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Improvement of Tea (*Camellia sinensis* L.) Soil Properties by Growing Different Green Crops

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Abstract

Long-term tea cultivation has led to degradation of the soil. Old tea soils require rehabilitation for restoring soil health. Soil rehabilitation by growing different green crops can break the chain of monoculture of tea. An experiment was conducted at The Bangladesh Tea Research Institute (BTRI) Farm during 2008-2011 to find out the efficiency of different green crops on the improvement of soil properties. Four green crops such as Guatemala, Citronella, Mimosa and Calopogonium were grown to develop the nutritional value of the degraded tea soil. Soil samples were collected and analyzed before and at the end of experiment. Soil pH was increased in all four green crops treated plots with the highest increase in Citronella treated plots (from 4.1 to 4.5). Highest content of organic carbon (1.19%) and total nitrogen (0.119%) were found in Mimosa and Calopogonium treated plots, respectively. Concentration of available phosphorus, calcium and magnesium in all green crops treated plots were above the critical values, while available potassium content was above the critical value in Guatemala, Citronella and Mimosa treated plots. Changes in soil pH and available potassium were significant, while changes in organic carbon content, total nitrogen and available calcium were insignificant. Changes in available phosphorus and magnesium were significant.

Keywords: Tea soil, rehabilitation, green crops, soil properties, nutrient concentration

1. Introduction

The soil after remaining under tea (*Camellia sinensis* L.) for a long time is usually denuded of nutrients and some (auto) toxins (allelopathic) also get accumulated (George and Singh, 1990; Othieno, 1992). It has also been noted that the food crops such as maize and beans, despite use of fertilizers, completely failed to grow in Kenya when planted immediately after uprooting of tea. Therefore, old tea soil requires rehabilitation for restoring soil health. A green manure crop can add organic matter, nitrogen or other nutrients. When green manures are turned into the soil and are decomposed, they provide nutrition for soil organisms, thus protecting and enhancing the soil's biological activity. The root mass of a green manure crop loosens and aerates the soil, thus improving the soil structure and reducing soil compaction (Hajra, 2001).

Green manure - (also cover crops) originated from practices of using primarily leguminous plants and plowing them down to fertilize soils. The use of green manuring crops in tea culture has long been in vogue to safeguard the young

tea in nursery from the stresses of drought and nutrition supply. Green manuring crops which are predominately leguminous plants, help enriching the soil fertility and soil moisture through their lopped materials. These also act as miniature shade trees and protect young plants in the nursery. In Bangladesh, green manuring crops with leguminous species, like *Crotalaria anagyroides*, *Tephrosia candida* (Bogamedeloa), *Priotropis cytisoides*, *Desmodium gyroides*, *Cajanus cajan* (Arhar) etc. are used in newly planted area for soil-rehabilitation (Sana, 1989).

A few grasses like *Tripsacum laxum* (Guatemala), *Pennisetum purpureum* (Napier), *Cymbopogon citratus* (Citronella), *Cymbopogon winteranus* (Lemon grass) are found to be useful for soil rehabilitation. As cover crops *Mimosa invisa*, *Calopogonium mucunoides*, *Strylosenthes gracilis* are effectively used in tea for conservation. These are twining or prostrating creepers and can smoother any weed including *Mikania scandens* and *Cuscuta* within a few months. Mulching with these crops provides manifold benefits, such as the addition of organic matter and nutrients check of soil erosion, and suppression of weeds (Sana, 1989).

The organic matter content of Bangladesh tea soil is generally low and is likely to be depleted further over time. Low level of soil organic matter is responsible for declining soil fertility and low crop production in tea estates. Green crops are grown to rehabilitate the old degraded tea soils and to increase the organic matter in proposed new extension tea areas. The green matter from green crops added to the soil is converted to humus and plant nutrients that help build up a good soil structure. A number of green crops are used in tea soil to increase the organic matter status. The objective of this experiment is to identify the efficiency of four green crops such as Guatemala, Citronella, Mimosa and Calopogonium on the development of soil properties.

