Assessment of Enzyme Activity and Functional Microbial Diversity in Coastal and Desert Soil Ecosystems of Gujarat

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Abstract

All living beings of various trophic levels in ecosystem depend on the soil as a source of nutrients and depend on soil organisms to release and recycle key nutrient elements by decomposing organic residues. Microbiota of soil plays critical role in the maintenance of soil health and quality by secreting important enzymes, which are capable of function even after being released by the cell. Comparing various types of soils, salinity is profoundly observed in coastal and desert region. Study of such type of soil may give insights for understanding the variations in microbial community and effect of various abiotic factors like, salt concentrations on the same. Studying diversity at the ecosystem level is important to understand range of processes and complexity of interactions. Polyphasic approach of studying microbial community by C source utilization profiling and soil enzyme activity measurement was employed in this study to compare desert and costal ecosystems. Functional diversity was studied by CLPP method using Ecoplate®. Six different soil enzyme activities were investigated. In some samples protease, urease and L-asparaginase activity were not detected at all. β-glucosidase and L-asparaginase showed significant positive correlation with all functional diversity indices, most of the microbial groups and temperature while negatively correlated with moisture and pH respectively. Alkaline phosphatase activity negatively correlated with temperature. PCA analysis based on enzyme activity showed that samples were grouped together geographically or according to the source of origin.

Keywords: Coastal and desert soil; Community Level Physiological Profiling (CLPP); Soil enzyme activity; Principle Component Analysis (PCA)

Introduction

Soil is fundamental and irreplaceable; it governs plant productivity of terrestrial ecosystems and it maintains biogeochemical cycles [1]. Members of all trophic levels in ecosystem depend on the soil as a source of nutrients and also depend on soil organisms to release and recycle key nutrient elements by decomposing organic residue [2]. Soil is a structured, heterogeneous and discontinuous system with microorganisms living in discrete microhabitats. Composition and activity of such habitat depends on soil texture, concentrations of various salts, moisture, pH and temperature of soil. Out of various categories of soil, desert and costal ecosystems are comparable in their salinity but they differ significantly in various other factors. Microbiota of soil plays critical role in the maintenance of soil health and quality by secreting important enzymes like, degradative enzymes, which even function after being released by the cell. Such microorganisms are involved in important soil ecological functions like nutrient cycling and environmental detoxification. Each species...
displays variety of morphological, physiological, and behavioural traits, many of which might influence the abundance of species and ecosystem functioning [3].

Such enormous number of organisms requires set of specific techniques to evaluate them. Studying diversity at the ecosystem level is important to understand range of processes and complexity of interactions. To reveal such complex interdependent system of microbial flora and their function, culture dependent and independent methods like, FISH, qPCR, DGGE and CLPP have been developed. Community Level Physiological Profiling has been widely used for characterizing various ecosystems like water, wastewater, various soil types and even biofilms. The contribution of microorganism in such system indirectly also is determined in terms of quantitative measurements of soil enzyme activity.

Enzyme activities are essential for energy transformation and nutrient cycling [2]. From an ecological perspective, extracellular enzymes are the mediators of decomposition, dissolved organic carbon(C) production, as well as nitrogen (N), and phosphorous (P) mineralization. According to location of the enzymes, they may be (1) Intracellular enzymes, (2)Periplasmic enzymes, (3)Enzymes attached to outer surface of cell membranes, (4) Enzymes released during cell growth and division, (5) Enzymes within non proliferating cells (spores, cysts, seeds, endospores), (6) Enzymes attaches to dead cells and cell debris, (7) Enzymes leaking from intact cells or released from lysed cells, (8) Enzymes temporarily associated in E-S complex and (10) Enzymes adsorbed to surfaces of clay minerals. Extracellular enzymes are the proximate agents of organic matter transformation in soils, however all of the above mentioned are important for normal functioning of ecological niche. Due to the effects of external disturbances on their activity, enzymes can serve as sensitive indicators of soil quality [4]. Soil enzyme activities have been related to soil physico-chemical characters, microbial community structure, vegetation, disturbance and succession.

