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SOIL ORGANIC CARBON, BIOLOGICAL PROPERTIES AND PLANT BIOMASS AS AFFECTED BY APPLICATION OF ORGANIC MANURES IN TEA

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ABSTRACT
A pot culture experiment was carried out using the soils collected from AAU tea garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, India during 2011-12 to assess the impact of application of organic manures on soil biological properties and biomass yields of tea. Results revealed that application of organic manures boost up the soil organic carbon, humic and fulvic acid content in soil in one way, and significantly increase the soil microbial populations, microbial biomass and enzymatic activity, in other. With different organic manures, maximum 81.91% increase in dehydrogenase activity over control was recorded. Tea leaf, stem and root biomass were increased by 99.27 to 105.09, 67.44 to 72.97 and 32.73 to 43.64%, respectively with 12.37% increase in Chlorophyll *a* and maximum 28.79% increase in Chlorophyll *b* in the tea leaf over absolute control treatment due to addition of different organic manures in the tea growing soils.

KEY WORDS: SOC, enzymatic activity, microbial populations, SMBC, chlorophyll.

INTRODUCTION
The Assam tea (*Camellia sinensis*) is famous in all over the globe. India is the leading producer of tea in the world, and contribution of Assam to total production of tea in India is over 50% (629.05 million kg.) from an area of 3.04 lakh hectare (Tea Board India, 2013-14). Tea is basically a rainfed crop which grows well in areas where annual rainfall varies from 115 – 600 cm (Carr and Stephens, 1992). Naturally, several factors including climatic situation lend credence for growing tea crop in Assam of North-east region of India. Tea plantation plays a pivotal role in maintaining ecosystem sustainability as it is grown with shade trees in a two tier system of planting besides diversified plantings like fire wood trees, seed baries, thatch baries and green manure crops. As a consequence, nutrient management in case of tea is one of the foremost concerns so far as production of quality tea is concerned. However, over dependence on inorganic fertilizers and other chemicals for higher return has caused decreases in soil fertility status, problem of residues of toxic chemicals in made tea and ecological imbalance (Singh *et al*., 1999). The loss of soil organic matter is also a matter of critical concern for quality tea production, because organic matter is straightly related to soil health and productivity. Furthermore, productivity of Indian tea soil is rapidly diminishing with the loss of soil organic matter to the tune of about 128 tonnes per hectares during every 40 years of cropping (Dey, 1971). Use of organics solely, at the present time, has gaining gradual momentum across the world. Growing awareness of health and environmental issues has demanded production of organic food which is emerging as an attractive source of higher income generation. While trends of rising consumer demand for organics are becoming discernible, sustainability in production of crops has become the prime concern in developmental strategy. Therefore, concern for deterioration in ecology, hazards against use of toxic chemicals and loss in biodiversity in and around tea plantations have led to think of a holistic approach in the cultivation of tea in organic way.

MATERIALS & METHODS
A pot culture experiment was carried out to understand the effect of different organic manures on soil properties of tea garden soils and biomass yield of tea plant in the year 2010 at Department of Soil Science, Assam Agricultural University, Jorhat, Assam (India). The soils of upper 0 to 15 cm depth were collected during winter season from two tea gardens *viz.* from the Experimental Tea Garden of Assam Agricultural University (AAU), Jorhat (located in latitude 26.44′N, longitude 94°12′E and altitude 86.00m) and from the Negheriting Tea Estate of Golaghat district (located in latitude 25.45′N, longitude 93°30′E and altitude 86.00m) of Upper Brahmaputra Valley Zone of Assam. The climate of the area is humid sub tropical characterized by hot and wet summer and dry and cool winter with mean annual temperature of 24.37°C and the average annual rainfall is about 1910 mm. The collected soil samples were mixed properly, dried in shade and were sieved through 2 mm mesh sieves, which were then used for both laboratory analysis and for the pot culture experiment. The initial soil properties of both the tea gardens are presented in Table 1. Three different organic sources of nutrients *viz.* compost, biogas digester slurry (BDS) and vermicompost were used and their properties are presented in Table 2. There were 4 treatments *viz.* T_1: Control; T_2: Compost; T_3: Biogas digester slurry and T_4: Vermicompost and thus, there were 8 treatment

combinations using the soils collected from AAU tea garden of Jorhat district and Negheriting Tea Estate of Golaghat district, separately. Each treatment combination was replicated three times in Factorial Randomized Block Design. Therefore, for the pot culture experiment, 24 numbers of earthen pots were arranged. Each pot was filled with 1.8 kg dry soil and the organic manures were added into each of the pot at the rate of 2.5% of the total soil used.

