EFFECT OF BOTANICAL PESTICIDES ON SOIL FERTILITY OF COFFEE-ORCHARDS

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ABSTRACT

Coffee (Coffea arabica; Rubiaceae) is a potential and emerging commercial crop. Coffee is planted in the midhills of Nepal (800 to 1250 meter above mean sea level) in Gulmi and Lalitpur districts. To control the major insect pests of coffee plant, locally prepared 'jaibik bishadi' (botanical pesticides) are used as alternatives of the synthetic insecticides. This study was undertaken to see the contribution of 'jaibik bishadi' in the fertility of the coffee orchards soil, for which soil samples from botanicals used and not used coffee orchards were collected to see the level of soil characteristics and soil nutrients such as soil texture, organic matter, soil nutrients (phosphorous and potassium). There was some difference in the soil texture of topsoil, but no difference could be seen in sand, silt and clay content of the subsoils from botanical used and not used orchards. The pH was significantly different between botanical used and not used soils, but such difference could not be observed between the topsoil and subsoil from the same sites. Jaibik bishadi used to control the coffee pests significantly contributed in the soil fertility, which could be seen in high positive correlation (r=0.9886) between organic matter and nitrogen in the soil.

Keywords: Coffee, jaibik bishadi, topsoil, subsoil, soil fertility

INTRODUCTION

Coffee (Coffea arabica; Rubiaceae) is a potential and emerging commercial crop, which is believed to uplift the livelihood of rural farmers in mid-hills of Nepal. The focus of mountain agriculture is shifting from traditional cereal crops farming to high value cash crops. There is great potentiality for coffee cultivation in hills due to suitable climate, soil structure, relative humidity, temperature and rainfall for arabica coffee. Coffee bush is a perennial plant and requires a constant supply of nutrients throughout the year. Coffee is cultivated in upland and sloppy upland under intensive multi cropping and mixed cropping pattern with fruits and fodders. It is one of the breaks-through from the traditional subsistence food crops to commercial and agro-based industrial crop, but a wide variety of insect pests is posing a great threat to this business. Coffee is planted in the midhills of Nepal (800 to 1250 meter above mean sea level) in western and mid development regions of Nepal. The reported major insect pests of coffee plant were larvae and adults of white stem borer (*Xylotrechus quadripes*; Cerambycidae; Coleoptera), larva of red stem borer (*Zeuzera coffeae*), green scale (*Coccus viridis*), and mealy bugs (*Planococcus citri*). Similarly, the other pests of minor significance were grasshoppers, nematodes (*Pratylenchus coffeae*), red ant, hairy caterpillars and white grubs (COPP, 2007). Management of insect pests is done by mechanical (uprooting and destroying), cultural (pruning and mulching), natural plant products (botanical pesticides) popularly known as 'jaibik bishadi' and other local practices (applying dung, red soil, ash, oil, urine, etc). Nepalese farmers have their own traditional knowledge and practices of pest management. Nepal is rich in botanical diversity and plants. Those are rich sources of biocidal compounds, and are used to control the agricultural pest. Locally prepared 'jaibik bishadi' is

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an extract of different plants or mixture of plants and such local preparations are preferred alternatives of the synthetic insecticides in coffee orchards for their dual functions as natural pesticides and fertilizers. The farmers were growing organic coffee with the belief that such coffee, being organic and free of pesticide residues, will occupy a good position in the coffee market and would bring more economic benefit without causing any adverse effects on the agro-ecosystem.

OBJECTIVES

This study was undertaken to see the contribution of 'jaibik bishadi' in the soil fertility of the coffee orchards and see the significance of this practice in the organic coffee farming.

