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Seasonal Variation in Microbial Communities in Rhizosphere and Non-Rhizosphere soil of Different Fruit Tree Species in Semiarid Irrigated Conditions of Haryana

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Abstract

The present study was undertaken to analyze seasonal variations in microbial communities in different fruit tree orchards (mango, guava, *ber*, bael, jamun, *aonla* and sweet orange) during summer, rainy and winter season of 2018-19 under semiarid irrigated ecosystem. In rhizosphere and non-rhizosphere, maximum TBC, PSB and nitrogen fixers were found in mango orchard during summer and rainy season while maximum fungal count in jamun orchard during all the seasons. Maximum actinomycete was counted in guava orchard during summer and winter while in mango during rainy season. In rhizosphere and non-rhizosphere, the total microbial count, phosphate solubilizing bacteria and nitrogen fixers were maximum in rainy season while fungal and actinomycetes count in summer season. The maximum increase in total microbial count, PSB and nitrogen fixers or diazotrophs were found in mango orchard during summer (11.61%, 7.88%, 7.67%) and rainy season (11.16%, 7.57%, 6.93%) respectively, over the control while lowest total bacterial count, phosphate solubilizing bacteria and nitrogen fixers count were observed in ber (20.03%), guava (10.25%) and sweet orange orchard (13.58%). However, maximum increase in fungal count over control was found in jamun orchard during summer (25.77%), rainy (21.83%) and winter season (33.44%). Maximum increase in actinomycetes count over control was found in guava orchard during summer (8.72%) and (9.37%) during winter season. Whereas in mango orchard during rainy (10.71%).

Keywords: Actinomycetes, bacteria, fruit orchard, fungi, phyllosphere, rhizosphere, season

1. Introduction

Soil is the first base for fruit tree cultivation, and micro-organisms present in the soil are the important component of soil ecosystem. Soil micro-organisms are group of living organisms that are present in the soil and these micro-organisms play a key role in mineralisation of different nutrients like nitrogen, phosphorus and sulphur present in the soil and which are vital for plant nutrition and contribute significantly to the formation of soil aggregates (Esperschutz et al., 2007). Microbial activity, its composition and diversity lead to changes in soil nutrient availability by altering soil processes and therefore, role of soil microbial community becomes important in maintaining soil fertility. Soil microbial biomass and their microflora composition constitutes bacteria, fungi and actinomycetes as the three biggest microbial groups and thus, reflected microbial numbers reflect the level of soil microbial

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activity (Kennedy and Papendic, 1995; Bossio et al., 2006). Microbial activity, its composition and diversity lead to changes in soil nutrient availability by altering soil processes and therefore, role of soil microbial community becomes important in maintaining soil fertility. Similarly, different seasons and plant species are also known to have significant impact on abundance of soil microbial community.

There is a complexity in environmental factors which affect and alter assemblage structure and functions of microbes. Therefore, it is well known that environmental and seasonal variables such as temperature, moisture or humidity, soil pH and nutrient availability influence the distribution and activity of soil micro-organisms (Oliveira and Oleveira, 2005). Similarly, different seasons and plant species are also known to have significant impact on abundance of soil microbial community. While rhizosphere is the narrow region of soil that is directly surrounded and influenced by the plant roots. Rhizosphere, which is counted as hot spot of plant-microbial interactions and is known to be a driving force of soil processes. Quantity and quality of carbon resources could be affected by plant species in the Rhizosphere, which influence the composition and diversity of microbial communities in different environmental conditions. Different amount and types of root exudates released by different plant species promote proliferation of different microbial communities (Philippot et al., 2013; Qiu et al., 2014). The ecosystem of fruit trees is based on its relationship with soil-microbes and their interaction with environmental conditions. A harmonious relationship in rhizosphere ecosystem, which is developed by fertilization, is found to be beneficial in nutrient absorption and normal growth and development of fruit tree species (Zhang et al., 2009). Plants release up to 40% of their photosynthetic products into the rhizosphere (Singh et al., 2017), due to which rhizospheric microbial population density is found much higher than that in the surrounding bulk soil (Berendsen et al., 2012) and is also known as rhizosphere effect. According to the effects of rhizosphere microbes on plant growth, they are divided as beneficial microbes, deleterious microbes and neutral microbes, exerting no direct effect on pathogens of plants.

