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Effect of land uses on soil dehydrogenase activity in recent alluvium

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Abstract : *The present study aimed at the assessment of soil dehydrogenase activity influenced by different land uses under recent alluvium, may be a good indicator of microbial activity in the soil. The pH, electrical conductivity (EC), organic carbon and available nitrogen were also determined. Soil samples at 0-15 cm depth were collected from the rice-wheat fallow, maize-wheat fallow, mango-orchard and bamboo cultivated field in south Bihar. The dehydrogenase activity was estimated by the reduction of triphenyl tetrazolium chloride (TTC) to formazan after incubating it at 37 ^{0}C for 24 hours in dark. In bamboo cultivated field, the dehydrogenase activity was highest with an average of 39.4 mg triphenyl formazan (TPF) activity g^{-1} soil day^{-1} due to non-tillage and litter accumulation. The mango orchard showed second highest dehydrogenase activity (average- 24.0 mg TPF activity g^{-1} soil day^{-1}). The permanent vegetative cover provided favourable conditions for microbial enzyme activity. The dehydrogenase concentration was very low in the maize-wheat fallow and the lowest activity was observed in the rice-wheat fallow (average 5.0 mg TPF activity g^{-1} soil day^{-1}). In these land uses, intensive tillage, excessive irrigation and indiscriminate use of agrochemicals had adversely affected the microbial component of the soil. The electrolyte concentration, organic carbon content and available nitrogen in these systems were found to be very low and these could be the possible reasons for the reduced enzyme activity.*

Key words: *Dehydrogenase, organic carbon, triphenyl tetrazolium chloride (TTC).*

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Introduction :

The state of Bihar is located at 21º 58' 10" N to 27º 31' 15" N and 83º 19' 15" E to 88º 17' 4" E. Total geographical area is 9.42 million ha and the mean elevation is 53 meters above the sea level. The climate is mainly subtropical and the temperature exists between 4.3 ºC to 44.3 ºC. The rainy season exists from June to September. The physiographical situation of the state has endowed with alluvial soils which have been deposited by rivers in millions of years by carrying silt from the Himalayan Mountains or from Chhotanagpur plateau. The soils sustaining the state constitute a part of Indo Gangetic alluvium (Pandey, 2005).

The agro-climatic zone of the state is divided into three main types, northwest alluvial plains, northeast alluvial plains and south alluvial plains. The south alluvial plain comprises of flat alluvial plains in the south of the Ganges, extending upto Kaimur hills and Chhotanagpur-Santhal Paragana plateau. It comprises of 40 lakh ha geographical area and contains districts of Patna, Magadh, Munger and Bhagalpur divisions (Das and Das, 2010). Wide variations are noticed in soil, climate, irrigation facilities and even nature of crops and cropping patterns. The main crops of Bihar are paddy, maize, wheat, sugarcane, potato and jute. Apart from field crops, horticulture crops are also important such as mango, litchi, guava, banana and vegetables. Trees such as sisam, teak and bamboo occupy considerable area in the state (Jha and Vishwanathan, 1999).

Farmers follow different land uses in Bihar. It affects the physical, chemical and biological properties of the soil. The soil microbes respond immediately to the changes in soil properties. The microbes living in the soil involve in nutrient transformations and influence the soil functions and plant growth in various ways. The soil enzymes secreted by the microbes are the main components in the activity of nutrient transformations from unavailable form to available form. The soil enzymes mediate critical nutrient-cycling functions such as, decomposition, nutrient mineralization and the soil organic matter transformation (Tabatabai, 1994). Dehydrogenase is one such enzyme present in the soil due to the microbial activities. As a respiratory enzyme, it plays a major role in energy production in microorganisms and is closely related to soil air-water conditions (Glinski and Stepniewski, 1985). The measurement of the dehydrogenase activity in soils and sediments has been used extensively as dehydrogenases are intracellular to the microbial biomass, common throughout the microbial species and are rapidly degraded following cell death (Rossel and Tarradellas, 1991). The soil dehydrogenase activity reflects the total range of oxidative activity of soil microflora as the enzyme is involved in the biological oxidation of soil organic matter (Skujins, 1973). Therefore, it can be used as a measure of biological redox system and consequently it may be a good indicator of the microbiological activity in the soil (Skujins, 1976).

