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Organic Fertilizers Requirement of Coffee (Coffea Arabica L) Review

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Abstract: *Coffee soils are exposed to nutrient leaching over a long period resulting in low organic matter content and require careful management to support good crop yields. Coffee produced in Ethiopia mainly by small-scale farmers is considered actually organic.. Organic fertilizers or materials added to the soil help in the buildup of the soil's organic matter and conditioning of the soil physical and chemical properties also provide for the needs of the various microorganisms which play an active part in the quality of the topsoil. Coffee pulp and husk, by-products of coffee processing, are organic residues that can be used as fertilizer for coffee. Coffee processing results in by-products such as pulp and mucilage that constitute around 60% of the wet weight of the fresh fruit. On large coffee farms the pulp is treated by composting and later used in the field as an organic conditioner of soils, thus reducing some of the cost of coffee production when compared to chemical fertilization. Therefore the objective of this paper is to review various investigations of coffee organic nutrient requirement & its influence on growth, yield and quality. .Mixture of 40% coffee pulp, 30% sugarcane filter cake, 20% poultry litter and 10% wood chips (bulking agent) resulted in a high quality compost within 50 days. Best combination of coffee pulp or husk and different organic materials such as FYM and leguminous plant material which resulted in accelerated composting process and better nutritional composition. Temperature and pH profiles of the compost mixtures were recorded regularly to evaluate the maturity of the composts. It was reported that compost piles containing higher proportion of organic residues exhibited higher temperatures along the process of organic matter degradation in around 45 days. During composting, temperature climbs sharply at first as the readily available compounds oxidize, reaching about 60 ^{O}C and 70^{O}c in 1 to 3 days. The C/N ratio of all piles decreased at the end of composting, reflecting mineralization of organic matter and an adequate evolution of the microbial composting process. Significant variation in the chemical properties of coffee pulp and husk before and after composting was reported. In coffee husk, pH increased from 5.63 to 6.15, electrical conductivity increased from 0.34 to 0.71 mmho/cm, exchangeable bases and higher total nitrogen. Available phosphorus also increased from 33.14 to 63.46 ppm,. In the case of coffee pulp, a slight reduction in CEC was observed. In addition, exchangeable K^+ decreased from 118.8 to 65.01 meq 100 g^{-1}. Applying composts prepared from coffee pulp and husk with different organic residues was found to increase significantly coffee yield. Compost prepared from coffee processing by-products can, therefore, provides much of the mineral nutrients required by the coffee tree for normal growth and sustained yield & enables the production of organic coffee which is of a worldwide demand today. Above all, these practices are environmentally friendly and economically sound.*

Keywords: *Coffee, Organic fertilizer, Compost*

1. INTRODUCTION

Arabica coffee (coffea Arabica) is one of the most important agricultural commodities. It grows wild in the forests. It is indigenous, which remains an important source of genetic resources for the world coffee industry (Gole, 2003). Of all the beverages worldwide, coffee is the most Stimulating and mood elevating non-alcoholic beverage (G.W.NAAKUBUZA et al., 2001).

In Ethiopia, most soils are exposed to nutrient leaching over a long period resulting in low organic matter content and require careful management to support good crop yields.

Ethiopian coffee is considered *actually* organic since chemical fertilizers and other synthetic inputs are not used in the production system. Production of organic coffee has increased very recently due to better awareness and market condition. In the year 2003 alone, the Oromya farmers' cooperative union produced 98550 tons of coffee of which 30415 tons was certified organic (www.fairtrade.org.uk).

Most farmers in Uganda try to increase coffee production by increasing the acreage for the crop but this is getting difficult because of the raising population pressure on the limited land. Coffee farmers being largely small holders have continued to produce without proper soil management practices. Very few farmers (20%) use some fertilizers in coffee production (Ngambeki *et al.*, 1992). Since coffee is exported the soils under its production are continually depleted of nutrients without replenishment.

More efforts are therefore needed to address the problem of soil fertility management in coffee producing areas (G.W. NAAKUBUZA et al., 2001).

Coffee pulp and husk, by-products of coffee processing, are organic residues that can be used as fertilizer for coffee. Huge amounts of such by-products are generated annually and disposed without proper utilization. Converting these by-products to usable organic fertilizer requires decomposition through composting which *w*as proved successful in various studies (Solomon, 2006).Coffee processing results in by-products such as pulp and mucilage that constitute around 60% of the wet weight of the fresh fruit (Calle, 1977).