Earlier studies have shown use of substrate utilisation profiles and enzyme activities along with the culture methods of functional groups of organisms as a Polyphasic approach to be useful for characterising coastal microbial communities [5]. Hence this study was undertaken to understand the functional diversity and their correlation with all functionally relevant enzyme activities in salt affected ecosystems. In India, state of Gujarat has the longest coastal belt of the country. Here coastal areas where salinity is contributed by sea water and inland desert areas where inherent salinity is present were expected to have similar microbial activities. Soil enzyme activities are considered as a measure of soil functional diversity, and are contributed by both the types of microbes, culturable as well as uncultivable. Hence, this study is focused on the objective of determining any correlation between the enzyme activities of various salt affected lands of the state with functional diversity determined using community level physiological profiling. Among the different enzymes involved in nutrient cycling, β-glucosidase, protease, urease, cellulase, L-asparaginase and phosphomonoesterase and dehydrogenase were studied [6].

Materials and Methods

Composite soil samples were collected from various coastal and desert regions of Gujarat (Table 1). Samples were stored at lower temperatures until they were processed for various physico chemical and microbial analysis. Table 1 enlists the sites of sampling and codes used here.

Determination of abiotic parameters

Various physico-chemical parameters like pH, temperature, moisture, water holding capacity, salinity, chloride, conductivity, organic carbon and total nitrogen were determined from soil and sediment samples [1,7,8].

Community level physiological profiling

Ecoplates® (Biolog® Inc., Hayward, California) containing 31 different C substrates in triplicates were inoculated with 100 µl of...
appropriately diluted soil suspensions [9]. Plates were incubated at 30 ± 2°C. Thirty one environmentally important substrates (Carbohydrates (10), Carboxylic and acetic acid (9), Amino Acids (6), Polymer (4) and Amine/ amides (2)) were analysed for their usability by microbial communities present in the whole soil samples. The dye tetrazolium in wells was reduced to produce violet colour due to microbial degradative activity and colour intensity was measured spectrophotometrically at regular time intervals in a microplate reader (Bio-Rad Laboratories Inc., Elisa Plate reader Model no. 680, Japan) [10].

Various diversity indices values were calculated using collected data of average well colour development and following formula [11].

\[ D_{\text{Shannon}} = H' = \sum_{i} (P_i \times \ln(P_i)) \]

Where,

\[ P_i = \frac{n_i}{n} \]

\[ S = \text{Number of species or Number of carbon substrates used in Ecoplate®} \]

\[ n_i = \text{Number of individuals of each species or Response of each C source utilization in CLPP} \]

\[ n = \text{Number of individuals in all species or sum of responses in all the wells or C substrates} \]

\[ H' = \text{Shannon diversity index} \]

The Margalef (1958) equation is based on the assumption that a relationship exists between S and n, total number of individual.

\[ R_{\text{Margalef}} = \frac{S-1}{\ln(n)} \]

Where,

\[ S = \text{Number of species present or Number of C sources utilized} \]

\[ n = \text{Number of individuals in all species or Sum of response of all the wells containing C sources} \]

The other component of species diversity indices is species evenness, which indicates the distribution of the individuals within species designations. This index group includes species abundances in its calculation. The evenness index that is most widely used is the ratio of the Shannon index [11,12]. Out of various described evenness values, \( E_{\text{Pielou}} \) was calculated using following formula,

\[ E_{\text{Pielou}} = \frac{H'}{\ln(S)} \]

Where,

\[ H' = \text{Shannon-Wiener diversity value} \]
\[ S = \text{Number of species present or Number of Carbon source utilized} \]

Quantitative measurement of various enzyme activities

Various enzymes having important functional roles in ecosystem can be categorised according to biogeochemical cycles they contribute to [6].

![Figure 2: Protease activity of coastal and desert samples.](image)

![Figure 3: β-Glucosidase activity of coastal and desert samples.](image)

**Table 2: Physico-chemical characteristics of soil and sediment samples.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Temperature (°C)</th>
<th>Moisture (%)</th>
<th>Water holding capacity (%)</th>
<th>Conductivity (µS)</th>
<th>Salinity (%)</th>
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<td>24</td>
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</table>

Enzymes involved in Nitrogen cycling

(i) Urease and L-asparaginase activity

For estimation of urease and L-asparaginase activity, before proceeding for actual procedure, 5 g soil was treated with 0.2 ml toluene and 9 ml of Tris buffer (50 mM, pH 9), the content was mixed properly. Treated soil samples were added with 1 ml urea or 1 ml 0.5 M L-asparagine solution and incubated for few seconds. After the incubation of 2 hour at 37°C, approximately 35 ml of KCl-Ag$_2$SO$_4$ (100 mg l$^{-1}$) solution was added. Content was brought up to 50 ml by addition of KCl-Ag$_2$SO$_4$ solution and it was mixed thoroughly. The resulting solution was used to estimate released ammonia using methods described by Bremner and Keeney (1966). Calibration curve was prepared using standard ammonia solution (50 μg NH$_4$-N ml$^{-1}$)

\[
\text{Urease activity (μg NH}_4\text{-N g}^{-1}\text{dwt 2h}^{-1}) = \frac{C \times 15}{\text{dwt}}
\]

