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MICROBIAL ORGANIC FERTILIZER APPLICATION FOR SAFE COFFEE PRODUCTION AT DAKLAK, VIETNAM

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ABSTRACT

A replacement for chemical fertilizers using microbial organic fertilizer was investigated for 2 years to decrease production cost for safe coffee production in DakLak province, Vietnam. Through experimental research and during the course of the establishment of production models, the yield and quality were maintained. In addition, the production cost was reduced, when 4 tons of microbial organic fertilizer replaced the combination of 70% of chemical fertilizers with 5 tons of normal manure. It is an easy method and has the advantage of producing microbial organic fertilizer in local production sites. The economic effectiveness of this replacement technology was higher than that of currently practiced coffee production methods by about 5 million VND per hectare. This increases the capability of stable coffee production in DakLak, Vietnam.

Key words: Chemical fertilizer**,** normal manure, coffee yield

INTRODUCTION

DakLak Province has suitable ecological conditions of soil and climate for coffee production. In the last few decades, the average yield of coffee has increased continuously: from 0.7 to 0.8 tons in 1980, to 3 to 4 tons coffee seeds per hectare at present. In order to attain such high coffee yield, however the producers have to invest heavily in inputs, especially in chemical fertilizers. By our survey most of the coffee producers in Daklak applied 270 kg N, 90 kg P_20_5, 270 kg K_20, and 5 tons of manure in order to meet the target of 3 tons *Robusta* seeds as well as 2.5 tons *Arabica* seeds per hectare. In Vietnam, coffee hectarage increased continuously from 1980 - 22,000 ha; 1990 - 119,000 ha; 2000 - 397,000 ha; 2003 - 470,000 ha and slowly increased in 2004 - 500,000 ha (General Statistical Office, 2000 and 2005). At present, the price of coffee is going down continuously, while the price of fertilizer is increasing dramatically. Coffee producers suffered from huge losses making coffee production unstable. In order to solve this problem, it would be necessary to look for new cultivation solutions to reduce cost and increase quality of coffee product.

One of the solutions may involve the use of microbial organic fertilizer. The companies, Noble Hilter (1896) and Pham Van Toan (2004) were successful in producing Nitragin for soybean and a special microbial fertilizer for some kinds of crops, respectively. It increased tomato yield by 20.5%, potato yield from 30.9 to 72.9%, peanut yield from 13.3 to 19.1%, and coffee yield by 16.2%. Nguyen Xuan Thanh (2003) showed that multiple functions of microbial organic fertilizer increased useful soil microbial density which led to increases in soybean bud ratio, 17.3%; plant height; 35.8%, living mass weight, 35.1%; effective nodules, 76.1%, and soybean yield, 33.8%. In the last decade, the Korean Natural Farming Association (KNFA) received a lot of attention because of its remarkable success in productivity and profitability with minimum labor requirement through full use of local natural microbe potential (Han and Koyama 1997). In Vietnam, the Vietnam Productivity Center (VPC) of Hanoi Agricultural University (HAU) transferred this technology successfully from Korea on rice and some kinds of vegetable, and showed that using microbial organic fertilizer could replace 50% of chemical

fertilizer while crop yield remained with improved safety. The NO_3^- content in the treated products is lower than that of untreated control and lower than the NO_3^- content threshold, $\leq$ 500 mg/1 kg fresh vegetable set by FAO and WHO as cited in Decree number 867/1998/QĐ-BYT of the Ministry of Public Health, Vietnam.

The research was conducted to demonstrate the utilization of local nutrient sources by using local microorganisms for coffee production in DakLak to increase productivity.

MATERIALS AND METHODS

The Ea Tul Coffee Company is located in the Ea Tul Commue, Cu M'gar district, DakLak Province. It is about 30 kilometers in the north east direction from the center of Buon Ma Thuot City and about 12 kilometers from the town of Cu M'gar.