MATERIALS AND METHODS

This study was conducted in coffee orchards of Gulmi (Ruru and Thanapati VDCs) and Lalitpur (Thulodurlung VDC) districts of Nepal during October and November in 2007. Composite soil samples (5 samples, each containing about half kilogram in zigzag pattern in the shape of 'M') were taken from 10 different coffee orchards using tube auger as described in Soil and Plant Analysis Laboratory Manual (Ryan et al., 2001). The samples were collected before the application of organic fertilizer (manure) in the orchards. Ten soil samples from botanicals used orchards included 5 samples from top soil from a depth of 15-20cm (TS1, TS5, TS6, TS7, and TS8) and 5 from the corresponding subsoils (SS2, SS3, SS4, SS9 and SS10) from a depth of 40 cm. Similar ten soil samples (TS2, TS3, TS4, TS9, TS10 of topsoil and SS2, SS3, SS4, SS9, SS10 of subsoil) from orchards where no botanical pesticide was used were also taken. The soil samples S1 to S8 were collected from Ruru and Thanapati VDCs of Gulmi and S9, S10 from Thulodurlung VDC of Lalitpur. The soil samples were brought to the laboratory and completely air-dried before they were subjected to laboratory analysis in College of Applied Sciences-Nepal and Agriculture Technology Center, Lalitpur. Soil texture was determined by Hydrometer and was classified according to USDA- System. Organic matter was determined by Walkey-Black method and pH was determined by pH meter (Deluxe pHmeter Model 101E). Among the soil nutrients, the total nitrogen was determined by Kjeldahl digestion method, potassium by flame-photometer and phosphorus by Olsen and Bray method based on pH reading (Bray method: pH < 5.5 and Olsen method: pH> 5.5). These methods were applied as described in (Jackson, 1967; FAO, 1995; Russel, 1958; Metson, 1956). The acquired data were subjected to statistical analysis (ANOVA and correlation) and the difference in the characteristics of the soil from botanicals used and not used orchards were studied to see the role of jaibik bishadi (botanical pesticides) in maintaining the soil nutrients of the coffee orchards.

RESULTS

Physical characteristics of soil

The soil type in Gulmi was found to be clayey loam except in few cases and sandy loam in Lalitpur (Annex 1). The subsoils from botanical used and not used orchards showed absolutely no difference in sand, silt and clay content, but there was some difference in physical characteristics of topsoil. This could be verified by 2-way ANOVA with replicate with the value 0.001334, which was much less than the critical value (F=4.2597). The sand, silt and clay contents of the topsoil from different coffee orchards showed highly significant relation

(p=0.0289). The difference in sand, silt and clay contents of the topsoil and subsoil within the same orchards was also not significant.

Soil fertility status

The pH of top soil from both botanical pesticides used and not used sites was slightly acidic ranging from 5.5 to 6.5 (Fig. 1A and Annex 2), and very much suitable for the C. arabica cultivation. The pH was significantly different (p=0.004992) between botanical used and not used soils, but such difference could not be observed between the topsoil and subsoil from the same sites.