Beneficial microbes of plant are studied for their positive effect on growth and healthy development (Lugtenberg, 2015). They facilitate nitrogen (N), phosphorus (P), and mineral uptake by plant, and also secrete plant hormones into the rhizosphere for promotion of plant growth. Plant growth promoting rhizobacteria (PGPR), also known as microbial pesticides e.g. *Bacillus* spp. and *Pseudomonas fluorescence* have beneficial effects on plants. PGPR inoculants are currently commercialized that seem to promote growth through at least one mechanism i.e. suppression of plant disease (termed Bio-protectants), improved nutrient acquisition (termed Bio-fertilizers), or phyto-hormone production (termed Bio-stimulants). Rhizobacteria induce resistance through the salicylic acid-dependent SAR pathway, or require jasmonic acid and ethylene perception from the plant for ISR. Rhizobacteria belonging to the genera *Pseudomonas* and *Bacillus* are well known for their antagonistic effects and their ability to trigger ISR. Resistance-inducing and antagonistic Rhizobacteria might be useful in formulating new inoculants with combinations of different mechanisms of action, leading to a more efficient use of them for bio control strategies to improve cropping systems. In the rhizosphere, a fierce battle is fought between plant-beneficial microbes and deleterious microbes (Berendsen et al., 2012). Hence, the composition of the microbial community in the Rhizosphere plays a very crucial role in the function of plants through influence on their physiology and development (Mendes et al., 2013).

In the present study, seasonal variation in the microbial communities in fruit orchards will be helpful in better understanding of the microflora which may be helpful in soil and plant health management in fruit orchard through nutrient cycling and also provides window for new research strategies for better understanding of the crop specific microbial interactions in fruit crops.

2. Materials and Methods

2.1. Study material

The following seven orchards of fruit tree species (Table 1) were used during the course of this investigation to assess microbial populations in rhizosphere and non-rhizosphere soil of seven fruit trees. The soil samples were collected from the experimental orchards of the department of Horticulture, CCS HAU, Hisar during the year 2018-19, situated at 215.2 m above mean sea level with coordinates of 29°10' N latitude and 75°46' E longitudes. Plants were kept under uniform orchard management practices during the study, where all the cultural practices were carried out as per package of practices for fruit crops, CCS HAU, Hisar.

Table 1: List of fruit tree species orchards studied during investigation

Sl. No.	Fruit Tree Species	Scientific name	Rootstock	Spacing
1.	Mango	*Mangifera indica*	Desi mango seedling	10×10 m^2
2.	Guava	*Psidium guajava*	L-49	6×6 m^2
3.	Sweet orange	*Citrus sinensis*	Rough lemon seedling	6×6 m^2
4.	Jamun	*Syzygium cuminii*	Desi jamun seedling	10 ×10 m^2
5.	Aonla	*Emblica officinalis*	Desi aonla seedling	10×10 m^2
6.	Bael	*Aegle marmelos*	Desi bael seedling	10×10 m^2
7.	Ber	*Ziziphus mauritiana*	Ziziphus rotundifolia	10×10 m^2

2.2. Collection, preparation and analysis of soil samples

For maximum representation of orchards, each fruit orchard was divided into three replication block. Ten samples from each replication were collected with the help of auger from the rhizospheric soil (under canopy) i.e. one meter away from the tree trunk and 0–30 cm depth as well as from inter row spaces (non-rhizospheric soil) during summer, rainy and winter season in zig-zag pattern for randomization. For control, soil samples were collected in the same manner from uncultivated land/ fallow land near the orchard. Each set of ten samples were mixed together to make a composite sample. Nearly 1.0 kg of soil sample was taken from each composite samples and a subset of this sample was placed in a sterile well marked plastic bag and kept at 4°C for further study of microbial population.