The average altitude of the study site is from 500 to 620 meters above sea level and was in the past a center of volcanic activities. Weathering of basalt rock of the site created Rhodic Ferralsols soil layers which are very fertile with a diversity of microorganisms and suitable for industrial crops like coffee. It has two distinct seasons: wet season and dry season. The dry season begins in November to April and wet season is from May to October. The average annual rainfall is 1,916 mm. and annual evaporation is 90 mm. The average air temperature is 23.4^0C and air humidity average is 83%. The experiment soil physical characteristics were: bulk density, 1.03 gram/cm^3; particle density, 2.66 gram/cm^3; porosity, 61.28 % and clay ratio: 60.58%

IMO is collected from the local forest or rice field after harvest by placing a box of steamed rice in the field and covering it with decayed leaves or straw for three to five days.

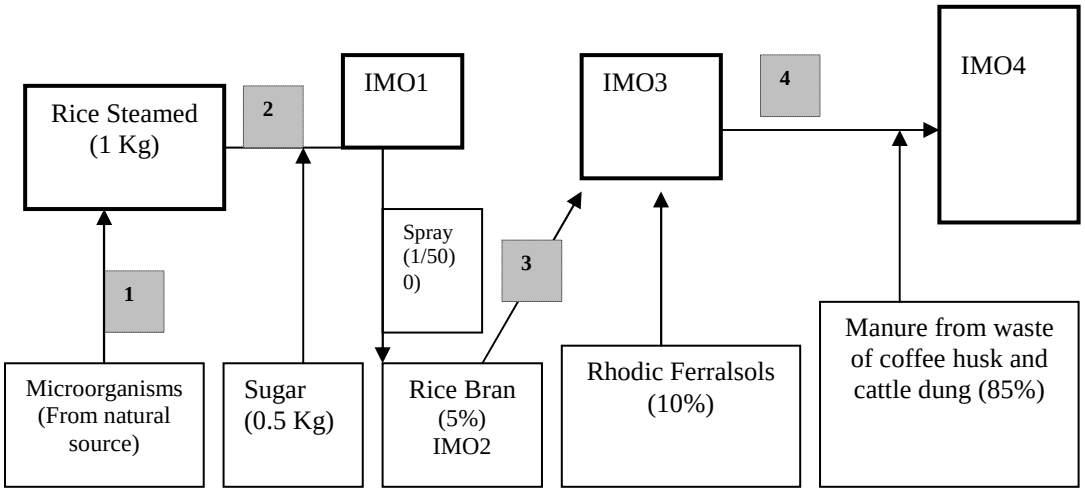

Fig. 1. Package technique to produce IMO4 that will replace manure in the experiment.

Notes: (1) = 3-5 days; (2) = 2-3 days; (3) = 5-7 days; (4) = 15-30 days

Both the experiment and household models were carried out on 5 year old *Coffea canephora var. Robusta* for two years. The main materials used included urea nitrogen: 1450 kg; Tecmophosphorus: 1235 kg; Kali Clorua: 1502 kg; manure: 15220 kg; rice bran: 860 kg, Rhodic Ferralsols soil and some sugar.

The field experiment included the following treatments:

Treatment 1(Control): NPK (270N – $90P_2O_5$ – 270 K_2O) + 5 tons of manure.
Treatment 2: 100% NPK + 1 ton IMO4
Treatment 3: 25% NPK + 4 tons IMO4
Treatment 4: 0% NPK + 5 tons IMO4

The application of fertilizer in Treatment 1 is according to farmer practice. The experiment was arranged based on a complete randomized block design, with plot size of 400 square meters with 3 replications (Gomez and Gomez, 1984).