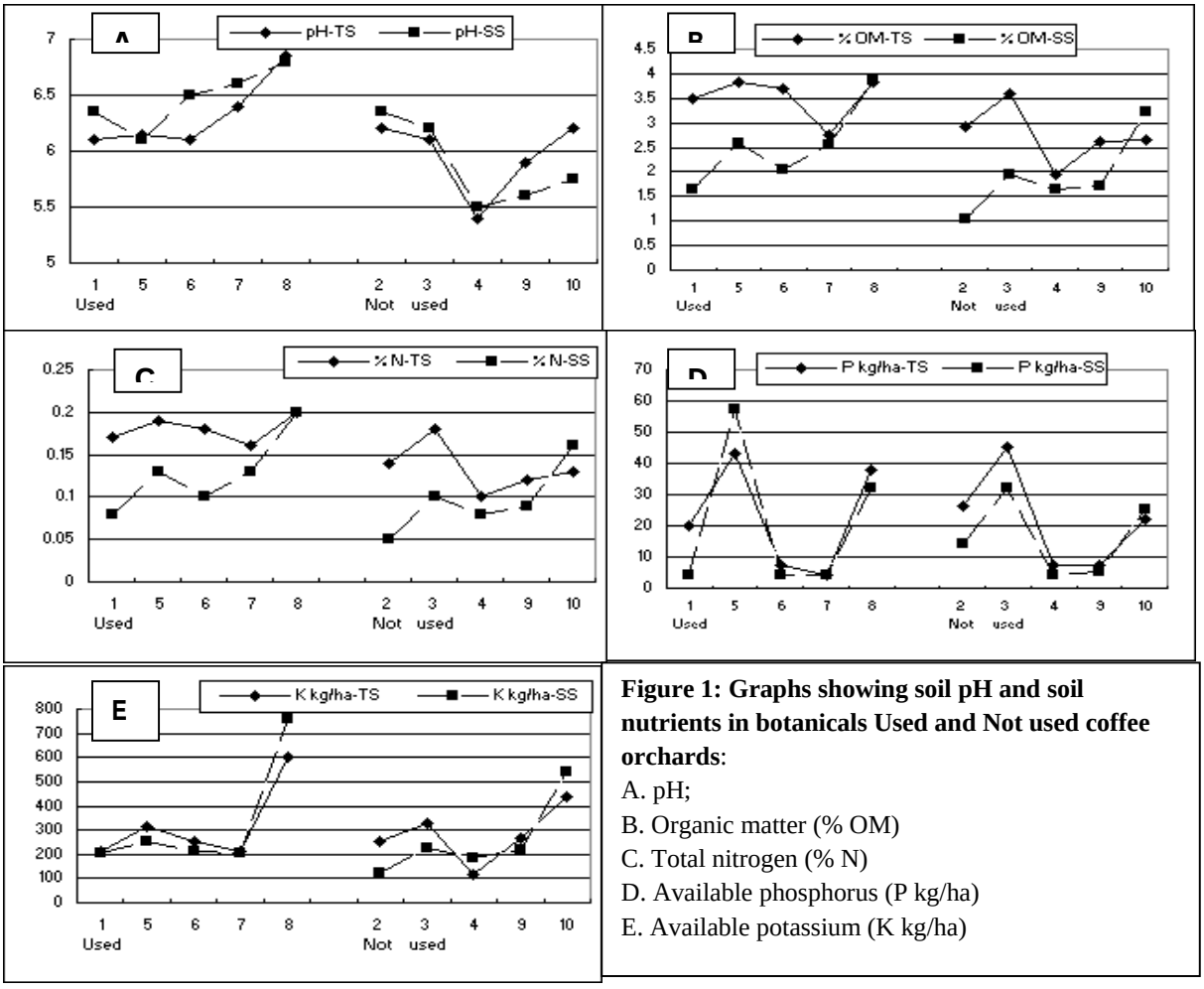

Figure 1: Graphs showing soil pH and soil nutrients in botanicals Used and Not used coffee orchards:
A. pH;
B. Organic matter (% OM)
C. Total nitrogen (% N)
D. Available phosphorus (P kg/ha)
E. Available potassium (K kg/ha)

Locally prepared botanical pesticides (jaibik bishadi) used to control the coffee pests due to their allomones were found to contribute significantly in the soil fertility. This contribution may be due various plant organic matters available in the crude preparations. The soil organic matter and nutrients (NPK) were higher in botanical used orchards than in those where no botanical was used (Fig. 1B-E). Difference in organic matter (OM) content was significantly high in botanical used and not used soils (p=0.03), as well as between topsoil and subsoil organic matter (p=0.00979). Nitrogen content in botanicals used soil was higher than in not used soil (Fig.1C and Annex 2), where the difference was significant at p=0.0232 level. Also, the nitrogen content in topsoil was higher in topsoil than in corresponding subsoil (p=0.0105).

However, the available phosphorous (Fig.1D and Annex 2) was found very much fluctuating within the soil samples, i.e. in topsoil and subsoil from the same sites. The difference was therefore not significant. Similar trend was found in soils from botanicals used and not used orchards. Except two sites of botanicals used and one of not used sites, which contained optimum amount of P (> 30 kg/ha) required in coffee growing soils, other orchards were poor (low to very low P) in available phosphorous. Potassium content in all the orchards at both topsoil and subsoil layers was within the range (110-280 kg/ha) required for coffee farming. These values were not significantly different between topsoil and subsoil and also between botanicals used and not used orchards, indicating no influence of the use of jaibik bishadi on the potassium content. As shown in (Annex 3), there was high positive correlation (r=0.9886) between organic matter and nitrogen in the soil. Such correlation between topsoil from botanicals used and that from not used orchards was also high (r=0.9605) indicating a close interrelation between organic matter and nitrogen in the soil of coffee orchards.

DISCUSSION

According to NTCDB (2003) most preferred soil for coffee was volcanic red soil, sandy loam and well aerated soil rich in humus and exchangeable bases, particularly potassium. The soil type in Gulmi was found to be clayey loam and sandy loam in Lalitpur with high potassium content. Hofner (1987) stated nitosol 25%, acrisol 17%, and luvisol 14% were the dominant coffee growing soil types with the soil texture varying from clay 13%, loamy clay 29%, silty clay 29% to sandy clay 22% in relative proportion. The soils mostly with clayey and silty clay texture found in Gulmi and Lalitpur districts were thus suitable for coffee farming. Optimum pH range for arabica coffee was reported to be 6.0-6.5 (NTCDB 2003) and 5.5-6.1 (CCRI 2007). Slightly acidic (5.5 to 6.5) soil found in Gulmi and Lalitpur coffee growing areas was thus very much suitable for the arabica coffee cultivation indicating a good prospect for coffee farming in these or similar mountain areas of Nepal. Coffee is an acidophilic plant but too much acidity may hamper the availability of nutrients from the soil. Karki (2004) however stated that generally lower pH increases availability of most micronutrients in the soil.

