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Microbial and Chemical Indicators of Rhizospheric Soils of Apple (*Malus domestica* Borkh.) Variety Delicious in Himalayan Kashmir

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Authors' contributions

This work was carried out in collaboration between all authors. Author MSA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MYZ and SK managed the analyses of the study. Authors SAW and FA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

With the introduction of high yielding varieties and hybrids during green revolution, the soils are getting depleted in nutrient reserves at a faster rate. As a consequence, nutrient deficiencies are becoming one of the major constraints in crop production, especially in coarse-textured soils. Microorganisms present in the rhizospheric soils supply principal elements to the plant and also

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promote other activities in the soil which improve its structure, aeration, and water holding capacity, which in turn improve the soil capabilities to respond to inputs. This investigation deals with the evaluation of thirty composite soil samples collected from different apple orchards of Shopian district of Kashmir valley, is popular for its cultivation, and analyzed for soil characteristics like organic carbon content, total available N, P, K, S; EC, pH, total viable bacterial, fungal and actinomycetes count as chemical and microbial indicators of rhizospheric soil health of apple orchards in Himalayan Kashmir. It was observed that the soil characteristics were significantly correlated at 95% to 99%confidence interval except available phosphorus and sulphur with each other.

Keywords: Green revolution; hybrid; microbes; nutrients; rhizospheric soil.

1. INTRODUCTION

Apples are one of the most important cropped and consumed fruits in the world. According to Brown [1], apples are the most produced temperate fruits and they are widely grown throughout almost the entire temperate climate region in the Northern and Southern hemispheres. It is grown at an altitude ranging from 1350 to 2600 meters above mean sea level with an annual rainfall of 125 to 175 cm. The average temperature for its optimum growth should be around 21-24°C with chilling temperature below 7°C to break rest period. Deep, well-drained loamy soils with pH range from 5.5 to 7.8 are suitable for its cultivation. Apple grown in Jammu and Kashmir which is located in the extreme north of India between 32°.17′ to 37°.50′ N latitude 72°.14′ to 80°.30′ E longitude is world famous for its colour, aroma and taste. Jammu and Kashmir occupies a significant position in the horticultural map of India with an area of 347223 ha under different fruit crops and annual production of 1742142 metric tons of fruit [2].

The chemical indicators of soil health include its reaction (pH), salinity (EC) and the nutrient ion concentration. All the parameters have a significant bearing on physical and biological health of soil and hence on the plant growth. The microbial activity and species composition of a soil are generally influenced by the physical characteristics and soil chemical properties. Soil bacteria and their activities have the important role in transformation of plant nutrients to available form and also have many metabolisms related to soil fertility improvement and soil aggregate stability [3]. Geofrey and Ritchie [4] reported that arbuscular mycorrhizal fungi are more widely distributed and associate with a wide range of plant species. The underground environment of a plant is as important for the plant health as the above ground part which contains harmonious friendly microorganisms to normalize the soil health and put pathogenic organisms to stress conditions, thus extend the lifespan of a soil [5]. Rhizobacteria colonize plant roots where they multiply and occupy all the ecological niches found on the roots at all the stages of plant growth [6]. Some of the rhizobacteria play a key role in the natural nutrient cycles. Some species of rhizobacteria are capable of N_2 fixation, some mobilizing phosphorus, potassium, and sulphur in accessible forms in the soils. The phosphorus and potassium are made available to plants when the minerals are slowly weathered or solubilized [7]. Bacteria, fungi and actinomycetes in the rhizospheric soils of apple trees may be taken as microbial indicators of their health status. Successful identification of an elite microbial strain capable of forming PGPS (Plant Growth Promoting Substances), solubilizing phosphorus, potassium, zinc and other essential minerals quickly in large quantity can conserve our existing resources and avoid environmental pollution hazards caused by heavy application of chemical fertilizers.

Keeping in view the adverse effects of agro-chemicals on the soil health of apple orchards and their effect on growth and yield of apple crop, an attempt through the present study was made to assess the microbial health status and available essential nutrients of the rhizospheric soils of apple trees in Himalayan Kashmir.

2. MATERIALS AND METHODS

The investigation was carried out at Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore during 2014-15. Thirty rhizospheric soil samples of apple trees (var. delicious) were collected from thirty representative orchards of ten selected villages of Shopian district in Jammu & Kashmir and brought in sterilized zip-locked polythene bags to the laboratory. The samples were analyzed after

due processing. Organic carbon was determined by Walkley and Black's wet oxidation method [8], available nitrogen by Kjeldhal method [9], available phosphorus by Olsen's method [10], available potassium by flame photometer method [11] and available sulphur by Chesnin and Yein method [12]. The electrical conductivity was determined by EC Bridge [8] and the pH of the soil was measured by using a digital pH meter [8]. Bacterial, fungal and actinomycetes populations were calculated by plate count method using colony counter. Data were subjected to the statistical analysis for correlation and significance as described by Gomez and Gomez [13].