2. Materials and Methods

The experiment was conducted during 2008 to 2011 at BTRI farm with five treatments in a Randomized Block Design with three replications. The treatments were control (T_1), Guatemala (T_2), Citronella (T_3), Mimosa (T_4), and Calopogonium (T_5). Recommended doses of fertilizer for the green crops were applied regularly. Fertilizer dose for rehabilitation crops are given below according to Kibria *et al*. (1994). The unit plot size was 4 m×4 m = 16 m^2. Green crops were planted and lopped subsequently. Lopping materials were uniformly distributed and incorporated into the soil in order to improve the nutrient status as well as physical conditions of the soil.

Table 1. The fertilizer dose for rehabilitation crops

Name of the green crops	Spacing	Fertilizer doses
Guatemala	1.00×0.75 m	N: P_2O_5: K_2O 120: 30: 90 (4:1:3) 3 Split:1 Split: 3 Split (40+40+40):30:(30+30+30)
Citronella	0.90×0.60 m	N: P_2O_5: K_2O 80: 20: 40 2 Split: 1 Split: 2 Split (40+40): 20: (20+20)
Mimosa	Row to row distance 1.2 m	Per 100 running ft.1 kg TSP
Calopogonium	(1.2×0.30 m after thinning)	Per 100 running ft.1kg MoP 10 kg or more cow-dung

Soil samples were collected from a depth of 0-9 inches before and at end of this experiment. The texture, pH and amount of organic carbon, total nitrogen, available phosphorus, potassium, calcium and magnesium of the soil samples were determined before and after completion of these experiments.

Soil texture was determined by hydrometer method and soil pH was determined by pH meter (Soil: distilled water = 1:2.5). Soil organic carbon was determined following Walkley and Black wet oxidation method. For determination of total nitrogen, Micro kjeldahl steam distillation method was adopted (Imamul Huq and Alam, 2005). Available phosphorus was determined colorimetrically.

For determination of available potassium, calcium and magnesium, soils were extracted with 77% ammonium acetate solution where potassium was determined by flame photometer and calcium and magnesium were determined by an atomic absorption spectrophotometer. Weight of loppings of different green crops was taken. Nitrogen, phosphorus and potassium content of green crops were analyzed. For N analysis sulphuric acid/selenium reagent was used and 0.1 M hydrochloric acid was used for P and K analysis. For determination of nitrogen in green crops, Micro kjeldahl steam distillation method was used. Colorimetric determination of phosphorus in green crops was done by spectrophotometric method. Potassium was determined by flame analyzer.

3. Results and Discussion

Initial soil analytical results show (Table 2) that soil pH, organic carbon (OC), total nitrogen (N), available phosphorus (P), potassium (K) and magnesium (Mg) were below the critical level. Soil texture was Sandy Clay Loam (SCL) in nature which is suitable for tea cultivation. Initial soil pH was below 4.5 which indicate its acidic character.

At the end of four years experiment after six looping, the study showed that, organic carbon, total nitrogen, available phosphorus, available potassium, calcium and magnesium increased from the initial soil analytical results, acidity decreased and texture remained unchanged (Table 3).

Table 4 represents weight of loppings of different green crops. Among the four green crops, Guatemala produced the highest amount of biomass which was 29.00 kg/plot and Calopogonium produced the lowest amount of biomass (4.00 kg/plot). Nutrient composition of different green crops are presented in the Table 5.

From the chemical analysis of the four green crops it was found that N content was greater in Mimosa (2.61%), while Guatemala, Citronella and Calopogonium contained 1.41%, 1.10% and 0.40% N, respectively. Phosphorus content was higher in Calopogonium while K content was higher in Citronella.