Coffee bush is a perennial plant and requires a constant supply of nutrients throughout the year. CCRI (2007) suggested that for yield of 782-781 kg/ha the optimum level of phosphorus (15-29 ppm) and potassium (75-140 ppm) should be available. MOAC (2004) has also recommended optimum requirements of phosphorus (30–55 kg/ha) and potassium (110-280 kg/ha) for good coffee production. The low availability of phosphorous in most of the sites in the present study may limit the production of coffee, but potassium was available in the prescribed range, and even more in some sites. The reason behind the minimum nutrient availability in subsoil might be due to that shade trees intercropped with coffee for many years developed extensive root systems and depleted the nutrients of coffee. DOA (2000) reported that the potassium content was at high to medium levels in Nepal. Similarly, Carson (1992) found that the Nepalese soils were generally endowed with high base levels of potassium and major deficiencies were not readily observed. According to MOAC (2004) the optimum range for nitrogen was 0.1-0.2 %. So, nitrogen was found to be medium to high in coffee cultivating soils. It might be due to addition of organic matter to the soil while applying botanicals (jaibik bishadi) or through decay of fallen leaves, fruits and other parts, which were intercropped with coffee, and thus might have facilitated the recycling of nutrients. Level of nitrogen was maintained at this level by applying more organic manures or and incorporating more nitrogen fixing leguminous crops. There was a close relationship among nitrogen supply, number of leaves and flower buds (Dierendonck ,1959). This view was found supported by a very high and positive correlation between the organic matter and

nitrogen observed during the present study. Farmers were using farmyard manures, green manures, vermin-composting, organic fertilizers. This might be still insufficient for a good coffee harvest, since coffee plants have high nitrogen and potassium requirements (Catani and Moraes, 1958). In Nepal, the recommended fertilizer application was 5 kg compost, 75 gms N, 55 gms P and 75 gms K per fruiting tree per year. According to CCRI (2007) the optimum level of organic matter should be 1.6-2.9% to have a yield of 782-781 kg/ha. The organic matter in all topsoils from botanicals used orchards and also some from no botanical applied soil was above the values recommended by MOAC (2004) for Nepal (2.5-5.0% of organic matter). Biswas and Mukherjee (1994) found that the surface soil received the litter falls rich in organic matter as compared to layer lying below. This indicated that mulching and manuring could be done to maintain the level of organic matter and soil fertility. The maintenance of organic matter and nitrogen contents in coffee orchards of Gulmi and Lalitpur districts was due to locally prepared jaibik bishadi (botanical pesticides), which on application had done dual functions as natural pesticides and fertilizers. Interestingly, the infestation of coffee pests, especially white stem borer was less than 2.5% in the region where botanicals were used, while it was more than 10% in regions, where no botanicals were used (Panthi, 2008). This fact showed that use of botanicals not only reduced the infestation level of stem borers, but also added the nutrients to the soil and thus increasing the vitality of the coffee plants. This practice was therefore very environment friendly.

RECOMMENDATIONS

The coffee farmers should be encouraged more to use environment friendly botanical pesticides Community approach to control coffee pests should be adopted by providing proper trainings on effective preparation and application of botanical pesticides. In order to encourage the farmers to grow more organic-coffee, they should be given proper knowledge on the types of pests and their proper control by using locally available plants, which have biocidal properties and also increase or maintain the soil fertility.

CONCLUSION

The soil type of coffee orchards ranged between clayey loam sandy loam in Lalitpur. The subsoils from botanical used and not used orchards showed absolutely no difference in sand, silt and clay content, but there was some difference in physical characteristics of topsoil. The pH of top soil from botanical used and not used sites was slightly acidic ranging from 5.5 to 6.5. Locally prepared botanical pesticides (jaibik bishadi) used to control the coffee pests due to their allomones were found to contribute significantly in the soil fertility. There was high positive correlation (r=0.9886) between organic matter and nitrogen in the soil. The major nutrient status was found to be optimum (N > 0.1 %, P > 30 kg/ha, K >110 kg/ha). The OM was also optimum in top soil (> 2.5 %) and lower in subsoil. The fertility status (NPK) and organic matter were also found to be higher in botanical used orchards as compared to those where no botanical was used.

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ANNEXES

Annex 1: Physical characteristics of soil from different coffee orchards of Gulmi and Lalitpur districts.