The household model treatments included the following:

Treatment 1: NPK (270N - 90 P_2O_5 - 270 K_2O) + 5 tons of manure
Treatment 2: 30% NPK (81N - 27 P_2O_5 - 81 K_2O) + 4 tons IMO_4

There were 5 household models, each of them with an area of 1 hectare, of which the area for treatment 1and 2 are 0.2 and 0.8 hectare, respectively. *Coffea canephora var. Robusta* trees were planted in 1996 with a plant density of 1,100 plants per hectare, and shadow trees fixed with a density of 80 plants per hectare. The five models in five farm households were: H'Mrao; H'Blonh; H'Ngong; H'Blon; H'Mon. Fertilizer application was dressed following the same common package technique for both experiment and models according to the time table:

Table 1. Time table of fertilizer dressing

Items	Percentage in each time of top dressing				
	March - April	**May**	**June - July**	**September - October**	**November-December**
Manure/IMO4					100
Nitrogen	15	25	30	30	0
Phosphorus	0	30	35	35	0
Potassium	0	50	0	50	0

Indicators studied

Several soil chemical characteristics before and after the experiment were analyzed to include: pH_{KCL}, organic matter, total of N, P, K available P, K, exchanged Ca, Mg, and CEC. Soil microorganisms before and after the experiment, were also evaluated including: nitrogen fixing bacterium, cellulose decomposing microbe, aerobic total microorganism, fungi. Coffee growth was also evaluated through length of branches, number of leaf pairs per branch, branch diameter, ratio of shed fruit, and nutrient concentration in coffee leaves. Weight and fruit size, weight and seed size, ratio of fresh fruits/seed were likewise monitored while productivity and economic effects were analyzed.

All the observed indicators on the growth and fruits, seed of coffee were sampled randomly following tree's canopy, medium growth situations. Except for indicators on fruits, seeds were observed right after harvest and randomly on stacks of coffee fruits. Methods for soil physical and chemical characteristics determination included:

1. bulk density was determined by Core method (Grossman et al., 2002)
2. particle density was determined by pycnometer method (Alan et al., 2002)
3. clay content was determined by pipetle method (Glendon et al., 2002)
4. organic matter (OM) was determined by Walkley-Black method (Nelson et al., 1996)
5. total nitrogen was determined by Kjeldahl method (Bremner, 1996)
6. total phosphorus: Digestion with perchloric acid to determine the P concentration by Ascorbic Acid method (Kuo, 1996)

7. available P is determined by Olsen method ($NaHCO_3$ extraction) (Schoenau and Karamanos, 1993)
8. total K: digestion by Smith, determine the K Concentration by flame photometric method (Vadzenin, 1975)
9. Available K: ammonium acetate method (Helmke 1996)
10. Available N is determined by Tiurin and Kononova method (Vadzenin, 1975)
11. Ca^{++} and Mg^{++}: ammonium acetate method (Suarez 1996)
12. soil microbial count by Agamedium method (Nguyen xuan Thanh, 2007).

All soil samples were sampled by mixed random method right after the last coffee harvest**.**

Data analysis

Basal statistical parameters are calculated by Excel Software and Analysis of Variance (ANOVA) for experimental data is done by IRRISTAT 4.0. Economic effect of applying microbial organic fertilizer to coffee was calculated based on price table of materials in the Appendix

RESULTS AND DISCUSSION

Field trials

Soil chemical characteristics, before and after the experiment, were analyzed and the results are presented in Table 2. There are no differences in the soil chemical indicators among treatments before or after the experiment. This proves that there were no significant changes in the soil chemical characteristics due to the treatments.

Table 2. Soil chemical characteristics before and after the experiment (0 - 30 cm soil layer).

