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Research Article

Spatio-temporal Variations of Dehydrogenase Activity and Some Soil Physical Parameters in High Density Guava Orchard

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ABSTRACT

Accurate estimation of soil enzyme activity gives information on the status of microbial activity of the soil; therefore, is considered to be the key factor for assessment of soil quality. The activity varies among different land use systems and management modules adopted with the exiting soil factors. Keeping this in view, the present study was conducted to assess the seasonal variations of dehydrogenase activity in relation to some soil physical properties in a twenty years old guava orchard (cv. Allahabad Safeda) with four different planting density (2200, 1100, 555 and 277 plants ha^{-1}). The seasonal variation in the soil dehydrogenase activity (DHA) was evident across the planting density (0.21 to 2.59 µg TPF g^{-1} h^{-1}). Highest dehydrogenase activity (1.98 ± 0.46µg TPF g^{-1} h^{-1}) was recorded across tree density and spacing during July. The seasonal DHA level under different guava plantations (2200, 1100, 555 and 277 tree ha^{-1}) varied 1.19 ± 0.036, 1.27 ± 0.028, 0.97 ± 0.025 and 1.14 ± 0.020 µg TPF g^{-1} h^{-1} respectively. Soil samples collected from closer to the tree trunk showed higher soil organic carbon content than the distant one in all population densities. The soil organic carbon ranged between 0.20 ± 0.04 and 0.65 ± 0.04 per cent. The monthly average soil organic carbon content (0.52 & 0.51 %) was also highest in the medium density (1100 plants ha^{-1}) for the soilsamples collected at 0.5 and 1.0 m from tree trunk respectively. Seasonal extremism accounted the spatio-temporal variability in the *in-situ* soil moisture and temperature dynamics in the guava orchards. The study indicated the positive effect guava plantation on the soil organic carbon and associated microbial activity. Therefore soil organic matter management in moderate to high density plantations should be adopted in order to sustain the optimum soil biological health.

Key words: Dehydrogenase activity, guava, high density, physical properties, subtropical climate.

Introduction

Soil enzymes participated in the majority of the biochemical processes in the soil environment, those are closely related to nutrient cycling, energy transfer, and environmental quality (Dick, 1994, 1997; Yao *et al*., 2006). It integrates the information on soil microbial status and soil physical-chemical conditions and are useful to study the effects of environmental changes of soil quality (Baum *et al*., 2003; Chen *et al*., 2003). The soil organic matter acts as an energy source for microorganisms and highly correlated with the soil's microbial activity (Bastida *et al*., 2006). Adak *et al*. (2014b) recorded the improvement in soil organic carbon content, available nutrient status and dehydrogenase activity in mango orchard soil undergoing different organic and inorganic amendments.

Due to the sensitivity, simplicity, accuracy and reproducibility, soil enzyme activities are considered to be the key variables for soil quality assessments (Dick *et al*., 1996; Bergstrom *et al*.,

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1998). The spatial variability in different soil enzyme activities depends on soil environmental conditions (Kandeler *et al*., 2001; Killham and Staddon, 2002). Dehydrogenase activity reflects the total range of oxidative activity of viable soil microflora and thus considered to be a good indicator of soil microbial activity (Wlodarczyk, 2000).

Guava is one of the most important commercially viable and economic fruit crops in India. Traditional system of guava cultivation take at least three to four years before they come into commercial bearing and overall cost of production per unit area is further increased with lower crop productivity and high labour input cost (Arsujo *et al*., 1999; Singh *et al*., 2003). Reduction of tree spacing is a method used for efficient and profitable land use called high-density planting. This method exploits light, water, and nutrients so effectively that highest total yield potential can be reached in the smallest possible area that assures effective use of fertilizers, pesticides and other input costs (Kumawat *et al*., 2014; Boswell *et al*., 1982; Singh, 2004).

The maintenance of soil fertility in different density plantations of guava orchard and plant nutrient supply to an optimum level is very essential and the challenge for sustaining the long term crop productivity and fruit quality at desired level (Hazarika *et al*., 2011). Vast area in Uttar Pradesh wherein fruit orchard plantation may be adopted with special nutrient management modules, specifically, where deficiency of different soil micronutrients *viz*. Fe, Mn, Zn, Cu, Bo and Mo exists (Kumar *et al*., 2011). The availability of these nutrients in the soil systems depends on the physico-chemical and biological properties of the soil. Kotur and Keshava Murthy (1998) reported that the major soil nutrient concentrations in guava orchard were concentrated in the surface soil up to 25 cm depth, and horizontally up to 160 cm as the active root zone for guava. The activity of root system in guava depends upon soil moisture, canopy volume and fruit load. The soil temperature also determines the level of soil microbial activity which leads to pattern of nutrient release from soil organic matter pool and ultimately uptake by roots (Subhani *et al*., 2001; Trasar-Cepeda *et al*., 2007; Cirilli *et al*., 2012). Therefore, the physical, chemical and biological property of soil often determines the nutrient availability to the crop. Floch *et al*. (2009) observed that enzymatic activities in orchard agroecosystem depend on the field management strategy. The land use history also played the important role on the spatio-temporal variability of soil enzymatic activity, and other related soil properties (Chu *et al*., 2007; Akmal *et al*., 2012; Hazarika *et al*., 2014; Singha *et al*., 2014a). Since the information on these aspects are meager, the present study was undertaken to assess the spacio-temporal variations of dehydrogenase activity in relation to some soil physical properties in different planting densities of guava under subtropical semi-arid condition.

