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Microbial dynamics in rhizosphere of fruit plants during summer and monsoon in arid environment

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ABSTRACT

The aim of this study was to assess the comparative efficacy of summer and monsoon season on the rhizospheric microbial population (actinomycetes, bacteria, fungi) and various soil enzymatic activities (acid and alkaline phosphatases, dehydrogenase and phytase) in three horticultural plant species of arid region. In general, microbial population, enzymatic activities and microbial biomass carbon (MBC) were higher in rhizosphere as compared to non rhizosphere soil. Monsoon season represents optimum conditions for proliferation of microbial population and thereby, increase in various enzymatic activities, which in turn was responsible for mobilization of unavailable nutrients for plants. During monsoon season rhizosphere soil of *Z. mauritiana* maintain 7.3% more moisture followed by *E. officinalis* (7.1%) and *P. dactylifera* (4.8%) as compared to non-rhizosphere soil. In general, an overall increase in acid phosphatase (65%), alkaline phosphatase (25%), phytase (30%), dehydrogenase (24%) and MBC (21%) was reported in rhizosphere as compared to non-rhizosphere soil.

Key words: Microbial dynamics, microbial biomass carbon, soil enzymes.

INTRODUCTION

High temperature combined with low relative humidity during summer result in severe desiccation of surface soil layers in arid regions and has an adverse effect on the survival and proliferation of soil microorganisms and leads to loss of microbial diversity. Seasonal variations in the enzyme activities of soil (Dormaar *et al*., 2) are biologically important because they change the quantity and quality of substrates upon which they act and are responsible for altering the rate of various soil processes. Production of horticultural crops has undergone significant changes in recent years due to development of innovative technologies including integrated nutrient management practices involving biofertilizers, which include bacteria and fungi. An attempt has been made to study the decline in microbial populations in summer and the extent of rebound if any during monsoon (rainy) season in arid regions, with an objective to have sustainable management of important fruit plants in arid environment.

MATERIALS AND METHODS

The study was conducted at Horticulture Farm, Central Arid Zone Research Institute, Jodhpur located at 26°18′N latitude and 73°01′E longitude. The farm soil is loamy sand (hyperthermic typic haplocamborthid, USDA classification) with pH (8.1), EC (0.23 dSm^{-1}), organic matter (0.34 %), total N (310 mg kg^{-1}), total P (710 mg kg^{-1}), available P (4.2 mg kg^{-1}.), mineral P (475 mg kg^{-1}), organic P (235 mg kg^{-1}), and phytin P (158 mg kg^{-1}). Data for rainfall received during the study period were collected from monsoon observatory, CAZRI, Jodhpur.

Three fruit plant species namely datepalm (*Phoenix dactylifera* L.), Indian gooseberry commonly known as *aonla* (*Emblica officinalis* Gaertn.) and *ber* (*Ziziphus mauritiana* L.) were selected for the study. The plant species were varying in age from 10-15 years. Rhizosphere soil samples 45 cm away and (0-45 cm deep) from main stem were drawn from three different plants grow at different locations, thus three replicate samples were analyzed for each attribute. The non rhizosphere soil samples were collected away from the beneath of the plant canopy with same depth as rhizosphere. For each sample one part was air dried and grounded to pass through a 2 mm sieve and used for physico-chemical analysis whereas another was stored immediately after sampling at 4 ± 1°C and used for enzyme and microbial analysis.

The physical and chemical analysis of the soil was determined as described by Singh *et al.* (11). Total P, mineral P and organic P of the soil were determined as described by Jackson (5). The phytin P was estimated by extraction of phytate with 15% CCl_3-COOH (trichloro-acetic acid) as described by Mega (7). Total actinomycetes, bacteria and fungal population was counted by serial dilution method using Ken-night, Thorton's and Rose-Bengal agar medium for actinomycetes, bacteria and fungi, respectively.