Enzyme activities are very sensitive to both natural and anthropogenic disturbances and show a quick response to the induced changes in soil ecosystems before changes in other soil properties are detected (Askin *et. al.*, 2004). Studying the enzyme activities involved in different nutrient cycling can provide information of soil metabolic or functional responses to changes in management practices. Natural forests, perennial orchards and intensively cultivated fields are examples of different land uses with soil disturbance in increasing order. Intensively cultivated fields severely disturb the physical, chemical and biological properties of the soil and microbial activities are reduced severely. The soil dehydrogenase activity responds to the changes in soil quality related to previous land usage and other factors such as soil pollution with heavy metals or herbicides (Dick, 1992; Bergstrom *et al*., 1998). Hence, the activity of dehydrogenase enzyme was determined under different land use systems like rice-wheat fallow, maize-wheat fallow, mango-orchard and bamboo cultivated field in recent alluvium of south Bihar. The soil dehydrogenase activity was related with the other parameters of soil including organic carbon and available nitrogen.

Materials and Methods :

Sampling area and sample collection : Soil samples were collected from major land uses in the recent alluvium of Munger and Lakhisarai districts of south Bihar that included rice-wheat-fallow, maize-wheat-fallow, mango orchard and bamboo cultivated field. Soil samples were collected from 0-15 cm depth at five sites of each land use during July, 2010, air dried and sieved through 2 mm sieve and stored for further analysis.

Study site : The research work was carried out in the laboratory of Indian Council of Agricultural Research, Research Complex for Eastern Region, Patna and Industrial Microbiology laboratory of Patna Women's College, Patna.

Measurements : The pH was measured in 1:2 soil-water suspension by pH meter (Jackson 1973). Electrical conductivity of the soil extract was determined using conductivity bridge (Richards 1964). Total organic carbon content was estimated by the wet-oxidation method with $K_2Cr_2O_7$ by Walkley and Black (1934) method. The available nitrogen in samples was determined by the alkaline $KMnO_4$ method (Subbiah and Asija, 1956).

The dehydrogenase activity (DHA) was determined by the classical TTC method suggested by Casida *et al*. (1964). In a test-tube, 5 g of sieved soil, 0.4 g of $CaCO_3$, 1 ml of 1.5% 2,3,5- triphenyl tetrazolium chloride (TTC) and 2.5 ml of pure water were taken and mixed well. The tubes were sealed and incubated for 24 hours at 37 ^{0}C in the dark. The product 1,3,5- triphenyl formazan (TPF), obtained by the reduction of TTC, was extracted using methanol and the volume was made up to 50 ml. The TPF concentration was measured spectrophotometrically at 485 nm where methanol was used as a blank.

Results :

The soil dehydrogenase activity was observed with wide variations among different land uses because of relatively undisturbed cultivation to intensive cultivation. Variations were also observed within the same land use due to variation in cultural practices by the farmers. In the rice-wheat fallow system, the dehydrogenase activity ranged from 1 to10 mg TPF activity g^{-1} soil day^{-1} and the average was 5 mg TPF activity g^{-1} soil day^{-1}. In the maize-wheat- fallow land use, the enzyme content ranged from 1 to 28 mg TPF activity g^{-1} soil day^{-1} and the average was 7.5 mg TPF activity g^{-1} soil day^{-1}. In case of mango orchard, the dehydrogenase activity varied from 16 to 46 mg TPF activity g^{-1} soil day^{-1} and the average activity was 24 mg TPF activity g^{-1} soil day^{-1} while in the bamboo plantation, the dehydrogenase activity was found maximum which ranged from 7 to 90 mg TPF activity g^{-1} soil day^{-1} and the average was 39.4 mg TPF activity g^{-1} soil day^{-1} (Table–1).

Some selected physical and chemical characteristics of the soil are presented in Table 2. The pH of the soil samples was mostly neutral to alkaline. Electrical conductivity ranged from 0.02-0.50 dS m^{-1} in all recent alluvial soils with- a lowest mean value of 0.09 dS m^{-1} in the rice-wheat fallow. The soil organic carbon was very low in the rice-wheat and maize-wheat fallow systems (mean 4.4 g ha^{-1} and 6.34 g ha^{-1} respectively) and highest in the bamboo cultivated field (mean 15.8 g ha^{-1}). The available nitrogen content was also highest in the bamboo cultivated field (mean 248.4 kg ha^{-1}) followed by the mango orchard and lowest in the maize-wheat fallow (mean 167.3 kg ha^{-1}).

