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Evaluation of Coffee Husk Compost for Improving Soil Fertility and Sustainable Coffee Production in Rural Central Highland of Vietnam

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Abstract Coffee husk supplemented with cow manure, and fertilizers (phosphorus and urea) were studied. The results showed that 5.0% thermophosphate fertilizer, 1.0% urea fertilizer and 1.2m in height of heap were suitable conditions for composting coffee husk. The quality of the compost was better than original coffee husk and some bio-organic fertilizers on the agriculture market. The compost was used for coffee plant on the field with amount of 2.0-3.0 kg.plant^{-1}.year^{-1} during 3 years and reduced using from 20% to 30% chemical fertilizers. The results showed that fertility of soil, mineral nutrients in the coffee leaf and the growth of the coffee were improved in comparison with plots that no using the compost.
This report demonstrates a method of using agricultural waste-coffee husk to produce compost and contributes to inhibit environmental pollution in rural and develop eco-sustainable agriculture.

Keywords Coffee Husk, Compost, Sustainable Farming

1. Introduction

Vietnam is one of the biggest coffee exporters in the world with an estimated annual production of one million tons, of which Central Highland contributes up to 90 percent of the total coffee production. Central Highland consists of five provinces: Dak Lak, Dak Nong, Gia Lai, Kon Tum and Lam Dong. These covers an area of 500,000 ha of coffee (*Coffea canephora* var *Robusta*) farm with a production of 800,000 to 900,000 tons coffee bean. Therefore, coffee husk waste released annually from coffee production in Central Highland ranges from 400,000 to 500,000 tons.

Generally, there are two methods for processing coffee cherries being dry and wet methods. These release solid waste such as coffee husk and coffee pulp. In Vietnam, over 90% of coffee cherries are processed by dry method. Pandey et al.[1]; Bressani and Braham[2] showed that coffee husk is rich in organic matter (cellulose, hemicelluloses, pectin and lignin), and chemical nutrients such as nitrogen (N) and potassium (K). Additionally, coffee husk also contains secondary compounds such as caffeine, tannin and polyphenol. Therefore, coffee husk and coffee pulp have great potential for biotechnology.

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Due to the high content of caffein and tannin, coffee pulp was fermented for animal feed. Composition of coffee pulp determined by Bressani and Braham[2] showed that it contains carbohydrate (63.2%), total protein (10.1%), reduced sugar (12.4%), ash (8.3%), and caffein (1.3%). After fermentation process, caffein and tannin contents are reduced in coffee pulp and used for animal feed[2-4]. Coffee husk and coffee pulp have been used as a suitable substrate for mushroom cultivation such as *Pleurotus* sp., *Pleurotus ostreatus*[5].

Coffee husk contains some amount of caffeine and tannins, which can make it toxic and slow degradation in nature, resulting the disposal problem. However, coffee husk is rich in lignocelluloses materials, which makes it an ideal substrate for microbial processes. Several solutions and alternative uses of coffee husk/pulp have been attempted. Coffee husk and coffee pulp have been used as a raw material for bioprocess to produce biogas, enzymes, mushroom and compost[6],[1],[7]. Coffee husk and coffee pulp have been usually incubated for composting as the recycling of organic wastes in agriculture. Composting of coffee husk was also reported by Biddapa et al.[8]. Mixture of coffee husk, animal manures and phosphate rock was fermented by two anaerobic and aerobic methods. The compost can be used for soil application after 6 months of composting. The quality of the compost was improved in comparision with before that. Coffee fruit peel was mixtured with swine waste, bovine manure and other agricultural

wastes and incubated for compost. The nutrients in the leaf and resistance of rust disease of coffee increased by the compost application has been discussed by Santos et al.[9]. Composting mixture prepared by mixing coffee husk, sawdust, biochar and poultry manure with various rate were reported by Dias et al.[7]. After 210 days of composting process, organic matter loss was from 67% to 78% compared with initial content. Generally, composting of coffee husk and other agricultural wastes reduce the consumption of natural resources and recycle nutrients, increase in soil organic matter and impove the physical, chemical and biological characteristics of soil[10].