Materials and Methods

The present study was carried out in 20 years old high density guava plantation (cv. Allahabad Safeda) at Rehmankhera farm of Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow (26.54°N Latitude, 80.45°E Longitude and 127 m above mean sea level), Uttar Pradesh, India during 2011. The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium with sandy loam texture and taxonomically classified as mixed hyperthermic family of Typic Ustochrepts. The climate of the study site is subtropical with hot dry summers and cold winters. The meteorological parameters of the period of study are presented in Table 1.

The soil samples were collected from 0-15 cm depth at 0.5 and 1.0 m distance from the tree trunk of twenty years old guava plantations at varying spacing of 1.5 × 3.0, 3.0 × 3.0, 3.0 × 6.0 and 6.0 × 6.0 m with plant density of 2200, 1100, 555 and 277 plants ha^{-1} respectively. The orchards were maintained under recommended horticultural and agronomic practices during first week of each calendar month throughout the year 2011. *In-situ* soil moisture and soil temperatures were recorded using WET sensor instrument at each soil sampling depth. Samples were air dried at room

Table 1. Meteorological parameters at the experimental site during the study period (2011)

Month	Temperature (°C) Max	Temperature (°C) Min	Relative humidity (%)	Bright sunshine hours (h)	Wind velocity (km/h)	Total rainfall (mm)	Pan evaporation (mm/day)
January	19.6	4.5	90.7	5.3	2.6	3.6	1.9
February	25.8	9.4	88.0	7.7	2.9	11.0	3.0
March	31.7	13.5	82.3	9.0	3.0	22.3	4.9
April	35.8	18.8	71.0	3.5	3.5	3.0	6.8
May	37.9	23.4	74.0	3.6	3.6	101.8	7.1
June	34.9	24.9	82.3	6.2	4.6	267.5	6.0
July	33.2	25.7	89.0	3.8	3.8	351.0	4.3
August	31.9	25.3	88.4	4.3	7.0	481.8	3.5
September	32.9	24.4	88.7	6.8	3.7	247.8	3.8
October	32.6	17.0	84.3	7.9	1.6	0.0	2.9

temperature and passed through 2 mm sieve and homogenized. Dehydrogenase activity was estimated using 2, 3, 5 triphenyal tetrazolium chloride using 1 gram air-dried soil (<2 mm) and expressed as µg of triphenyl formazan (TPF) formed per gram of oven dried soil per hours (Casida *et al*., 1964). Soil organic carbon content was determined using wet digestion method (Walkley and Black, 1934). All statistical analyses were performed using SPSS version 12.0. Histogram, pie diagram and Univariate statistical analysis were developed using MS Excel software.

Results

Seasonal variations of dehydrogenase activity (DHA)

We observed the seasonal variability in soil dehydrogenase activity ranged between 0.21 to 2.59 µg TPF g^{-1} h^{-1} across the variable tree density and distance from the tree trunk (Table 2). Temporal variability of dehydrogenase activity was accounted to climatic factors viz. rainfall and temperature exposure. The soil dehydrogenase activity gradually increased from January (0.66 ± 0.19 µg TPF g^{-1} h^{-1}) to March (1.09 ± 0.37 µg TPF g^{-1} h^{-1}) with gradual increase in soil and air temperature and then decreased drastically to the lowest value during the pre-monsoon months (April and May; 0.32 ± 0.06 and 0.33 ± 0.20 µg TPF g^{-1} h^{-1}). The lowest dehydrogenase activity in April and May was preferably due to drier condition; highest mean monthly maximum temperature of 35.8 and 37.9^{0}C and highest mean monthly pan evaporation of 6.8 and 7.1 mm d^{-1} respectively. Furthermore, this may also be due to reduced secretion of root exudates due to complete defoliation of leaves in April-May. The activity again increased in the following monsoon months and reached to the highest level in the month of July (1.98 ± 0.46 µg TPF g^{-1} h^{-1}) due to conducive soil moisture and temperature and also due to leaf litter fall during April-May. The activity however, decreased gradually during winter months as coolers season restrict enzymatic activity due to low soil temperature (Table 4). Pooled data of univariate statistical analysis showed the highest average dehydrogenase activity (1.39 ± 0.044 and 1.16 ± 0.023 µg TPF g^{-1} h^{-1}) for the soils under medium density (1100 plants ha^{-1}) guava plantation at 0.5 and 1.0 m distance from tree trunk respectively (Table 3). The dehydrogenase activity showed wide variability throughout the year across different density plantations. The average DHA level varied across different guava densities viz. 2200, 1100, 555 and 277 plants ha^{-1}, by 1.19 ± 0.036, 1.27 ± 0.028, 0.97 ± 0.025 and 1.14 ± 0.020 µg TPF g^{-1} h^{-1} respectively. Dehydrogenase activities were grouped into three categories *viz*. low (0-1.0 µg TPF g^{-1} h^{-1}), medium (1.0-2.0 µg TPF g^{-1} h^{-1}) and high (2.0 µg TPF g^{-1} h^{-1} and above) and accordingly 11.5 and 49% were observed to be in

