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Assessment of soil biological activity as an ecological indicator for mango orchard soils

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ABSTRACT

Soil microbial/enzymatic activities acted as an ecological indicator for a number of agro-ecosystem. In this study, soil enzymatic activities like dehydrogenase (DHA) and fluorescein diacetate (FDA) were assessed in 88 diverse soil samples collected from 22 different mango orchards of Lucknow, UP, India to assess the ecological status of these fruit producing orchards. Wider variability was recorded across the mango orchards. The highest activity of DHA (0.805 μg TPF g^{-1} h^{-1}) was recorded in CISH mango orchards (block III-II) followed by Nabipanah fixed I orchard (0.764 μg TPF g^{-1} h^{-1}). In the case of FDA, maximum activity (584.73 μg fluorescin g^{-1} h^{-1}) was recorded in Mehmoodnagar fixed II mango orchard followed by 444.78 μg fluorescin g^{-1} h^{-1} in Malihabad fixed II mango orchard. Unfortunately higher activities in both the enzymes were registered in a lower percentage. Low soil organic carbon content of 0.31 to 0.46% was estimated. The highest percentage of productivity (77.3%) in the lower range of 5.0 to 8.0 t ha^{-1} was recorded. Results indicated that soil microbial activities may act as an excellent indicator and recognizes the need for optimum soil management approaches for improving the soil health condition of a mango orchard.

Keywords: Biological activity, dehydrogenase, fluorescein diacetate, mango orchard soil

INTRODUCTION

Several soil health milestones may act as an ecological indicator for the system per se (Jourgholami *et al.*, 2019; Adak and Pandey, 2019; Srinivasarao *et al.*, 2018). Among the various components in any fruit production system, biological indicators are the key components and are designated as one of the best indicators to indicate the rapid changes in production trends. The vast microflora present in the soil ecosystems is a function of soil-crop-climate interactions and is prone to changes in the way the ecosystem functions (Uddin and Robinson, 2017). Enzymatic activities in soil are a functioning orchard ground floor management system along with the soil properties; influenced directly by the Physico-chemical indicators (Adak *et al.*, 2017). Sometimes, soil's physical properties change throughout crop production and are subject to the impact of the kinetics of enzymatic dynamics (Nosalewicz and Nosalewicz, 2011). The rates of enzyme release are also a function of time and vary over the periods of crop production. The biological activities indicate the ecological niche for a given kind of fruit orchards and fruit production system over a large area/region.

Fruit productivity of orchards is subjected to climatic variations and in a given season, its effect mainly depends on the resource utilization. Mango is an economically viable fruit crop for millions of growers in Asia and particularly in India. The mango orchard soil undergoes dynamic changes over the periods of cultivation. Farmers are cultivating mango for decades, although productivity is lower (<10 t ha^{-1}) than in neighboring country China (15-18 t ha^{-1}) (Dong *et al.*, 2018). The ecological zone where the mango is being grown acts as a hotspot region to recognize certain parameters for quality fruit production. However, differences in orchard management by the growers, many a times lead to the differential product harvest (Adak *et al.*, 2020). The soil properties in different orchards were also varied due to the adoption of non-uniform management practices. In this study, we analyzed the biological properties of soil in terms of enzymatic activity to indicate the ecological indicator for mango orchards and further plan to overcome constraints in mango production faced by the farmers in the nearby areas of the Institute.

MATERIAL AND METHODS

In the present study 22 mango cv. Dashehari orchards were selected from nearby villages and the ICAR-CISH experimental farm at Rehmakhera, Lucknow. The location of these orchards falls between 26°41.708 N to 26°58.656 N latitude, 80°42.436 E to 80°51.240 E longitude, and 343 to 382 m altitudes. The area is recognized as a subtropical region. To have an idea about the climatic conditions particularly the evapo-transpiration and pan evaporation of the mango orchards, climatic data was collected, and ET_0 was estimated using the equation (Allen *et al*., 1998) as follows:

$$ET_0 = \frac{0.408\Delta\,(Rn - G) + \gamma\,(900\,/\,(T + 273))\,u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)}$$

Where, ET_0 is the reference crop ET (mm day^{-1}), Rn is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux at the soil surface (MJ m^{-2} day^{-1}), T is mean daily air temperature (°C), 900 is a conversion factor, u_2 is mean daily wind speed (m s^{-1}), e_s is mean saturation vapor pressure (kPa), e_a is mean actual vapor pressure (kPa), $e_s - e_a$ is the saturation vapor pressure deficit, Δ is the slope of the saturation vapor-pressure-temperature curve (kPa°C^{-1}), γ is psychrometric constant (kPa°C^{-1}), e_a was calculated based on temperature and relative humidity, and net radiation was calculated from the difference between the incoming net shortwave radiation and outgoing net longwave radiation.