The *bi-clonal* seeds of tea (cultivar: TS-463) were placed singly in each pot. All the pots were kept openly under natural condition. The tea seeds were germinated after one month and necessary care were taken to all the seedlings of the pots. Data for leaf, stem and root were taken at the age of 12 months and were expressed in oven dry basis. Chlorophyll of leaf was determined as per the method of Arnon (1949). After 12 months of the tea seedlings, soil samples were collected from each of the pots, processed and were analysed for soil organic carbon (Walkley and Black, 1934), humic acid and fulvic acid (Griffith and Schnitzer, 1975). For studying the biological parameters, a separate set of soil samples were collected from each of the pots after 12 months and were incubated for one month with distilled water at field capacity moisture regime at room temperature. The dehydrogenase activity was determined by the method of Casida *et al.* (1964) and microbial populations were determined by the plate count technique of Wollum (1982) through respective media for each group.

Soil microbial biomass carbon (SMBC) was estimated by using chloroform fumigation incubation method (Jenkinson and Powlson, 1976). Here, collected soil samples (20 gm in dry weight) were fumigated with ethanol free chloroform vapour in a sealed desiccator lined with moist filter paper for 24 hrs at 25^0 C and after fumigation, extraction was done with 0.5 M K_2SO_4 (1:4 soil: solution ratio) for 1 hr. Thus, the increase in organic C following the fumigation of soil samples has been used to estimate the amount of C held in the soil microbial biomass. Control samples were also maintained with non fumigated soil samples keeping in a desiccator lined with moist filter paper for 24 hrs at 25°C.

TABLE 1: Initial soil properties of Experimental Tea Garden of AAU (Jorhat) and Negheriting Tea Estate (Golaghat district)

Soil properties	Soil of AAU Tea Garden	Soil of Negheriting Tea Estate
Soil texture	Sandy loam	Loamy
Soil organic carbon (%)	0.98	1.30
pH	4.80	5.18
Humic acid (%)	0.33	0.57
Fulvic acid (%)	0.55	0.76
Available N (Kg/ha)	160.57	202.38
Available P (Kg/ha)	8.77	11.12
Available k (Kg/ha)	75.19	81.19
Soil microbial biomass carbon (µg/g)	65.57	91.38
Dehydrogenase activity (µg TPF/g dry soil/ 24 h)	69.42	87.04
Bacterial population (cfu $g^{-1} \times 10^5$)	73.33	76.00
Fungal population (cfu $g^{-1} \times 10^5$)	42.00	46.67
Actinomycetes population (cfu $g^{-1} \times 10^5$)	40.00	52.33

TABLE 2: Nutrient composition of different organic sources

Organic sources	Nutrient content (%)				
	N	P_2O_5	K_2O	Humic acid	Fulvic acid
AAU Compost	1.97	1.15	0.91	13.30	29.56
Biogas digester slurry	1.60	0.88	1.10	13.21	30.40
Vermicompost	1.94	0.98	1.60	15.08	32.00

RESULTS & DISCUSSION

Soil organic carbon

The data on soil organic carbon (SOC) as affected by application of different organic manures are presented in Table 3. SOC content increased significantly in the soils that had received organic sources *viz.* compost, biogas digester slurry and vermicompost over the control treatment. Application of biogas digester slurry showed the highest increase in SOC in case of the soils collected from the Experimental Tea Garden of AAU, Jorhat district; whereas SOC increase was highest due to application of vermicompost in case of soils collected from the Negheriting Tea Estate of Golaghat district of Assam. However, the mean SOC increase due to application of different types of organic manures in case of the tea soils were ranged from 48.25 to 53.51% and the highest increase in mean SOC content over control was recorded in case of biogas digester slurry followed by vermicompost and compost. Such finding is in agreement with the observations of earlier workers (Jenkinson and Johnson, 1976; Juma and McGill, 1986; Lee and Wani, 1989; Varalakshmi *et al*., 2005; Sharma *et al*., 2005).