Microbial count was taken in the rhizospheric and non-rhizospheric soil by taking 10 g of soil from the composite sample (preserved at 4°C) and was added into 90 ml water blank. Later, it was placed on rotary shaker for half an hour. Serial dilutions (up to 10^{-6}) of samples were made in 9.0 ml water blanks and 0.1 ml of appropriate dilution was spread on freshly prepared media plates.

a) Total microbial count (cfu) using soil extract Agar media
b) Nitrogen fixers (cfu) using Jensen's N_2 free media
c) Phosphate solubilizers (cfu) using Pikovskayas agar media
d) Actinomycetes (cfu) using Kenknight agar media
e) Total fungal count (cfu) using CzapekDoxs' media

The plates were incubated at 28±2°C in a BOD incubator for 3-4 days. Based on the morphotypes, different bacterial colonies were counted for total microbial count. The counts were calculated on per gram soil basis using the formula:

$$\text{Total Count: - No. of cfu (colony forming units)} \times \text{dilution factor} / \text{Volume taken (ml)}$$

2.3. Statistical analysis

Data recorded was compiled and subjected to statistical analysis (Pense and Sukhatme, 1987) as per the design of the experiment (Three factorial RBD) and tested for variances at 5% level of significance for microbial population data of both Rhizospheric and Non-rhizospheric samples was analyzed through descriptive statistics

3. Results and Discussion

3.1. Microbial population in rhizospheric and non-rhizospheric soil

Microbial population in all the fruit orchards varied with the fruit tree species, seasons and sampling sites. Similarly, Peng et al. (2018) demonstrated that fruit tree species showed significant impact on soil microbial community. Microenvironment of the rhizosphere soil was shaped by eight common deciduous fruit trees. In the present study, total bacterial count was found remarkably higher than fungal count and other microorganisms viz. PSB, nitrogen fixers and actinomycetes. Urbanova et al. (2015) discovered that fungal communities have more unique taxa and diversity than bacterial communities in deciduous fruit tree orchard. Peng et al. (2018) reported that fungal communities were significantly lower than the bacterial communities in fruit tree orchards.

3.2. Total microbial count

The total microbial count (TMC), phosphate solubilizing bacteria (PSB) and nitrogen fixer's count or diazotrophs were found highest in rainy season at both the sampling sites. Yadav et al. (2011) reported maximum increase in MBC in the rhizosphere of *P. dactylifera* followed by *E. officinalis* and *Z. mauritiana* as compared to non-rhizosphere soil during monsoon season. Phosphatase and phytase activity during monsoon season increased due to higher moisture content and thereby, increasing microbial population and activity as compared to the summer season. Similar results were earlier reported by, Shilpkar et al. (2010) that all the micro-organisms were found highest during monsoon season in rhizospheric soil of *Aegle marmelos* tree. Total microbial count varied 0.96% to 11.61% higher during summer; 4.44% to 11.16% higher during rainy season and 10.48% to 20.03% higher during winter season over control i.e. uncultivated land, in all the fruit tree orchards (Table 2). The maximum increase in TBC

Table 2: Effect of seasonal variation on total microbial count (cfu g^{-1}) in rhizospheric soil under the canopy of different fruit tree species

Fruit tree species	Total microbial count*			Seasonal variation over control (%)		
Fruit tree species	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	8.17	8.27	7.17	11.61	11.16	10.48
Guava	7.66	8.06	7.73	4.64	8.33	19.11
Ber	7.71	8.12	7.79	5.33	9.14	20.03
Jamun	7.67	8.12	7.19	4.78	9.14	10.79
Sweet orange	7.49	7.98	7.20	2.32	7.26	10.94
Aonla	7.39	7.91	7.30	0.96	6.32	12.48
Bael	7.57	7.77	7.72	3.42	4.44	18.95
Control (uncultivated land)	7.32	7.44	6.49	0.00	0.00	0.00