A total of 88 soil samples were collected from 22 mango orchards at 0-30 cm depth and processed at the Soil Science Laboratory of ICAR-CISH for their analysis. Soil enzymatic activities like dehydrogenase (DHA) (Casida *et al*., 1964) and fluorescein diacetate (FDA) (Adam and Duncan, 2001) activities were estimated. Soil organic carbon content was estimated by the standard wet digestion method. Microsoft Excel software was used for data and graphical analysis. Soil variability across orchards and within the orchards along with the standard deviations was calculated to indicate the variations of enzymatic activities in these orchards.

RESULTS AND DISCUSSION

The climatic condition during the study indicated that reference ET_0 (3.64 mm day^{-1}) was gradually decreasing from October to a lower value of 0.83 mm day^{-1} in January and then again gradually increasing trend was noticed. Thereafter, ET_0 again increased during the fruit developmental periods (Fig. 1) and estimated values were from 0.90 to 6.89

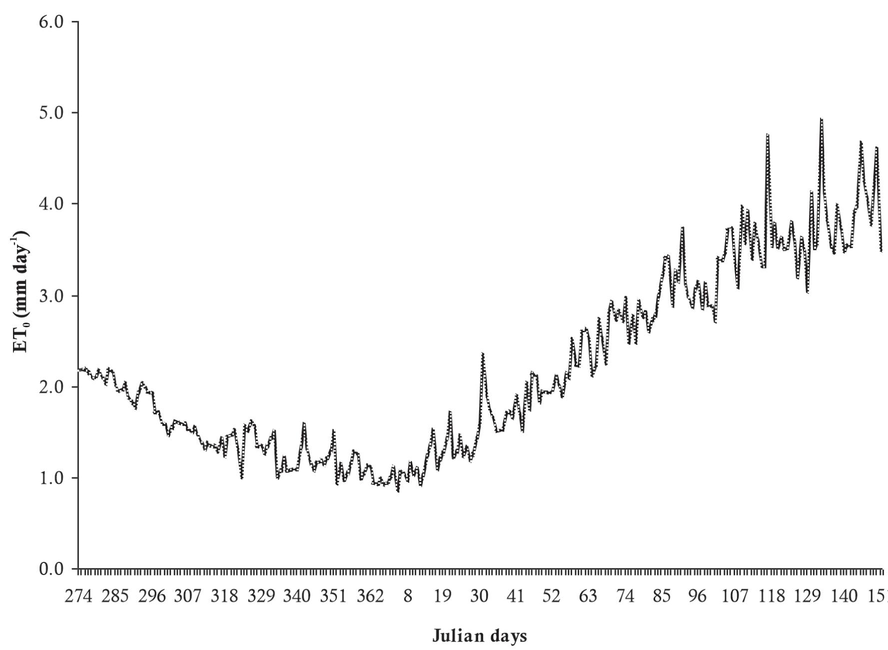

Fig. 1. Dynamics of reference ET_0 during the study period in the Lucknow region, UP, India

