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ENHANCED SOIL BIODIVERSITY IN ORGANIC AND BIODYNAMIC TEA CULTIVATION SYSTEMS IN COMPARISON TO A CONVENTIONAL SYSTEM

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ABSTRACT

Sustainable farming is based on building healthy soils through ecologically sound agricultural practices. Organic and biodynamic agricultural systems satisfy such improvements through non chemical practices replaced with environmentally friendly crop, soil and environmental management methods. Nevertheless, indepth studies on soil biological information in such systems are scarce except for a few examples in temperate countries. Thus, the present study was conducted with the objective of comparing the biological, chemical and physical properties of tea soils: earthworm biomass, micro-arthropod and free living nematode densities and soil respiration in soils exposed to biodynamic, organic and conventional systems of the ongoing "BIDORCON" trial at the Tea Research Institute, Talawakelle prior to first pruning, as indicators of soil health and biodiversity.

The earthworm biomass was significantly higher in both 0-15 cm and 15-30 cm soil depths of biodynamically and organically treated soils when compared to that of conventional soils (P>F 0.0044 and P>F 0.0124 respectively). A large density of saprophytic organisms was observed in these in soils with high organic matter and decomposing materials when agrochemicals were not used. A greater population of free living nematode species, insects, mites, Collembolans and Myriapods were also seen in biodynamically and organically treated soils in comparison to the conventional tea soils.

In overall terms, activation, conservation and enumeration of important soil biological resources in agricultural soils were evident with immensely enhanced soil respiration under organic and biodynamic systems. The negative impacts of synthetic agrochemicals and the importance of maintaining soil biological assets in sustaining the productivity of tea even with a very low dependence on external agro inputs are presented.

Key words: *Soil biodiversity, organic and biodynamic tea cultivation, earthworms, micro-arthropods, free living nematodes, soil respiration*

INTRODUCTION

Soil is a dynamic, living matrix that is an essential part of the terrestrial ecosystem. It is a critical resource not only to agriculture production and food security, but also to the maintenance of most life processes. Soil encompass enormous numbers of living organisms assembled in complex and varied communities ranging from invisible microbes, bacteria and fungi to the more familiar macro fauna such as earthworms and termites. Plant roots are also considered soil organisms in view of their symbiotic relationships and interaction with other soil biological components. They interact with the eco system, environmental factors, such as temperature moisture and acidity as well as with agricultural management practices. Biological diversity is an important character of a living system which brings several benefits to the environment. Nevertheless, depletion of soil biodiversity could affect soil productivity and crop production systems as reported by Fliebach and Mader, 2000, Entz *et al.*, 2004, Mohotti *et al.*, 2002 and Tu *et al.*, 2006.

The soil biodiversity complex is well explained by OPQ triangle which reflects the living organisms (O), physico-chemical environment (P), and the chemical composition or quality of the organic matter (Q). Direct and indirect benefits of soil biological components in agricultural systems include economic, environmental and food security benefits. Estimates show that a fertile soil contains around 1-6 million bacteria /g and about one million fungi/g, 8 million /ha earthworms and immense diversity of all the algae, protozoa, nematodes, arthropods and insects (Glover *et al.*, 2000; Mohotti *et al.*, 2002).

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The importance of soil biodiversity to plant diversity and agricultural productivity has been the subject of anecdotal and empirical investigations for some time which recently gathered greater attention in many temperate countries. As a result, soil biologists and agriculturists are challenged to address major global concern of provision of greater food security for all nations on earth in a sustainable way with minimal damage to the environment. However, the R&D attempts on long term impacts of agricultural practices under sustainable agricultural systems are scarce in Sri Lanka and elsewhere, except a few case studies as reported by Glover *et al.* (2000) and Mohotti *et al.* (2002).