Table-1: Effect of land uses on soil dehydrogenase activity

No. of sites	Rice-wheat fallow	Maize-wheat fallow	Mango orchard	Bamboo cultivated field
Site 1	6.0*(Munger)	1.0*(Lakhisarai)	16.0*(Munger)	7.0*(Munger)
Site 2	1.0(Munger)	5.0(Lakhisarai)	46.0(Munger)	30.0(Munger)
Site 3	6.0(Lakhisarai)	28.0(Lakhisarai)	21.0(Lakhisarai)	20.0(Lakhisarai)
Site 4	10.0(Lakhisarai)	9.0(Munger)	19.0(Lakhisarai)	50.0(Lakhisarai)
Site 5	2.0(Lakhisarai)	1.0(Munger)	25.0(Lakhisarai)	90.0(Lakhisarai)
Site 6	—	1.0(Munger)	17.0(Lakhisarai)	—
Average	5.0	7.5	24.0	**39.4**
S_d^	3.22	9.62	10.26	28.94

* mg TPF activity g^{-1} soil day^{-1}

^ Standard deviation (±)

Table-2: Effect of land uses on some soil properties

Land uses	pH			Electrical Conductivity(dS m–1)			Organic carbon(g ha–1)			Available N (kg ha^{-1})		
	Range	Mean	S_d^	Range	Mean	S_d^	Range	Mean	S_d^	Range	Mean	S_d^
Rice-wheat fallow	6.9-7.5	7.2	0.20	0.06 -0.07	0.09	0.02	2.24-8.74	4.4	2.33	175.6-238.3	200.7	20.99
Maize-wheat fallow	7.1-7.3	7.2	0.08	0.02 -0.50	**0.25**	0.15	2.24-10.30	6.34	2.70	106.6-213.3	167.3	33.91
Mango orchard	7.2-7.5	**7.4**	0.09	0.10 -0.39	0.20	0.09	7.39-15.23	11.3	2.64	163.1-288.5	207.0	45.81
Bamboo cultivated field	7.2-7.3	7.2	0.06	0.17 -0.30	0.23	0.04	10.08-19.71	**15.8**	3.19	225.8-276.0	**248.4**	18.86

^ Standard deviation (±)

Discussion :

The soil dehydrogenase activity was found highest in the bamboo cultivated field (Fig-1). Vigorous growth and constant litter fall till the removal of trees might be the reason for highest enzyme activity in the soil. The increased organic matter in the soil, litter quality and quantity and root-exudates positively influenced the soil microflora. Also, there was high amount of available nitrogen in the soil which might have supported optimum growth of microbes (Table–2). Perez *et al* (2009) also found similar results that forest soils recorded higher level of dehydrogenase activity than pasture land in Jalisco. According to the research conducted by Harris and Birch (1989), dehydrogenase activity ranged from 140 to 580 µg TPF g^{-1} soil 24 h^{-1} in undisturbed control soils, whereas the disturbed soils had the activity of 10 to 220 µg TPF g^{-1} soil 24 h^{-1}. The smallest dehydrogenase activity was recorded in the most recently reinstated soil, indicating that disturbances have depressed the microbial activity.

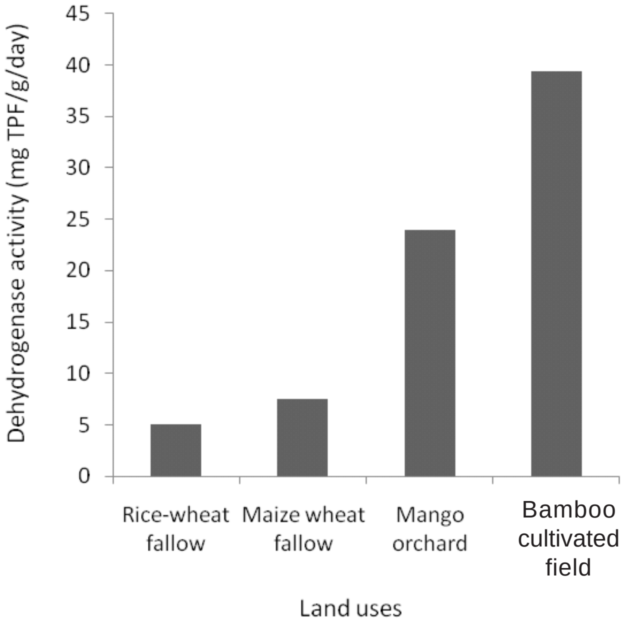

Fig-1: Effect of different land uses on soil dehydrogenase activity (mg TPF activity g^{-1} soil day^{-1})