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Acid and Alkaline phosphatase activity was assayed by adopting the standard method of Tabatabai and Bremnar (13) using acetate buffer (pH 5.4) and sodium tetra borate-NaOH buffer (pH 9.4), respectively. The enzyme activity was expressed as enzyme unit (EU). One unit is the amount of enzyme, which hydrolyses 1.0 μmol of p-nitropheneyl phosphate sec^{-1}at pH 5.4 (acid phosphatase) or 9.4 (alkaline phosphatase) at 35°C. Phytase activity was assayed by measuring inorganic phosphate (Pi) hydrolyzed from sodium phytate in acetate buffer (pH 4.5) incubating at 37°C for 1 h (Ames, 1). Dehydrogenase activity, a measure of total microbial activity was assayed by the method of Tabatabai as described by Singh *et al.* (11). The soil samples were incubated with 2,3,5-triphenyl tetrazolium chloride (TTC), and triphenyl formazan (TPF) produced was determined spectrophotomitrically at 485 nm. The dehydrogenase activity was reported as p kat g^{-1} soil. One p kat is the 1.0 μmol TPF produced sec^{-1}.

Microbial biomass carbon (MBC) was determined using the chloroform fumigation-extraction method (Vance *et al.*, 16). A factor of K_{EC}= 0.45 (Joergensen, 6) was used to convert the C content to MBC and reported as mg kg^{-1}. The data were subjected to analysis of variance and LSD test was carried out. The means were compared using standard errors of the mean (Sokal and Rohlf, 12).

RESULTS AND DISCUSSION

Weekly climatic characteristics of the experimental site during June to September are presented in Fig. 1. The total rainfall received during the study period was 250 mm. The maximum rainfall was received during 9th week (27th July to 2nd August) followed by 5th week (29th June to 5th July) of study periods. There was no precipitation received during 1st, 3rd, 8th, 11th to 14th and 17th weeks of study periods.

The maximum temperature varies between 33 to 43°C, while minimum temperature varies 24 to 30°C (Fig. 1). A decrease with the onset of rain and increase intermittently with offset of the rain was observed in both maximum and minimum temperature.

Fig. 1 represents low relative humidity prevails during the month of June. Humidity builds up sharply during July and August when monsoon current brings in high amount of water vapours. The relative humidity drops sharply during September due to the low rainfall. The moisture content of rhizosphere and non-rhizosphere soil (0-45 cm) was less than 1% under the entire study area during the peak summer (Fig. 2). It was also observed that *Z. mauritiana* rhizosphere maintain 7.3% more moisture than non-rhizosphere soil followed by *E. officinalis* (7.1%) and *P. dactylifera* (4.8%). Maximum moisture in rhizosphere and non-rhizosphere soils were observed during the month of July in all the three plant species. Soil water availability depended on the rainfall received, particularly during the monsoon season. The relatively high soil water in July compared to other months occurred because regular and high rainfall during this period enhanced soil water availability. The presence of plants may influence the soil moisture through the accumulation and retention of soil water, reduced evaporation, and lowers the temperature.

The microbial population was higher in the rhizosphere as compared to non-rhizosphere soils of all the three plant species (Fig. 3). There was no significant (p = 0.05, n = 36) difference in microbial population within plants. Bacteria were the most dominant organisms at all the sites, followed by actinomycetes and fungi. Bacterial, actinomycetes and fungal population ranged from 139 to 221, 83 to 166 and 20 to 49 × 10^5 c.f.u. g^{-1} dry soil respectively under rhizosphere soils of selected plant species, whereas it varies between 120 to 194 × 10^5 g^{-1} dry soil (for bacteria), 66 to 118 × 10^5 g^{-1} dry soil (for actinomycetes) and 12 to 36 × 10^5 g^{-1} dry soil (for fungi) under non-rhizosphere soils. In general, over all increase of 25 to 62% in bacteria, 10 to 80% in actinomycetes and 40 to 192% in fungi population was noted during monsoon season under non rhizosphere; however 16 to 57% in bacteria, 20 to 99% in actinomycetes and 18 to 145% in fungi population increased under rhizosphere. Higher microbial population in rhizosphere soil can be related to better soil condition in terms of nutrients.

Table 1. Correlation coefficient values of soil moisture and microbial groups under different fruit plants.