Composting by earthworms can be considered as a special process where worms and microorganisms are involved in the decomposition process. The red worm (*Eisenia fetida)* is usually used for this process In Colombia, annual coffee pulp production is approximately 2 million tons (Rodríguez, 2003). On large coffee farms the pulp is treated by composting and later used in the field as an organic conditioner of soils, thus reducing some of the cost of coffee production when compared to chemical fertilization. Therefore the objective of this paper is to review various investigations of coffee organic nutrient requirement & its influence on growth, yield and quality.

2. Organic Fertilizer Management

2.1. Organic Coffee Fertilizer from Coffee by-Product

Soil fertility and fertilizer research should receive high priority and research on organic sources of nutrients must be encouraged and strengthened. Some have argued that continued research investment should be directed toward the low-potential and problem areas of SSA in order to arrest soil degradation and promote efficient types of extensive farming; however, fertilizer should probably not play a major role in strategies for low potential areas, particularly those for which increasing soil organic matter would be problematic under any circumstances (Vleck 1993).

The most important organic materials that can easily be used as fertilizers for coffee are coffee pulp and husk, which are by-products of wet and dry processing, respectively. Huge amounts of such by-products are generated annually and disposed without proper utilization. Converting these by-products to usable organic fertilizer requires decomposing them through composting which was proved successful in various studies (Solomon, 2006).

Coffee tree requires sufficient and regular supply of nutrients to produce high yield and good quality beans. Since it is a heavy feeder of nutrients, it extracts huge quantities of mineral nutrients from the soil (Table 1). Compost prepared from coffee processing by-products is therefore believed to supply much if not all of the mineral nutrients required by the coffee tree for optimal growth and sustained yield. Varying nutrient composition figures of coffee pulp compost have been reported I (Vander V., 2004) from different countries (Table 2).

Table1. *Approximate nutrient uptake (kg) by Arabica coffee producing 1t green beans/ha/year*

Plant part	N	P	K
Green beans (1.0 t dry wt)	40	4	45
Pulp + Parchment (1.25 dry weight)	35	7	53
Vegetative growth	60	5	22
Total	135	16	120

Source: *Wringley (1988)*

Methods of accelerated composting of coffee fruit waste in Mexico were discussed where a regularly aerated mixture of 40% coffee pulp, 30% sugarcane filter cake, 20% poultry litter and 10% wood chips (bulking agent) resulted in a high quality compost within 50 days (Sanchez et al., 1999). Result of a similar work at Jimma Research Center also indicated that high quality compost can be prepared from a mixture of 70% coffee pulp, and 20% FYM or 70% coffee pulp, 10% FYM, and 10 % leguminous plant materials (Solomon, 2006). Composting is a deliberate biological and chemical decomposition and conversion of organic or plant refuse and residues for producing humus (Samann, 1997). It can also be considered as a waste management strategy, but its fertilizer value differs according to crop and climate characteristics and soil fertility and structure (Rodrigues *et al.*, 1995).

Table2. *Nutrient content of organic residues and manures*

Type	Percent dry matter		C/N ratio	
	N	P	K	
Coffee pulp, fresh (India)	2.4	0.5	4.2	-
Coffee pulp, composted (India)	2.0	0.2	2.5	-
Coffee pulp, composted (Mexico)	3.8	0.4	-	10
Coffee pulp, fresh (Kenya)	3.7	0.4	6.5	-
Cattle manure (India)	0.4	0.2	0.2	-

Source: *Vander Vossen (2004).*

Coffee is a commercial plantation crop, grown in ecologically vulnerable ecosystem like Western Ghats. Coffee processing industries, are posing environmental hazards due to large-scale disposal of coffee pulp, husk, and effluents from these units. This practice poses a greater threat to water and land quality around the coffee processing units. Presence of toxic compounds like phenols in these byproducts restricts their direct use in agriculture. In addition, the indiscriminate use of fresh coffee pulp also affects crop through acid formation and local heat generation in the process of its fermentation. In order to restrain from the possibility of adverse effect of the disposal of coffee wastes, there need a healthier and productive way of utilizing these wastes.

Coffee pulp is usually disposed without any treatment and left to degrade naturally in heaps, with the uncontrolled liberation of noxious odors and nutrient loaded leachate consequently. When it is left for natural degradation, it may take 6 to 8 months to achieve a stabilization of the organic matter . It is therefore believed that composting is a feasible and cheap technology in dealing with by-products of coffee processing. Composting of coffee pulp can be done with very low capital investment to produce a very high quality organic fertilizer in a short time than natural stabilization (Olguin, 1996). Compost produced from coffee processing by products mainly coffee pulp and husk can be used successfully as an organic fertilizer for coffee production. A significant improvement in growth and yield of mature coffees was reported in response to coffee pulp and husk compost application (Chane, 1999).