Where,

\[
C = \text{measured NH}_4\text{-N concentration (μg NH}_4\text{-N ml}^{-1}\text{ soil suspension)}
\]

\[
\text{dwt} = \text{dry weight of 1 g moist soil}
\]

(ii) Protease activity

It was performed using methods described by Ladd and Butler (1972). One gram of moist, sieved soil (2mm) was placed in a test tube, and 5 ml of Tris buffer (50 mM pH 8.1) and 5 ml of sodium caseinate solution (2%) were added to it. Contents were mixed and incubated for 2 h at 50 °C on a water bath. Five ml of TCA solution (15%) was added and mixed thoroughly. The resulting soil suspension was centrifuged at 12,000 rpm for 10 min. Five ml of the clear supernatant was mixed with 7.5 ml of the alkaline reagent and incubated for 15 min at room temperature. After addition of 5 ml of the Folin reagent, mixture was filtered through Whatman filter. Absorbance was measured after 1 h of incubation at 700 nm. Calibration curve was prepared using standard tyrosine solution 500 μg ml$^{-1}$. The measured absorbance was corrected for the controls and was calculated as follows,

\[
\text{Protease activity (μg tyrosine g}^{-1}\text{dwt 2h}^{-1}) = \frac{C \times 15}{\text{dwt}}
\]

Where,

\[
C = \text{measured tyrosine concentration (μg ml}^{-1}\text{supernatant)}
\]

\[
\text{dwt} = \text{dry weight of the 1 g of moist soil}
\]

Enzymes involved in Phosphorous cycling

(iii) Phosphomonoesterase has been reported to be involved in hydrolysis of organic phosphonooester to inorganic phosphorous and makes it available for plants. Activity of this enzyme was determined by Tabatabai and Bremner (1969). One gram of moist, soil

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total activity (n)</th>
<th>H’ Shannon</th>
<th>S</th>
<th>E’Pielou</th>
<th>R’Margale</th>
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<td>8</td>
<td>0.936</td>
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</table>
Activity of β-glucosidase was measured using 1 g of moist sieved soil treated with 0.25 ml of toluene and 4 ml of MUB solution. 1 ml of p-nitrophenol β-glucoside (PNG) (25 mM) was allowed to react with soil and mixture was incubated for 1 h at 37°C. After the incubation, 1 ml of CaCl₂ solution (0.5 M) and 4 ml of TRIS buffer (0.1 M, pH 10) were added, the flask was swirled and soil suspension was filtered immediately. Colour intensity was measured at 400 nm using UV-Visible spectrophotometer [16,17]. Calibration curve was prepared using standard p-nitrophenol solution (25 mM). The result was corrected for the blank and was calculated according to the following relationship:

\[
p\text{- nitrophenol (μg g}^{-1}\text{dwt h}^{-1}) = \frac{C \times v}{dwt \times SW \times t}
\]

Where,
- \(C\) = measured phenol concentration (μg phenol ml\(^{-1}\) filtrate)
- \(dwt\) = dry weight of 1 g of moist soil
- \(t\) = incubation period
- \(SW\) = Weight of soil sample

(vi) Cellulase activity

For cellulase activity, 1 g of moist soil was treated with 5 ml of acetate buffer (0.1 M) and 0.5 g of Avicel were added. Tubes were incubated for 16 h at 40°C in shaking conditions. Reaction was stopped by centrifugation (2500 g, 10 min.). One ml of supernatant was added with 1 ml of Copper reagent and were kept in a boiling water bath for 20 min. After cooling 1 ml of diluted Arsenate-molybdate solution was added and mixed thoroughly. The mixture was diluted with 3 ml of distilled water and optical density was measured at 520 nm. Calibration curve was prepared using glucose monohydrate solution (28 μg ml\(^{-1}\)). Following formula was used to determine activity.

\[
\text{Glucose (μg g}^{-1}\text{dwt 16 h}^{-1}) = \frac{C \times v}{dwt}
\]

Where,
- \(C\) = measured glucose concentration (μg ml\(^{-1}\) supernatant)
- \(v\) = volume of the soil suspension (5.5 ml)
- \(dwt\) = dry weight of 1 g of moist soil