Additionally, untreated coffee husk has been used as pote tial biosorbents for treatment of dye contaminated waters and heavy metals[11],[12]. Coffee ground is one of the wastes has been studied to recycle by composting and vermicompo sting[13].

In Vietnam, coffee husk is normally burnt or covered on the coffee field, so, untreated coffee husk will spread diseases and pets to next crop. Some farmers mix up coffee husk with manure, but this way shows less efficiency. Generally, Coffee farmers have used mainly chemical fertilizers and lack of organic fertilizer for long time, therefore, the soil has been degrading. Whereas, about 500,000 tons of coffee husk, a good organic material has not been used or used not efficiently. Coffee husk was also used as compost supplemented with 5% of lime, and 10% phosphorus fertilizer, but not used microbial seed, resulted in long time of composting process, slow degradation of organic matter.[14].

Generally, coffee husk and coffee pulp has been applied by mixturing with animal manures, other agricultural wastes used as compost and the incubation period of composting has been taken for long time, because most researches have used natural micro-organisms for composting, which are noteffective.

The aim of this research was to evaluate the effects of coffee husk compost on soil fertility, uptake of nutrients in the leaves, growth and yield of coffee plants. This is to ensure sustainability of coffee production and reduce enviro nmental pollution resulting from coffee processing in the generation,

2. Materials and Methods

2.1. Materials

Microactive seed for compost was obtained from Biotech nology Center, Tay Nguyen University, Vietnam. Contents: *Trichoderma* sp., *Streptomyces* sp. with 10^9CFU.g^{-1}.

Cow manure was collected from cow farms in Ea Kar District and cows from this farm only feed on natural grasses. Urea (46% total N) was a product of Phu My company, Vietnam and thermophosphate (16% available phosphorus) was a product of Van Dien thermophosphate fertilizer factory, Vietnam.

2.2. Methods

Coffee husk compost

Coffee husk (875 kgs) was mixed with 10% cow manure (w/w), supplemented 2% lime (w/w), 0.5% urea (w/w) and water to reached 60% humidity of the mixture. One kilogram of effective microorganisms containing *Trichoderma sp.* and *Streptomyces sp.* being suspended in 50 liters of fresh water and sprayed for 1000kgs of the mixture. The mixture was heaped up with 120cm in height and covered with agriculture wastes such as leaves, rice paddy and incubated for 90 days.

The mixture was composted for 3 months, and then supplemented with 0.1% (w/w) effective microorganisms consisting nitrogen fixing *Azotobacter* sp. and soluble phosphate bacteria *Bacillus megaterium.* The application of compost was carried out on the coffee field in Coffee Company No. 721 for years. Coffee plants (*Coffea canephora* var *robusta)* have been planted on ferralsols since 1990. The experiment had 5 formulas and triplicates (total 15 plots; 25 coffee plants for each plot) with the same cultivation technique and different fertilizer application:

– Control (C): 100% chemical fertilizer application was same technical process of the coffee company (N: P_2O_5 : K_2O: 220-80-240).

– Formula 1 (F1): 70% chemical fertilizer of the control and 3 kg of the compost.

– Formula 2 (F2): 80% chemical fertilizer of the control and 2 kg of the compost.

– Formula 3 (F3): as the control and addition of 2 kg of the compost.

– Formula 4 (F4): as control and addition of 3 kg of the compost.

Chemical fertilizers were applied in three phases: early, mid and the end rainy season and all of the compost was applied with the first application of chemical fertilizer in early rainy season.

2.2. Sampling Methods

The compost and soil samples were collected from 5 different places each plot and mixed up one sample. Growth of branches and mature fruit ratio of coffee was measured 5 branches each plant and 5 plants each plot. The leaf samples were collected from 5 plants each plot and 5 leaves each plant in the morning after 2 months fertilizer application.

