of SOM are significant differences between the treatments due to the effects of tea-pruned mulches and addition of different microbial products (Table 4). The contents of SOM in all treatments with tea residue mulches are higher than the control.

After a year of application (2010), the content of SOM increased to the highest level of 3.45% in the treatment of tea residues mulches with additional EM (Trt.5), then in the treatment with additional Compost Maker (Trt.4) 3.38%, the treatment with additional cellulose decomposition product (Trt.6) 3.26%, and the treatment with additional EMUNIV (Trt.3) 3.02%. However, the content of SOM in the treatment of tea-pruned mulches only (Trt.2) increase slightly to 2.87% form 2.70% in the control, and still lower than in all treatments of tea residue mulches with addition of microbial products.

The high contents of SOM in the treatments of tea-pruned mulches with addition of microbial products at this time may be caused by strongly activities of microorganisms supplied by microbial products. So that tea residues should be decomposed quickly and added more humus substances to soils. These results reflect the important role of microbial products to promote tea residues decomposition and accumulation of organic matter in soils. The similar results on the effects of mulches to improve SOM also reported by David et al. (2005) [15], Kristia et al. (2013) [16], Ha Thi Thanh Doan and Nguyen Van Toan (2013) [17].

Table 4: Effects of tea pruned mulches and microbial products on soil organic matter

Treatment	Soil organic matter (%)		
	2010 (a)	2012 (b)	(b - a)
Trt.1	2.70	2.55	-0.15
Trt.2	2.87	3.24	+0,37
Trt.3	3.02	2.19	-0.83
Trt.4	3.38	2.92	-0.46
Trt.5	3.45	2.63	-0.82
Trt.6	3.26	2.75	-0,51

In the third year (2012), the contents of SOM have clearly reduced in all treatments supplemented with microbial products while the content of SOM matter in the treatments with tea-pruned mulches only (Trt.2) continue increasing from 2.87% in 2010 to 3.24% in 2012. These results indicate that the tea residues may last longer due to slowly decomposition processes in the natural conditions without supplied microbial products, especially in the first year of utilization. Over time, the decay processes of tea residues is promoted and as the results of SOM accumulation increase. These results also shows that EM, Compost Maker and Cellulose decomposition bacteria are more effective than EMUNIV in decomposition of tea residues.

It can be said that the purpose of adding microbial products expected increasing decomposition of crop residues to increase the accumulation of organic matter in soil is not achieved good results in the long run. The decline of SOM in all treatments with adding microbial products show the negative effects of them to SOM

accumulation for long time. The results of this study also indicate that the abuse of microbial products to crop production will not be beneficial to the accumulation of SOM. The enrichment of soil micro biota by "pressure cooked" through the addition of microbial products can create a "shock" ecological imbalance. Soil processes change sharply in a short time may create certain risks to soil ecosystems and accelerate CO<sub>2</sub> emissions.

### *B. Effects of tea pruned mulches and microbial products on accumulation of humic substances in soil*

The effects of tea-pruned mulches and microbial products on accumulation of soil humic substances, i.e., humic acid and fulvic acid, are presented in Table 5. After a year of application in 2010, the lowest value 0.35% of total humic substance is observed in the control (Trt.1). The contents of humic substances are higher in all treatments with tea residue mulches, especially when tea residue mulches with addition of microbial products. The highest contents of humic substances is 2.40% in the treatment with adding cellulose decomposition bacteria (Trt.6), then in the treatment with adding EM (Trt.5) 2.13%, treatment with adding Compost maker (Trt.4) 1.61%, and with adding EMUNIV (Trt.3) 1.34%. However, in the treatment with tea residue mulches only (Trt.2), the contents of humic substance in soils is much lower, only 0.74%.

Table 5: Effects of tea pruned mulches and microbial products on accumulation of humic and fulvic acids in soils

Treatment	Humic substances (%)					
	Humic acid		Fulvic acid		Humic+Fulvic	
	2010	2012	2010	2012	2010	2012
Trt.1	0.11	0.12	0.24	0.21	0.35	0.33
Trt.2	0.22	0.53	0.52	0.48	0.74	1.01
Trt.3	0.47	0.26	0.87	0.37	1.34	0.63
Trt.4	0.72	0.37	0.89	0.42	1.61	0.79
Trt.5	0.97	0.28	1.16	0.37	2.13	0.65
Trt.6	1.13	0.21	1.27	0.38	2.40	0.59

In term of humic acid, after one year of the experiment, in 2010, the contents of humic acid increase in all treatment with tea-pruned mulches, and reach the highest value 1.13% at treatment with tea residue mulches with additional cellulose decomposition bacteria (Trt.6). However, after three years of the experiment, in 2012, the contents of humic acid decline in all treatments compared to the contents of humic acid in 2010, except in the treatment with tea residue mulches only (Trt.2). In Trt.2, the content of humic acid increased sharply to 0.53% compared to 0.22% at time of one year after the application.

The trends of fulvic acid accumulation in soil also place similar to humic acid. It means that after one year of experiment in 2010, the contents of fulvic acid have higher values in all treatments, especially when tea residue mulches with supplemented microbial products and then they decline quickly at three years of the experiment in 2012. After a year of the experiment, the contents of fulvic acid reach the highest value 1.27% in the treatment of tea

residue mulches with addition of cellulose decomposition bacteria (Trt.6). Meanwhile after three years of the experiment, the highest content of fulvic acid 0.48% is observed in the treatment with tea residue mulches only (Trt.2). The results from this study also show the proportions of fulvic acid are higher than humic acid in all treatment, except in the Trt.2 after three year of application. The dominant fractions of fulvic acid over humic acid indicate a high mobilization of humic substances in these soils.

