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RESEARCH PAPER

Dynamics of Soil Organic Carbon and Microbial Activity in Oil Palm Growing Soils of Andhra Pradesh

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ABSTRACT

Five adult oil palm plantations in Andhra Pradesh grown under irrigated conditions were selected for studying the dynamics of soil organic carbon, microbial activity and microbial biomass carbon. Soil samples were collected at different distances from palm (1 - 5 m) and depths (0-15, 15-30, 30-60 cm) by using standard triangular method. Standard methods were followed for analyzing dehydrogenase activity, β-glucosidase activity, microbial biomass carbon and organic carbon. The dehydrogenase activity ranged from 12.50-20.37 µg tpf g^{-1} day^{-1}, while β-glucosidase activity ranged from 2.59-6.14 p-nitrophenol g^{-1} soil h^{-1}. The soil organic carbon ranged from 0.19-0.57 %, while microbial biomass carbon ranged from 58.14-96.27 µ C/g soil. A decreasing trend of dehydrogenase activity, β-glucosidase activity, microbial biomass carbon and organic carbon was observed with increase in depth and distance. Maximum enzyme activities were observed at 0-15 cm depth and decreased as soil depth increased. There was a positive correlation between soil organic carbon and microbial biomass carbon ($p < 0.05$). The study indicated that soil organic carbon has beneficial effect on the enzymatic activity in the oil palm growing soils of Andhra Pradesh.

Key words : Organic carbon, microbial activity, dehydrogenase, β-glucosidase.

INTRODUCTION

Oil palm is basically a humid tropical crop native to the Guinea Coast of West Africa, and is the highest edible oil yielding crop giving up to 4-6 tonnes of oil per hectare per year. Presently, oil palm is being cultivated in an area of 2.10 lakh ha in India. It requires adequate rainfall evenly distributed throughout the year along with bright sunlight (5 h per day) and humidity of more than 80% for better growth and yield. Scientific technologies and sincere attempts are being made towards the sustainable production of oil palm in coastal Andhra Pradesh.

Soil is an important component of all terrestrial ecosystems as well as a main source of production in agriculture and forestry. Soil is a dynamic system in which, continuous interaction takes place between soil minerals and organic matter and organisms that influence the physicochemical and biological properties of terrestrial system. Several studies have examined the ecological requirements and environmental impact of oil palm on soil (Aweto and Enaruvbe, 2010). Its function is essential for the maintenance of biogeochemical cycles of all nutrients and affects other components of ecosystems, both biotic and abiotic (Monty Kujur *et al*., 2012). Enzymes catalyze the biochemical reactions and play an integral part of nutrient cycling in the soil (Tabatabai, 1994). Soil enzymes are considered to be indicative measure of soil fertility (Zahir *et al.,* 2010) due to the fact that they participate in elemental cycling, decomposition of organic matter, rapid response to changes in soil management and hence are considered fundamentally good indicators for soil quality (Dick,1994; Kizilkaya *et al.,* 2007; Abdalla and Langer, 2009). Soil enzyme activity is variable with substrate supply (Degens, 1998; Tateno, 1988) and provides useful linkage between microbial community composition and carbon processing (Waldrop *et al.,* 2000).

Total soil enzymatic activity is composed of both intracellular and extracellular enzymes. The dehydrogenase group of enzymes is the best example of exclusively intracellular enzymes and good indicator for overall microbial activity (Garcia *et al*., 1997; Pascule *et al.,* 1998; Taylor *et al.,* 2002; Quichano and Maranon, 2002). Dehydrogenases play a significant role in the biological oxidation of soil organic matter by transferring the proton from substrates to acceptors (Rossel *et al*., 1997). Hence, their activity is considered an indicator of the oxidative metabolism in soil and thus also of microbial activity (Quilchano and Maranon, 2002).

β-glucosidase is common and predominant enzyme in soil (Eivazi and Tabatabai, 1998).It plays an important role in soils as it is involved in catalyzing the hydrolysis and biodegradation of various β-glucosidase present in plant debris decomposing in the ecosystem (Ajwa and Tabatabai, 1994; Martinez and Tabatabai, 1997). It is also an important carbon energy source of life to microbes in the soil (Esen, 1993). β-glucosidase is characteristically useful as a soil quality indicator and may give a reflection of past biological activity, the capacity of soil to stabilize the soil organic matter and can be used to detect management effect on soils. This has greatly facilitated its adoption for soil quality testing (Bandick and Dic, 1999; Ndiaye *et al*., 2000).