2.3. Analytical Methods

The temperature of the compost heap was measured by thermometer at 9:0 a.m. every day. The pH of the compost was measured on a 1: 10 (w/v) water suspension of the composting samples. The organic matter (OM) content was determined by loss on ignition of the dry mass at 550℃. Organic content (OC) of the samples was determined by Walkley-Black method[15] and total nitrogen was determined by Kjeldahl method. Total phosphorus was digested by fluoro boric acid procedure[16] and available phosphorus were measured by the colorimetric molybdate

blue method[17]. Total and available potassium was measured by flame spectrophotometer. Total calcium and total magnesium were measured by titration with Trilon B. Exchangeable Ca^{2+} and Mg^{2+} were extracted from soil by ammonium acetate method (Thomas, 1982)[18] and measured by titration with Trilon B.

Bulk density of the soil is weight of 1 cm^3 disturbed soil calculated by equation:

$D = P/V$

Where D is bulk density (g/cm^3); P is dried weight of the soil; V is volume of the soil (cm^3).[19]

Particle density of the soil was determined by using a graduated cylinder and determination of pore spaces by Tan et al. 1990 method.[19]

2.4. Statistical Analysis

Differences in means between treatments were tested by one-way ANOVA, and multiple factors by 2-way ANOVA with subsequent post comparisons of mean (LSD test, at P=0.05).

3. Results and Discussions

3.1. Composting Process Performance

Before research of composting process, coffee husk for composting was analyzed (Table 1).

Table 1. Chemical nutrient composition of the coffee husk compost after three months composting

Nutrient data	Composition of coffee husk	Composition of the coffee husk compost
Moisture (%)	17.3	22.3
OC %	50.8	28.2
pH_{KCl}	5.74	7.50
N%	1.27	2.07
P%	0.06	0.55
K%	2.46	2.87
Ca%	0.37	0.77
Mg%	0.42	1.01
C/N ratio	40.02	13.6

The composition of coffee husk shown in Table 1 indicated that coffee husk was a organic rich material, OC of coffee husk was high up to 50.83% in which over 20% lignin; 1.27% total N; high potassium (2.46% K) and C/N ratio of 40.02. Composition of coffee husk is dependent on cultivation condition, particularly, amount of fertilizers, soil, and kind of coffee. It was clear that composition of coffee husk in Brazil is same as the coffee husk in Vietnam reported by Dias et al.[7] and Santos et al.[9] and a good material for composting process. The results also showed that content of phosphorus was very low and C/N ratio is so high for plant. Therefore, to improve the quality of compost and reduce time of incubation, we proposed supplement of thermophos phate fertilizer, cow manure and urea and lime.

Dias et al.[7] reported that when mixing up poultry manure and coffee husk with 1:1 ratio and composting, organic matter loss was about 63% and 78.9% in poultry manure after 3 months of incubation. The organic matter loss of our experiment was lower than the Dias's report because mixing ratio of poultry manure was higher and this waste was easy for degradation.

Composition of the coffee husk compost after three months of incubation was shown in Table 1. Organic carbon (OC%) of coffee husk reduced from 50.8% down to 28.2% after composting and nitrogen content increased from 1.27% up to 2.07%. The result leaded to reducing C/N ratio down to 13.6 after three months composting. This C/N ratio was suitable for growth of plants. The C/N ratio traditionally considered as a parameter to determine degree of maturity of compost. Morais and Queda[20] proposed that C/N ratio below 20 is an indicator for acceptable compost and lower 15 being preferable. Additionally, content of potassium, calcium, phosphorus and magnesium also were improved clearly after composting process. Number of effective microorganisms was also a important data to evaluate the quality of the compost. The activity of effective microorganisms during composting process is the major mechanism for solubilisation of insoluble phosphorus and potassium and therefore, they play an important role for increasing in available nutrients for plants.[21]

Table 2. Effect of application of the coffee husk compost on fertility of the soil