Soil moisture		Actinomycetes	Bacteria	Fungi
Phoenix dactylifera L.	NR	0.19*	0.17*	0.29**
	R	0.19*	0.18*	0.17*
Emblica officinalis Gaertn.	NR	0.19*	0.17*	0.29**
	R	0.20*	0.16*	0.20*
Ziziphus mauritiana Lam.	NR	0.09*	0.21**	0.33**
	R	0.17*	0.13*	0.18*

NR = Non-rhizosphere; R = Rhizosphere; *,**Significant at 5 and 1%, respectively.

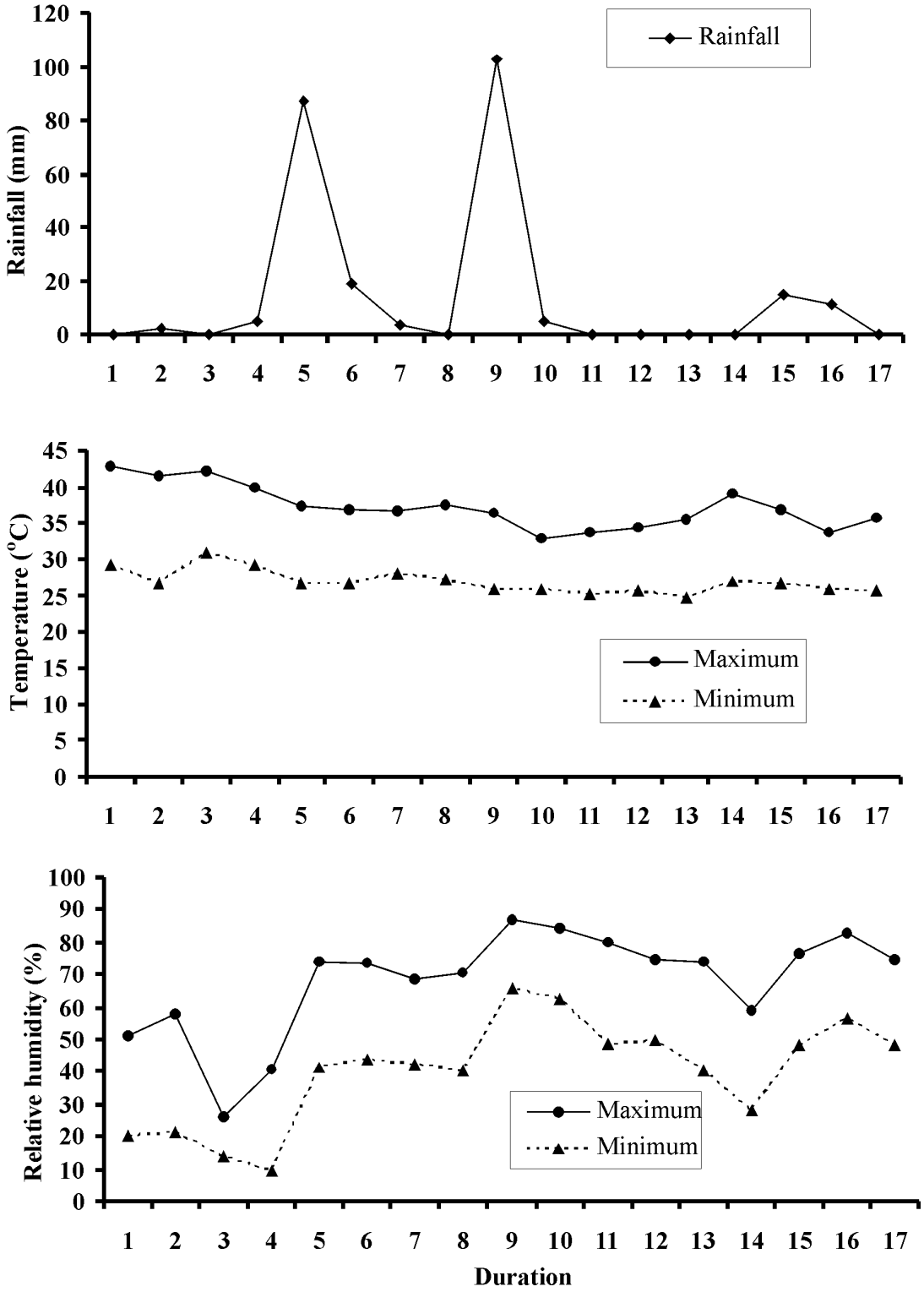

Fig. 1. Weekly distribution of climatic conditions of the study site in arid ecosystem.
(1) 1st June - 7th June (2) 8th June - 14th June (3) 15th June - 21st June (4) 22nd June - 28th June (5) 29th June - 5th July (6) 6th