2.2. Composting of Coffee Pulp

Composting can be defined as the biological decomposition and stabilization of organic residues by microorganisms. The temperatures during composting are increased above 50°C because of the microbiological activity resulting in a stable product, rich in humic substances, which can be used as organic fertilizer for conditioning soils without causing negative impact on the environment. Composting is also an ecological practice because it allows the return of the organic matter to the soils.

Both pulp and husk have high amounts of nutrients. Husk contains 1.5% nitrogen, 0.5% phosphorus and 2.2% potash. For every ton of clean coffee produced, one ton of dry matter is obtained either as cherry husk or fruit pulp. 7000 kg of fruits results in a net gain of 15 kg nitrogen, 3kg phosphorus and 35kg potash. Pulp or husk has to be composted and only then applied to the field. (Refer The Fine Art of Composting In Coffee Plantations. Un decomposed or fresh husk may lead to production of acids and thus bring down the pH of the soil. Composting is a dynamic process that involves the combined activity of several types of microorganisms: bacteria, fungi, actinomycete and other biological populations, that participate in different stages of the decomposition of the substrate (Rodale, 1971). In several investigations it has been demonstrated that the bacteria initiate the decomposition causing an increase in temperature, and the breakdown of organic molecules of complex structures such as proteins (Leon, 1982).

The high temperatures generated during composting also cause the breakdown of the cellular membrane of fungi, and therefore some internal components of the cell (e.g. antibiotics, fitohormones, fitoauxins, and citoquinines) are inactivated, giving a compost with an acceptable level of humic acids, but without biostimulants (Compagnoni, 1988). Composting by earthworms can be considered as a special process where worms and microorganisms are involved in the decomposition process. The red worm (Eisenia fetida) is usually used for this process. The product ‘vermicompost’ consists of the dung material of the worms which can be used as a biological fertilizer and also of the biomass of worms, which can be used for new vermicultivation, In earthworm composting biostimulants remain because the destruction of fungi cells occurs in the enteric tube of the worms and therefore the inactivation of these compounds is avoided (Compagnoni, 1988). While composting can be considered as a technique for treatment of organic residue on a large scale, earthworm composting is a relatively recent technique, developed on a smaller scale (Mustin, 1987).

Coffee processing results in by-products such as pulp and mucilage that constitute around 60% of the wet weight of the fresh fruit (Calle,1977). Because of their abundance, chemical composition and physical characteristics, these residues should be handled in an appropriate way in order to avoid environmental pollution.. If poorly managed, they could become sources of mould contamination for coffee beans.

In Colombia, annual coffee pulp production is approximately 2 million tons (Rodríguez, 2003). On large coffee farms the pulp is treated by composting and later used in the field as an organic conditioner of soils, thus reducing some of the cost of coffee production when compared to chemical fertilization. On small coffee farms composting by earthworms is more widely used. Fresh coffee pulp contains a vast microbial population of bacteria, fungi and yeast. During composting of pulp, an increase of mesophile and actinomycete populations has been observed (Blandón, Rodríguez; Dávila, 1998). Fungi play an important role in the initial steps of composting because of their saprophytic activity and the attack of lignin and cellulose transforming them into simple carbohydrates (Compagnoni, 1988).

According to common Colombian practice, coffee pulp is stored in rooms made from bamboo with cement floor, and zinc roofs. The mass is turned every 15 days in order to increase the ventilation and to speed transformation of substances composting takes between four to five months. For earthworm composting red worms are placed in layers of approximately 10 to 15cm thickness. Beds can be made from bamboo or brick, 1m wide, 0.4m height and of a variable length; the floor should be constructed from cement or be covered with plastic to isolate the culture from ground.

Compost obtained from coffee pulp is one of the best residues from vegetal origins, but it cannot be considered as a complete fertilizer, as it does not contain all the necessary nutrients for a coffee plantation. However, vermicompost contains several compounds, and, by some measures, has better physical characteristics when compared to chemical fertilizers (Aranda, 1995).