Humic acid and fulvic acid

In the present investigation, the different organic manures had a significant effect on humic and fulvic acid content in tea soils (Table 3). When different types of organic manures were applied, there were 190.90 – 196.97% and 101.75 – 112.28% increase in humic acid over control was recorded in the soils collected from AAU Experimental

Tea Garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, respectively. Same trend was also followed in case of fulvic acid; where 56.36 – 58.18% and 48.68 – 50.00% increase in fulvic acid was recorded in case of the soils collected from AAU Experimental Tea Garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, respectively. However, the mean data (in Table 3) showed 142.22 and 51.52% increase respectively in humic and fulvic acid content in tea soils when different types of organic manures were applied over control (*i.e.* over no organic manure treatment). Thus, it was noted that increase in humic acid was (approximately 2.76 fold) more as compared to fulvic acid when different types of organic manures were applied in case of tea soil of Assam. The increase in concentration of humic acid than fulvic acid regardless of treatments with organic substances may be attributed to the facts that fulvic acid is primarily a humic acid precursor (Anderson, 1979) and there were improvement in soil physical conditions encouraging the environment for the formation of humic acid in the soil (Muthuvel *et al*., 2001). Therefore, in the present investigation, the organic matter representative *i.e.* humic and non humic substances are greatly influenced by different organic substances which were also reported earlier by Budhilal and Rao (1977).

Dehydrogenase activity in soils

The effect of different sources of organic manures on dehydrogenase enzyme in tea soils is presented in Figure 1 and the values are ranged between 78.23 and 142.31 µg TPF/g dry soil/ 24 hrs. With different organic manures, maximum 81.91% increase in dehydrogenase activity over control was recorded. The maximum dehydrogenase activity was found in the treatment receiving biogas digester slurry followed by the treatments of vermicompost and compost over the control. Significant increase in dehydrogenase activity with the application of organic manures might be due to increase in microbial growth with addition of carbon substrate (Manna *et al.,* 1996). This was in conformity with the earlier findings (Nannipieri *et al.,* 1983; Selvi *et al*., 2004; Qureshi *et al.,* 2005).

Microbial populations

Soil microbial populations were significantly affected by the application of different types of organic manures in the tea soil. This may be due to fact that the population size of soil microorganisms in mineral soil is directly related to soil organic matter content (Alexander, 1961). The mean data (Table 4) as affected by the different treatments under investigation revealed that the bacterial, fungal and *Actinomycetes* population were varied from 75 – 115, 44 – 73 and 46 – 67 cfu $g^{-1} \times 10^5$, respectively. Highest populations of these microbes were recorded in case of the treatment receiving vermicompost as compared to the treatments receiving compost and biogas digester slurry. It was also noted that the bacterial populations were more as compared to fungal and *Actinomycetes* in the tea soil. Similar results were also observed by Allison (1973) by adding abundant organic sources where bacterial populations in soil were rises as compared to other microbes. On the other hand, minimum populations of microbes were found in case of absolute control treatment receiving no any source of external nutrients.

Microbial biomass carbon

Significant variations were observed in soil microbial biomass carbon (SMBC) due to application of different types of organic manures as compared to control (Table 4). In the present investigation, the data in SMBC varied from 65.57 – 129.03 and 91.38 – 143.15 µg/g in case of the soils collected from AAU Experimental Tea Garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, respectively. Mean values of SMBC as affected by different organic manures showed a maximum 71.56% increase in case of biogas digester slurry which was at par with vermicompost treatment. The MBC turn over in the soils collected from Negheriting Tea Estate (Golaghat district) was remarkably higher over the soils collected from the AAU Experimental Tea Garden (Jorhat district) which may be attributed to higher native organic carbon content in Negheriting Tea Estate soil as compared to AAU Experimental Tea Garden soil. More in native soil organic carbon *i.e.* higher availability of food sources might have resulted increase in microbial population in soil (Manna *et al.,* 1996).