July - 12th July (7) 13th July - 19th July (8) 20th July - 26th July (9) 27th July - 2nd Aug (10) 3rd Aug - 9th Aug (11) 10th Aug - 16th Aug (12) 17th Aug - 23rd Aug (13) 24 th Aug - 30th Aug (14) 31st Aug - 6th Sep (15) 7th Sep - 13th Sep(16) 14th Sep - 20th Sep (17) 21st Sep - 27th Sep.

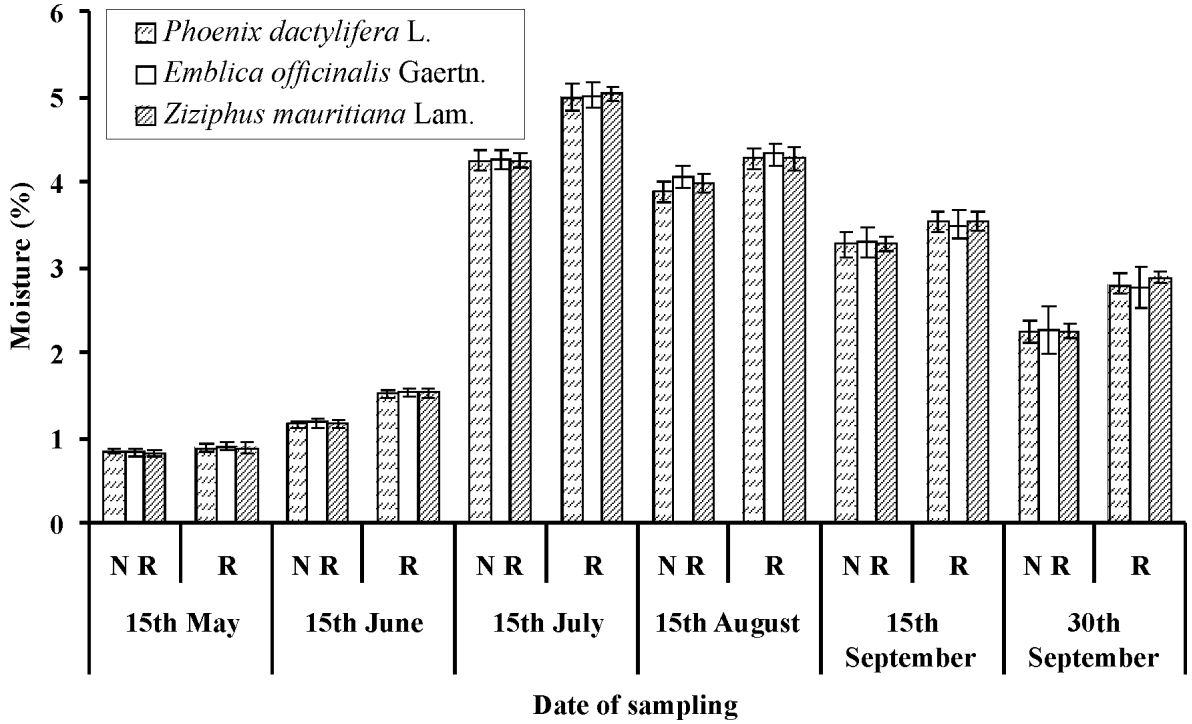

Fig. 2. Dynamics of soil moisture in non-rhizosphere (NR) and rhizosphere (R) soils of fruit plants. Vertical bars are standard errors of the mean.

Table 2. Correlation coefficient values of microbial population and enzyme activities under different fruit plants.