Yields in coffee production are the same (or improved) when compost from coffee pulp is used compared to traditional chemical fertilization. It is recommended to use doses of 6kg/pulp/plant/year on the surface of the soil. In the case of vermicompost from coffee pulp,0.5kg/plant/year may be used (Sadeghian, 2002).

2.3. Coffee Pulp and Husk with Different Organic Residues

This activity was carried out to determine the best combination of coffee pulp or husk and different organic materials such as FYM and leguminous plant material (e.g. Desmodium *sp.*) which resulted in accelerated composting process and better nutritional composition (Table 3).Temperature and pH profiles of the compost mixtures were recorded regularly to evaluate the maturity of the composts. It was reported that compost piles containing higher proportion of organic residues exhibited higher temperatures along the process of organic matter degradation in around 45 days (Solomon, 2006). During composting, temperature climbs sharply at first as the readily available compounds oxidize, reaching about 60 ^{O}C and 70^{O}C in 1 to 3 days (Olguin, 1996).

The results reported indicated that the C/N ratio of all piles decreased at the end of composting, reflecting mineralization of organic matter and an adequate evolution of the microbial composting process. The C/N ratio is expected to reach minimum values when mineralization of organic matter has finished. The general quality of the compost produced in piles with organic amendments was reported to be superior to that of the control pile (Table 4). Results from similar experiments accomplished elsewhere emphasized the beneficial effects of organic accelerators in producing coffee pulp and husk compost with short maturity time and superior quality (Sanchez, *et al.*, 1999).

Table3. *Proportion of coffee pulp and husk with different organic residues*

Pile type	Treatments					
	1 (Control)	2	3	4	5	6
Coffee pulp/husk	90	80	70	80	70	70
FYM	0	10	20	0	0	10
LM	0	0	0	10	20	10
Topsoil	10	10	10	10	10	10

Treatments: 1 = 90% CP, 2 = 80% CP + 10% FYM, 3 = 70% CP + 20% FYM, 4 = 80% CP + 10% CM, 5 = 70% CP + 20% CM, 6 = 70% CP + 10% FYM + 10% CM

Table4. *Quality parameters of coffee pulp compost in piles with different organic residues at the end of composting period (49 days).*

Parameter+	1	2	3	4	5	6
Moisture (%)	38.23	30.89	36.97	28.48	36.12	34.59
pH	7.69	7.49	7.50	7.54	7.60	7.51
TN (%)	0.80	0.81	0.90	1.04	1.06	0.83
OC (%)	7.15	6.71	6.71	5.67	5.62	5.88
C/N	8.50	8.30	7.50	5.50	5.30	7.10

+ CP= coffee pulp, FYM= farm yard manure, LM =

2.4. Effect of Composting on Chemical Properties of Coffee Pulp and Husk

Significant variation in the chemical properties of coffee pulp and husk before and after composting was reported by Chane (1999). In coffee husk, pH increased from 5.63 to 6.15, electrical conductivity increased from 0.34 to 0.71 mmho/cm (Table 6). The content of exchangeable bases also increased with composting. Available phosphorus also increased from 33.14 to 63.46 ppm (Table 5). In the case of coffee pulp, a slight reduction in CEC was observed. In addition, exchangeable K^+ decreased from 118.8 to 65.01 meq 100 g^{-1} that could probably be attributed to leaching of the element due to its high mobility and, in turn may have accounted for the reduction in CEC. On the other hand, higher total nitrogen content was found at the end of composting in almost all compost heaps containing organic amendments (JRC, 2005). The overall assessment shows the composting ratio of 70% coffee pulp: 20% FYM gave the highest nitrogen content at the end of composting (Fig. 1). Though the piles with amendments had higher content of nitrogen at the end of the composting process, the content of nitrogen was generally lower than the results reported by other authors (Chane, 1999). It is known that the application of organic fertilizers or materials brings about long-term improvements in the soil's physical and chemical characteristics rather than immediate and specific nutrient availability effects as in the case of mineral fertilizers. In this regard, Chane (1999) reported that the application of both non-composted and composted coffee processing by-products significantly improved soil chemical properties.