Several studies have showed a close relationship between soil microbial biomass and nutrient availability to plants (Jenkinson and Lad, 1981; Houot and Chaussod, 1995). Microbial activity and soil fertility are generally closely related because it is through the biomass that the mineralization of the important organic elements occur (Frankenberger and Dick, 1983). Studies of microbial biomass carbon and enzyme activities provide information on the biochemical processes occurring in the soil and there is growing evidence that soil biological parameters may have a potential to act as early and sensitive indicators of soil ecological stress and restoration (Dick and Tabatabai, 1992). In many arable agriculture soils, the soil microbial biomass is related to the soil organic matter content (Houot and Chaussod, 1995) and biomass carbon generally represents 2-3% of soil organic carbon (Anderson and Domsch,1989). Soils in semi arid areas have a very low microbial activity (Garcia *et al.,* 1994a), low levels of microbial biomass and low organic matter content. Thus microbial biomass, being the living part of soil organic matter can be a good index for natural ecosystem (Ross *et al.,* 1982). The relationships between soil organic matter, microbial biomass and microbial activity have been proposed as indicators of soil maturity (Machulla *et al.,* 2005).

As research on the role of microbial activity in the oil palm growing soils is very scarce under Indian conditions, the present study was taken up to understand the dynamics of soil organic carbon and activity in oil palm growing soils of Andhra Pradesh.

MATERIALS AND METHODS

The study was conducted in five adult oil palm plantations located nearer to Pedavegi, West Godavari District, Andhra Pradesh. Pedavegi is situated at 16.8 N, 81.11E, 13.41 m above mean sea level. The mean temperature ranged from a minimum of 24^0C to maximum of 34^0C with an average rainfall of 648 mm during sampling period. The palms were planted in a 9 m triangular spacing and standard agronomical practices were followed.

Soil sampling was done by triangular sampling method as per Tailliez (1971) by using an auger (Chan, 1976). The triangle was sub divided into 16 sub triangles with sides 2.20 m and from each centre of sub triangle, one core of sample was taken with the help of augur (10 cm diameter). Circular soil cores were collected at three consecutive depths from surface (0-15, 15-30, 30-60 cm) and collected in plastic bags. Two sets of samples were collected by quartering technique from three triangles of three depths. Immediately after sampling, excess water was drained off and visible root fragments were separated and stones were removed manually. One set was used for estimating dehydrogenase enzyme and the other was air dried, sieved with 2 mm sieve and stored in polythene bags for organic carbon estimation.

Soil dehydrogenase activity was estimated by reducing with 2, 3, 5 triphenyl tetrazolium chloride (TTC) as per Klein *et al.,* 1971. Results were expressed in µg TPF g^{-1} day^{-1}. Soil moisture was measured gravimetrically while soil organic carbon was analyzed by means of wet digestion as per Walkley and Black (1934). Soil microbial biomass carbon was measured by modified chloroform fumigation extraction method with fumigation at atmospheric pressure (Witt *et al.,* 2000). Soil samples, 35 g on an oven-dry basis (48h at 105^0C), were weighed into 500 ml glass schott bottles and fumigated by adding 2 ml ethanol free chloroform directly onto the soil. Microbial biomass carbon (C_{mic}) was estimated by extracting the fumigated soil with 0.5 M K_2SO_4 and extractable C was determined by modified dichromate digestion of soil extract (Vance *et al.,* 1987). β-glucosidase activity was assayed following the method of Eivazi and Tabatabai (1988), using spectrophotometer (Model SL-177, Elico, Hyderabad, India). All the data were tabulated and analyzed statistically.

RESULTS AND DISCUSSION

Variations in soil organic carbon were observed at different depths and distances from palm. A perusal of data (Table 1) indicated that soil organic carbon content decreased as the soil depth and distance from palm increased. The soil organic carbon at different depths and palm distances ranged between 0.19 and 0.57 %. The highest soil organic carbon was observed at 0-15 cm depth at 1 m distance from palm. The lowest soil organic carbon was recorded at 30-60 cm depth at 5 m distance from palm. At 0-15 cm depth, highest soil organic was observed at 1 m palm distance, while it was lowest at 5 m distance. Similar trend was observed at other two soil depths also. The mean soil organic carbon content was highest (0.44%) at 1 m palm distance and it decreased as the palm distance increased.

Study revealed that the soil microbial biomass carbon (C_{mic}) was maximum at 0-15 cm depth and 1 m distance. The minimum soil microbial biomass carbon was observed at 30-60 cm depth and 5 m distance from palm. The mean C_{mic} ranged from 67.70 µg Cg^{-1} soil to 84.30 µg Cg^{-1} soil. As the soil depth and distance increased, soil microbial biomass carbon decreased. The soil microbial biomass carbon is one of the major determinant and indicators of the soil fertility and quality and is closely related to soil productivity (Aref and Wander,1998; Al-Kaisi*et al.,* 2005).