Application	pH_{KCl}	OC %	Total mineral nutrients %			Available nutrients (mg $100g^{-1}$ soil)		Exchangeable cations (me $100g^{-1}$ soil)	
			N	P	K	P_2O_5	K_2O	Ca^{+}	Mg^{++}
The fertility of the soil before experiment									
C	4.41	3.4	0.16	0.11	0.06	7.8	16.1	3.0	2.8
F 1	4.47	3.6	0.17	0.13	0.07	8.1	15.4	3.2	2.8
F 2	4.51	3.3	0.17	0.10	0.06	8.9	15.4	3.0	2.4
F 3	4.35	3.4	0.17	0.12	0.07	8.0	16.5	3.2	2.6
F 4	4.38	3.5	0.18	0.13	0.07	9.4	17.3	3.3	2.6
The fertility of the soil after 3 years application									
C	4.11	3.2	0.15	0.09	0.06	6.6	14.7	2.4	2.0
F1	4.48	3.8	0.18	0.13	0.07	9.3	16.0	3.2	2.8
F 2	4.52	3.6	0.18	0.12	0.06	8.9	16.1	3.1	2.5
F 3	4.65	3.2	0.18	0.13	0.07	9.4	17.2	3.4	2.8
F 4	4.62	3.8	0.19	0.14	0.08	9.5	17.5	3.3	2.7

Finally, suitable composting process was determined as followings: Ingredients of the compost mixture were 10 to 20% manure; 70 to 80% coffee husk; 1% urea; 5% thermop hosphate fertilizer; 2% lime; 0.1% effective microorganisms; moisture of the mixture was 60%. The mixture was heaped up with 120 cm in height, covered with agricultural by products; maintained the 60% of humidity of the pile during composting process. After three months of composting, the compost was ready for use.

3.2. Effect of the Compost Application on Fertility of the Soil

The compost was applied for coffee plants. 2kgs to 3kgs of the compost were used to substitute partially chemical fertilizer with purpose being to reduce using chemical fertilizers, improve the fertility of the soil and protect soil environment from erosion and degradation. The first year of application, the fertility of soil was not improved in comparison with control (using 100% chemical fertilizer), because the compost was organic fertilizer, so it was slow effectiveness on the fertility of soil and plants shown in Table 2.

The fertility of the soil in the control expressed degradati on such as: pH decreased from 4.41 down to 4.11; OC% from 3.41 down to 3.28; available and total nutrients as nitrogen, phosphorus and potassium also reduced clearly. It indicated that if cultivation of coffee only used chemical fertilizers leaded to degradation of the soil and coffee production became unsustainable. In formulas that applying from 2kgs to 3kgs of the compost improved the fertility of the soil. pH of the soil increased from 4.11 to 4.52 in plots that applied 2kgs to 3kgs of the compost after three years of the treatment. Particularly, OC% and N% and total phospho rus enhanced significantly in comparison with the control. For examples: OC% enhanced from 3.28% in control (C) up to 3.82% (F2); total N% from 0.154% (C) up to 0.18% (F2). Available nutrients and cationic exchange also improved clearly compared with the control.

In addition, physical structure of the soil such as bulk density, particle density and pore space also trend to improv ement better than the control. Particularly, pore space of the soil increased from 55.2% (control) up to 58.3% (F2). Improvement of pore space makes plants adsorption of the nutrients better and effective microorganisms growth strong er. It is lead to reduce using chemical fertilizer and maintain the fertility of the soil (Table 3).

After three years of the compost application on the coffee field, the results shown in Table 2 concluded that applying only chemical fertilizers in cultivation of coffee leaded to reducing in pH, OC %, total N%, P%, K% and available nutrients and increasing in degradation of the soil. Our results were as same as report of Santos et al.[9] on composting coffee fruit peel with swine waste and some other waste. After two years applying the compost for coffee plant, fertility of the coffee soil as OM%, total N%, P%, K% was improved in comparison with control test.