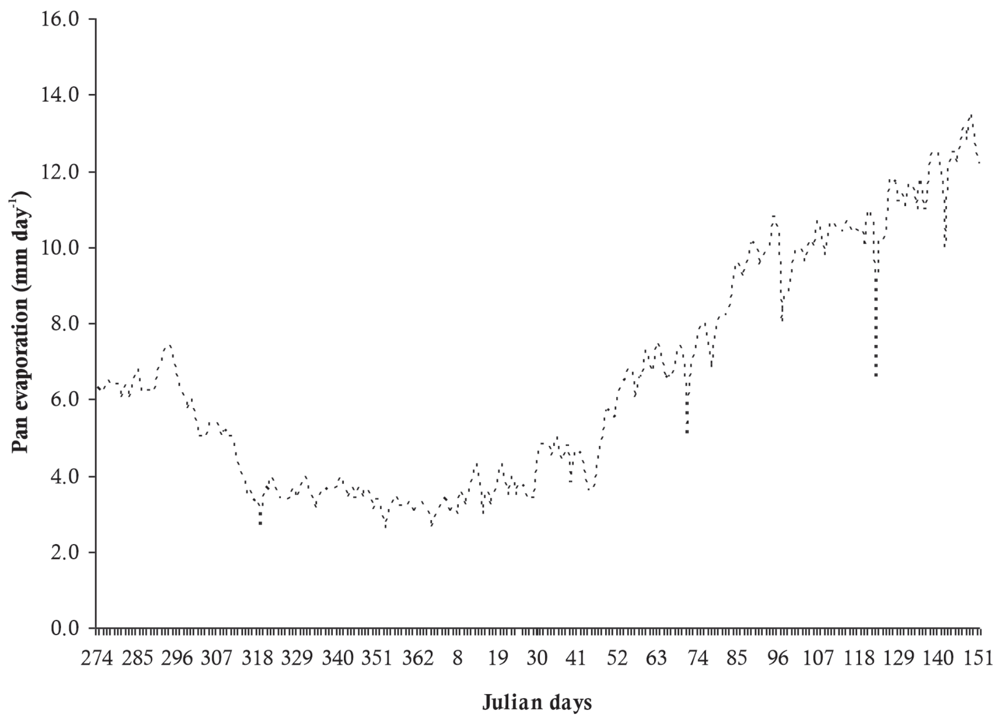

Fig. 2. Dynamics of pan evaporation during the study period in the Lucknow region, UP, India

mm day^{-1} in May. While pan evaporation had a value of 2.6 to 13.5 mm day^{-1} during 274 to 151 Julian days (Fig. 2). Soil enzymatic activities are always affected by the weather parameters and the rate of decreasing trend with the increase in dried condition was noticed. The temperatures influence the enzymatic processes (Razavi *et al.,* 2010). Further, seasonal dynamics (0.32 to 1.98 µg TPF g^{-1} h^{-1}) in dehydrogenase (DHA) activity, under high-density guava fruit production system in subtropical climatic conditions, were also noted (Singha *et al.,* 2016). Similarly, several researchers reported that weather plays a significant role in the enzyme release and its functioning under different ecological regimes (Kramer and Green, 2000; Bloñska, 2010; Veeraragavan *et al.,* 2018).

Data of estimated enzymes showed dehydrogenase (DHA) had wider variability in some mango orchards (Table 1). The lowest was 0.102 µg TPF g^{-1} h^{-1} (Orchard number 18) followed by 0.104 µg TPF g^{-1} h^{-1} (Orchard number 1) and 0.137 µg TPF g^{-1} h^{-1} (Orchard number 15). While higher values of 0.805 µg TPF g^{-1} h^{-1} (Orchard number 12), 0.764 µg TPF g^{-1} h^{-1} (Orchard number 19), and 0.645 µg TPF g^{-1} h^{-1} (Orchard number 13) were recorded in some orchards. The wider coefficient of variations was also confirmed that both within the mango orchards and across the orchards, enzymatic activity was different. Further, when the DHA activity was divided into three categories: 0 to 0.500, 0.501 to 1.00, and >1.01 µg TPF g^{-1} h^{-1}, 52, 32 and 4 percent samples fell in the respective categories (Fig. 3). Estimated fluorescein diacetate (FDA) activity ranged from 146.55 (Orchard number 6 and 7) to 584.73 (Orchard number 17) µg fluorescin g^{-1} h^{-1} across these 22 mango orchards (Table 1). The pattern of FDA in terms of categories- up to 200, 201 to 500, and >500 µg fluorescin g^{-1} h^{-1} was 46, 37, and 5%, respectively (Fig. 4). Mango orchard soils had 0.31 to 0.46% soil organic carbon content (Table

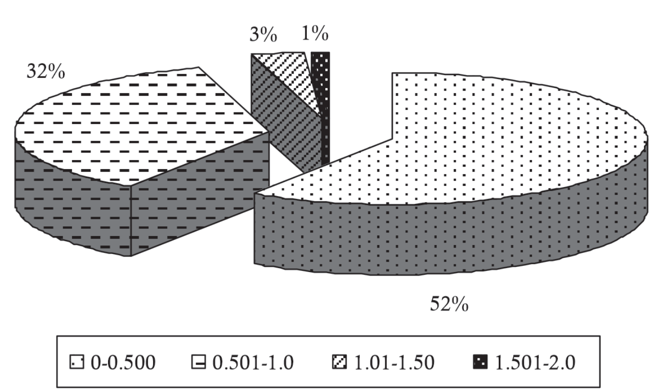

Fig. 3. Distribution of Dehydrogenase activity (DHA) among the 88 soil samples collected from 22 diverse mango orchard locations of Malihabad, Lucknow region