Samples	Sand (%)	Silt (%)	Clay (%)	Soil texture	Samples	Sand (%)	Silt (%)	Clay (%)	Soil texture
Botanicals used topsoil (TS)					Botanicals used subsoil (SS)				
TS1	44.8	36.6	20.6	Cl	SS1	37.2	33.6	29.2	Cl
TS5	24.8	35.6	39.6	Cl	SS5	20.2	32.6	47.2	Cl
TS6	14.8	44.6	40.6	Si.c	SS6	7.2	45.6	47.2	Si.c
TS7	24.8	40.6	34.6	Cl	SS7	22.2	40.6	37.2	Cl
TS8	4.8	42.6	52.6	Si.c	SS8	0.2	40.6	59.2	Si.c
Botanicals not used topsoil (TS)					Botanicals not used subsoil (SS)				
TS2	44.8	29.6	25.6	Cl	SS2	44.2	27.6	28.2	Cl
TS3	32.8	34.6	32.6	Cl	SS3	29.2	32.6	38.2	Cl
TS4	31.8	32.6	35.6	Cl	SS4	26.2	32.6	41.2	Cl
TS9	22.7	50.3	27.0	Cl	SS9	17.7	45.3	37.0	Si.c
TS10	16.7	40.3	43.0	Si.c	SS10	10.7	42.3	47.0	Si.c

(Cl- clayey, Si.c- silt clayey)

Annex 2: Comparison between soil organic matter and nutrients in botanicals used and not used orchards (values given below are: Organic matter OM in %, total nitrogen N in %, available phosphorus P in kg/ha and available potassium K in kg/ha)

Samples	pH	OM	N	P	K	Samples	pH	OM	N	P	K
Fertility status of top soil (TS) and subsoil (SS) where botanicals were used											
TS1	6.10 (sa)	3.48 (m)	0.17 (m)	20.03 (m)	211.2 (m)	SS1	6.35 (sa)	1.64 (l)	0.08 (l)	4.11 (vl)	206.4 (m)
TS5	6.15 (sa)	3.84 (m)	0.19 (m)	43.11 (m)	312.0 (h)	SS5	6.10 (sa)	2.60 (m)	0.13 (m)	57.41 (h)	249.6 (m)
TS6	6.10 (sa)	3.70 (m)	0.18 (m)	7.18 (vl)	249.6 (m)	SS6	6.50 (n)	2.04 (m)	0.10 (m)	4.11 (vl)	211.2 (m)
TS7	6.40 (sa)	2.76 (m)	0.16 (m)	4.11 (vl)	211.2 (m)	SS7	6.60 (n)	2.56 (m)	0.13 (m)	4.11 (vl)	206.4 (m)
TS8	6.85 (n)	3.84 (m)	0.20 (h)	38.10 (m)	600.0 (e)	SS8	6.80 (n)	3.86 (m)	0.20 (h)	32.04 (m)	758.4 (e)
Fertility status of top soil (TS) and subsoil (SS) where botanicals were not used											
TS2	6.20 (sa)	2.92 (m)	0.14 (m)	26.10 (l)	249.6 (m)	SS2	6.35 (sa)	1.04 (l)	0.05 (l)	14.35 (l)	124.8 (m)
TS3	6.10 (sa)	3.60 (m)	0.18 (m)	45.10 (m)	326.4 (h)	SS3	6.20 (sa)	1.96 (l)	0.10 (m)	32.04 (m)	225.6 (m)
TS4	5.40 (a)	1.96 (l)	0.10 (m)	7.18 (vl)	115.2 (m)	SS4	5.50 (a)	1.64 (l)	0.08 (l)	4.11 (vl)	182.4 (m)
TS9	5.90 (sa)	2.62 (m)	0.12 (m)	7.40 (vl)	264.0 (m)	SS9	5.60 (sa)	1.72 (l)	0.09 (l)	5.40 (vl)	216.0 (m)
TS10	6.20 (sa)	2.65 (M)	0.13 (m)	22.03 (l)	436.8 (h)	SS10	5.75 (a)	3.24 (m)	0.16 (m)	25.04 (l)	537.0 (e)

(pH: sa- slightly acidic, e- excess, a- acidic, n- neutral; Organic matter (OM) and nutrients: h- high, m- medium, l-low, vl- very low)

Annex 3: Correlation (r) between soil characteristics

	pH	Organic matter	Nitrogen	Phosphorous	Potassium
pH	1				
Organic matter	0.3359	1			
Nitrogen	0.3776	0.9886	1		
Phosphorous	0.2196	0.5188	0.5066	1	
Potassium	0.4438	0.6501	0.6643	0.4542	1