Tea cultivation is based on high inputs, demanding synthetic fertilizers and agro chemicals for continued production. In comparison to general agriculture sector, tea cultivation is exposed to rational use of agrochemicals. Nevertheless, ecological awareness over factors such as pesticide residues in made tea and worker safety are among a few growing concerns internationally. In parallel, more environmental friendly, socially just and economically feasible cultivation systems such as organic and biodynamic cultivation in tea are emerging. In this connection, it is significant that Sri Lanka pioneered organic tea production in the world.

Owing to the importance of self reliance and recycling of natural resources under sustainable tea cultivation systems, attributes to sustained yield and productivity of tea have been well experimented in long term field trials. As a result, various aspects have been evaluated on organic, biodynamic and conventional tea cultivation systems. The present study was aimed at concentrating on biodiversity status of tea soils prior to the first pruning under biodynamic, organic and conventional systems of the ongoing "BIDORCON" trial at the Tea Research Institute, Talawakelle. As measurements, free living nematodes, earthworm biomass, micro arthropod densities and soil respiration were evaluated as soil biodiversity indicators in this study. Green leaf yield of the three systems were also recorded to study the impacts of the soil biodiversity.

METHODOLOGY

The data were monitored at the ongoing "BIDORCON" trial at Nature Farming Experimental and Model Area of the Tea Research Institute of Sri Lanka, Talawakele planted with Assam hybrid seedling tea. The trial consisted of organic, biodynamic and conventional chemically treated plots.

Treatments

The three cultivation systems used were, Biodynamic (application of biodynamic preparations according to the Sri Lankan biodynamic calendar), Organic (according to IFOAM guidelines, without synthetic fertilizers or pesticides, compost application two times per year at the rate of 2 kg/plant) and Conventional (fertilizer and pesticides as per TRI recommendations). The treatments were arranged in Randomized Complete Block Design (RCBD) with three replicates. To avoid contaminations of different treatments, each block was separated with a deep drain and guard rows were maintained around each plot. All plots were managed with Good Agricultural Practices following TRI recommendations.

Soil Biodiversity Measurements

Random soil samples were taken from each plot and composite aliquots were used for the following measurements.

Soil Microbial Activity

Soil respiration of different treatment plots were determined by using the method described by Anderson (1982).

Free-living nematode populations

Population of free-living nematodes in soils under different treatments was assessed as per Southey (1981) at the Nematology laboratory.

Micro-arthropod assessment

Soil micro arthropods were extracted in water using a simple modification of Berlese apparatus at the Nematology laboratory. The numbers of insects, mites, Collembolans and Myriapods were counted using a compound microscope.

Earthworm Assessment

The earthworm biomass was assessed by taking soil samples from 0-15 cm and 15-30 cm depths. The soil of 3375 cm^3 volume was removed at each depth, and carefully separated the earthworms and eggs in each sample. This was then extrapolated to the earthworm population and earthworm eggs per ha.

Data analysis

Data were analyzed using Analysis of Variance (ANOVA) and the means were compared using the Duncan's New Multiple Range Test (DNMRT).

RESULTS AND DISCUSSION

Soil Microbial Activity

The tea ecosystem is generally undisturbed with a relatively stable micro climate and as such biodiversity components are close to a natural forest. In this study, the measurements of soil respiration revealed that both organic and biodynamic treatments enhanced soil biological activity over that of the conventional treatment (Figure 1). Although not significant, the microbial activity under organic and biodynamic cultivation systems has shown an increase presumably due to environmentally friendly soil management practices; in contrast, chemical management under conventional tea cultivation system has led to reduced microbial activity (Fliebach and Mader, 2000, Entz *et al.*, 2004, Mohotti *et al.*, 2002, Tu *et al.*, 2006).