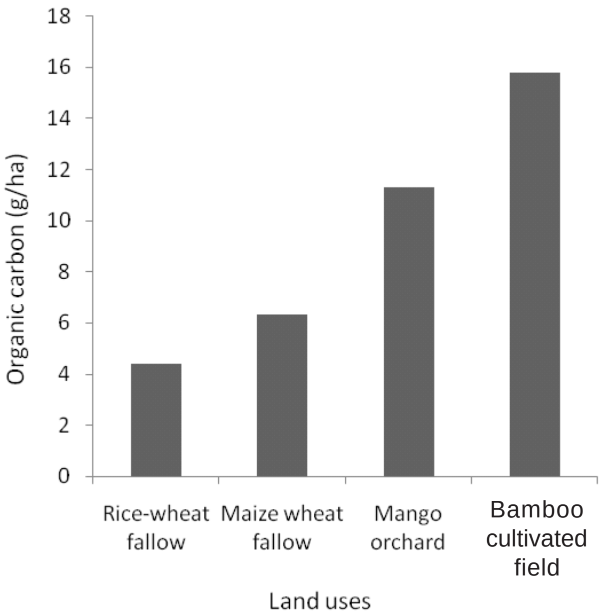

Fig- 2: Effect of different land uses on soil organic carbon (g ha^{-1})

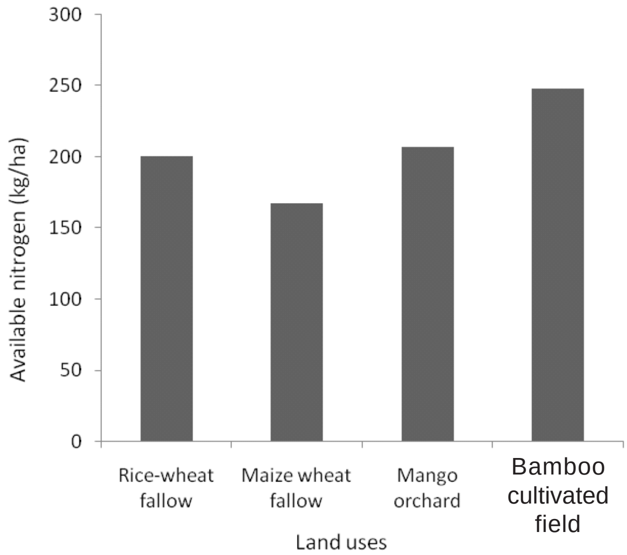

Fig- 3: Effect of different land uses on soil available nitrogen (kg ha^{-1})

The mango orchard recorded the second highest dehydrogenase activity in the soil (Fig-1). No tillage with litter accumulation in the soil might have provided congenial environment for microbial growth. Mango orchards were more than 10 years old which might have developed optimum physical conditions of the soil for soil microorganisms. In both of these agroecosystems, there was cessation of both intensive tillage and application of agrochemicals. There was less organic carbon in the soil under maize-wheat-fallow system (Fig-2). Here the dehydrogenase activity was also very low which showed a significant correlation between these two parameters. Lowest soil available nitrogen was also observed with the system which is all the possible reason for the lower enzyme activity (Fig-3).

The lowest soil dehydrogenase activity was observed with rice-wheat-fallow cropping system (Table-1) also the soil organic carbon and electrolyte concentration were observed to be lowest in this system (Table-2). Udawatta *et al* (2009) also found the lowest dehydrogenase activity and soil carbon content within the cropped area compared to permanent vegetation and agroforestry buffers.

Intensive tillage, excessive irrigation and indiscriminate use of agrochemicals with high yielding varieties of crops might have obstructed the microbial activity and reduced the dehydrogenase activity.

Conclusion :

It was found that the soil dehydrogenase activity is influenced by several variables like organic matter content, non tillage, irrigation and other agricultural practices. Low intensive cultivation with fast growing perennial crops such as, bamboo supported the soil system with the evidence of highest dehydrogenase activity followed by mango orchard. The increased enzyme activity was attributed to increased organic matter as well as improved soil physical parameters. High intensive cultivation with indiscriminate use of agrochemicals (fertilizers and pesticides) and agricultural inputs such as, water had severely affected the soil ecosystem as observed with low activity of soil dehydrogenase. Low intensive tillage or minimum tillage, addition of sufficient quantity of organic residues and integrated use of nutrient sources in rice-wheat fallow and maize-wheat fallow systems would support optimum soil conditions and favorable environment for microbial activities.

Thus, spatial analysis of dehydrogenase activity in different land uses can be useful for assessing soil quality and health as well as for developing appropriate agricultural management practices.

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