Table5. *Composting effect on chemical properties of coffee pulp and husk*

Properties	Unit	Coffee Husk		Coffee pulp	
		Uncomposted	Composted	Uncomposted	Composted
pH	pH scale	5.63	6.15	5.54	7.17
Electrical conductivity	mmho cm^{-1}	0.34	0.71	Trace	1.26
Cation exchange	meq $100g^{-1}$	58.72	65.01	83.76	69.74
Exchangeable K	meq $100g^{-1}$	11.36	16.11	118.80	65.01
Exchangeable Na	meq $100g^{-1}$	2.30	2.61	7.16	5.10
Exchangeable Ca	meq $100g^{-1}$	18.96	20.46	2.50	8.98
Exchangeable Mg	meq $100g^{-1}$	6.62	8.25	4.46	5.00
Organic carbon	%	38.78	21.15	33.84	14.21
Organic matter	%	66.86	36.47	58.34	24.49
Total nitrogen	%	1.71	1.15	2.23	1.39
C/N ratio	ratio	22.68	18.39	15.17	10.22
Available phosphorus	pm	33.14	63.46	89.42	96.88

Source: *(Chane, 1999)*

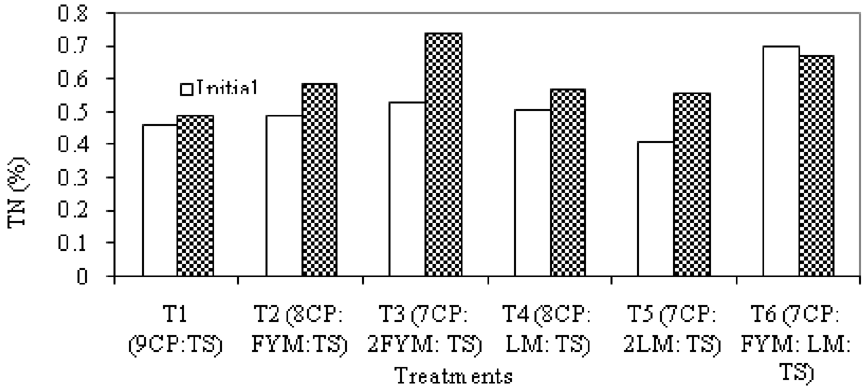

Figure1. *Total nitrogen content in coffee pulp compost at the initial and final weeks*

2.5. Growth and Yield of Coffee and Vegetables to Pulp and Husk

Different rates of coffee pulp and husk composts were investigated to evaluate their effects on growth and yield of Arabica coffee (Chane, 1999). Response of matured coffee to coffee pulp and husk composts is given below (Tables 6). Plant height, measured from the soil surface to the tip, increased from 19.0 to 50.0 cm and 33.7 to 57.0 cm in response to compost application at Gummer and Gomma sites, respectively. However, the highest and lowest height values were recorded from plots amended with NP fertilizer and without amendment, respectively, height increments were noted due to the application of coffee pulp and husk composts at both locations. In addition, the data on girth indicated similar improvements in response to the application of composts (Table 6). Application of coffee pulp and husk composts similarly affected clean coffee yield (Table 6). The highest average clean coffee yield was reported from plots receiving NP fertilizer as compared to the compost treatments. However, increasing rates of coffee pulp and husk composts resulted in significant improvements in coffee yield.

According to Chane (1999), both composted by-products of coffee pulp and husk have proved to be better than the non-composted or partially composted products in their effect on total clean coffee production and efficiency per unit weight. Incorporation of un decomposed or partially decomposed by-products with relatively high C/N ratio may have adverse effects on production such as inducing nitrogen deficiency (Gray et al., 1971). The effect of coffee by-product compost on the growth of vegetables, coffee, and maize was also examined at Melko (Paulos, 1989). The compost was prepared from piles of coffee husk from dry processing stations. Different quantities (treatments) of compost, and nitrogen and phosphorous fertilizers were used to test the response of vegetables, maize and coffee seedlings grown on pots. Finally, it was reported that application of compost together with nitrogen and phosphorous fertilizers resulted in significant improvements in maize plant height (Paulos, 1989). However, the effect of coffee husk compost on coffee seedlings was rather negative; hence, further investigation with more factors and control was recommended.

Table6. *Effect of coffee by products on the growth of coffee tree and Clean coffee yield (kg ha^{-1}) at two locations, (Chane, 1999)*