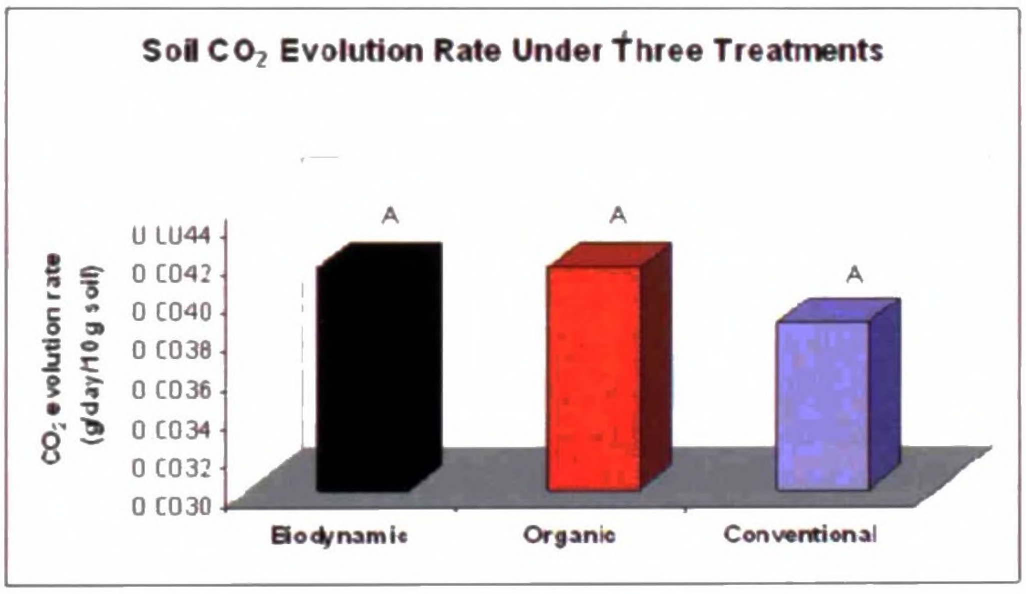

Figure 1. Soil microbial activity under organic, biodynamic and conventional cultivation systems.

Free-living nematode populations

A large density of saprophytic organisms is associated in soils with high organic matter and decomposing materials. Various fungal species, free living nematodes and micro arthropods are among these, where undisturbed natural soil systems generally promote such species. In the present study, a greater population of free living nematode species was seen associated with organic and biodynamic tea soils (Figure 2). The results agree with records of significantly increased free living nematode densities in organic matter incorporated tea soils as reported by Mohotti *et al.* (2002).

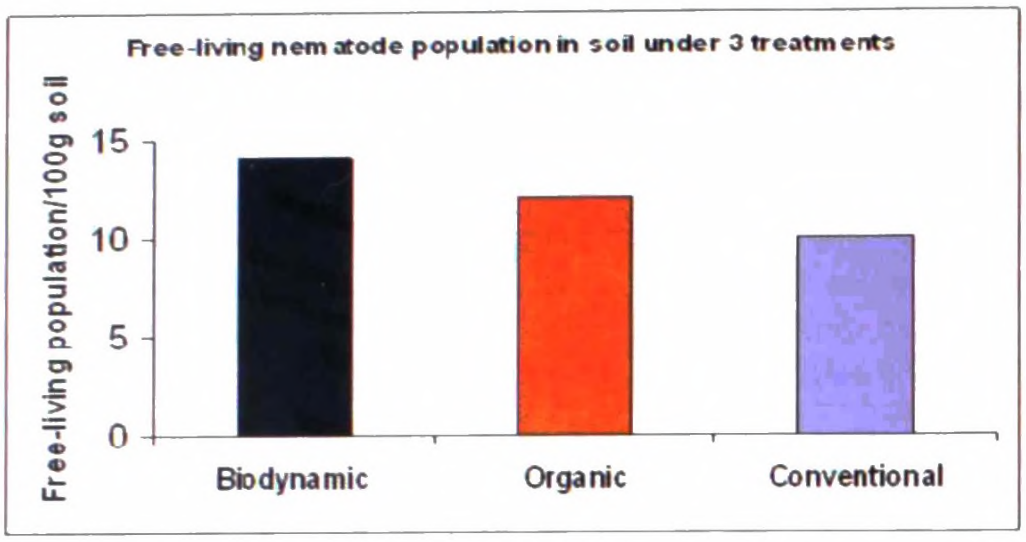

Figure 2. Mean free-living nematode populations in soil under organic, biodynamic and conventional management systems