Table 2. Dehydrogenase activity and soil organic carbon content in high density guava orchard soil

Distance from tree trunk (m)	Planting density (Plants ha^{-1})	Month												CD (0.05)
		January Mean ± sd	February Mean ± sd	March Mean ± sd	April Mean ± sd	May Mean ± sd	June Mean ± sd	July Mean ± sd	August Mean ± sd	September Mean ± sd	October Mean ± sd	November Mean ± sd	December Mean ± sd	
Dehydrogenase activity (µg TPF g^{-1} hr^{-1})														
0.5	2200	0.62 ± 0.20	0.78 ± 0.34	0.64 ± 0.17	0.32 ± 0.12	0.81 ± 0.19	1.45 ± 0.66	2.41 ± 0.18	1.20 ± 0.31	1.30 ± 0.23	1.09 ± 0.27	2.24 ± 0.47	1.96 ± 0.26	0.55
	1100	0.95 ± 0.59	0.89 ± 0.54	0.74 ± 0.31	0.32 ± 0.06	0.29 ± 0.14	1.81 ± 0.73	2.36 ± 0.22	1.40 ± 0.42	1.71 ± 0.34	2.03 ± 0.61	2.14 ± 0.05	1.98 ± 0.27	0.73
	555	0.63 ± 0.11	0.63 ± 0.27	0.69 ± 0.50	0.26 ± 0.06	0.23 ± 0.14	0.51 ± 0.22	2.15 ± 0.77	0.87 ± 0.75	1.11 ± 0.19	1.13 ± 0.20	1.91 ± 0.51	1.83 ± 0.43	0.71
	277	0.58 ± 0.35	1.22 ± 0.56	1.47 ± 0.23	0.29 ± 0.08	0.28 ± 0.03	1.15 ± 0.65	1.79 ± 0.16	1.88 ± 0.38	2.19 ± 0.49	1.35 ± 0.33	1.77 ± 0.31	1.44 ± 0.20	0.62
1.0	2200	0.41 ± 0.13	1.01 ± 0.16	1.09 ± 0.23	0.42 ± 0.27	0.36 ± 0.06	1.17 ± 0.77	2.59 ± 0.58	0.71 ± 0.17	0.82 ± 0.07	1.33 ± 0.30	1.96 ± 0.53	1.79 ± 0.49	0.61
	1100	0.88 ± 0.43	0.94 ± 0.39	1.57 ± 2.10	0.39 ± 0.12	0.21 ± 0.05	0.64 ± 0.01	1.68 ± 0.19	1.37 ± 0.15	1.42 ± 0.28	1.62 ± 0.31	1.77 ± 0.14	1.43 ± 0.03	NS
	555	0.46 ± 0.36	0.59 ± 0.20	1.08 ± 0.67	0.30 ± 0.08	0.22 ± 0.09	1.11 ± 0.72	1.42 ± 0.85	0.87 ± 0.34	1.04 ± 0.42	1.13 ± 0.25	1.72 ± 0.26	1.42 ± 0.16	0.72
	277	0.74 ± 0.12	0.92 ± 0.60	1.41 ± 0.24	0.23 ± 0.11	0.23 ± 0.02	1.24 ± 0.55	1.44 ± 0.36	0.64 ± 0.14	1.04 ± 0.23	1.70 ± 0.52	1.39 ± 0.58	1.02 ± 0.29	0.60
	Mean	0.66 ± 0.19	0.87 ± 0.21	1.09 ± 0.37	0.32 ± 0.06	0.33 ± 0.20	1.14 ± 0.42	1.98 ± 0.46	1.12 ± 0.42	1.33 ± 0.44	1.42 ± 0.33	1.86 ± 0.26	1.61 ± 0.33	
Soil organic carbon (%)														
0.5	2200	0.31 ± 0.04	0.48 ± 0.13	0.22 ± 0.02	0.40 ± 0.08	0.62 ± 0.02	0.56 ± 0.14	0.55 ± 0.06	0.55 ± 0.07	0.42 ± 0.06	0.51 ± 0.06	0.62 ± 0.06	0.52 ± 0.04	0.12
	1100	0.40 ± 0.04	0.47 ± 0.07	0.36 ± 0.10	0.44 ± 0.08	0.48 ± 0.07	0.57 ± 0.05	0.65 ± 0.04	0.64 ± 0.06	0.59 ± 0.07	0.58 ± 0.08	0.58 ± 0.06	0.52 ± 0.06	0.12
	555	0.32 ± 0.07	0.33 ± 0.09	0.27 ± 0.04	0.35 ± 0.03	0.46 ± 0.10	0.39 ± 0.10	0.44 ± 0.04	0.64 ± 0.01	0.58 ± 0.08	0.55 ± 0.12	0.60 ± 0.05	0.53 ± 0.04	0.13
	277	0.27 ± 0.03	0.33 ± 0.10	0.35 ± 0.05	0.44 ± 0.07	0.50 ± 0.06	0.53 ± 0.03	0.64 ± 0.08	0.61 ± 0.05	0.59 ± 0.06	0.56 ± 0.06	0.55 ± 0.02	0.47 ± 0.02	0.11
1.0	2200	0.29 ± 0.04	0.40 ± 0.04	0.20 ± 0.04	0.36 ± 0.09	0.47 ± 0.06	0.55 ± 0.03	0.57 ± 0.03	0.48 ± 0.15	0.43 ± 0.06	0.48 ± 0.09	0.61 ± 0.09	0.57 ± 0.06	0.13
	1100	0.40 ± 0.07	0.39 ± 0.20	0.37 ± 0.21	0.48 ± 0.07	0.50 ± 0.14	0.58 ± 0.04	0.51 ± 0.05	0.63 ± 0.02	0.57 ± 0.06	0.59 ± 0.02	0.57 ± 0.04	0.53 ± 0.04	NS
	555	0.33 ± 0.05	0.34 ± 0.10	0.24 ± 0.16	0.33 ± 0.01	0.49 ± 0.07	0.40 ± 0.18	0.45 ± 0.05	0.58 ± 0.08	0.42 ± 0.11	0.47 ± 0.08	0.54 ± 0.07	0.57 ± 0.05	0.18
	277	0.34 ± 0.08	0.35 ± 0.10	0.40 ± 0.15	0.44 ± 0.03	0.42 ± 0.06	0.53 ± 0.10	0.58 ± 0.09	0.48 ± 0.13	0.54 ± 0.12	0.46 ± 0.07	0.52 ± 0.01	0.45 ± 0.04	NS
	Mean	0.33 ± 0.05	0.39 ± 0.06	0.30 ± 0.08	0.41 ± 0.05	0.49 ± 0.06	0.51 ± 0.08	0.55 ± 0.08	0.58 ± 0.07	0.52 ± 0.08	0.52 ± 0.05	0.57 ± 0.03	0.52 ± 0.04	