Dehydrogenase activity

(vi) Dehydrogenase activity

It was performed by methods described by Thalmann [18]. Five gram of moist soil was treated with 5 ml of Triphenyltetrazolium chloride (TTC) solution. 1 g of moist soil was treated with 5 ml of TTC solution (0.1%) and 5 ml of distilled water was added. Tubes were incubated for 1 h in shaking conditions. Reaction was stopped by centrifugation (2500 g, 10 min.). One ml of supernatant was added with 1 ml of Copper reagent and were kept in a boiling water bath for 20 min. After cooling 1 ml of diluted Arsenate-molybdate solution was added and mixed thoroughly. The mixture was diluted with 3 ml of distilled water and optical density was measured at 520 nm. Calibration curve was prepared using glucose monohydrate solution (28 μg ml\(^{-1}\)). Following formula was used to determine activity.

\[
\text{Glucose (μg g}^{-1}\text{dwt 16 h}^{-1}) = \frac{C \times v}{dwt}
\]

Where,
- \(C\) = measured glucose concentration (μg ml\(^{-1}\) supernatant)
- \(v\) = volume of the soil suspension (5.5 ml)
- \(dwt\) = dry weight of 1 g of moist soil

Table 4: Correlation of diversity indices with abiotic parameters.

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Diversity indices</th>
<th>Positive Correlation</th>
<th>Negative Correlation</th>
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<td></td>
<td>Factor</td>
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<td>Factor</td>
</tr>
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<td>1</td>
<td>H</td>
<td>Temperature (0.604)**</td>
<td>Moisture (0.456)*</td>
</tr>
<tr>
<td>2</td>
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<td>Moisture (0.563)**</td>
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<td>3</td>
<td>S</td>
<td>Temperature (0.604)**</td>
<td>Moisture (0.563)**</td>
</tr>
</tbody>
</table>

Note: **: Correlation is significant at the P<0.05 (2-tailed); *: Correlation is significant at the P<0.01 (2-tailed); H = Shannon diversity, R = Richness, S = Substrate Richness
The electrical conductivity (EC) in various soil samples of coastal and desert regions of Gujarat ranged between 56-4750 mS/cm. Temperature was found below 30 °C and was highest in Dhordo White Rann (41750 mS/cm) and lowest was found in Bhuj near shrub sample (56.5 mS/cm).

Overall moisture content was found to be high by varying in the range of 3-24%. The moisture content of the soil causes the soil to compact. Studies had shown that the compact soil had significantly lower biomass C (38% decrease) and lower enzyme activities (decrease in range from 41-75%) than the un-compact soil [21-23].

Microbial diversity analysis

Functional Diversity based on CLPP was first analysed by comparing AWCD (Average Well Colour Development) patterns displayed by all samples along the incubation time till 137 h (data not presented) and based on that, for calculation of diversity indices, the data of 98 h was selected. The C-source utilization by microbial communities of coastal soils was very poor as only two to three substrates were utilized by these communities, whereas among the desert soils maximum 11 substrates out of 31 were utilized by Bhuj samples.

The total activity and AWCD was obtained in the following decreasing order, BNS > KNS > DPC > MC >DNS> PC > AC > DC > OC > VC (data of AWCD not shown). Higher total activity (n), richness and H, indices indicates a greater rate of substrate utilization (catabolic potential) by the microbial community and greater functional diversity [24], however low total activity (n), substrate richness (S), diversity (H’) was observed in coastal and desert samples (Table 3). Highest H’ value was obtained in soil samples of Bhuj and lowest was obtained in Dhordo near shrub sample.

Table 4 presents the ‘r’ values for significant correlation between diversity indices and abiotic parameters. Pearson’s correlation were calculated between diversity indices and abiotic parameters and only significant correlation values are presented. The coastal samples were having low richness as compared to desert samples, but microbial community present were able to utilize more C sources.

Diversity indices showed significant positive correlation with temperature and negative correlation with moisture. i.e. as temperature increases, H’, richness and substrate utilized (S) also increase while as moisture increases H’ and substrate utilized (S) decrease due to increased compactness of the soil.

**Enzyme Activity**

**Nitrogen cycle enzymes**

Nitrogen cycling is one of the most important nutrient cycles of the ecosystem. Soil becomes one of the largest return site of nitrogen due to tremendous involvement of nitrifiers and denitrifiers. Before functions of such autotrophs come in picture, there is cascade of enzyme functioning e.g. urease, asparaginase, protease etc.