Micro arthropod populations

Interestingly, tea soils exposed to organic and biodynamic cultivation systems exhibited greater densities of mites, myriapods and collembolans as compared to that of the conventional system (Figure 3). Species richness too was high under these organic systems while the chemical usage in the conventional system has resulted in lowered micro arthropod levels as shown by Mohotti *et al.* (2002).

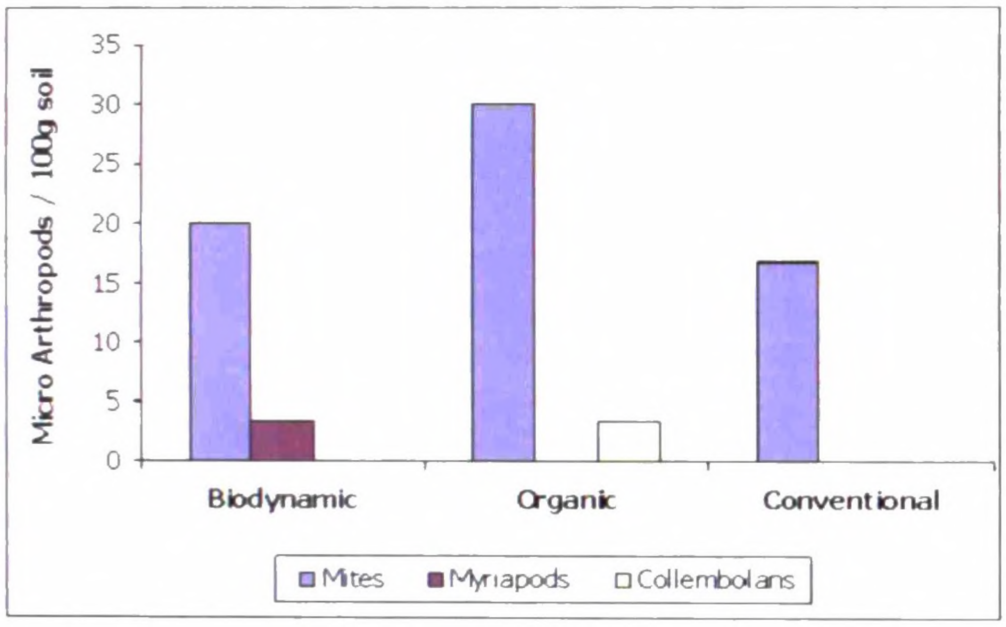

Figure 3. Mean micro arthropod species in soils under organic, biodynamic and conventional management systems

Earthworm Biomass

As shown in Table 1, the earthworm biomass was significantly higher in both 0-15 cm and 15-30 cm soil depths of biodynamically and organically treated soils than that of conventional soils ($P>0.0044$ & $P>0.0124$ respectively). Mohotti *et al.* (2006) also reported a significant elevation of earthworm biomass in soils under organic, biodynamic tea fields when compared to conventional fields.

Table 1. Mean earthworm activity in soils under organic, biodynamic and conventional management systems

Treatment	Number per ha ('000)			
	Earthworms		Eggs	
	0 – 15 cm	15 – 30 cm	0 – 15 cm	15 – 30 cm
Biodynamic	866.67 [a]	1000.00 [a]	53.33 [b]	146.67 [b]
Organic	1120.00 [a]	893.33 [a]	200.00 [a]	226.67 [a]
Conventional	53.33 [b]	66.67 [b]	0.00 [b]	0.00 [b]
P > F	**0.0044**	**0.0124**	**0.0080**	**0.0050**