Table 3. Univariate statistical analysis of dehydrogenase activity and soil organic carbon content under high density guava plantations

Parameter	Distance from tree trunk (m)	Planting density (Plants ha^{-1})	Range	Mean±SEM	Standard daviations	CV%	Skewness	Kurtosis
Dehydrogenase activity (µg TPF g^{-1} hr^{-1})	0.5	2200	0.32-2.41	1.23 ± 0.037	0.67	54.3	0.59	-0.72
		1100	0.29-2.36	1.39 ± 0.044	0.72	52.3	-0.31	-1.41
		555	0.23-2.15	1.00 ± 0.035	0.65	65.2	0.71	-0.76
		277	0.28-2.19	1.28 ± 0.032	0.62	48.3	-0.52	-0.68
	1.0	2200	0.36-2.59	1.14 ± 0.039	0.69	60.4	0.86	0.22
		1100	0.21-1.77	1.16 ± 0.023	0.53	45.8	-0.65	-0.98
		555	0.22-1.73	0.95 ± 0.019	0.47	49.9	-0.12	-0.87
		277	0.23-1.70	1.00 ± 0.019	0.47	47.2	-0.42	-0.69
	Pooledmean	2200	0.37-2.50	1.19 ± 0.036	0.66	55.6	0.84	-0.12
		1100	0.25-2.02	1.27 ± 0.028	0.58	46.8	-0.50	-0.68
		555	0.22-1.80	0.97 ± 0.025	0.54	55.8	0.38	-0.89
		277	0.26-1.62	1.14 ± 0.020	0.49	43.3	-1.00	-0.26
Soil organic carbon (%)	0.5	2200	0.22-0.62	0.48 ± 0.001	0.12	25.3	-1.01	0.51
		1100	0.36-0.65	0.52 ± 0.001	0.09	17.8	-0.42	-0.95
		555	0.27-0.64	0.46 ± 0.001	0.12	27.3	0.02	-1.38
		277	0.27-0.64	0.49 ± 0.001	0.12	23.9	-0.65	-0.65
	1.0	2200	0.20-0.61	0.45 ±0.001	0.12	27.3	-0.76	0.08
		1100	0.37-0.63	0.51 ±0.001	0.09	16.9	-0.52	-0.94
		555	0.24-0.58	0.43 ±0.001	0.11	24.8	-0.16	-0.81
		277	0.34-0.58	0.46 ±0.001	0.07	16.3	-0.10	-0.77
	Pooledmean	2200	0.21-0.61	0.47 ± 0.001	0.12	25.7	-1.04	0.49
		1100	0.36-0.63	0.52 ± 0.001	0.09	16.7	-0.56	-0.98
		555	0.25-0.61	0.44 ± 0.001	0.11	25.4	-0.17	-1.09
		277	0.31-0.61	0.47 ± 0.001	0.09	19.7	-0.52	-0.66