Table 1. Dehydrogenase (µg TPF g^{-1} hr^{-1}) and Fluorescein diacetate activity (µg fluorescin g^{-1} h^{-1}) across 22 mango orchards of Malihabad Lucknow region, UP, India

Sl. No.	Orchard name	Dehydrogenase activity (µg TPF g^{-1} h^{-1})			Fluorescein diacetate activity (µg fluorescin g^{-1} h^{-1})		
		Mean	sd	CV(%)	Mean	sd	CV(%)
1	Meethenagar Fixed I	0.104	0.05	51.6	165.60	31.5	19.0
2	Allupur fixed II	0.505	0.37	73.4	220.92	61.8	28.0
3	Meethenagar Fixed II	0.528	0.38	71.6	230.82	81.3	35.2
4	Allupur fixed I	0.500	0.11	21.2	275.15	101.4	36.8
5	NBD Dhaneva Fixed II	0.586	0.17	28.7	227.52	127.6	56.1
6	NBD Dhaneva Fixed I	0.528	0.29	54.0	146.55	0.10	0.05
7	Kanar fixed I	0.429	0.09	21.3	146.55	0.10	0.07
8	Ulrapur fixed I	0.198	0.07	37.4	220.19	64.1	29.1
9	Kanar fixed II	0.639	0.56	88.2	194.18	95.3	49.1
10	Ulrapur fixed II	0.543	0.25	45.4	222.02	58.9	26.5
11	Hafizkhera fixed II	0.366	0.07	20.2	162.30	16.9	10.4
12	Hafizkhera fixed I	0.160	0.06	36.1	298.23	197.4	66.2
13	Kakori fixed I	0.645	0.23	36.0	157.17	21.2	13.5
14	Kakori fixed II	0.503	0.24	48.4	194.55	33.9	17.4
15	Malihabad fixed I	0.137	0.11	80.8	260.49	127.0	48.8
16	Malihabad fixed II	0.145	0.14	94.5	224.95	46.5	20.7
17	Mehmoodnagar fixed II	0.322	0.28	86.5	584.73	421.9	72.2
18	Mehmoodnagar fixed I	0.102	0.04	36.5	208.47	18.30	8.80
19	Nabipanah fixed I	0.764	0.57	75.2	234.85	96.4	41.1
20	Nabipanah fixed II	0.404	0.17	42.8	412.54	380.4	92.2
21	CISH block III -I	0.604	0.38	62.2	298.96	84.20	28.2
22	CISH block III - II	0.805	0.35	43.4	276.98	61.60	22.3

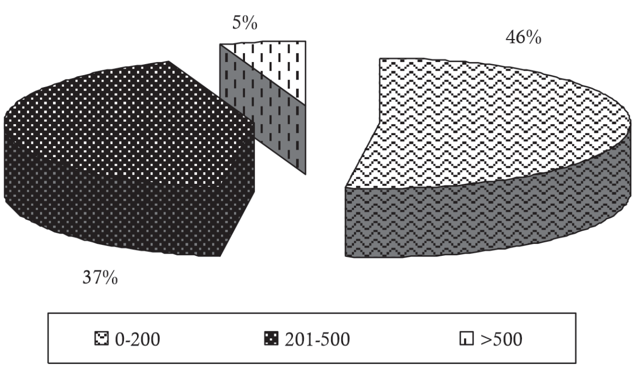

Fig. 4. Distribution of Fluorescein diacetate (FDA) activity across 88 soil samples of 22 mango orchards of Malihabad, Lucknow region

2). A 9.1 to 33.6% coefficient of variations was noticed across these orchards.