: Values indicated in table are log values of total microbial count ($\times 10^6$); **: (-) indicates decrease

over the control was found in mango orchard during summer (11.61%) and rainy (11.16%) season. This may be due to bigger canopy in mango which causes shading effect and lowers the temperature under the canopy resulting in congenial environment for proliferation of microbial population in both the seasons (Table 3). During winter season, maximum increase in TBC over the control was found in ber orchard (20.03%), as it may be due to complete litter fall in ber during summer months followed by monsoon and hence fast decomposition of leaves leading to addition of more organic

Table 3: Effect of seasonal variation on total microbial count (cfu g^{-1}) in non-rhizospheric soil of inter rows of different fruit tree species

Fruit tree species	Total microbial count*			Seasonal variation over control (%)		
Fruit tree species	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	7.72	7.83	7.19	5.46	5.24	10.79
Guava	7.54	7.81	7.12	3.01	4.97	9.86
Ber	7.39	7.79	7.26	0.96	4.70	11.86
Jamun	7.66	8.06	7.23	4.64	8.33	11.40
Sweet orange	7.6	8.05	7.13	3.83	8.20	9.86
Aonla	7.44	7.81	7.24	1.64	4.97	11.56
Bael	7.89	7.92	7.29	7.79	6.45	12.33
Control (uncultivated land)	7.32	7.44	6.49	0.00	0.00	0.00

: Values indicated in table are log values of total microbial count ($\times 10^6$); **: (-) indicates decrease

matter in the rhizospheric soil in post monsoon and autumn months further resulting into increase in microbial population.

3.3. Phosphate solubilizing bacteria

Phosphate solubilising bacterial count under the canopy was 3.80% to 7.88% higher during summer; and 2.86% to 8.14% higher during rainy season and 1.58% to 10.25% higher during winter season over the control i.e. uncultivated land, while in inter row non-rhizospheric soil, PSB count was found 3.21% to 11.68% higher during summer season; 0.29% to 12.29% higher during rainy and 4.26% to 7.10% higher during winter season over the control (Table 4). The maximum increase in PSB count under the canopy was found in mango orchard during summer (7.88%) and rainy season (7.57%) while in guava orchard during winter season (10.25%) over the control. The

Table 4: Effect of seasonal variation on phosphate solubilizing bacterial count (cfu g^{-1}) in rhizospheric soil under the canopy of different fruit tree species

Fruit tree species	Phosphate solubilizing bacterial count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	7.39	7.53	6.61	7.88	7.57	4.26
Guava	7.11	7.25	6.99	3.80	3.57	10.25
Ber	7.34	7.36	6.44	7.15	5.14	1.58
Jamun	7.17	7.20	6.78	4.67	2.86	6.94
Sweet orange	7.36	7.47	6.83	7.45	6.71	7.73
Aonla	6.47	6.69	6.81	-5.55**	-4.43**	7.41
Bael	7.30	7.57	6.63	6.57	8.14	4.57
Control (uncultivated land)	6.85	7.00	6.34	0.00	0.00	0.00

*: Values indicated in table are log values of phosphate solubilizing bacterial count ($\times 10^6$); **: (-) indicates decrease

possible reason may be due to higher, organic matter added in rhizospheric soil due to litter fall and decomposition of leaves in the previous months increased the PSB count. The possible reason might be due to addition of phosphatic fertilizers under the canopy. Between inter row non-rhizospheric soil, (Table 5) maximum increase in PSB count was found in bael orchard (11.68%) during summer season; sweet orange (12.29%) during rainy season and in guava orchard (7.10%) during winter season. Similar to the results Balota et al. (2011) explained that there was increase in the available phosphorus in the inter rows. The increase of the phosphorus value over time in the inter rows may be explained by P cycle through

Table 5: Effect of seasonal variation on phosphate solubilizing bacterial count (cfu g^{-1}) in non-rhizospheric soil of inter row of different Fruit tree species