In the present study, dehydrogenase activity ranged from 12.50 to 20.37 µg tpf g^{-1} soil $24h^{-1}$. The

Table 1: Variation in soil organic carbon and microbial biomass carbon in oil palm growing soils

Distance from palm base (m)	Soil organic carbon (%)				Microbial biomass carbon (µg C g^{-1} soil)			
	Soil depth (cm)				Soil depth (cm)			
	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean
1	0.57	0.48	0.28	0.44	96.23	92.42	64.25	84.30
2	0.48	0.43	0.26	0.39	92.19	85.2	62.45	79.95
3	0.38	0.35	0.27	0.33	95.65	78.5	59.48	77.88
4	0.33	0.31	0.26	0.30	83.24	85.2	60.21	76.22
5	0.27	0.22	0.19	0.23	82.5	62.47	58.14	67.70
Mean	0.41	0.36	0.25		89.96	80.76	60.91	

Table 2: Variation in soil dehydrogenase activity and β- D- glucosidase activity in oil palm growing soils

Distance from palm base (m)	Dehydrogenase activity (µg tpf g^{-1} soil $24h^{-1}$)				β- glucosidase activity (p-nitrophenol g^{-1} soil h^{-1})			
	Soil depth (cm)				Soil depth (cm)			
	0-15	15-30	30-60	Mean	0-15	15-30	30-60	Mean
1	20.37	15.20	14.10	16.56	6.14	5.12	4.58	5.28
2	18.23	14.70	12.70	15.21	6.12	4.83	3.25	4.73
3	16.21	13.77	12.83	14.27	5.84	4.58	4.12	4.85
4	16.90	13.67	13.53	14.70	5.84	4.97	4.12	4.98
5	15.40	13.80	12.50	13.90	5.21	3.28	2.59	3.69
Mean	17.42	14.23	13.13		5.83	4.56	3.73	

maximum activity was observed at 0-15 cm depth. Minimum activity was observed at 30-60 cm depth. There was considerable variation in enzyme activity at different depths and distances from palm. Higher dehydrogense activity observed at 1m distance might be due to higher organic matter content and relatively higher microbial biomass carbon (Wlodarczyk *et al.*, 2002). Soil dehydrogense activity has been used as a parameter to study biological activity of soil (Nannipieri *et al.,* 2002) and an important indicator of microbial activity in flooded soils (Chendrayan *et al.*, 1980).

β- glucosidase activity showed a decreasing trend with increase in depth as well as distance. The data recorded indicates (Table-2) highest β-glucosidase activity at 0-15 cm depth and 1m distance (6.14 p-nitrophenol g^{-1} soil h^{-1}) while lowest enzyme activity (2.59 p-nitrophenol g^{-1} soil h^{-1}) was observed at 30-60 cm depth and 5m distance. β-glucosidase is a widely abundant enzyme and is synthesized by soil microorganisms due to the presence of suitable substrate (Turner *et al.,* 2002). Sparling (1985) reported a strong positive relation between microbial activity and soil microbial biomass carbon. The β-glucosidase activity depends on organic matter, fertility, and microbial biomass contained in the soil (Dick and Tabatabai, 1984). When organic matter decreases due to its decomposition, enzymatic activity also gets decreased (Garcia *et al.,*1993).

Enzyme activities of soil are usually correlated with their organic carbon contents (Taylor *et al.,* 2002).

Table 3: Correlation matrix between soil organic carbon and microbial activity in oil palm growing soils

	Organic carbon	Microbial biomass carbon	Dehydr-ogenase activity	β-glucosidase activity
Organic carbon	—	0.844**	0.813**	0.778**
Microbial biomass carbon	—	—	0.781**	0.879**
Dehydrogenase activity	—	—	—	0.846**
β-glucosidase activity	—	—	—	—

Higher levels of organic carbon stimulate microbial activity and therefore enzyme synthesis. In the present study, the microbial biomass carbon was significantly correlated with organic carbon (0.844**) (Table 3). Soil organic constituents are thought to be important in forming complexes with free enzymes (Marx *et al.,* 2005). Soil enzyme activities were strongly influenced by depth and distance. Higher enzyme activities were found in the upper layers than deeper layers. In the present study, the enzyme activities were highly correlated with organic carbon and microbial biomass carbon contents of soil. Maximum enzyme activities were observed at 0-15 cm depth and decreased as soil depth increased. There was a positive correlation between soil organic carbon and microbial biomass carbon ($p < 0.05$). The study indicated that soil organic carbon has beneficial effect on the enzymatic activity in the oil palm growing soils of Andhra Pradesh.

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