3. RESULTS AND DISCUSSION

A perusal of the data presented in Tables 1 & 2 revealed that organic carbon (OC) in the rhizospheric soil samples of apple trees ranged between 1.61% and 1.90% with the mean value of 1.80% and standard deviation of 0.08. Available nitrogen was 408.21 to 466.45 kg ha^{-1} with mean value of 445.66 kg ha^{-1} having standard deviation 17.37. Similarly, available phosphorus ranged from 18.04 to 19.75 kg ha^{-1} with the mean of 18.81 kg ha^{-1} having the standard deviation of 0.48. The available potassium ranged from 180.12 to 194.15 kg ha^{-1} with mean value of 187.49 kg ha^{-1} with standard deviation of 3.98. The results are in conformation with the results found by Subash, and Tahir [14]. The upper limit for available sulphur was recorded as 28.05 kg ha^{-1} and the lower limit was 22.78 kg ha^{-1}. The mean available sulphur was recorded as 25.92 kg ha^{-1} having standard deviation of 1.73. The electric conductivity (EC) of the soil samples were from 0.19 to 0.28 dS m^{-1} with mean value of 0.24 dS m^{-1} and standard deviation 0.03. The pH recorded of the collected samples was slightly acidic narrowly ranged from 6.3 to 6.5. The viable bacterial population per gram of soil samples ranged from 77.36 x 10^6 to 86.16 x 10^6 with the mean value of 82.40 x 10^6. The results are in conformity with the results found that bacteria are single-celled organisms, rapidly reproducing (one bacterium reproducing more than 110 million in just 24 hours), most numerous with populations ranging from 100 million to 03 billion in a gram of soil and about 80 to 90% of all biogeochemical process of elements carried in the soil are mediated by soil bacteria. Due to the high surface area to volume ratio of these microbes, they play an important role in soil health [15]. The viable fungal population per gram of soil sample ranged between 52.05 x10^4 and 60.58x10^4 with the mean value of 58.41x10^4. The viable actinomycetes ranged from 32.75 x10^5 to 29.60 x10^5 with the mean value of 31.62 x10^5. Bossio and Scaw [16] reported that major groups of soil microorganisms are bacteria (including actinomycetes), fungi and protozoa. Because these microorganisms are best characterized by the roles they play rather than by their individual species, they are often categorized into functional groups. Soil microbial biomass, soil enzymes and soil respiration are among the most important biological parameters and have proven to be powerful tools in monitoring soil quality [17].

With the increase in the pH, the availability of organic carbon, available phosphorus, potassium, sulphur and viable bacterial and fungal count decreased significantly (Table 3). Yan et al. [18] while studying implications for soil enzyme activities and organic matter decomposition reported that the change in pH affects the availability of plant nutrients, a microbial process in the soil as well as the rate of organic carbon decomposition and formation. At 95% to 99% confidence interval, Organic Carbon, available nitrogen, available phosphorus, available potassium and available sulphur showed positive significant correlation with each other and with viable bacterial and fungal populations except between available phosphorus and available sulphur (Table 3). The results are in conformity with the reason put forth by Shishido et al. [19] and Sofi et al. [20]. The viable bacterial and fungal population in the rhizosphere of apple showed positive statistical significance with each other and with organic carbon, available nitrogen, phosphorus, potassium and sulphur (Table 3). It has been reported that application of *Agrobacterium* sp., *Arthrobacter* sp. in apple soil increased nitrogen, phosphorus, potassium concentration and thus play an important role as soil health indicator [21]. Raman [22] identified *Azotobacter chroococum* from rhizosphere of apple and its role in the increase of micronutrient and macronutrient in the soil which is an important parameter of soil health. Masto et al. [23] reported that soil microbial populations including actinomycetes are the driving force behind regulating soil processes such as organic