Fruit tree species	Phosphate solubilizing bacterial count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	7.25	7.32	6.69	5.84	4.57	5.52
Guava	7.26	6.98	6.79	5.99	-0.29**	7.10
Ber	6.55	7.49	6.27	-4.38**	7.00	-1.10**
Jamun	7.07	7.23	6.62	3.21	3.29	4.42
Sweet orange	7.13	7.86	6.61	4.09	12.29	4.26
Aonla	7.24	7.13	6.74	5.69	1.86	6.31
Bael	7.65	7.02	6.78	11.68	0.29	6.94
Control (uncultivated land)	6.85	7.00	6.34	0.00	0.00	0.00

*: Values indicated in table are log values of phosphate solubilizing bacterial count ($\times 10^6$); **: (-) indicates decrease

P redistribution in undisturbed soil. Similar results were reported by Franchini et al. (2004).

3.4. Nitrogen fixers count or diazotrophs

The diazotrophs count under the canopy was 0% to 7.67% higher during summer; 0% to 6.93% higher during rainy and 4.42% to 13.58% higher over the control during winter season in respect of different fruit tree orchards, while in inter row non-rhizospheric soil, diazotrophs were found 1.01% to 11.43% higher during summer; 1.56% to 10.18% higher during rainy and 7.53% to 12.27% higher over control during winter season among different fruit tree orchards (Table 6). Some of the studies suggested that geographical location has greatest influence on community composition. While other workers suggested that host genotype is the primary factor driving the community. Maximum increase in diazotrophs over control was found in mango orchard during summer (7.67%) and rainy (6.93 %) season and during winter season in sweet orange orchard (13.58%). Contrast to it, maximum increase in diazotrophs over control was found in jamun (11.43 %) during summer season, in bael (10.18%) during rainy season and in mango (12.27%) orchard during winter season (Table 7). Balota et al. (2011) reported that cultivation of different ground cover between the rows of orange trees and soil systems influence the microbial biomass both in the position under the tree canopy and in the inter row. Soil microclimate and environmental factors as soil temperature, pH, and nutrients significantly affect the distribution of microbial community (Shi et al*.,* 2014). Similarly, Wang et al. (2014) concluded that direct effects of climate or seasonal change on soil microbial activity and reproduction were supposed to be caused by changes in soil moisture, humidity and temperature.

Table 6: Effect of seasonal variation on nitrogen fixers count (cfu g^{-1}) in rhizospheric soil under the canopy of different fruit tree species

Fruit tree species	Nitrogen fixers count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	7.44	7.56	6.38	7.67	6.93	4.42
Guava	6.86	7.23	6.77	-0.72**	2.26	10.80
Ber	7.10	7.20	6.66	2.75	1.84	9.00
Jamun	6.39	7.36	6.82	-7.53**	4.10	11.62
Sweet orange	7.04	7.07	6.94	1.88	0.00	13.58
Aonla	6.91	7.03	6.85	0.00	-0.57**	12.11
Bael	7.16	7.23	6.49	3.62	2.26	6.22
Control (uncultivated land)	6.91	7.07	6.11	0.00	0.00	0.00

*: Values indicated in table are log values of nitrogen fixers count ($\times 10^6$); **: (-) indicates decrease

3.5. Fungal count

In the present study, under canopy (UC) fungal count was recorded highest during summer season, as fungal activity is negatively correlated with the moisture content in the soil. It may also be due to higher litter fall during spring season

Table 7: Effect of seasonal variation on nitrogen fixers (cfu g^{-1}) in non-rhizospheric soil of inter rows of different fruit tree species

Fruit tree species	Nitrogen fixers count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	6.98	7.27	6.86	1.01	2.83	12.27
Guava	7.55	7.30	6.57	9.26	3.25	7.53
Ber	7.14	6.83	6.67	3.33	-3.39**	9.17
Jamun	7.70	7.32	6.59	11.43	3.54	7.86
Sweet orange	7.03	7.18	4.80	1.74	1.56	-21.44**
Aonla	6.75	7.51	4.40	-2.32**	6.22	-27.99**
Bael	7.06	7.79	5.20	2.17	10.18	-14.89**
Control (uncultivated land)	6.91	7.07	6.11	0.00	0.00	0.00