Items	Before	After			
		Trt 1	Trt 2	Trt 3	Trt 4
pH_{Kcl}	4.00	4.22	3.91	4.05	3.85
OM (%)	3.28	3.28	3.38	3.35	3.50
N (%)	0.16	0.16	0.15	0.16	0.16
K_2O (%)	0.06	0.06	0.07	0.06	0.06
P_2O_5 (%)	0.20	0.19	0.19	0.19	0.19
K_2O (mg/100g soil)	13.13	13.9	14.10	12.30	12.90
P_2O_5 (mg/100g soil)	5.50	6.60	6.10	5.70	5.10
Ca^{2+} (me/100g soil)	3.20	2.50	3.10	3.00	3.10
Mg^{2+} (me/100g soil)	1.70	1.90	1.70	2.00	1.80

Regarding the soil microbial components, all treatments where microbial organic fertilizer had been applied at different levels, the soil microbial component increased much more than the soil microbial component in untreated controls (Table 3). The more microbial organic fertilizer applied, the more the microbial density increased. This is a good opportunity for transferring organic matter in the soil and converting unavailable matter into available matter to increase crop productivity.

In addition, with the high density of nitrogen fixing bacteria, the nitrogenous content in the soil would be enriched. This can be an advantage for improving soil fertility and increasing crop productivity.

Table 3. Soil microbial component after the experiment.

Items	Trt 1	Trt 2	Trt 3	Trt 4
Humidity (%)	31	32	32	32
Total aerobic microorganism (10^6)	9.10	19.10	40.30	35.50
Total anaerobic bacterium (10^3)	0.48	3.38	12.10	12.00
Total fungi CFU (10^3)	11.45	13.86	17.60	15.78
Total untinomycete CFU (10^3)	6.70	8.90	14.98	14.37
Ammonificator CFU (10^3)	0.36	4.40	5.33	5.21
Phosphorus lysogenic bacterium CFU (10^3)	32.40	39.20	52.40	55.90
Cellulose lysogenic bacterium CFU (10^3)	0.92	1.32	1.95	1.86
Azotobacter CFU (10^3)	12.65	26.53	43.89	42.68
Rhizobium CFU (10^3)	6.30	7.,80	30.78	31.45
Clostridium CFU (10^2)	0.13	0.48	1.07	0.98

In order to determine the role of the microbial organic fertilizer to coffee, the nutrient profile in the coffee leaves of the various treatments were monitored (Table 4). There is no clear difference in coffee leaf nutrient indicators of the different treatments. It is the same situation for treatments with IMO_4 at different rates.

Table 4. The effect of microbial organic fertilizer (IMO4) on nutrient concentration in experimental coffee leaves.

Treatment	Nutrient content (%)				
	N	P	K	Ca	Mg
100%NPK + 5 tons manure	3.09	0.13	2.35	1.63	0.51
100%NPK + 1 ton IMO_4	3.10	0.12	2.28	1.55	0.53
25%NPK + 4 tons IMO_4	2.95	0.13	2.31	1.53	0.50
5 tons IMO_4	2.98	0.13	2.28	1.59	0.48

The effect of different fertilizer treatments on the growth of branches and leaves of coffee were also monitored (Table 5). The growth of main branch and leaf pairs per branch of coffee is different between treatments. The lowest growth occurred in Treatment 2 (100% NPK + 1ton IMO_4) and the differences among other treatments are not statistically significant. Nevertheless, branch and leaf growth in Treatment 3 (25% NPK + 4 tons IMO_4) represents a better trend. In this case, the role of manure fertilizer, especially IMO_4, is very important for the growth of branches and leaves of coffee because in IMO_4 there are microorganisms that can break down organic matter into accessible type, and it can also fix nitrogen from the air to provide to coffee.

Table 5. The effect of microbial organic fertilizer on growth of main branch and leaf pair per branch.

Treatment	Main branch		Leaf pair/branch	
	cm*	(%)	No. of pairs*	%
100% NPK + 5 tons manure	26.8[a]	100.00	2.5[a]	100.00
100% NPK + 1 ton IMO_4	23.0[b]	86.01	2.3	92.13
25% NPK + 4 tons IMO_4	27.4[a]	102.45	2.5[a]	99.84
5 tons IMO_4	27.3[a]	102.03	2.4[b]	99.07
$LSD_{0.05}$	**3.38**		**0.43**	

* The numbers in one column having the same letter in superscript are not significantly different.