Table 4. Soil moisture and temperature in high density guava orchard soil

Distance from tree trunk (m)	Planting density (Plants ha^{-1})	Month												CD (0.05)
		January Mean ± sd	February Mean ± sd	March Mean ± sd	April Mean ± sd	May Mean ± sd	June Mean ± sd	July Mean ± sd	August Mean ± sd	September Mean ± sd	October Mean ± sd	November Mean ± sd	December Mean ± sd	
Soil moisture (%)														
0.5	2200	8.20 ± 0.70	8.43 ± 0.93	10.40 ± 1.11	10.27 ± 1.07	10.83 ± 0.71	25.73 ± 1.16	26.60 ± 1.11	25.97 ± 1.89	23.33 ± 1.66	13.53 ± 1.17	9.47 ± 0.71	8.13 ± 0.49	2.10
	1100	8.83 ± 0.60	9.90 ± 1.06	10.93 ± 1.27	10.60 ± 0.53	12.70 ± 0.82	20.13 ± 1.50	25.93 ±1.50	23.93 ± 1.89	22.93 ± 1.57	9.80 ± 1.30	11.10 ± 0.10	8.67 ± 0.75	2.32
	555	8.50 ± 1.00	10.33 ± 1.27	7.30 ± 1.35	9.73 ± 0.61	11.83 ± 1.89	19.70 ± 1.04	24.63 ± 0.38	23.73 ± 1.69	20.97 ± 1.42	9.33 ± 1.05	8.97 ± 1.62	8.47 ± 0.49	2.09
	277	7.97 ± 0.21	9.47 ± 1.72	9.47 ± 1.42	9.83 ± 1.80	12.10 ± 1.13	19.00 ± 1.85	24.43 ± 1.76	21.17 ± 1.59	21.07 ± 1.12	8.90 ± 2.01	8.77 ± 0.64	8.63 ± 0.67	2.79
1.0	2200	7.73 ± 0.76	8.93 ± 1.01	8.20 ± 1.77	9.93 ± 1.80	11.43 ± 1.12	24.73 ± 2.27	26.03 ± 1.87	29.07 ± 2.61	24.30 ± 1.01	12.90 ± 1.74	9.80 ± 0.26	8.30 ± 0.10	2.83
	1100	7.80 ± 0.80	9.43 ± 0.60	10.70 ± 1.93	10.07 ± 1.00	10.63 ± 0.91	19.57 ± 1.35	26.13 ± 1.10	23.80 ± 1.18	25.43 ± 1.46	10.67 ± 1.70	11.37 ± 0.46	8.77 ± 0.61	1.85
	555	7.87 ± 0.68	10.57 ± 0.78	7.90 ± 1.20	9.57 ± 0.51	10.70 ± 1.31	21.87 ± 1.59	24.33 ± 0.72	23.93 ± 1.72	22.60 ± 0.75	9.40 ± 0.75	9.17 ± 0.93	8.50 ± 0.66	2.12
	277	7.67 ± 0.47	10.00 ± 0.61	10.13 ± 1.11	9.47 ± 1.46	14.47 ± 1.07	19.97 ± 0.64	24.40 ± 1.99	23.47 ± 1.11	22.93 ± 2.04	9.53 ± 0.86	8.30 ± 0.56	8.33 ± 0.68	2.04
Mean		8.07 ± 0.41	9.63 ± 0.71	9.38 ± 1.40	9.93 ± 0.37	11.84 ± 1.29	21.34 ± 2.56	25.31 ± 0.95	24.38 ± 2.29	22.95 ± 1.50	10.51 ± 1.75	9.62 ± 1.10	8.48 ± 0.21	
Soil temperature (°C)														
0.5	2200	16.37 ± 0.75	18.07 ± 0.51	29.93 ± 2.74	25.37 ± 0.55	31.33 ± 1.50	32.40 ± 0.72	29.13 ± 0.58	28.83 ± 1.91	28.97 ± 0.06	23.43 ± 0.06	14.73 ± 0.21	10.73 ± 0.40	1.89
	1100	17.70 ± 0.20	18.03 ± 0.31	29.53 ± 1.40	25.73 ± 0.25	30.80 ± 0.35	33.33 ± 1.11	28.37 ± 0.32	28.10 ± 0.10	30.23 ± 1.10	24.57 ± 0.59	14.40 ± 0.10	10.37 ± 0.21	1.09
	555	17.10 ± 0.95	18.63 ± 0.76	29.07 ± 0.86	26.67 ± 0.29	32.13 ± 0.15	31.50 ± 1.05	29.43 ± 0.40	29.50 ± 0.44	28.20 ± 0.35	25.67 ± 1.16	14.77 ± 0.06	10.80 ± 0.10	1.27
	277	20.80 ± 2.00	18.77 ± 0.40	29.17 ± 0.25	25.03 ± 0.06	30.93 ± 0.91	32.63 ± 0.71	28.57 ± 0.25	28.97 ± 0.68	28.30 ± 0.85	25.87 ± 1.02	15.20 ± 0.66	12.37 ± 1.03	1.45
1.0	2200	16.10 ± 1.35	18.17 ± 0.42	28.67 ± 1.15	25.50 ± 0.44	30.67 ± 0.58	32.40 ± 0.53	29.00 ± 0.30	28.00 ± 0.36	29.73 ± 1.17	23.73 ± 1.11	14.63 ± 0.38	10.77 ± 0.55	1.24
	1100	17.23 ± 0.21	18.00 ± 0.17	28.37 ± 0.58	25.90 ± 0.10	30.93 ± 0.32	32.67 ± 1.23	28.03 ± 0.90	28.00 ± 0.36	29.90 ± 0.36	24.00 ± 0.26	14.30 ± 0.10	10.57 ± 1.07	1.10
	555	18.07 ± 1.53	17.77 ± 1.42	28.77 ± 1.52	27.33 ± 0.84	31.80 ± 0.92	32.67 ± 0.76	29.33 ± 0.55	29.47 ± 2.28	27.93 ± 1.01	24.87 ± 1.00	14.03 ± 0.90	11.57 ± 0.15	2.26
	277	19.20 ± 0.26	17.93 ± 0.74	28.43 ± 2.03	25.37 ± 0.55	30.17 ± 0.32	32.23 ± 0.38	28.57 ± 0.32	28.97 ± 0.55	28.37 ± 1.18	24.77 ± 0.60	15.13 ± 0.21	12.17 ± 0.91	1.50
Mean		17.82 ±1.55	18.17 ±0.35	28.99 ±0.54	25.86 ±0.77	31.10 ±0.63	32.48 ±0.51	28.80 ±0.50	28.73 ±0.62	28.95 ±0.89	24.61 ±0.87	14.65 ±0.40	11.17 ±0.76	

