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Soil microbial properties as influenced by agri-silvi-horticultural system under semi-arid region of Haryana

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ABSTRACT

The study was carried out at Forestry Research Farm, CCSHAU, Hisar to assess the effect of agri-silvi-horticultural system, i.e. on different soil microbial properties. Surface soil (0–15 cm) samples were collected randomly and then these samples were immediately used for analyzing potentially mineralizable nitrogen, microbial biomass carbon, dehydrogenase activity, alkaline phosphatase activity and urease activity under 3 treatments (5 replications), i.e. control (wheat), Kinnow + wheat and Kinnow + *Eucalyptus* + wheat. Significant improvement in soil biological properties was observed under tree-based system as all biological properties were recorded highest in Kinnow + *Eucalyptus* + wheat system followed by Kinnow + wheat as compared to control. Dehydrogenase and alkaline phosphatase activity were higher under Kinnow + *Eucalyptus* + wheat (69.3 and 33.8%) followed by Kinnow + wheat (39.6 and 12.2%) over control. Similarly, microbial biomass carbon (MBC) and urease activity were observed to be higher under Kinnow + *Eucalyptus* + wheat (50.3 and 31.9%) followed by Kinnow + wheat (28.9 and 12.3%) over control. A linear positive regression relationship was observed among organic carbon vs. microbial biomass carbon. The coefficient of determination for organic carbon and microbial biomass carbon explained variability of 98.3%. The result of the study showed that tree-based agroforestry system can significantly increase the soil biological properties. Based on the present study, it was suggested that soil microbiological activities can be enhanced by adopting agroforestry or tree-based system.

Keywords: Agri-silvi-horticultural, *Eucalyptus*, Kinnow, Soil biological properties, Tree

Trees play a major role in increasing soil fertility through ecological and physico-chemical changes they induce in soil (Singh *et al.* 2002). The evidence from most indigenous agroforestry systems, as recognized by the farmers, shows a positive trend in the maintenance of soil fertility. The main effects of trees on soil properties are a consequence of above-ground organic matter inputs through litterfall or pruning and root debris. Soil microorganisms are the key factor for improved soil fertility and plant growth, which is directly linked with increased agricultural productivity (Parthasarthi 2006). However, the variation in microbial biomass and their activities is attributed to different management practices such as nutrient, soil, and crop management practices (Hendrix *et al.* 1986). Different management practices like agroforestry system can affect the activity and diversity of soil-microbial flora. Dehydrogenase activity indicates the oxidative activity of soil microorganisms enables a good indicator for enzymatic activities, whereas a major role for the transformation of phosphorus from organic to inorganic form is carried out by phosphatase enzyme. Soil biological properties were significantly influenced both by tree densities and soil depths (Uthappa *et al*. 2015). The incorporation of trees with crops led to an increase in organic matter inputs through litterfall; this in turn enhances the amount of nutrients for soil microflora, which ultimately led to an increase in microbial activities. Kumar *et al.* (2008) also observed higher microbial activity under plantations of different tree species in the upper surface of soil due to the presence of higher organic carbon content.

However, the information regarding the effect of the agri-silvi-horticultural system on soil health is inadequate. Secondly, due to the complex nature of agroforestry, methods of soil fertility assessment are not sensitive enough to work out the changes in the available nutrients and other soil physico-chemical properties. Therefore, it is wise to assess soil biological properties along with these parameters. These soil properties facilitate the appropriate assessment of ecosystem services and environmental benefits by agroforestry.

MATERIALS AND METHODS

The present investigation was conducted in September

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2017 at Research Farm, Department of Forestry, Chaudhary Charan Singh Haryana Agricultural University, Hisar. It was located at 29º 09' N latitude and 75º 43' E longitude at an elevation of 215 m amsl which comes under the semi-arid region of North-west India. The site has various problems such as uneven and untimely rainfall, water scarcity, and less fertile soils as the organic carbon was below 0.4%. The climate of the site is mainly featured by a very hot summer, uneven and short rainy season, and a very cold winter. The average annual rainfall is 350-400 mm and the climate is sub-tropical. Randomized Block Design (RBD) having five replications and three treatments were used to carry out this experiment. There were three treatments, i.e. Kinnow + *Eucalyptus* + wheat, Kinnow + wheat, and control (devoid of trees). Collection of surface soil samples (0-15 cm) was done in September 2017 before sowing of wheat crop from different treatment plots. The experimental site was having sandy loam soil which was medium in organic carbon, available N, P, and K.

