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Studies on the influence of organic and inorganic inputs on soil biological parameters in Darjeeling tea gardens

A. BISHNU[1], P. BHATTACHARYA[1], S. TRIPATHI[2],
A. CHAKRABORTY[3] AND T. SAHA[1]

[1]*Institute of Environmental Studies and Wetland Management, Salt Lake City, Calcutta, West Bengal*
[2]*Department of Agricultural Chemistry and Soil Science, Calcutta University, Calcutta, West Bengal*
[3]*Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal*

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ABSTRACT

The aim of the present work was to investigate the status of the sol biological parameters of the tea soils under organic and inorganic (conventional) input management practices. The soils were collected from selected conventional and organically managed tea gardens during the month of June. 2008. The results showed that the soil biological parameters (e.g., microbial biomass carbon (MBC), soil respiration (basal (BSR) and substrate induced (SIR)), fluorescein diacetate hydrolyzing activity (FDHA) and β-glucosidase activity, muramic acid and ergosterol contents were higher in organically than the conventionally managed tea gardens. Data revealed that the organic compared to conventional management practices improved soil biological parameters which in turn may help to improve the soil health.

Key words: Biological parameters, inorganic inputs, microbial biomass carbon, muramic acid, organic inputs

Tea (*Camellia sinensis* L.) produced in Darjeeling Hills of West Bengal, India, holds the place of pride in the world. Recent trends show a decline in crop productivity arising from natural ageing of the tea bushes (Bishnu *et al.*, 2008) which may also reflect loss of soil quality. Tea planters use a wide range of pesticides to compensate for the loss of productivity due to pests, pathogens and weeds infestation. Public concerns over environmental health, pesticide residues in made tea, and in soil (Bishnu *et al.*, 2008) have led to developing alternative input management practices that rely on natural biological resources. Both organic and inorganic (conventional) systems of input management are prevalent in the tea gardens of Darjeeling Hills.

Crop growth and productivity is a function of soil quality as well as ecological status of the environment. Wide ranges of ecotoxicological tests were developed for risk assessment of pesticides application to soil. These include determination of microbial biomass carbon as undifferentiated whole, microbial community (Pal *et al.*, 2006), ergosterol and muramic acid as biomarkers of fungi and bacteria respectively. Soil respiration, specific enzyme activity like β-glucosidase and broad spectrum enzyme activity like that of fluorescein diacetate hydrolysing activity (FDHA) have been used as measures of soil microbial activities.

We attempted to make a comparative study on some selected soil quality indicators between organic and inorganic systems of input management in selected tea gardens of Darjeeling Hills.

MATERIALS AND METHODS

In this study, soils were collected from six different tea gardens in the Darjeeling Hills with different input management practices. The age of the tea bushes ranged from 8 to12 years. The organic tea gardens received 120-180 kg $ha^{-1}year^{-1}$ well-decomposed cow dung manure and leaf litter. Manual weeding and spraying of bio-pesticides are the intercultural operations done in the organic tea gardens. On the other hand, conventional (inorganic) tea gardens received 120:90:170 kg $ha^{-1}year^{-1}$ N, P and K respectively. The fertilizers urea and muriate of potash to supply N and K, respectively, while single superphosphate and diammonium phosphate fertilizers were used to supply P. A variety of chemical insecticides and herbicides are used to control pests in the conventional tea gardens.

Soil samples were collected from each tea garden by dividing into 6 transects with an area of 100 x 50 m. Surface soils (0-15 cm depth) from three portions of each transect were collected and composited into one sample during June of 2008. Altogether 36 samples from the Darjeeling Hills were collected and brought to the laboratory in properly sealed sterile polythene bags.

Visible plant debris and fauna were removed from the collected soil samples by hand and the soils were gently sieved (< 2 mm fraction) and stored in sealed polythene boxes at 4°C before microbial and biochemical analyses. A portion of the soil samples was air-dried and the same was used for physico-chemical analyses.

The pH (1:2.5 H_2O), cation exchange capacity, organic C, total N, available P and available K were determined by standard methods (Jackson, 1967). The MBC of soil was determined by fumigation-extraction method (Joergensen, 1995) followed by determination of the K_2SO_4 extractable C (Vance *et al.*, 1987) of fumigated and unfumigated soils. Basal and substrate (glucose) induced

Email : avhikb@yahoo.co.in

respirations, FDHA, β-glucosidase activity, muramic acid and ergosterol content of the soil samples were determined by standard methods (Alef, 1995; Schnürer and Rosswall, 1982; Alef and Nannipieri, 1995; Appuhn *et al.*, 2004; Djajakirana *et al.*, 1996).