Green Leaf Yield of Tea

As presented in Figure 4, it was interesting to note that the plant responses to organic and biodynamic cultivation practices have been superior to that of the conventional system despite the limited resources. The improved soil health discussed above and altered chemical and physical properties experienced in tea soils maintained under sustainable agronomic practices have complemented the growth and yield sustenance under organic and biodynamic systems as reported by Mohotti and Mohotti (2008). The improved soil biological resources have certainly helped activation of natural nutrient cycles as well as providing macro and micro nutrients

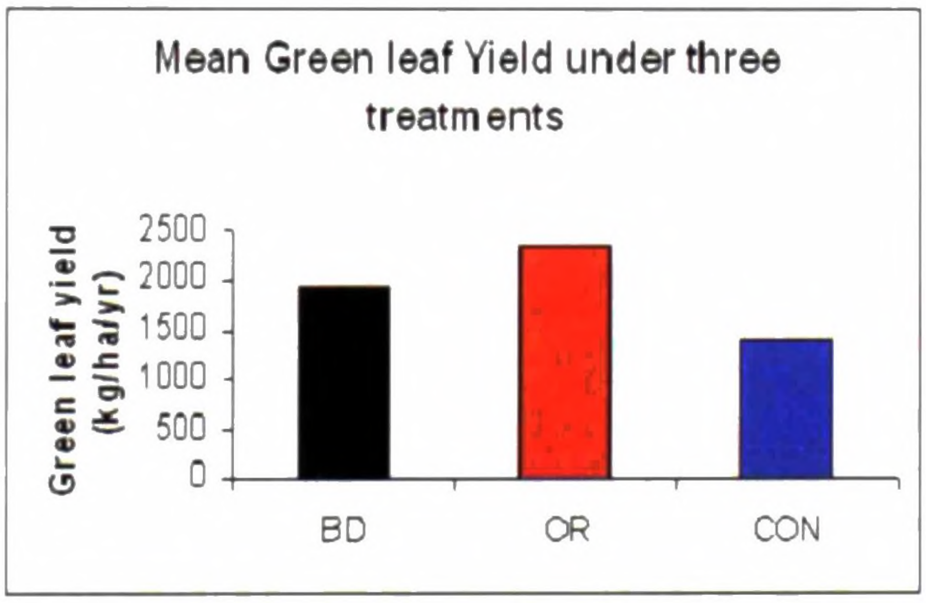

Figure 4. Mean green leaf yield under organic, biodynamic and conventional management systems.

CONCLUSIONS AND THE FUTURE

The overall results clearly show that organic and biodynamic cultivation practices have improved biological properties in tea soils despite low soil agro-inputs. The important soil biodiversity components responsible in assuring soil health such as earthworms and micro arthropods have clearly been enumerated under such systems while there is a direct negative impact by chemical agricultural methods (Glover *et al.*, 2000; Mohotti *et al.*, 2002, Fliebach and Mader, 2000, Tu *et al.*, 2006, Entz *et al.*, 2004.

With the results experienced in the tea ecosystem, the importance of soil biological assets in maintaining the productivity of agricultural lands is clearly illustrated. One step to sustainable agricultural methods and practices is the use of the best practices learnt in the organic, biodynamic and conventional management systems. These illustrate the potentials of sustaining the productivity, with low dependence on external inputs and to act as an ecosystem service and support in low carbon agriculture through activation, conservation and enumeration of important soil biological resources in agricultural soils. Undoubtedly, these would result in saving foreign exchange on synthetic agro inputs and increasing cost benefits of the environmentally friendly and ecologically sound agricultural systems. Further, non -erosive land degradation through deteriorating soil health by use of agrochemicals could be nullified through integration of various sustainable methods as opposed to intensive farming methods which damage soil properties.

While the relationship between the levels of soil biodiversity components and the soil and crop productivity status were elucidated, the results of this study corroborated with those of Mohotti (2002) on the potential of using soil biodiversity measurements. These could be highlighted in certification of organic and biodynamic lands as clear determinants.

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