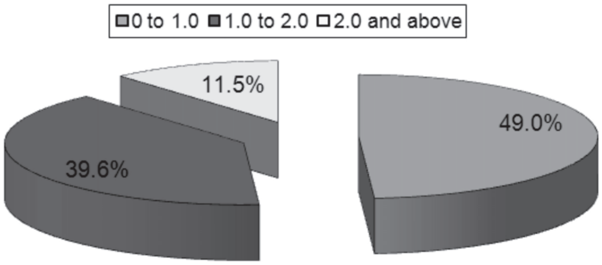

Fig. 1. Distribution of dehydrogenase activity across different category level

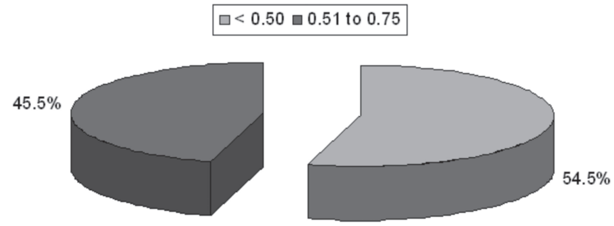

Fig. 2. Distribution of soil organic carbon across different category level

the high and low categories while 51.4 % soil samples were in the medium category (Fig. 1).

Spatio-temporal variations in soil organic carbon (SOC)

Soil organic carbon showed major variations throughout the year irrespective of plant densities. The range of soil organic carbon varied between 0.20 ± 0.04 to 0.65 ± 0.04 per cent (Table 2). Due to lower soil moisture and temperature (Table 4), it had lower range of 0.33 ± 0.05% in the month of January, 0.39 ± 0.06% in the month of February and finally decreased in the month of March (0.30 ± 0.08%). There was significant increase in soil organic carbon after March and higher level was continuously maintained till November-December. This might have been possibly due to leaf litter addition in the soil through natural leaf fall during April-May along with favorable environmental conditions. During monsoon months (June to September), the organic carbon increased. We observed the highest soil organic carbon (0.58 ± 0.07%) during August. Pooled data of univariate statistical analysis showed medium density (1100 plants ha^{-1}) guava plantation had highest average SOC content >0.5% across season and distance from tree trunk (Table 3). Soils closer to tree trunk showed higher soil organic carbon content than the distant one in all planting densities. Majority of soil samples had soil organic carbon content below the critical level (0.5%). Most of the soil samples (54.5%) had low soil organic carbon content (≤0.5%) whereas only 45.5% samples recorded medium SOC content (0.51-0.75%) (Fig. 2). Correlation study was employed in order to quantify the variations in dehydrogenase activity as dependent variable and SOC as independent variable It was inferred that positive but non-significant relationship existed between dehydrogenase activity with soil organic carbon content at 0.5m and 1.0 m distance as well as over our entire experimental tenure.