RESULTS AND DISCUSSION

The studied physico-chemical properties had statistical variation between the soils collected from six tea gardens (Table 1). The pH of the soils varied from 4.68 to 5.60. The soils were more acidic in the conventional tea gardens than the organic gardens due to the intense application of ammonium sulphate, ammonium nitrate and urea as fertilizers (Chong *et al.*, 2008). The CEC of the soils ranged from 12 to 37.92 cmol (p+) kg^{-1} with higher values in the organically managed gardens. Organic carbon content and total N were consistently higher across all the organically managed than the conventional gardens. Averaged across all the locations there was 14.5, 18.6% and 65% more organic carbon, total N and available P respectively in soil under organically managed than the conventional gardens. Increase in soil quality parameters in organic farming pratices is reported by Condron *et al.*, (2000). The elevated levels of organic carbon in the organically managed gardens might have resulted from regular application of organic residues. It is generally assumed that organically farmed systems will have lower nutrient losses (especially N and P) compared with conventionally farmed systems that rely on soluble fertiliser inputs to achieve the desired level of plant and/or animal production. However, this assumption is often based on subjective judgement because very few reliable comparisons of nutrient fluxes and budgets have been made between the two systems. However a reverse trend could be observed in the available K content of the soils under two management practices. There was a 15.6% decrease in available K content of the soils under organic management than the conventional gardens. The MBC of the soils under study varied from 202 to 497 μg g^{-1} soil (Table 2). The MBC content of the soils varied significantly among themselves. The MBC in the organically managed tea garden soils was higher than the conventional gardens. The variation in soil MBC of organically managed gardens seemed to be related to higher organic carbon content (Jenkinson and Ladd, 1981).

The BSR was studied as a measure of overall, potential microbial activity (Gray, 1990). Furthermore, the SIR was also determined to measure the total physiologically active part of the soil microflora (Anderson and Domsch, 1978). Both the methods are commonly applied to characterize the microbiological status of soils (Stenberg *et al.*, 1998) and are considered as bio indicators of soil health or soil quality (Gregorich *et al.*, 1994; Pankhurst *et al.*, 1995).

The BSR of the studied soils varied from 0.20 to 1.72 μg CO_2-C g^{-1} h^{-1}(Table 2), and the organically managed gardens showed comparatively higher values than the conventional gardens, which corresponds to the higher MBC content of the soils. Since soil respiration is a measure of microbial activity, higher basal respiration of the organically managed garden indicated higher microbial activity than conventional gardens. It also indicates higher amount of mineralisable organic carbon at the disposal of the microbes in the organically managed soils compared to those in the conventionally managed soils (Nannipieri *et al.*, 1990).

The SIR of the soils varied between 2.06 and 3.50 and it followed the same trend as that of the BSR. In the organic gardens the values ranged from 3.13 to 3.50 μg CO_2-C g^{-1} soil h^{-1} while in the conventional gardens it varied from 2.06 to 3.04 μg CO_2-C g^{-1} h^{-1}. The SIR is a measure of the total physiologically active part of the soil micro flora (Anderson and Domsch, 1978). The results indicated that the organically managed tea garden soils harboured more physiologically active soil microbes than the conventionally managed tea garden soils.

Soil enzyme assays may not always reflect overall microbial activity of soil, because the enzymes are substrate specific (Nannipieri *et al.*, 1990). In this respect the measurement of FDHA is a promising method of overall soil microbial activity (Dick, 1994) as this hydrolysis is mediated simultaneously by protease, lipase and esterase. The β-glucosidase is an important enzyme in terrestrial carbon cycle in producing glucose, which contributes important energy source for microbial biomass (Tabatabai, 1994). The β-glucosidase activity has been suggested as a good indicator of soil quality (Bishnu *et al.*, 2008) among other hydrolytic enzyme activities.