(i) **Urease Activity**

Among various soil enzymes, urease (urea amidohydrolase, EC 3.5.1.5) is closely associated with the transformation, biological turnover and bioavailability of nitrogen and is a key enzyme [25,26]. Since the relationship between increased salinity (or/and sodicity) and reduced urease activity appears to be highly predictable, it may be used as indicator of soil quality [27].

However, coastal soil urease activity was falling in the range of 0-5457 µg NH₄-N g⁻¹ dwt (Figure 1) which was found to be higher in some cases than desert region. Highest activity was observed in Okha sediment and lowest in Daman polluted sediment. In Mandvi, Veraval coast, and Daman coast soil samples urease activity was not detected at all. In desert samples urease activity was found in the range of 0-758 µg NH₄-N g⁻¹ dwt 2h⁻¹.

Less enzyme secretion in most of desert soil may be explained by the high salinity/sodicity of the soil. In addition, urease is extracellular, stable and form complexes with the organic and mineral colloids [28,29], while salinity may induce degradation in arid or semiarid soils.

(ii) **L-Asparaginase Activity**

In general, L-Asparaginase activity was found to be quite high in all samples except Okha and Porbandar samples where it was not detected (Figure 2). In coastal samples, L-asparaginase activity found was in the range of 300-1040 µg NH₄-N g⁻¹ dwt 2h⁻¹. Highest activity was observed in Veraval coast and lowest in Daman polluted sediment. In desert samples L-asparaginase activity was not detected at all. L-Asparaginase activity was found in the range of 345-1200 µg NH₄-N g⁻¹ dwt 2h⁻¹.

Less enzyme secretion in most of desert soil may be explained by the high salinity/sodicity of the soil. In addition, urease is extracellular, stable and form complexes with the organic and mineral colloids [28,29], while salinity may induce degradation in arid or semiarid soils.

(iii) **Protease Activity**

Daman, Mandvi and Porbandar among coastal samples had very low protease activity while desert samples showed average activity (Figure 2). All the samples showed protease activity except Mandvi sediment.

In coastal soil samples, protease activity was found in the range of 0-23 µg tyrosine g⁻¹ dwt 2h⁻¹. In desert samples protease activity was found in the range of 0.4-16 µg tyrosine g⁻¹ dwt 2h⁻¹. Highest was observed in Bhuj near shrub and lowest in Khavda near shrub.

**Carbon cycle enzymes**

(i) **β-Glucosidase Activity**

The order of average β-glucosidase in costal soil was, MC> AC> OS> AS> OC> VC> PS> DS> DPS> VS> PC> DC (Figure 3). Analysis showed that activity in soil collected from coast of Daman region was significantly lower than other samples (Activity being 0.50 µg g⁻¹ dwt h⁻¹). In desert samples, β-glucosidase activity was found in the range of 4.8-300 (µg g⁻¹ dwt h⁻¹). Highest activity was observed in Bhuj samples and lowest in Dhordo virgin soil sample. The specific activity of β-glucosidase has been correlated with monounsaturated fatty acids, typical of Gram-negative bacteria [30].

The differences in the sources of substrate availability and composition may lead to the changed behaviours of the activity of hydrolytic enzymes, such as phosphomonoesterase, urease and β-glucosidase in soils. Soil organic carbon (SOC) and microbial biomass have been reported to be negatively correlated in case of wasteland soil ecosystem and β-glucosidase activity [31].

(ii) **Cellulase activity**

Cellulase activity was detected in all the coastal and desert samples analyzed (Figure 4). In coastal samples, cellulase activity was found in the range of 1-72 (µg g⁻¹ dwt 16 h⁻¹). Highest activity was observed in OS (Okha sediment) and lowest in OC (Okha coast). In desert samples, cellulase activity was found in the range of 7-44 (µg g⁻¹ dwt 16 h⁻¹).

Highest activity was observed in Khavda soil near shrub (KNS) and lowest in virgin soil of Bhuj. This may be due to the positive effect of plant organic matter present in soil near shrub. In general, coastal soils displayed higher cellulase activity as compared to desert samples. In a field study conducted in the Negev Desert over three seasons, concentration of cellulase in the soil was determined by monitoring the rate of solubilization of chromophoric molecules covalently linked to artificial insoluble cellulose (cellulose-azure). It was observed that, when cellulose of plant or paper origin was added to the study soils it was influenced by the cellulase source. It was also markedly affected by seasonal changes over the year [32].

**P cycle enzymes**

**Phosphomonoesterase Activity**

In coastal soil, alkaline phosphatase activity was found in the range of 88-443 p-nitrophenol µg g⁻¹ dwt h⁻¹ (Figure 5).