Plant biomass yield

The application of different organic manures significantly increased the biomass yield of tea crop over absolute control treatment (Table 5). In the present investigation, the leaf, stem and root biomass yields were varied from 2.75 – 5.64, 3.44 – 5.95 and 1.65 – 2.37 gm $plot^{-1}$, respectively. Data revealed that the leaf, stem and root biomass were increased by 99.27 to 105.09, 67.44 to 72.97 and 32.73 to 43.64%, respectively over control due to addition of different organic manures in the tea growing soils. Organic sources stimulate microbial activities and metabolism and also influence microbial populations. As a consequence more available nutrients and microbial hormones are released into the soil which in turn increased nutrient uptake and yield components. Similar results were also reported earlier by Ostos *et al*. (2008) and Lazcano *et al*. (2010).

Chlorophyll content in leaf

Results from this investigation revealed that Chlorophyll *a* and *b* content of leaf were considerably affected by different organic manures treatments (Table 5). Organic manures are statistically at par in raising the chlorophyll content in tea leaf over the control. Addition of different organic manures in soil showed 12.37% increase in Chlorophyll *a* and maximum 28.79% increase in Chlorophyll *b* in the tea leaf as compared to the treatment receiving no external sources of nutrients (*i.e.* control treatment). Organic manure influences plant growth through its effects on the physical, chemical and biological properties of soil (Stevenson and Schnitzer, 1982). Besides, organic manures provide nutrients to the plants and thus, there might be higher availability of N and Mg in soil leading to high content of chlorophyll *a* and *b* in the tea leaf (Paknejad *et al*., 2007; Sharma, 2008).

TABLE 3. Effect of organic sources on organic carbon, humic acid and fulvic acid in case of tea soil

Treatment	Soil organic carbon (%)			Humic acid (%)			Fulvic acid (%)		
	S_1	S_2	Mean	S_1	S_1	Mean	S_1	S_2	Mean
T_1	0.98	1.30	1.14	0.33	0.57	0.45	0.55	0.76	0.66
T_2	1.21	2.17	1.69	0.96	1.21	1.09	0.86	1.14	1.00
T_3	1.43	2.08	1.75	0.96	1.15	1.06	0.87	1.13	1.00
T_4	1.22	2.18	1.70	0.98	1.20	1.09	0.87	1.13	1.00
S.Ed.±	-	-	0.06	-	-	0.02	-	-	0.01
CD-5%	-	-	0.12	-	-	0.03	-	-	0.02

Note: T_1: Control; T_2: Compost; T_3: Biogas digester slurry; T_4: Vermicompost; S_1: Experimental Tea Garden of AAU, Jorhat; S_2: Negheriting Tea Estate of Golaghat district

TABLE 4. Effect of organic sources of nutrients on microbial population and microbial biomass carbon in tea soil

Treatment	Bacterial population (cfu $g^{-1} \times 10^5$)			Fungal population (cfu $g^{-1} \times 10^5$)			Actinomycetes population (cfu $g^{-1} \times 10^5$)			Microbial biomass carbon (µg/g)		
	S_1	S_2	Mean	S_1	S_1	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	73	76	75	42	47	44	40	52	46	65.57	91.38	78.48
T_2	104	98	101	56	58	57	62	61	62	116.16	136.31	126.24
T_3	95	80	88	61	80	70	56	66	61	129.03	140.25	134.64
T_4	109	121	115	66	79	73	62	72	67	125.65	143.15	134.40
S.Ed.±	-	-	0.74	-	-	1.00	-	-	0.86	-	-	0.52
CD-5%	-	-	1.55	-	-	2.11	-	-	1.81	-	-	1.09

Note: T_1: Control; T_2: Compost; T_3: Biogas digester slurry; T_4: Vermicompost; S_1: Experimental Tea Garden of AAU, Jorhat; S_2: Negheriting Tea Estate of Golaghat district

TABLE 5. Effect of organic sources on plant biomass yield (gm/pot) and chlorophyll content (mg/g) of leaf