Soil enzymatic activity is an indicator of the soil processes acting within the agroecosystem. Field management impacts soil enzymatic activity (Bandick and Dick, 1999). The amount and types of soil organic matter added to the soil influence the soil microbial activities (Wodarczyk, 2000). Soil physico-chemical properties also determine the biological soil health apart from the exogenously added organic and /or inorganic inputs. Variations of DHA i.e. 49% in the 0-1.0, 39.6% in 1.0-2.0 and only 11.5% in the ≥ 2.0 µg TPF g^{-1} h^{-1} categories were recorded in high density guava plantation systems. Even temporal and depth-wise variations in biological activities were recorded in red clover and timothy crops (Niemi *et al.*, 2005). The lower soil organic carbon content may be either due to rapid transformation under subtropical climatic conditions leading to lower enzymatic activities or growers had applied lower quantities. The differential variations in soil enzymatic activities in mango orchard soil could be because growers might have opted for different orchard ground floor management practices. Orchard productivity followed a system; it is a soil-tree interaction in which the soil part plays a major role to indicate ecological functioning (Adak *et al.,* 2018, 2019). Mango cv. Dashehari being GI to this place and cultivated over the century, identification of soil indicators is urgently important to maintain the nutrient cycle on a positive note. Soil biochemical processes either in short term or long term basis indicate the changes occurring within the soil. Thus, they are beneficial for considering as indicators to support the ecological niche (Lagomarsino *et al.,* 2009). The productivity level of

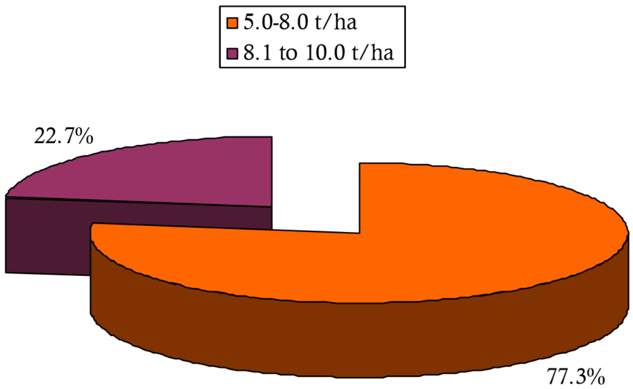

Fig. 5. Productivity level in the mango orchards of Lucknow, UP, India

Table 2. Soil organic carbon (%) content across 22 mango orchards of Lucknow region, UP, India

Sl. No .	Orchard name	Soil organic carbon (%) Mean	sd	CV(%)
1	Meethenagar Fixed I	0.36	0.12	33.6
2	Allupur fixed II	0.45	0.10	23.2
3	Meethenagar Fixed II	0.46	0.07	15.7
4	Allupur fixed I	0.35	0.04	12.0
5	NBD Dhaneva Fixed II	0.37	0.09	24.7
6	NBD Dhaneva Fixed I	0.42	0.05	11.1
7	Kanar fixed I	0.37	0.07	18.7
8	Ulrapur fixed I	0.35	0.04	12.1
9	Kanar fixed II	0.38	0.09	23.9
10	Ulrapur fixed II	0.37	0.05	13.6
11	Hafizkhera fixed II	0.33	0.06	17.4
12	Hafizkhera fixed I	0.37	0.04	11.5
13	Kakori fixed I	0.39	0.04	9.1
14	Kakori fixed II	0.34	0.04	13.1
15	Malihabad fixed I	0.36	0.10	28.8
16	Malihabad fixed II	0.36	0.03	9.4
17	Mehmoodnagar fixed II	0.32	0.07	20.7
18	Mehmoodnagar fixed I	0.35	0.03	9.6
19	Nabipanah fixed I	0.33	0.04	13.3
20	Nabipanah fixed II	0.31	0.04	14.1
21	CISH block III -I	0.32	0.07	22.2
22	CISH block III - II	0.33	0.05	14.5

5.0 to 8.0 t ha^{-1} and 8.1 to 10.0 t ha^{-1} recorded for 77.3 and 22.7% of orchards, respectively, indicate the need for immediate attention towards optimized orchard management (Fig. 5). Based on the analysis of 250 soil samples from mango orchards concluded that biological activities need to be improved as only 43.6 and 47.2% of DHA and FDA were in medium ranges (Adak *et al.*, 2016). An integrated approach is needed or conversion to organic farming may also be a viable option.

CONCLUSIONS

The present study was conducted to know the status of the mango orchards and also to identify orchards that urgently need management attention for which soil biological indicators were employed. Soil enzymatic activities like dehydrogenase and fluorescein diacetate were estimated and found to vary across orchards and within the orchards. Analysis showed lower values and assessment of both the enzymatic activities indicated that the biological status of the mango orchards was poor and thus there is a need for better management through the application of organic sources. Lower soil organic carbon and biological activity could be the possible reasons for lower productivity levels.

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