*: Values indicated in table are log values of nitrogen fixers count (10^6); **: (-) indicates decrease

Table 8: Effect of seasonal variation on fungal count (cfu g^{-1}) in rhizospheric soil under the canopy of different fruit tree species

Fruit tree species	Fungal count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	3.88	3.67	3.41	8.68	8.26	6.56
Guava	4.07	3.76	3.87	14.01	10.91	20.94
Ber	4.15	4.04	3.69	16.25	19.17	15.31
Jamun	4.49	4.13	4.27	25.77	21.83	33.44
Sweet orange	4.06	3.98	4.01	13.73	17.40	25.31
Aonla	4.17	3.9	4.1	16.81	15.04	28.13
Bael	3.68	3.3	3.57	3.08	-2.65**	11.56
Control (uncultivated land)	3.57	3.39	3.2	0.00	0.00	0.00

*: Values indicated in table are log values of fungal count ($\times 10^3$); **: (-) indicates decrease

and decomposition of leaves which might have led to higher buildup of fungal and other microbial population in summer. Fungal count further decreased from summer season to rainy season (Table 8). Fungal count under the canopy rhizospheric soil was 3.08% to 25.77% higher during summer season; 8.26% to 21.83% higher over control during rainy season, except in bael orchard where fungal count decreased (2.65%) due to anti-fungal properties of bael leaves. During winter season, fungal count increased from 6.56% to 33.44% over control while in inter row non-rhizospheric soil, it was 4.36% to 27.25 % higher during summer; 1.53% to 29.97 % higher during rainy and 5.00% to 31.25% higher during winter season among different fruit tree species. Burke et al. (2011) confirmed that fungal communities were found to vary with the season, sampling location and depth with differences being consistent between the years. Similarly, Balota et al. (2011) reported that microbial biomass varied between under canopy and inter row. Higher microbial biomass may indicate greater accumulation in the organic pool and could represent either a sink or a source of plant available nutrients. Organic residues in soil are used as energy and nutrient source by microorganisms. Root exudates of crop species and cover crops serve as substrate for microbial growth in soil under the canopy. Under the canopy rhizospheric soil observed maximum increase in fungal count in jamun orchard during summer (25.77%), rainy (21.83%) as well as in winter season (33.44%) over the control. It may be due to bigger canopy and more number of fruits. As, fruit drop and rotting in jamun during summer season provides a better substrate for fungal growth under the canopy while during rainy season the tree canopy get washed out and some of the colony and spores were added to the soil, increases the fungal population. In inter row non-rhizospheric soil, mango orchard increased during summer (27.25%), ber orchard during rainy (29.97%) and aonla orchard (31.25%) during winter season had maximum increase in fungal count (Table 9). In mango crop, bigger canopy with more leaves at mature or senescence stage and fruit drop in summer season might have contributed in fungal growth while ber leaves are easily decomposed in rainy season, increasing fungal population and changes in

Table 9: Effect of seasonal variation on fungal count (cfu g^{-1}) in non-rhizospheric soil of inter rows of different fruit tree species

Fruit tree species	Fungal count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	4.67	4.02	3.47	27.25	22.94	8.44
Guava	3.83	3.32	3.56	4.36	1.53	11.25
Ber	4.38	4.25	3.84	19.35	29.97	20.00
Jamun	4.11	4.05	3.36	11.99	23.85	5.00
Sweet orange	4.08	4.01	3.98	11.17	22.63	24.38
Aonla	4.26	3.77	4.2	16.08	15.29	31.25
Bael	4.37	3.69	3.72	19.07	12.84	16.25
Control (uncultivated land)	3.67	3.27	3.2	0.00	0.00	0.00

*: Values indicated in table are log values of total fungal count (×10^3); **: (-) indicates decrease

temperature and moisture conditions have been linked to changes in the soil microbial community composition.