Treatment	Leaf biomass yield (kg/ha)			Stem biomass yield (kg/ha)			Root biomass yield (kg/ha)			Chlorophyll- a (mg/g)			Chlorophyll- b (mg/g)		
	S_1	S_2	Mean	S_1	S_1	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	2.48	3.02	2.75	3.34	3.55	3.44	1.62	1.68	1.65	1.00	0.94	0.97	0.63	0.68	0.66
T_2	5.08	5.88	5.48	5.52	6.00	5.76	2.30	2.44	2.37	1.09	1.09	1.09	0.82	0.88	0.85
T_3	5.13	6.03	5.58	5.68	6.21	5.95	2.02	2.35	2.19	1.09	1.09	1.09	0.82	0.88	0.85
T_4	5.26	6.02	5.64	5.58	6.20	5.89	2.40	2.33	2.37	1.09	1.09	1.09	0.81	0.87	0.84
S.Ed.±	-	-	0.11	-	-	0.11	-	-	0.13	-	-	0.01	-	-	0.01
CD-5%	-	-	0.23	-	-	0.23	-	-	0.28	-	-	0.02	-	-	0.02

Note: T_1: Control; T_2: Compost; T_3: Biogas digester slurry; T_4: Vermicompost; S_1: Experimental Tea Garden of AAU, Jorhat; S_2: Negheriting Tea Estate of Golaghat district

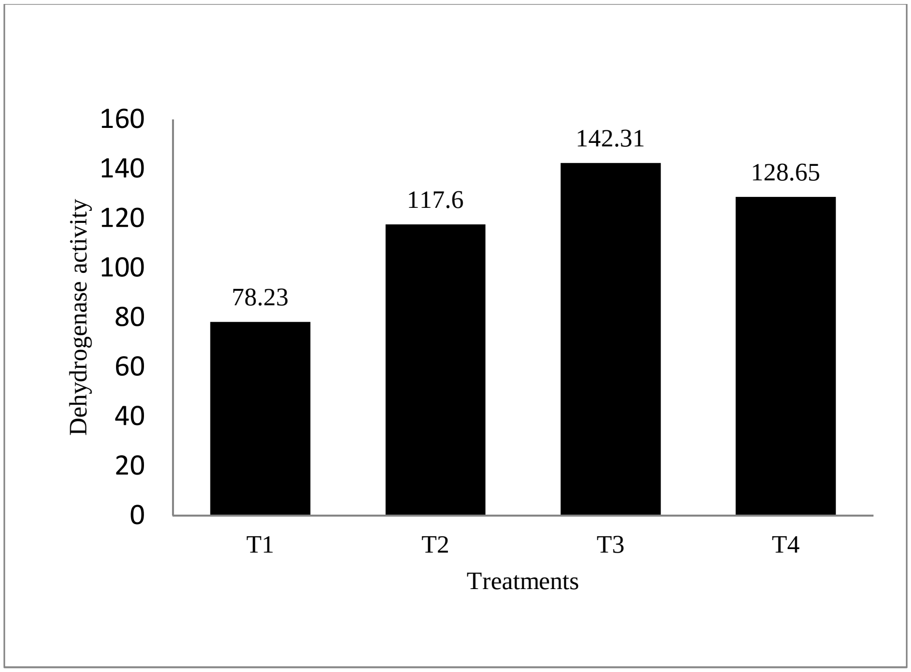

FIGURE 1: Effect of organic manures on *dehydrogenase* activity (*µg TPF/g dry soil/ 24 h*) in tea soils
Note: T1: Control, T2: Compost, T3: Biogas digester slurry, T4: Vermicompost

CONCLUSION

Deteriorating soil quality, health hazards and declining factor productivity are major concerns of Indian agriculture today. Thus, organic soil management is slowly becoming a necessary compulsion not only for organic conversion but also to restrict productivity depletion under chemical farming practice. From the present study, results indicated that organic manures improve the soil health by increasing the organic carbon, organic acids, enzymatic activity, microbial populations and microbial biomass carbon content in soil. Besides, addition of organic manure in soil also enhances the biomass yields and chlorophyll content in case of tea leaf.

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