Table 3. Effect of the compost on the soil density and pore space after 3 years application

Formulas of fertilizer application	Bulk density (g/cm^3)	Particle density (g/cm^3)	Pore space (%)
C	1.18±0.04	2.61	55.2
F1	1.07±0.02	2.52	57.6
F2	1.07±0.02	2.62	58.3
F3	1.12±0.03	2.57	55.8
F4	1.12±0.03	2.57	55.8
LSD 0.05	NS	NS	2.32

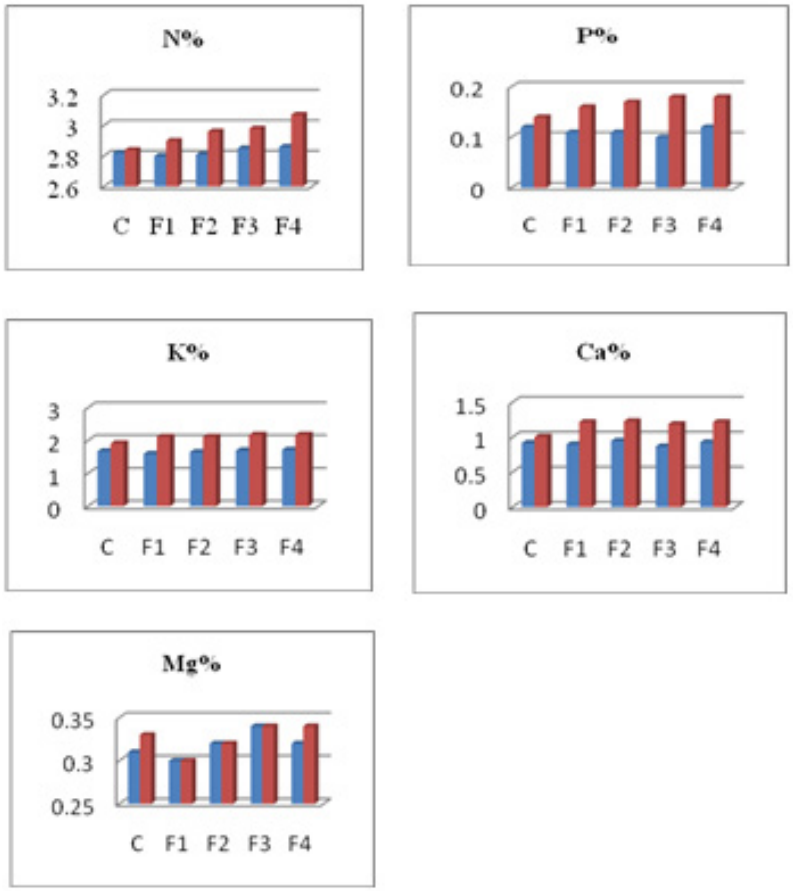
* NS: no signification

With unchanged production input, application from 2kgs to 3kgs of the compost substituted chemical fertilizers not only inhibit erosion and degradation of the soil, but also express clearly improvement of the soil fertility.

3.3. Effect of the Compost Application on Uptake of Mineral nutrients in the Coffee Leaves

The content of mineral nutrients in the soil has close interrelation with uptake of mineral nutrients in the leaves. After 2 months of fertilizer application, the coffee leaves were collected and analyzed. Results shown in Fig 1 indicated that a partial substitution of compost application had not been effective on uptake of nutrients in the leaves before experiment. This expressed in Table 3 that the fertility of the soil unchanged between formulas of application. It had even reduced slightly in F2 and F3 in comparison with the control (application of 100% chemical fertilizer). It was explained that chemical fertilizer was easy for uptake, but using the compost needed long time to degrade and minerali ze and express effectiveness. Westerman and Bicudo also showed that increasing in using organic fertilizer contributed to improve the physical, chemical and biological characteris tics of soil and sustainable agricultural cultivation[10]. In addition, activity of effective microorganisms in the compost such as nitrogen fixing bacteria and phosphate soluble bacteria also play important roles to increase in uptake mineral nutrients in the leaves of the coffee. Morikawa and Saigusa also showed that application of coffee ground compost increased available Fe for plants[22].