Table 2. Initial soil analytical results

Treatments	Depth (cm)	Texture	pH	OC (%)	Total N (%)	Av. P (ppm)	Av. K (ppm)	Av. Ca (ppm)	Av. Mg (ppm)
T_1	0-23	SCL	4.2	0.95	0.093	13.13	22.95	202.4	10.3
T_2	0-23	SCL	4.2	0.85	0.083	8.44	18.8	160.3	14.7
T_3	0-23	SCL	4.1	0.86	0.083	7.5	17.94	174.55	15.15
T_4	0-23	SCL	4.1	0.94	0.092	8.13	21.15	196.5	17.85
T_5	0-23	SCL	4.2	0.92	0.090	11.56	24.2	199.75	10.75

Table 3. Changes in the soil physical and chemical properties after 6 loppings of green crops (at the end of experiment)

Treatments	Depth (cm)	Texture	pH	OC (%)	Total N (%)	Av. P (ppm)	Av. K (ppm)	Av. Ca (ppm)	Av. Mg (ppm)
T_1	0-23	SCL	4.2	0.80	0.072	7.44	16.72	160.41	8.91
T_2	0-23	SCL	4.5	1.11	0.098	18.78	80.95	187.90	26.52
T_3	0-23	SCL	4.5	1.07	0.105	20.43	80.17	181.02	56.32
T_4	0-23	SCL	4.3	1.19	0.098	35.33	88.36	205.70	39.56
T_5	0-23	SCL	4.5	1.18	0.119	22.16	59.20	254.80	54.55

Table 4. Weight of loppings of different green crops

Name of the green crops	Weight of loppings (kg/plot)
Guatemala	29.00
Citronella	12.00
Mimosa	7.50
Calopogonium	4.00

Table 5. Nutrient composition of different green crops

Green crops	Nutrient concentration (%)		
	N	P	K
Guatemala	1.41	0.60	1.71
Citronella	1.10	0.76	4.60
Mimosa	2.61	0.63	1.01
Calopogonium	0.40	1.50	1.60

Soil pH increased to 4.5 in Guatemala, Citronella and Calopogonium treated plots. Organic carbon raised above 1% in all the green crops treated plots. Highest content of organic carbon (1.19%) was found in Mimosa treated plots. Total nitrogen also increased to above 0.1% in Citronella and Calopogonium treated plots and highest content (0.119%) was found in Calopogonium treated plots. Total nitrogen (0.098%) in both Guatemala and Mimosa treated plots was very close to the critical value. Concentration of available phosphorus, calcium and magnesium in all green crops treated plots were above the critical values, while available potassium content was above the critical value in Guatemala, Citronella and Mimosa treated plots. Available phosphorus and potassium content was the highest in Mimosa treated plots which were 35.33 ppm and 88.36 ppm, respectively. The highest content of calcium (254.80 ppm) was found in Calopogonium treated plots, while Citronella treated plots contained the highest amount of magnesium which was 56.32 ppm. Before starting the experiment, the soil pH was below 4.3, while at the end of experiment pH raised to 4.3 and above which was statistically significant at 1% level ($t = 3.58$). So, planting of green crops might have some influence to increase the soil pH. At the end of experiment, it was found that organic carbon in the soil increased from the initial value (0.85 to 0.95%) due to growing of different green crops.

However, the changes in organic carbon were statistically insignificant. It might have occurred due to the rapid degradation of organic matter by the influence of climatic condition. Total nitrogen content was also increased by growing different green crops but the changes of nitrogen content were also statistically insignificant. Phosphorus content was increased and it was statistically significant at 5% level (t = 2.42). So, growing of green crops has favoured in increasing the content of plant available phosphorus in soil. Available potassium content in soil was also increased at the end of experiment. Statistical analysis shows a significant changes of potassium content which was at 1% level of significance (t = 3.38). This might be due to the influence of green crops. Changes of available calcium content were also observed at the end of experiment but this change was statistically insignificant. Increment of magnesium content was statistically significant at 5% level (t = 2.61).

4. Conclusions

From the above discussion it is clear that green crops can improve soil properties and can play an important role on replenishment of plant nutrients to the soil. The practice of green manuring and soil rehabilitation is as old as agriculture itself. Leguminous crops such as Mimosa, Calopogonium and non-leguminous crops like Guatemala, Citronella can reduce soil acidity. It can also enrich organic carbon, total nitrogen, available phosphorus, potassium, calcium and magnesium content in soil and can thereby improve soil nutrient status. Thus, deteriorated tea soil can be rehabilitated by growing different green crops.

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