3.6. Actinomycetes count

Similarly, actinomycetes count under the canopy in rhizospheric soil (UC) in all the fruit tree species was recorded highest during summer season. In inter row non-rhizospheric soil, maximum increase in actinomycetes count over control was found in bael orchard during summer (16.63%) and in guava (8.63%) orchard during winter season (Table 10). Similar to our results, Yadav et al. (2011) reported that fungi and actinomycetes increased differentially in rhizosphere and non-rhizosphere during monsoon season. Shilpkar et al. (2010) reported that all microorganisms were found highest in monsoon season while actinomycetes are found dominant in post monsoon season in rhizospheric soil of *Aegle marmelos* tree. Further, it was confirmed that rhizosphere of bael tree contains gram negative bacteria, rhizobium, *azotobacter,* actinomycetes, yeast etc. and their count as well as dominance changes with moisture content in rhizosphere. Under the canopy rhizospheric soil showed maximum increase in actinomycetes count in guava orchard during summer (8.72%), in mango orchard during rainy (10.71%) season and in guava orchard (9.37%) during winter season over the control. Aactinomycetes count in rhizospheric soil was 2.06% to 8.72% higher during summer, 0.00% to 10.71% higher in rainy season and 0.70% to 9.37% higher during winter season over the control while, it was 4.66% to 16.63% higher during summer and 1.44% to 8.63% higher during winter season among different fruit tree species. However, actinomycetes count decreased during rainy season over control in all the fruit tree species and from 0.93% to 17.40% during rainy season (Table 11). Shilpkar et al. (2010) reported that all microorganisms were found highest in monsoon season while actinomycetes are found dominant in post monsoon season in rhizospheric soil of *Aegle marmelos* tree. Solano et al. (2009) also reported that culturable diversity was found in actinomycetes at different locations in coastal region of Costa Rica, since moisture content in soil, actinomycetes species and location played a key role.

Table 10: Effect of seasonal variation on actinomycetes count (cfu g^{-1}) in rhizospheric soil under the canopy of different fruit tree species

Fruit tree species	Actinomycetes count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	4.62	4.55	4.56	5.96	10.71	6.79
Guava	4.74	4.3	4.67	8.72	4.62	9.37
Ber	4.59	4.43	4.51	5.28	7.79	5.62
Jamun	4.69	4.11	4.48	7.57	0.00	4.92
Sweet orange	4.45	4.41	4.37	2.06	7.30	2.34
Aonla	4.61	4.2	4.3	5.73	2.19	0.70
Bael	4.56	4.11	4.43	4.59	0.00	3.75
Control (uncultivated land)	4.36	4.11	4.27	0.00	0.00	0.00

*: Values indicated in table are log values of actinomycetes count (×10^4); **: (-) indicates decrease

Table 11: Effect of seasonal variation on actinomycetes count (cfu g^{-1}) in non-rhizospheric soil of inter rows of different fruit tree species

Fruit tree species	Actinomycetes count*			Seasonal variation over control (%)		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Mango	4.82	4.27	4.37	6.87	-0.93**	4.80
Guava	4.78	4.24	4.53	5.99	-1.62**	8.63
Ber	4.98	4.07	4.33	10.42	-5.57**	3.84
Jamun	4.72	3.91	4.14	4.66	-9.28**	-0.72**
Sweet orange	4.97	3.77	4.34	10.20	-12.53**	4.08
Aonla	4.89	3.88	4.23	8.43	-9.98**	1.44
Bael	5.26	3.56	4.41	16.63	-17.40**	5.76
Control (uncultivated land)	4.51	4.31	4.17	0.00	0.00	0.00

*: Values indicated in table are log values of actinomycetes count ($\times 10^4$); **: (-) indicates decrease

4. Conclusion

The total microbial count, phosphate solubilizing bacteria and nitrogen fixers count were maximum in rainy season while fungal and actinomycetes count were maximum in summer season. Maximum TBC, PSB and nitrogen fixer were found in mango during summer and rainy while maximum fungal count was found in jamun during all the seasons over control. Maximum increase was found in actinomycetes over control in guava during summer and winter season while in mango during rainy season.

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