All the samples tested from various region displayed Phosphomonoesterase activity. Highest activity was observed in Veraval sediment and lowest in Daman sediment. As reported by Dick et. al.[21], low alkaline phosphatase activity was observed in desert samples as compared to acid phosphatase activity as the soil salinity inhibited the enzyme activity of alkaline phosphatase.

**Dehydrogenase Activity**

Dehydrogenase activity in soil has been used as a measure for overall microbial activity. Estimation of dehydrogenase activity
in all coastal and desert soil samples indicates the presence of microorganisms active in metabolism. Figure 6 displays the results of dehydrogenase activity of samples.

In coastal soil samples, dehydrogenase activity was found in the range of 1-121 µg Triphenylformazan (TPF) /dwt (g), where as in desert soil samples, dehydrogenase activity was found in the range of 3-31 TPF (µg)/dwt (g). Highest activity was observed in soil sample of Bhuj region collected around shrimp and lowest activity was observed in Khavda soil sample unaffected by manual disturbances as well as having no plant growth.

Microorganisms growing under water-logged conditions have been shown to have lower TTC dehydrogenase activity [33]. However, only in Mandvi and Okha sediment soil, lower dehydrogenase activity than in coastal soil sample was observed. Studies have shown that dehydrogenase activity can be severely inhibited by salinity [34], hence it was assumed that dehydrogenase activity was low due to inhibition by high salinity.

**Principal Component Analysis of various enzyme activity**

Enzyme activities of all the samples were analysed using Principal Component Analysis (SPSS, ver. 17.0). Principle component analysis of enzyme activity data of coastal and desert samples is presented in Figure 7. On the basis of enzyme activity, soil samples were found to cluster together in 8 different groups according to regions except OS (Okha sediment). Coastal and sediment soil samples were grouped together while virgin and near shrub soil of desert samples were grouped together, except for Bhuj samples which formed a different cluster (as shown in blue colour).

Here total 3 principal components were extracted. The variance explained by PC1 was 25.44%, PC 2 was 19.18% and PC3 explained 16.02% variance present in the data.

The correlation coefficient values were calculated from enzyme activity data and various abiotic factors, where temperature was observed to be important factor affecting enzyme activity (Table 5). Pearsons’ correlation values were calculated between enzyme activity and abiotic parameters for analysis of positive and negative impact of abiotic factors on enzyme functioning.

Enzyme activities of β-glucosidase and L-Asparaginase showed a significant positive correlation with temperature i.e. activity of these enzyme increases with the increase in temperature while they showed negative correlation with pH and moisture respectively i.e. activity of β-glucosidase decreases with increase in pH and activity of L-Asparaginase decreases with increase in moisture. Moisture was seen to affect microbial activity and enzyme activity and a significant negative correlation was observed in Pearsons’ bivariate correlation analysis. Alkaline phosphatase showed negative correlation with temperature and acid phosphatase showed positive correlation with water holding capacity. Other enzyme activities didn’t show any significant correlation with abiotic parameters.

Diversity indices showed positive correlation with most of the microbial groups (data not shown). When the enzyme activities were correlated with functional diversity indices values, significant positive correlation was found only for two enzyme assays (Table 6). Pearsons’ correlation coefficient values between functional diversity indices and soil enzyme activity were analysed and only significant correlation coefficient values are presented.

Diversity indices showed significant positive correlation with β-glucosidase and L-Asparaginase. When enzyme activities were correlated with quantitative values of diversity indices, very high significant correlation values (r>0.8) were observed. Such high values were not obtained in other cases. Hence it can be concluded that functional diversity deduced by CLPP could be correlated with the soil enzyme activity and can give insight of ecosystems having functionally active microbial systems.

**Conclusion**

Combination of two approaches, CLPP and enzyme activity quantification proved to be good tool to analyse functional microbial diversity of coastal and desert regions of the state. One of the major observations of the study indicates that although being almost near in salinity values, samples differed a lot in the functionality of the microbial flora. Abiotic factors as reported have definite correlation with enzyme activity and diversity indices. Looking to the values of diversity indices, microbial diversity was found to be low due to effect of salinity of soil. However enzyme activity and diversity indices could be correlated very well, indicating strong influence of microbial presence on nutrient cycling of such versatile ecosystem. Further analysis of community structure may help in dissecting the interactions and identification of the type of microbes but CLPP and soil enzyme activity study hold the importance for evaluation of functions of salinity affected soil systems.

**References**