The decline in the contents of SOM overtime in all treatments of tea-pruned mulches with adding microbial products may be due to a large quantity of tea residues is decomposed in the first year forming compounds of free humus acids in the topsoil layer. However, when almost amount of tea residues is decomposed and when soil microorganisms switch to a new decomposition of organic substances existing in soils and causing decline the contents of SOM. An other reason for these problem may be due to high mobility of humic substances, leaching process should occur and causing sharply decline in the contents of SOM over time.

Chivenge et al. (2007) concluded that developing viable conservation agriculture practices to optimize SOM contents and long-term agroecosystem sustainability should prioritize the maintenance of organic matter inputs (e.g. residue retention) to coarse textured soils, but should focus on the reduction of SOM decomposition (e.g. through reduced tillage) in fine textured soils [18].

In short, the study indicate positive effects of tea-pruned mulches on accumulation of SOM in both quantity and quality. Tea residue mulches tend to increase gradually the contents of SOM for long run, at least three years. However, the adding microbial products only maintain the contents of SOM in short period of about two years. So that the best cycle of tea-pruned mulches should be repeated every three years. But when mulches with adding microbial products, the time for tea-pruned mulches should be repeated in every two years.

### *3. Effects of tea-pruned mulches and microbial products on micro biota in soils*

The data in Table 6 show the positive effects of tea-pruned mulches and addition of microbial products on the number of bacteria, actinomycetes and fungi compared to the control. Especially the number of bacteria increase sharply and dominate over a place.

After three years of the experiment, in 2012, the number of microorganisms remained higher than the control in all treatments. It can be said that tea-pruned mulches and microbial products have effects to improve the activities of microorganisms in soils. However, the effects of different microbial products on micro biota only occur during the first year of application, and these effects is not significant deference after three years of the experiment.

This mulch provides a protective layer to the soil surface that is extremely effective in halting soil erosion and also amends the soil ecology and the activity of soil micro biota as well. The research of Olaf Erenstein (2002) also indicated the mulch tends to stabilise, and occasionally even enhance, crop yield. it implies factor substitution and

input use efficiency alterations. Therefore, crop residues mulch is not a simple add-on technology, but instead a complete package of cultural practices [19]. The microbial biomass and microbial activity were generally higher in organically than conventionally managed soils with mulch

being most effective. The organic additions increased soil microbial biomass and activity by 103–151% and 88–170% over a period of two years, respectively, leading to a 182–285% increase in potentially mineralizable N, compared to the control [20].

Table 6: Effects of tea-pruned mulches and microbial products on micro biota in soils (CFU/g)

Treatment	Bacteria		Actinomyces		Fungi	
	2010	2012	2010	2012	2010	2012
Trt.1	4.9x10 <sup>6</sup>	3.5x10 <sup>6</sup>	2.1x10 <sup>2</sup>	1.3x10 <sup>3</sup>	1.1x10 <sup>3</sup>	3.5x10 <sup>3</sup>
Trt.2	9.1x10 <sup>7</sup>	3.2x10 <sup>7</sup>	4.1x10 <sup>4</sup>	2.0x10 <sup>4</sup>	1.8x10 <sup>4</sup>	9.3x10 <sup>4</sup>
Trt.3	6.2x10 <sup>9</sup>	4.4x10 <sup>7</sup>	6.3x10 <sup>3</sup>	3.0x10 <sup>3</sup>	2.4x10 <sup>4</sup>	1.2x10 <sup>3</sup>
Trt.4	8.5x10 <sup>9</sup>	5.2x10 <sup>7</sup>	3.8x10 <sup>3</sup>	2.0x10 <sup>3</sup>	2.2x10 <sup>4</sup>	2.1x10 <sup>3</sup>
Trt.5	7.8x10 <sup>9</sup>	8.6x10 <sup>7</sup>	4.4x10 <sup>3</sup>	2.0x10 <sup>3</sup>	2.5x10 <sup>4</sup>	1.3x10 <sup>3</sup>
Trt.6	5.3x10 <sup>9</sup>	4.1x10 <sup>7</sup>	6.7x10 <sup>4</sup>	1.6x10 <sup>3</sup>	2.7x10 <sup>4</sup>	5.2x10 <sup>3</sup>

#### IV. CONCLUSION

The use of tea-pruned mulches significantly increases soil moisture, reduces soil bulk density and improved contents of soil organic matter. Tea-pruned mulches with adding microbial products cause dramatic changes in the composition and performance of the microorganisms in soils. When tea-pruned mulches with adding microbial products have promoted the decomposition rate of tea residues and accumulation of humic substance in soils. However, the addition of microbial products has spurred activity of soil microorganisms to organic matter mineralization that also lead to rapidly reduce the organic contents in soils in a short time. Which uses EM, Compost Maker and Cellulose decomposition bacteria products work more to increase decomposition processes of tea residues than EMUNIV. Therefore, the need for supplements of these microbial products with tea-pruned mulches should be careful application. The cycle for tea-pruned mulches should be repeated every three years, but the time intervals for tea-pruned mulches with adding microbial products is about two years.

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