Initial soil properties	
EC (dS/m)	0.55
pH	8.12
Organic carbon (%)	0.38
Available nitrogen (kg/ha)	110.60
Available phosphorus (kg/ha)	10.20
Available potassium (kg/ha)	226.00
Calcium carbonate	0.79
Zn (mg/kg)	0.96
Fe (mg/kg)	5.40
Cu (mg/kg)	0.38
Mn (mg/kg)	7.20

Details of treatments

Agri-silvi horticultural system: The plants of clonal *Eucalyptus* (HC 2045) were planted at a spacing of 6 m × 6 m in September 2011. In between every two *Eucalyptus* plants, one kinnow plant (virus free) was planted. During same period, Kinnow plants were planted at the spacing of 6 m × 6 m. Wheat crop in *rabi* and greengram in *kharif* season was taken in association with Kinnow and *Eucalyptus* trees. In the adjacent field wheat crop in *rabi* and greengram in *kharif* season was grown, which is considered as control or sole crop. In this experiment, the recommended packages of practices were followed separately for the *Eucalyptus*, Kinnow and intercrops. Along with the natural incorporation of the foliage, the remaining biomass of the intercrops was also incorporated (after harvest) in the respective treatments.

Potentially mineralizable nitrogen and microbial properties: For the determination of potentially mineralizable nitrogen, the soil was adjusted with 60% water-holding capacity and then incubated for 30 days at 30°C. Before incubation analysis for the initial amount of inorganic N was done using steam distillation (Keeney and Nelson 1982). Mineralized N was calculated by subtracting initial inorganic N values from those obtained after 30 days of incubation. For MBC analysis, the chloroform fumigation method proposed by Vance *et al.* (1987) was followed. Soil-dehydrogenase activity was determined by estimating the rate of production of tri-phenyl formazan (TPF) from tri-phenyl tetrazolium proposed by Casida *et al.* (1964). Alkaline phosphatase activity was estimated by the method proposed by Tabatabai and Bremner (1969). Tabatabai and Bremner (1972) method was adopted for the determination of urease activity.

Statistical analysis: Statistical methods proposed by Panse and Sukhatme (1989) were employed to analyze the observations. Analysis of variance technique given by Fisher (1950) was used to analyze the data statistically to find the significant effect of treatments. 'F' test at 5% level of significance was employed to relate the significant difference among the means of two treatment effects, the critical difference (CD) was computed by:

$$\text{CD} = \frac{\sqrt{2\,EMS}}{\text{N}} \times \text{t value at 5\%}$$

where, CD, critical difference; EMS, error mean sum of square; N, number of observations; T, value of t-distribution at 5% level of error degree of freedom.

RESULTS AND DISCUSSION

Potentially mineralizable nitrogen: Minimum (34.8 mg/kg) total mineralizable N was recorded under control at zero days of incubation, whereas maximum was recorded (96.0 mg/kg) at 30 days of incubation under Kinnow + *Eucalyptus* + wheat system (Table 1). Nitrate nitrogen was found comparatively higher than ammonical nitrogen at 0 and 30 days of incubation. Significant increased PMN was noticed under tree-based system. Ammonical nitrogen was significantly highest in Kinnow + *Eucalyptus* + wheat system (31.6 and 37.3 mg/kg) followed by Kinnow + wheat (24.7 and 27.1 mg/kg) and lowest was under control (16.2 and 17.8 mg/kg) at 0 and 30 days of incubation respectively. Similarly, nitrate nitrogen was significantly highest under Kinnow + *Eucalyptus* + wheat system (39.9 and 58.7 mg/kg) followed by Kinnow + wheat (29.6 and 45.8 mg/kg) and lowest was under control (18.6 and 23.1 mg/kg) at 0 and 30 days of incubation respectively. Total mineralizable nitrogen at 0 and 30 days of incubation followed the respective sequence under different system: Kinnow + *Eucalyptus* + wheat (71.5 and 96.0 mg/kg) > Kinnow + wheat (54.3 and 74.9 mg/kg) > control (34.8 and 40.9 mg/kg). Increase in PMN after 30 days of incubation was highest under Kinnow + *Eucalyptus* + wheat (34.2%) system and Kinnow + wheat (34.2%) system. Whereas lowest was under control (17.5%).