Dynamics of soil moisture and soil temperature

Soil moisture and temperature are functions of current weather conditions of any region, change in ambient temperature and rainfall pattern may have profound influence on hydrothermal regimes of any orchard. We recorded the wide variations in these two weather parameters in different guava plantations, mainly because of seasonal extremism, canopy density and distance from tree trunk. Soil moisture in these guava plantations ranged between 7.30 ± 1.35 to 26.60 ± 1.11% and 7.67 ± 0.47 to 29.07 ± 1.7% across different months and tree densities at 0.5 and 1.0 m away from the tree trunk, respectively (Table 4 & 5). Lower mean soil moisture content was observed during October to May (8.07 ± 0.41 to 11.84 ± 1.29 %) and higher in the months of June to September (21.34 ± 2.56 to 25.31 ± 0.95 %) irrespective of tree densities and distance from tree trunk. During the monsoon months continuous higher soil moisture content was maintained. We observed that denser canopy plots retained more soil moisture as compared to lower density plantations during monsoon season preferably due to reduced evaporation. Likewise, the range of soil temperature varied from 10.37 ± 0.021°C to 33.33 ± 1.11°C across different density of plantations and seasons. The temporal variation in soil temperature may be attributed to variations in ambient temperature and soil

Table 5 Univariate statistical analysis of soil moisture and temperature under high density guava plantations

Parameter	Distance fromtree trunk (m)	Spacing (m)	Plant density (Plants ha^{-1})	Range	Mean±SEM	Standard daviations	CV%	Skewness	Kurtosis
Soil moisture(%)	0.5	1.5*3.0	2200	8.13-26.60	15.08 ± 5.07	7.80	51.8	0.73	-1.56
		3.0*3.0	1100	8.67-25.93	14.62 ± 3.60	6.57	44.9	0.85	-1.19
		3.0*6.0	555	7.30-24.63	13.63 ± 3.61	6.58	48.3	0.84	-1.21
		6.0*6.0	277	7.97-24.43	13.40 ± 3.12	6.12	45.6	0.86	-1.13
	1.0	1.5*3.0	2200	7.73-29.07	15.11 ± 5.69	8.26	54.7	0.78	-1.39
		3.0*3.0	1100	7.80-26.13	14.53 ± 4.04	7.03	48.4	0.90	-1.12
		3.0*6.0	555	7.87-24.33	13.87 ± 4.36	6.96	50.2	0.78	-1.55
		6.0*6.0	277	7.67-24.40	14.06 ± 3.71	6.67	47.5	0.70	-1.49
	Pooled mean	1.5*3.0	2200	7.97-27.52	15.09 ± 5.35	8.01	53.1	0.75	-1.53
		3.0*3.0	1100	8.32-26.03	14.58 ± 3.83	6.78	46.5	0.87	-1.18
		3.0*6.0	555	7.60-24.48	13.75 ± 3.81	6.76	49.2	0.80	-1.41
		6.0*6.0	277	7.82-24.42	13.73 ± 3.39	6.38	46.5	0.77	-1.35
Soil temperature(°C)	0.5	1.5*3.0	2200	10.73-32.40	24.11 ± 4.48	7.33	30.4	-0.67	-1.04
		3.0*3.0	1100	10.37-33.33	24.26 ± 4.50	7.35	30.3	-0.73	-0.73
		3.0*6.0	555	10.80-32.13	24.46 ± 4.31	7.19	29.4	-0.83	-0.76
		6.0*6.0	277	12.37-32.63	24.72 ± 3.50	6.48	26.2	-0.81	-0.51
	1.0	1.5*3.0	2200	10.77-32.40	23.95 ± 4.34	7.21	30.1	-0.69	-0.99
		3.0*3.0	1100	10.57-32.67	23.99 ± 4.31	7.19	30.0	-0.71	-0.81
		3.0*6.0	555	11.57-32.67	24.47 ± 4.32	7.20	29.4	-0.74	-0.96
		6.0*6.0	277	12.17-32.23	24.28 ± 3.56	6.54	26.9	-0.74	-0.81
	Pooled mean	1.5*3.0	2200	10.75-32.40	24.03 ± 4.40	7.27	30.2	-0.68	-1.01
		3.0*3.0	1100	10.47-33.00	24.13 ± 4.40	7.27	30.1	-0.72	-0.77
		3.0*6.0	555	11.18-32.08	24.46 ± 4.30	7.18	29.4	-0.78	-0.87
		6.0*6.0	277	12.27-32.43	24.50 ± 3.52	6.50	26.5	-0.77	-0.66

moisture. Non-significant differences in soil temperature at 0.5 and 1.0 m distances from tree trunk were observed.