Treatment	Rate	Gummer		Gomma-II			
	(t ha^{-1})	Height (cm)	Girth (mm)	Height (cm)	Girth (mm)	Gummer	Gomma-II
CON	0	19.0	10	33.7	11	252	412
NCH1	5	21.3	13	34.3	12	300	436
NCH2	10	27.0	14	38.0	14	352	465
NCH3	15	30.0	15	41.7	16	379	516
CCH1	5	24.3	14	34.0	14	315	495
CCH2	10	30.7	15	42.7	15	436	566
CCH3	15	32.0	17	44.3	17	417	623
NCP1	5	25.7	14	34.7	15	334	492
NCP2	10	29.7	14	39.0	17	322	510
NCP3	15	32.7	15	39.0	17	414	548
CCP1	5	26.3	13	35.0	14	400	543
CCP2	10	33.3	14	42.0	17	475	710
CCP3	15	34.0	18	43.3	18	433	605
NP	176/32 *	50.0	20	57.0	23	517	857
Mean		29.7	15	39.9	16	382	556
SE (±)		1.2	0.6	1.9	0.6	15	24
LSD(0.05)		2.5	1.2	3.8	1.2	30	47

*CON: control, NCH: non composted coffee husk, CCH: composted coffee husk, NCP: non composted coffee pulp, CCP: composted coffee pulp, NP: nitrogen and phosphorus fertilizer, * kg/ha*

3. GREEN MANU RING

New clearings or establishment of Plantations in marginal lands is a long drawn process and takes almost a decade in the establishment of a Robusta Plantation and around 6 years for Arabica. In such a situation, the normal practice followed is the introduction of green manuring crops like daincha, sun hemp, fodder legumes, sesbania grandiflora, sesbania aculuta, red gram. The soil is loosely tilled and the seeds of the green manure crops are broadcasted into the field. In about 10 days time the seedlings emerge and are allowed to grow for a period of 10 to 12 weeks and thereafter incorporated into the soil. Since the green manure crops have nodules on the roots (Sesbania grandiflora has root as well as stem nodules), nitrogen fixing bacteria harvest atmospheric nitrogen and make it available to the plant. Once the crop is incorporated into the soil, the subsequent mineralization of nutrients takes place and the coffee plant is benefited by slow release of nutrients as well as improvement in the organic matter content of the soil (Anand and Geeta, 2008).Green manure in situ application: Refers to growing green manure crops and burying them in the same field either as a pure crop or as an intercrop.

The subsequent mineralization releases nutrients which coincide with the nutrient requirement of the plant. Green leaf manure: Generally, the valleys associated with coffee plantations are used to growing green manuring trees or shrubs like Glyricidia maculate Pongamia pinnata, etc. These leaves are incorporated into the soil or recycled into compost pits to bring down the C:N ration for quick multiplication of beneficial microorganisms.

4. ORGANIC FERTILIZERS AND THEIR COMBINATION

Seed multiplication produced 80, 85, 30 and 40 kg of viable seeds of mucuna, lupine, cannavalia and crotalaria respectively. The ploughing under was done in the trial blocks, and sampling for nutrient release monitoring was done for one year. The inclusion of the different litter sources seemed to affect the topsoil more than the subsoil, with Lupine and Mucuna releasing more Nitrogen than the others during the first two months. The other trials on combinations of organic and inorganic fertilizers are progressing well, with organic manure being applied this year to the relevant sub-plots. by including some additional parameters in order to integrate scenarios whereby both organic and inorganic nutrient sources are used. Further extension of the model will allow us to estimate the parameters of mono crop versus intercropped coffee and ‘shaded’ versus ‘open sun’ exposure. We will then validate the model through on farm field trials. 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 NO3 - content in the treated products is lower than that of untreated control and lower than the NO3 - content threshold, ≤ 500 mg/1 kg fresh vegetable (FAO and WHO 1998). .Poultry droppings are a peculiar organic waste because both urine and solid excreta are excreted together. Hence there is no loss of nitrogen from urine. These poultry droppings make excellent organic manure because of their excellent C:N ratio as well as high amounts of phosphorus and potash. The manure is also rich in uric acids. Generally for every 25 tons of cattle dung, 7 tons of poultry droppings are mixed along with straw and green manure, composted and broadcasted in the field (Anand and Geeta, 2008).

5. CONCLUSION AND SUMMARY

Applying composts prepared from coffee pulp and husk with different organic residues was found to increase significantly coffee yield. Compost prepared from coffee processing by-products can, therefore, provides much of the mineral nutrients required by the coffee tree for normal growth and sustained yield & enables the production of organic coffee which is of a worldwide demand today. Above all, these practices are environmentally friendly and economically sound.

In general, composting of coffee pulp and husk with legume plant materials and farmyard manure significantly accelerated composting process and better nutrient balance. Integrated nutrient management through the combined use of organic and inorganic sources, and agro-forestry shrubs and trees need to be assessed in the different coffee production systems and agro-ecologies of the country.

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