These results corroborate with the findings of Wojewoda and Russel (2003) who emphasized that trees contributed to increasing soil nutrient pools which resulted in higher total N and mineralizable N in the agroforestry compared to the conventional agricultural system. Rivest *et al.* (2013) concluded that tree above and belowground competition

Table 1 Effect of agri-silvi-horticultural system on soil biological properties

System	Days of incubations 0			30			Mineralized N (mg/kg/30 days)	Dehydrogenase activity (mg TPF/kg soil/24 h)	Alkaline phosphatase activity (mg PNP/kg soil/h)	Microbial biomass C (mg/kg soil)	Urease activity (mg NH_4^+-N/g/h)
	NH_4^+-N	NO_3^- -N	Total Mineral N	NH_4^+-N	NO_3^- -N	Total Mineral N					
Control (wheat)	16.2	18.6	34.8	17.8	23.1	40.9	6.1	105.8	77.5	166.6	52
Kinnow + wheat	24.7	29.6	54.3	27.1	45.8	72.9	18.6	147.8	87	214.9	58.4
Kinnow + *Eucalyptus* + wheat	31.6	39.9	71.5	37.3	58.7	96	24.5	179.2	103.7	250.5	68.6
Mean	24.1	29.3	53.5	27.4	42.5	69.9	16.4	144.2	89.4	210.6	59.6
LSD (P=0.05)	1.2	1.6		1.5	2.8			6.1	2.2	7.1	1.4

may also reduce crop biomass production near mature windbreaks. Alternatively, differences in total soil C and N between agroforestry and conventional agricultural systems could depend on depend upon contribution of organic matter ultimately resulting in improvement of soil properties. Mineralizable N was measured as the net increase in mineral N (NH_4^{+} + NO_3^-) over 30 days aerobic, dark incubations (at 30°C).

Dehydrogenase activity: Data (Table 1) showed that the tree-based system had a significant effect on dehydrogenase activity. Dehydrogenase activity varied from 105.8 TPF/kg soil/24 h under control to 179.8 mg TPF/kg soil/24 h in Kinnow + *Eucalyptus* + wheat system. Significant highest dehydrogenase activity was observed under Kinnow + *Eucalyptus* + wheat system (179.2 mg TPF/kg soil/24 h) followed by Kinnow + wheat system (147.8 mg TPF/kg soil/24 h) compared to control (105.8 mg TPF/kg soil/24 h). Dehydrogenase activity was recorded higher by 69.3% and 39.6% under Kinnow + *Eucalyptus* + wheat and Kinnow + wheat system respectively than control.

Soil-dehydrogenase activity presented a significant increase under tree-crop combination than without trees or sole-cropping system (Chander *et al.* 1998). Dhaliwal *et al.* (2018) also found higher dehydrogenase activity (49.9 µg TPF/g/h) under the agroforestry system followed by the agri-horticulture system (27.8 µg TPF/g/h) as compared to the maize-wheat system (21.6 µg TPF/g/h). The grass pastures treatment revealed significantly greater dehydrogenase activity compared to the cropping treatment (Paudel *et al.* 2012).

Alkaline phosphatase activity: Similarly, alkaline phosphatase activity varied from 77.5 mg PNP/kg soil/h under control to 103.7 mg PNP/kg soil/h under Kinnow + *Eucalyptus* + wheat system (Table 1). Significantly highest alkaline phosphatase activity was recorded under Kinnow + *Eucalyptus* + wheat system (103.7 mg PNP/kg soil/h) followed by Kinnow + wheat system (87.0 mg PNP/kg soil/h) over control (77.5 mg PNP/kg soil/h). Alkaline phosphatase activity was recorded higher under Kinnow + *Eucalyptus* + wheat and Kinnow + wheat system by 33.8% and 12.2%, respectively over control.