Growth of coffee branch diameter and ratio of shed fruit for the various treatments are shown in Table 6. There was no difference in the growth of branch diameter among treatments. The difference is clear for the ratio of shed fruit between Treatment 2 (100% NPK + 1 ton IMO_4) compared to the other treatments. The ratio of shed fruit in Treatments 3 and 4 are the lowest. Thus, in this case IMO_4 affects the growth of branch diameter and it can limit the ratio of shed fruit.

Table 6. The effect of microbial organic fertilizer on coffee growth of branch diameter and ratio of shed fruit.

Treatment	Branch diameter		Ratio of shed fruit (%)
	mm*	%	
100%NPK + 5 tons manure	3.26[ab]	100.00	3.9
100%NPK + 1 ton IMO_4	3.17[b]	97.14	4.6
25%NPK + 4 tons IMO_4	3.47[a]	106.46	3.2
5 tons IMO_4	3.38[ab]	103.55	3.2
$LSD_{0.05}$	**0.22**		

* The numbers in one column having the same letter in superscript are not significantly different.

There is no statistically significant difference between treatments on all of the recorded indicators of plant growth (Table 7).

Table 7: The effect of microbial organic fertilizer on fresh fruit ratio/seed and fruit weight of coffee.

Treatment	Fresh fruit ratio /seed*	Weight of 100 fruits (g)*	Volume of 100 fruits (cm^3)*
100%NPK + 5 tons manure	6.94[ab]	137.8[a]	134.2[a]
100%NPK + 1 ton IMO_4	6.84[b]	134.8[a]	131.2[a]
25%NPK + 4 tons IMO_4	7.00[a]	138.3[a]	133.9[a]
5 tons IMO_4	7.01[a]	136.9[a]	132.4[a]
$LSD_{0.05}$	**0.29**	**8.52**	**5.78**

* The numbers in one column having the same letter in superscript are not significantly different.

Data on coffee yield of fresh fruit and seed of the different fertilizer treatments are presented in Table 8. There is no statistical difference which means that the use of organic fertilizer is not inferior to that of chemical ones.

Table 8: The effect of microbial organic fertilizer on the yield of coffee fresh fruit and seeds.

Treatment	Yield of fresh fruit* (tons per hectare)	Yield of seeds* (tons per hectare)
100%NPK + 5 tons manure	16.450[a]	2.380[a]
100%NPK + 1ton IMO_4	15.110[a]	2.190[a]
25%NPK + 4 tons IMO_4	16.592[a]	2.380[a]
5 tons IMO_4	15.520[a]	2.210[a]
$LSD_{0.05}$	**3.661**	**0.509**

* The numbers in one column having the same letter in superscript are not significantly different.

The recorded quality of coffee seeds are presented in Table 9. The results demonstrated no statistically significant difference on the weight of 100 seeds between treatments. It has been demonstrated that coffee seeds that are bigger in size have better quality (Nguyen Sy Nghi, 1982). In this study two treatments (1. applying enough 100% NPK + 1 ton IMO_4 and 2. Only 5 tons IMO_4) having significantly lower ratio of seed with large seed size (>6.3mm). Thus, replacing 5 tons manure with 4 tons IMO_4 reduced 70 percent of chemical fertilizer amount than the usual but the quality of coffee seeds was still maintained. In addition, the production cost is reduced and the safety of the products was also improved.

Table 9. The effect of microbial organic fertilizer on quality of coffee seeds.