Total microbial population in		Acid phosphatase	Alkaline phosphatase	Phytase	Dehydrogenase
Phoeni dactylifera L.	NR	0.14*	0.10*	0.19*	0.08*
	R	0.11*	0.07*	0.12*	0.17**
Emblica officinalis Gaertn.	NR	0.11*	0.13*	0.21*	0.06*
	R	0.07*	0.19*	0.12*	0.13**
Ziziphus mauritiana Lam.	NR	0.19*	0.25**	0.19*	0.26**
	R	0.19*	0.35**	0.14*	0.31**

NR = Non-rhizosphere; R = Rhizosphere; *,**Significant at 5 and 1%, respectively.

Similar observation was made by Gogoi *et al.* (3). Increase in microbial population during monsoon season is related to the greater availability of nutrients and other favourable conditions such as moisture and diurnal soil temperature fluctuation at mesophillic range (25-30°C).

During summer season, acid phosphatase activity was reported 15% more in *P. dactylifera* and *E. officinalis* and 11% more in *Z. mauritiana* under rhizosphere soil as compared to non-rhizosphere soils. However, during monsoon season the acid phosphatase activity increased 26% (*P. dactylifera*), 23% (*E. officinalis*) 21% (*Z. mauritiana*) in acid phosphatase activity was observed in rhizosphere soils as compared to non-rhizosphere soils. In general, an overall increase in acid phosphatase activity was observed during monsoon season which was 11-14% under non-rhizosphere soils and 13-85% under rhizosphere soils as compared to summer season.

Alkaline phosphatase activity was 24% more in *P. dactylifera*, 25% more in *E. officinalis* and 27% more in *Z. mauritiana* rhizosphere as compared to non-rhizosphere.An overall increase in alkaline phosphatase activity was observed during monsoon in both rhizosphere (56-70%) and non-rhizosphere (43-45%) soils as compared to peak summer. In general, a