Enhancing the phosphatase activity under *Eucalyptus*-based agroforestry attributed to enhanced phosphatase production in the rhizosphere on the addition of organic material through litterfall (Zhang *et al.,* 2012). Wan and Chen (2004) and Yadav *et al*. (2011) also envisaged the alkaline phosphatase activity to increase under agroforestry compared to control. Agroforestry tree species may acquire organic phosphorus unavailable to crops while also enhancing the phosphatase activity under tree roots.

Microbial biomass carbon: Data inferred that significant improvement in SMBC was recorded under tree-based system as compared to control (devoid of trees). Microbial biomass carbon was observed significantly highest under Kinnow + *Eucalyptus* + wheat (250.5 mg/kg soil) followed by Kinnow + wheat (214.9 mg/kg soil) while lowest was under control (166.6 mg/kg soil). The microbial biomass carbon (MBC)

Table 2 Correlation coefficient of organic carbon, nitrogen with biological properties under different tree-based system

Variable	Organic C	Available N
Organic C	1	
Available N	.998**	1
MBC	.630*	.658*
Dehydrogenase activity	.592*	.621*
Alkaline phosphatase activity	.649*	.676*
Urease activity	.660*	.687*

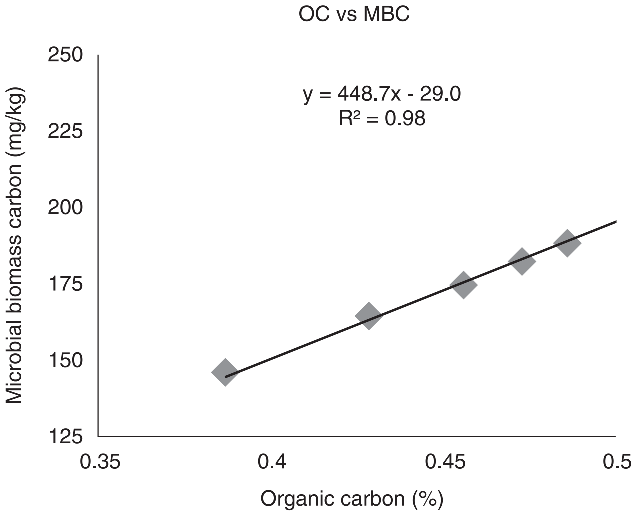

Fig 1 Relationship between organic carbon and MBC.

was increased to the tune of about 50.3% and 28.9% under Kinnow + *Eucalyptus* + wheat and Kinnow + wheat system, respectively compared to control (Table 1).

Prasad and Mertia (2005) reported an increase in microbial biomass carbon in the tree rhizosphere. This was due to more supply of carbon and nutrients from the tree litter, dead root cells, and rhizo-depositions. Microbial biomass carbon (MBC) and MBN concentrations showed an initial phase of decline and then increased significantly with plantation age. These findings are also supported by Cortez *et al.* (2014) who investigated the soil microbial C, N, respiration, carbon-use efficiency, and microbial C: N among *Eucalyptus grandis* plantations. In general, soil microbial properties decreased in initial years of land-use change but recovered after four years.

Urease activity: Similarly, urease activity in soil was significantly higher under Kinnow + *Eucalyptus* + wheat (68.6 µg NH_4^+-N/g/h) followed by Kinnow + wheat system (58.4 µg NH_4^+-N/g/h) and lowest was under control (52.0 µg NH_4^+-N/g/h). An increase of 31.9% and 12.3% in urease activity recorded under Kinnow + *Eucalyptus* + wheat and Kinnow + wheat system, respectively over control (Table 1).

Tian *et al.* (2013) also found similar trends in urease activity in surface and subsurface soil, agroforestry system as compared with pure tea plantation. In the Armeniaca agroforestry compound system, urease activity presented the variation that increased initially and then decreased, and reached highest under Pyrus-based agroforestry system (Xiang-yun 2013).

Correlation coefficient and regression relationship between MBC and OC: The correlation matrix inferred a significant positive correlation of organic carbon and nitrogen with MBC, dehydrogenase activity, alkaline phosphatase activity, and urease activity (Table 2). A linear positive relationship was observed among organic carbon vs microbial biomass carbon. The coefficient of determination explained variability of 98.3 % (Fig 1).

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