The FDHA of the studied soils varied from 80.5 to 135 μg fluorescein g^{-1} soil h^{-1}. The FDHA of the organically managed garden soils varied from 129 to 135 μg fluorescein g^{-1} soil h^{-1}. In contrast, the FDHA of the conventional garden soils ranged between 80.5 and 89 μg fluorescein g^{-1} soil h^{-1}. The range of FDHA values were within the limits 25 to 125 and 31 to 89 μg fluorescein g^{-1} soil h^{-1} as reported by Dick (1994) and Sengupta *et al* (2009) in temperate and tropical soils respectively.

The β-glucosidase activity of the soils varied from 33.5 to 45.23 μg pNpg^{-1} soil h^{-1}. It followed the same trend as that of the FDHA with comparatively higher values in the organically managed gardens than the conventional managed gardens. This could be related to higher organic carbon content of the organically managed tea garden soils as soil organic carbon is highly positively correlated with the enzyme activities (Bishnu *et al.*, 2009).

Ergosterol is endogenous almost exclusively to fungi, with certain green microalgae and protozoa being the only non-fungal sources, and so may be a useful index of fungal presence (Newell, 1992).The ergosterol contents of the studied soils varied from 1.68 to 2.67μg g^{-1} (Table 2) with comparatively higher values in the organically managed gardens. In the conventional gardens it ranged between 1.68 and 1.95μg g^{-1}. The major part of the variation is presumably species specific, but may also depend on the nutrient management and the quality of carbon input (Djajakirana *et al.*, 1996).

Muramic acid is one of the most specific biomarkers, as it occurs exclusively in bacterial cell walls especially in the murein skeleton of the gram positive species (Joergensen *et al.*, 2010). The muramic acid contents of the soils were highly correlated with the soil microbial biomass with higher values in the organically managed tea gardens. Our result corroborates the findings of Scheller and Joergensen (2008) who stated that long term application of farmyard manure in combination with organic farming practices promotes the accumulation of bacterial residues.

Table 1: Physico-chemical properties of the studied soils

Sampling Site	pH	CEC (cmol (p+) kg^{-1})	Organic carbon (g kg^{-1})	Total N (g kg^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Makaibari Tea Estate*	5.60	23.17^b	31.7^b	3.50^a	46^b	161^c
Monteviot Tea Estate*	5.25	22.92^b	32.8^a	3.28^b	52^a	143^e
Selim Hill Tea Estate*	5.30	37.92^a	30.1^c	2.96^c	42^c	182^b
Margaret's Hope Tea Estate**	5.39	14.00^d	29.5^{cd}	2.80^d	30^e	282^a
Tindharia Tea Estate **	5.19	12.00^e	28.5^d	2.96^c	36^d	152^d
Castleton Tea Estate**	4.68	17.08^c	24.5^e	2.43^e	29^e	143^e

Table 2: Microbiological and biochemical properties of the studied soils

Sampling Site	MBC (μg g^{-1})	BSR (μg CO_2-C g^{-1})	SIR (μg CO_2-C g^{-1})	FDHA (μg fluorescein g^{-1})	β-glucosidase (μg pNp g^{-1})	Ergosterol (μg g^{-1})	Muramic Acid (μg g^{-1})
Makaibari Tea Estate*	421^b	1.50^b	3.48^a	130.0^b	43.69^{ab}	2.45^b	68^b
Monteviot Tea Estate*	497^a	1.72^a	3.50^a	135.0^a	45.23^a	2.67^a	75^a
Selim Hill Tea Estate*	385^c	0.78^c	3.13^b	129.0^b	39.91^b	2.12^c	66^b
Margaret's Hope Tea Estate**	241^d	0.49^d	3.04^c	89.0^c	34.99^c	1.95^d	61^c
Tindharia Tea Estate **	228^e	0.31^e	2.70^d	84.5^c	34.15^c	1.80^e	61^c
Castleton Tea Estate**	202^f	0.20^f	2.06^e	80.5^d	33.50^c	1.68^f	59^c

**Organically managed gardens, ** Conventionally managed gardens, (a,b...) alphabets denote Duncan's test results*

It is evident from the study that the management system for the production of tea has a strong impact on microbial biomass and its activities. Organically management system stimulates simultaneously both bacteria and fungi, the dominant players of nutrient and geochemical cycling as well as abatement of soil toxicity. This helps in sustainable crop production as well as to maintain soil quality. Soil quality does not depend merely on physico-chemical parameters of soil, it is also intimately related to microbiological parameters of soil. So from ecological point of view, organically management of tea garden is preferable.

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