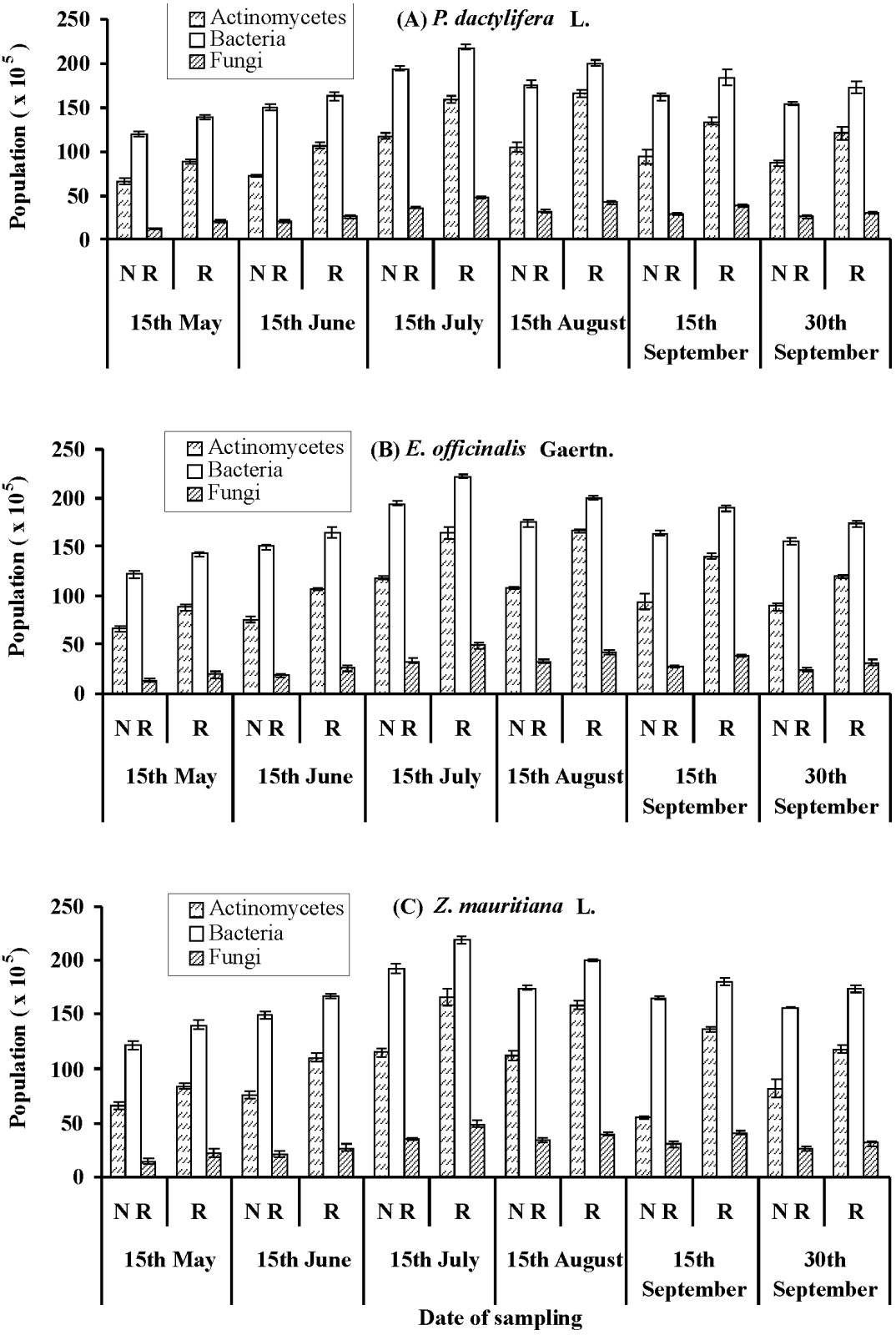

Fig. 3. Changes in microbial population with non-rhizosphere (NR) and rhizosphere(R) soils of fruit plants. Vertical bars are standard errors of the mean.