Discussion

Maintenance of soil fertility in high density guava orchard is very important for sustain long term production and supply of high quality guava (Meena *et al*., 2013). Orchard management practice determined the supply of nutrients to the fruit trees in a right proportion at a right stage. Critical soil factors like soil organic carbon, soil moisture, soil temperature and meteorological factors like rainfall and air temperature measurements are the deciding factor to determine the nutrient release pattern in the soil solution through biological transformations of vital nutrients from complex forms to available forms. All the transformations processed by the soil microorganism's *vis-à-vis* soil microbial activities govern the availability of nutrients to the standing tree crops in any established orchards. Soil enzymatic activities are the early indicator of soil health under different agro-ecosystems. These enzyme activities contribute to the total biological activities as they were directly involved in catalyzing reactions necessary for the stabilization of soil structure. Under this circumstance, dehydrogenase activity is considered to be the one of the best ecological indicator for soil microbial activity that indicates the magnitude of nutrient release in the soil. However, soil microbial activity depends on the content of organic matter in the soils along with other soil physical properties. Root exudation often play a vital role in controlling the dynamics of soil microbial activities. Tree density directly related to the root biomass into the soil *via.* root exudates (Feungchan *et al*., 1992). Organic root exudates are the great source of carbon compounds and in general, higher the root exudates greater is the microbial activity.

The dehydrogenase activity was higher during monsoon months and lower in pre-monsoon as well as winter season. The probable reason for such dynamic variations in dehydrogenase activity may be due to higher soil moisture content during rainy season while in winter, cold temperature often restricts the microbial activity. Kotur and Keshava Murthy (1998) observed that root activity in a seven year old Arka Mridula guava was high in late rainy season because of presence of high volumetric soil moisture and lower during winter season due to depletion of soil moisture content. We observed the higher dehydrogenase activity in the soils nearer to tree trunk (0.5 m) because of higher root activity that gradually decreased with increasing the distance far away from the tree trunk (1.0 m). In general, maximum microbial activity resides on surface layer. Singha *et al*. (2014b) reported that significant higher dehydrogenase activity in top 0-10 cm soil layer (2.09 µg TPF g^{-1} h^{-1}) as compared to deeper depths in a mango orchard. We observed higher variability of the enzymatic activity in surface soil. Pooled dehydrogenase activities were higher in higher plant density as compared to lower density plantations. This may be because of the fact that higher root activity under densely populated orchards may be responsible for contributing higher root exudates.

The monthly average soil organic carbon content (0.52 & 0.51%) was also highest in the medium density (1100 plants ha^{-1}) at 0.5 and 1.0 m from tree trunk respectively. Increased microbial activity supported our observations of enhanced soil organic carbon content consequently the soil dehydrogenase activity (Kujur and Patel, 2014). According to Kujur and Patel (2014) soil dehydrogenase activity indicate a change in composition and activity of soil microorganisms and thus it can be used as an effective indicator to monitor and evaluate soil quality. Several researchers have reported soil dehydrogenase activity was positively and significantly correlated to the soil organic carbon content (Nannipieri *et al*., 1990; Aon and Colaneri, 2001; Maurya *et al*., 2011; Adak *et al*., 2014a). The correlation studies in this experiment revealed a positive but non- significant relationship between dehydrogenase activity and the soil organic carbon content. This non significant correlation may be due to large amount of variations in dehydrogenase activity and soil organic carbon throughout the year.

Soil moisture and temperature are one of the most important factors for microbial activity in the soils that also depends on the canopy density in the orchard. Densely populated plots may contribute to greater retention of soil moisture than the sparse canopy due to less evaporation from surface soil. Highest soil moisture was thus recorded in higher plant density (2200 and 1100 plants ha^{-1}) and gradually decreased towards the lower planting density. Weather factors like ambient temperature plays an important role in the dynamics of soil temperature. Any change in higher air temperature may influence the soil temperature. Thus, the dynamics of soil moisture and temperature directly affect microbial activity and its population density (Singha *et al*., 2012).

Conclusions

The study thus indicated that the medium density orchards are most suitable for maintaining maximum dehydrogenase activity in guava orchard ecosystem. Spatio-temporal variability of dehydrogenase activity and other soil factors was observed mainly due to difference in tree population and weather factors particularly rainfall and temperature observations. Monsoon months (June to September) are the most favourable for optimizing microbial activity in the soil as compared to winter season. This suggests that application of biofertilization to guava orchards should be giver during June-July for maximum use efficiency. For future study, the quantity and type of root exudates released by guava plants throughout the year in relation to different soil factors, plant densities and their impacts on soil biological properties of soils needs to be quantified.

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