It was clear that content of mineral nutrients in the leaves were improved significantly in formulas which substituted partially with the compost. The content of N%, P% and K% in the formula 1 and formula 2 increased higher by 4.2%, 14% and 10% than control. For examples: 2.84% N; 0.14% P; 1.92% K in the control increased up to 2.96% N; 0.17%P and 2.12%K in the F2. The content of mineral nutrients in the control had a trend of slight deficiency, but it was suitable for the growth and development of coffee in F2, F3 and F4. The balanced nutrients in the leaves of coffee was very important for growth and sustainable yield[23].



* Blue columns are the value of the first year
* Brown columns are the value of 3 years later

Figure 1. Effect of the compost application on mineral nutrients of coffee leaves

3.4. Effect of the Compost Application on the Growth and Yield of Coffee on the Field

Growth of coffee branches effects strongly on the yield of next crop. Supplementation of the compost which had rich organic fertilizer for coffee increased in growth rate of coffee branches such as Table 4.

Improvement of the soil fertility (shown in Table 2, Table 3) and nutrient uptake in the leaves (shown in Fig 1) leaded to increase in the growth of coffee branches and crop yield (Table 4).

Table 4. Effect of the compost on the growth of coffee branches and crop yield after three years application

Formulas application	Growth rate of branches (cm.month^{-1})	Rate of fallen fruit (%)	Yield (Fresh kg.plot^{-1})
C	3.09	25.1	251.0
F1	3.24	19.8	283.3
F2	3.86	18.8	287.6
F3	3.78	18.2	289.0
F4	3.83	17.5	297.3
LSD 0.05	0.42	3.38	34.29

After three years of the application, the growth rate of branches increased from 3.09 cm month^{-1} up to 3.24 and 3.86 cm month^{-1} in F1 and F2. The rate of fallen fruits also reduced from 25.1% down to 18.8% in F2 and 17.5% in F4. The difference of rate of fallen fruits among formulas which the compost application was statistically significant. The results shown in Table 4 also indicated that the yield of coffee increased from 251.0kgs (control) up to 283.3kgs (F1); 287.6kgs (F2) and 297.3 kg (F4). Substitution of a part of chemical fertilizer with the compost that produced from coffee husk increased up to 14% the yield compared with the control in unchanged production input.

According to Santos et al.[9] application of untreated coffee husk for coffee with amount of 5 liters (for first year) and 10 liters (for second year) per plant reduced the yield of coffee compared to the control (swine manure application). Because rate of leaf drop was higher and coffee rust disease and brown eye spot was higher than the control. Although, the fertility of the soil applied with coffee peel and bovine manure compost was improved clearly in comparison with the control. Santos et al. found out applying untreated coffee husk or coffee peel gave imbalance of nutrients in the coffee leaves. There was increase in K content in the leaves increased and reduction in Ca content[9]. Addition, untreated coffee husk had high C/N ratio (30-40) and these was not suitable for plant[20].

In our work, coffee husk was fermented for 3 months by the effective microorganisms and fermentation process made

quality of the compost better than the untreated coffee husk or coffee husk mixed with swine and cow manure only as Santos et al.[9]. Using the effective microorganisms in our protocol reduced nearly 60% time of the process compared to Dias's protocol[7].

4. Conclusions

Coffee husk, a rich organic agricultural waste and potassium was good material for composting process. To reduce the time of composting and improve the quality of the compost should supplement 1% urea, 5% thermo phosphate fertilizer, 10-20% animal manure and 0.1% effective microorganisms. After three months of incubation by heap method, the compost was ready for using and reduced 60% time of the process compared to Dias's protocol[7]. Partial substitution of chemical fertilizer with the compost contributed to improve the fertility of the coffee soil, nutrient uptake in the leaves, the rate of branch growth and increase up to 14% yield in comparison with control and Santos's work[9]. Additional, using the compost also contributed to inhibit environmental pollution in rural and develop eco-sustainable agriculture.

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