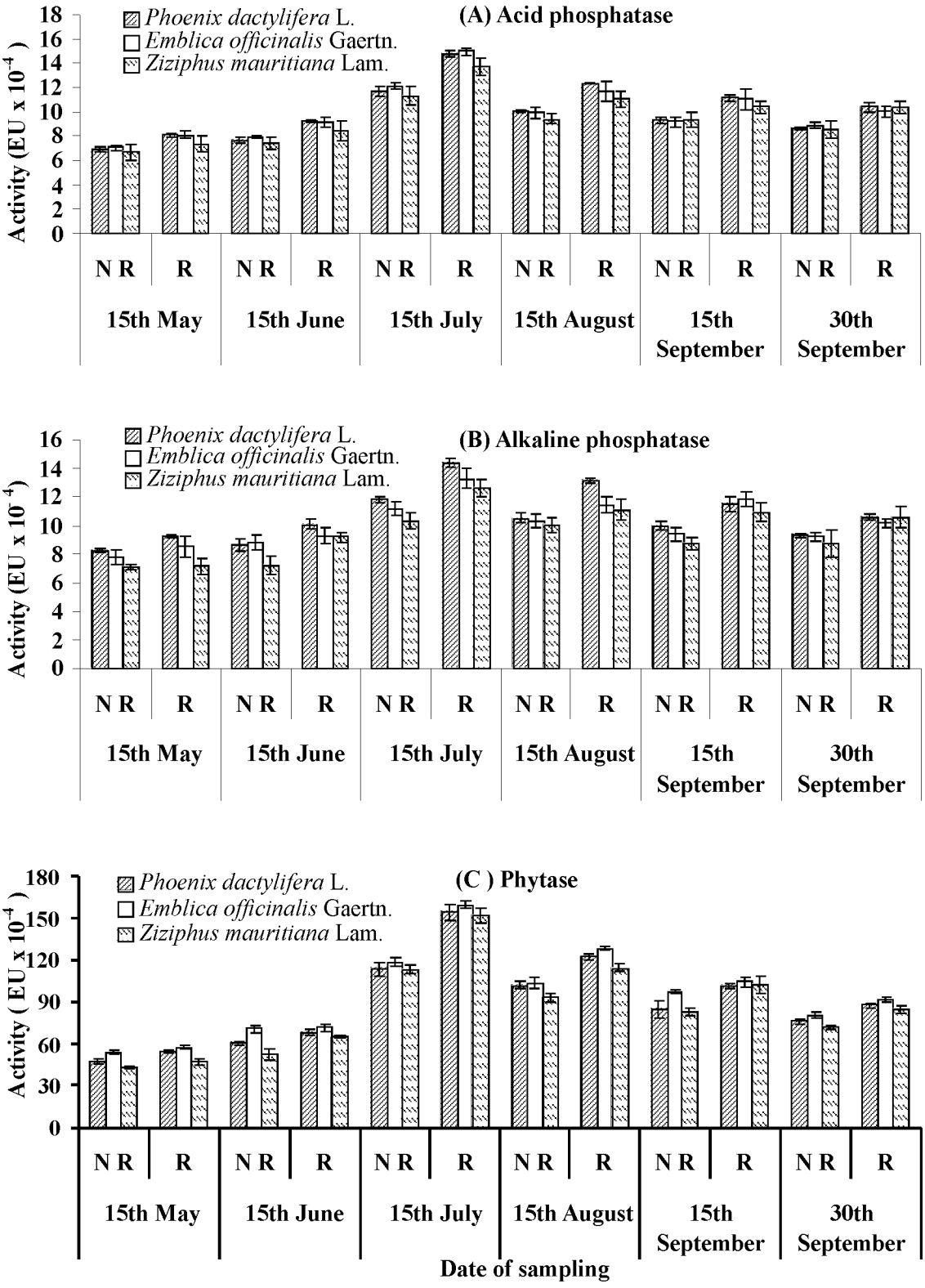

Fig. 4. Enzyme activities of non-rizosphere (NR) and rhizosphere (R) soils of fruit plants. Vertical bars are standard errors of the mean.