Treatment	weight of 100 seeds* (g)	Ratio of seed size (%)		
		> 5.1 mm*	5.1 – 6.3 mm*	> 6.3 mm*
100%NPK + 5 tons manure	11.8[a]	3.56[b]	85.58[ab]	10.87[a]
100%NPK + 1 tons IMO_4	11.5[a]	4.40[ab]	86.62[a]	8.98[c]
25%NPK + 4 tons IMO_4	11.4[a]	4.42[ab]	85.11[b]	10.47[ab]
5 tons IMO_4	11.5[a]	4.89a	85.42[ab]	9.69[bc]
$LSD_{0.05}$	**0.8**	**1.11**	**1.21**	**1.13**

* The numbers in one column having the same letter in superscript are not significantly different.

The account of economic effect of this technique should be checked whether it can increase economic effect (Table 10). We determined that it is the same gross income in both treatments, where 100% NPK + 5 tons manure and 25% NPK + 4 tons IMO_4, were applied. In the second case, the price of coffee was higher because it is a safer product, thus its gross income would be higher. Because this involved reducing 70 percent of the chemical fertilizer from the usual, the production cost was greatly reduced by about 4,000 VND per hectare resulting in an increase in net income for the second case.

Table 10. Economic effect of applying microbial organic fertilizer to coffee.

Treatment	Cost*			Gross income*	Net income*
	Fertilizer	Other Costs	Total		
100%PK + 5 tons manure	7,348	12,000	19,348	38,080	18,732
100%PK + 1 tons IMO_4	5,298	12,000	17,298	35,040	17,742
25%PK + 4 tons IMO_4	3,012	12,000	15,012	38,080	23,068
5 tons IMO_4	2,250	12,000	14,250	35,360	21,110

* Thousand VND per hectare

Model farm trials

Five models were established in 5 farm households with two treatments in each model. Treatment 1 was the traditional one: 100 % chemical NPK and 5 tons manure while Treatment 2 was an improved one: 25% chemical NPK and 4 tons IMO_4. In all of the model farms, the production cost for Treatment 2 is always lower than that of treatment 1, by about 2 million VND per hectare, but the yield was higher than that of Treatment 1 (Table 11). Thus, gross income from Treatment 2 in all 5 models is higher than gross income of Treatment 1. This creates a net income of all Treatment 2 in 5 models that are higher than that of Treatment 1. The higher numbers range from about 4.3 to 7.3 million VND per hectare and the increased income average is 5.245 million VND per hectare.

Table 11: Economical effect of coffee models in 2005 (Thousand VND per hectare).

Household Models	Treatment	Total Cost	Gross income	Net income	Difference in net income (Trt 2-Trt 1)
H'Mrao	1	17,680	41,745	24,065	
	2	15,504	45,045	29,541	5,476
H'Mon	1	17,680	36,630	18,950	
	2	15,504	39,270	23,766	4,816
H'Blon	1	17,680	36,960	19,280	
	2	15,504	42,075	26,571	7,291
H'Ngong	1	17,680	39,105	21,425	
	2	15,504	41,250	25,746	4,321
H'Blonh	1	17,680	34,815	17,135	
	2	15,504	36,960	21,456	4,321
Average	1	**17,680**	**37,851**	**20,171**	
	2	**15,504**	**40,920**	**25,416**	**5,245**

CONCLUSION

The use of microbial fertilizers can replace to some extent the use of chemical fertilizers in coffee production in DakLak, Vietnam. The technology resulted in reduced production cost and increased gross income such that net income increased. One hectare of coffee produced by using microbial organic fertilizer can give the benefit of 5.2 million VND (equal 26%) higher than the traditional way. This will open a new direction for safe coffee production at DakLak by utilization of local manure source together with local micro-organisms to make microbial organic fertilizer for coffee production. This will contribute to a stable and safe coffee production in the region.

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APPENDIX TABLE

The price of some material items and man power

Items	Unit	Amount	Price (VND)
Urea	Kg	1	5,000
Termophosphorus	Kg	1	1,200
Potassium	Kg	1	4,500
IMO4	Kg	1	450
Coffee seed	Kg	1	16,500
Man power and Irrigation fee	Ha	1	12,000,000
USD		1	15,500