Table 1. Mean characteristics of soil samples collected from district Shopian

Place	Organic carbon (%)	Available nitrogen ($kgha^{-1}$)	Available phosphorus ($kgha^{-1}$)	Available potassium ($kgha^{-1}$)	Available sulphur ($kgha^{-1}$)	Electrical conductivity (dSm^{-1}) [EC]	pH	Total viable bacteria ($x\ 10^6 g^{-1}$)	Total viable fungi ($x\ 10^4 g^{-1}$)	Total viable actinomycetes ($x\ 10^5 g^{-1}$)
Saidpora Bala	1.61	408.21	18.04	180.12	22.78	0.23	6.50	77.87	54.80	29.60
Zawoora	1.78	431.45	18.46	184.08	24.30	0.26	6.40	81.95	59.46	32.18
Zainpora	1.90	466.45	19.75	194.15	28.05	0.19	6.30	86.16	60.58	32.75
Imam Sahib	1.82	453.96	18.86	188.40	26.71	0.28	6.30	82.22	57.54	29.88
Trenz	1.78	431.08	18.56	184.48	24.00	0.24	6.40	82.00	59.50	32.12
Kachdoora	1.80	446.26	18.53	186.46	25.44	0.20	6.40	77.36	52.05	29.90
Boonshan	1.84	455.12	18.97	189.25	26.98	0.25	6.30	83.81	60.27	32.48
Kiloora	1.81	448.19	18.60	187.01	26.15	0.24	6.30	83.53	59.79	32.29
Pinjora	1.87	458.73	19.25	190.79	27.46	0.27	6.30	84.67	60.06	32.55
Memendar	1.86	457.16	19.14	190.14	27.30	0.25	6.30	84.44	60.08	32.53

Table 2. One sample statistics of Shopian district

	t	Mean	Standard deviation	Standard error mean	95% confidence interval of the difference	
					Lower	Upper
Organic Carbon	71.797	1.807	0.080	0.025	1.750	1.862
Available Nitrogen	81.105	445.661	17.376	5.495	433.231	458.091
Available Phosphorus	122.764	18.816	0.485	0.153	18.469	19.163
Available Potassium	149.005	187.488	3.979	1.258	184.642	190.334
Available Sulphur	47.305	25.917	1.732	0.548	24.678	27.156
EC	26.778	0.241	0.028	0.009	0.221	0.261
pH	283.981	6.350	0.071	0.022	6.299	6.400
Viable Bacteria ($x\ 10^6$)	91.472	82.401	2.849	0.901	80.363	84.439
Viable Fungi ($x\ 10^4$)	65.256	58.413	2.831	0.895	56.388	60.438
Viable Actinomycetes ($x\ 10^5$)	78.026	31.628	1.282	0.405	30.711	32.545

Table 3. Correlation of various soil characteristics of Shopian district

	Organic carbon	Available nitrogen	Available phosphorus	Available potassium	Available sulphur	EC	pH	Bacteria	Fungi	Actinomy-cetes
Organic Carbon	**1**									
Available Nitrogen	0.960**	1								
Available Phosphorus	0.887**	0.894**	1							
Available Potassium	0.936**	0.969**	0.975**	1						
Available Sulphur	0.912**	0.981**	0.912**	0.973**	1					
EC	0.016	-0.009	-0.121	-0.105	0.031	1				
pH	-0.898**	-0.932**	-0.794**	-0.876**	-0.933**	-0.248	1			
Viable Bacteria (x 10^6)	0.784**	0.729*	0.832**	0.794**	0.767**	0.199	-0.825**	1		
Viable Fungi (x 10^4)	0.565	0.453	0.583	0.517	0.491	0.349	-0.636*	0.925**	1	
Viable Actinomycetes (x 10^5)	0.655*	0.503	0.608	0.563	0.505	0.060	-0.581	0.848**	0.885**	1

*** Correlation is significant at the 0.01 level.* * *Correlation is significant at the 0.05 level.*

matter decomposition and nutrient cycling. Ventura et al. [24] reported actinomycetes are widely distributed in both terrestrial and aquatic systems but mostly are present in the soil and play a role in the biodegradation, humus formation and nutrient cycling and thus play an important role in soil quality. Ge et al. [25] studied effect of soil organic carbon and total nitrogen by investigating a large number of apple orchards in China and reported soil organic carbon and nitrogen as the main nutrition for soil microbes and these microbes are used for assessment of soil health and sustainable land use management.

4. CONCLUSION

The following conclusion could be drawn from the present investigation. Soil is a dynamic ecosystem that harbours many microorganisms which are closely related to the plants. The presence of microorganisms like bacteria including actinomycetes and fungi in rhizospheric soils of apple play important role in nutrient cycling thereby releasing organic carbon; nitrogen fixation; solubilization of phosphorus, potassium, sulphur; plant growth promotion; and alleviation of stress and have the ability to increase plant growth and productivity. The distribution of microorganisms like bacteria and fungi in the rhizospheric soils of apple are statistically and significantly correlated with essential macronutrients available in the rhizosphere thereby increase growth and yield quality of apple. So conserving the microbial activity in the soil is very important for the discharge of essential nutrients in the rhizosphere for plant uptake and sustainable growth of the trees which are important indicators of soil health status.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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