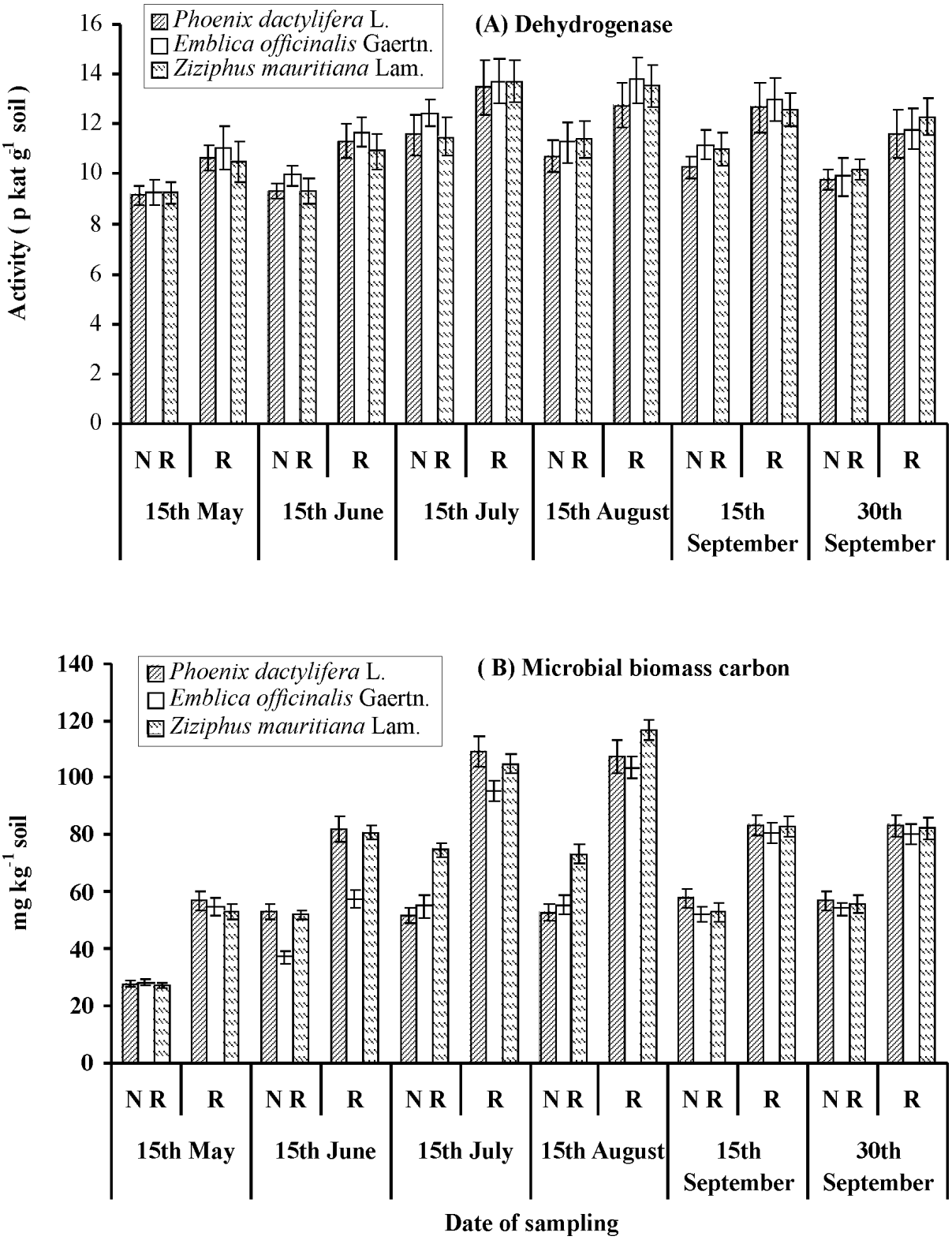

Fig. 5. Dehydrogenase activity and microbial biomass C of non-rizosphere (NR) and rhizosphere (R) soils of fruit plants. Vertical bars are standard errors of the mean.

higher phytase activity was observed during monsoon as compared to peak summer, which was 31% higher in rhizosphere and 8% higher in non-rhizosphere soils of fruit plants.

Phosphatases and phytase producing microorganisms and the root may account for the higher enzyme activities in rhizosphere (Tarafdar, 14). Panwar *et al.* (8) reported higher phosphatase activities in rhizosphere of different plant species of arid regions as compared to non-rhizosphere soil. Phosphatase and phytase activity during monsoon increase as compared to summer may be due to higher moisture content and therefore microbial population and activity (Rao and Tarafdar, 9).

Higher dehydrogenase activity (14 to 20%) was observed in rhizosphere as compared to non-rhizosphere soil during peak summer (Fig. 5). During monsoon season dehydrogenase was 24% higher in *P. dactylifera* followed by 22% higher in *E. officinalis* and 21% higher in *Z. mauritiana* rhizosphere as compared to non-rhizosphere soil. The higher dehydrogenase activity might be due to higher microbial biomass, root exudates and greater amount of carbon input in the rhizosphere soil by plants than the non-rhizosphere soil. Specific stimulation of microorganisms by root exudates has been also reported by Greaves and Wabley (4). In desert soil, higher temperature and soil drying during summer brings down the microbial population to very low levels resulting in low dehydrogenase activity. The higher dehydrogenase activity during the monsoon may be due to optimum moisture and temperature for the growth of microorganisms (Rao and Venkateswarlu, 10).

During peak summer the amount of microbial biomass carbon (MBC) was about two times higher in all the three plants rhizosphere as compared to non-rhizosphere soil (Fig. 5). Maximum increase in MBC was observed in the rhizosphere of *P. dactylifera* (2.1 fold) followed by *E. officinalis* (1.9 fold) and *Z. mauritiana* (1.6 fold) as compared to non-rhizosphere soils during monsoon season. The higher MBC during the monsoon may be due to optimum moisture and temperature for growth of microorganisms as these are key factor that affect MBC (Van *et al.*, 15).

Correlation studies between soil moisture in non-rhizosphere and rhizosphere with microbial groups are presented in Table 1. All the microbes had significantly positive correlated with soil moisture. The actinomycetes and bacterial population were statistically insignificant in both the soil (rhizosphere and non-rhizosphere), however it was significantly higher in case of fungi. Table 2 presented the correlation between microbial population and enzyme activities. All the enzymes were positively correlated with microbial population. The alkaline phosphatase and dehydrogenase activity were significantly higher in *Z. mauritiana,* while in case of *P. dactylifera* and *E. officinalis* it was highly significant in rhizosphere soil. The present study represents that monsoon season represents optimum conditions for proliferation of microbial population and thereby increase in various enzymatic activity responsible for mobilization of unavailable nutrients. In conclusion, our results shows that plant root exudates play a vital role in increasing MBC and various enzyme activities in the rhizosphere soils.

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