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Review Article

Seasonal effect on physicochemical properties in rhizospheric soil of fruit tree species

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Abstract
These days fruit tree species are facing a serious problem of nutrient deficiency which results in poor and inferior quality of produce thus seriously hampering the health of fruit trees. Different seasons summer, rainy and winter have significant effect on the physicochemical properties, organic matter content and its quality along with composition and abundance of soil microbial community of rhizospheric soil. The availability of micronutrients depends on soil pH, organic carbon content and absorptive surface like $CaCO_3$ and clay content and other physical, chemical and biological conditions of the rhizosphere. The amount of water in rhizosphere soil was found to affect chemical properties of soil and reported maximum pH in monsoon than post monsoon season and pH under the tree canopy was lower than in the inter row because acidification processes are more intense near the edge of the tree canopy. Similarly CEC, OC, EC, Available N, P, K and Micronutrients are significantly affected by the seasons in different fruit tree species.

Keywords: fruit tree species, physicochemical properties, rhizosphere, seasons, micronutrients

Introduction
Soil is the first base for fruit tree cultivation and in recent years, fruit orchards faced a major problem of decreased soil fertility, which has resulted in weakened tree vigour, decline in production and deterioration in fruit quality, thus, seriously hampering the healthy economic development of the fruit industry (Li *et al*., 2005) [27]. Soil compaction and reduction in microbial population are the two major factors contributing to this decreased soil fertility. It is caused by the result of overemphasis on increasing fruit yield, lack of orchard investment and single or non-standard soil management systems (Ramos *et al*., 2011) [38]. Long span of farming and management practices in agricultural and horticultural land use systems, such as orchards and croplands, break the ecological balance of natural soil and further leading to microbial decomposition of soil organic matter due to damage caused to its physical protective layer. The dynamics and ecology of soil micro-organisms varied both spatially and temporally (Lorgio *et al*., 1999) [29] and any fluctuations in the soil ecosystem sensitizes soil microbial diversity for change (Cheng *et al*., 2017) [9]. 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 and nutrient availability (Oleveira and Oleveira 2005) [33]. Similarly, different seasons and plant species are also known to have significant impact on soil physicochemical properties, organic matter content and its quality along with composition and abundance of soil microbial community.

Physicochemical properties of soil
The physicochemical characteristics of soil have interrelationships with each other and affect the availability of nutrients to the plants. Soil properties, such as bulk density, porosity, pH value, cationic exchange capacity (CEC), soil organic carbon (SOC), and moisture content are closely related to soil quality. Rengel (2001) [39] the nutrients with limited mobility in soils are transported to roots by diffusion, which is a slow process. Nutrients, though present in relatively large amounts in the soil, but the plant-available fraction and their concentration in the soil solution in the rhizosphere may be insufficient to satisfy plant requirements.

Jones *et al.* (2004) [21] and the availability of nutrients is controlled by the combined effects of soil properties, plant characteristics, and the interaction of roots with microorganisms in the rhizospheric soil. Shilpkar *et al.* (2010) [43] in the rhizosphere of *Aegle marmelos* the amount of water in rhizosphere soil, affect soil chemical properties. Soil pH, organic carbon, CN ratio, available N and available P were recorded maximum in monsoon, whereas electrical conductivity and total nitrogen content were found maximum in post-monsoon. Wemedo *et al.* (2012) [51] the physicochemical parameters of mango and almond orchards, and control soil showed that the mean data obtained for pH, electrical conductivity (dS/m), nitrate (ppm), and available P (ppm) were: 5.90, 0.29, 11.11, and 43.65 respectively for mango soil; 6.20, 0.37, 29.61 and 60.84 respectively for almond soil; 5.40, 0.43, 46.45 and 104.43 respectively for control soil. The data were within normal ranges that supported bacterial growth.

Huang *et al.* (2013) [19] the relationships of plant species, soil physical and chemical properties and microbial communities between high- and low-yield organically managed fruit orchards for eight typical orchards. There were significant of higher microbial biomass and lower bulk density in the soils of high-yield orchards than that in low-yield orchards. Zhihua *et al.* (2014) [54] the bamboo forests had significantly higher levels of soil organic matter, total nitrogen, available nitrogen, total phosphorus, available phosphorus, total potassium, and available potassium and lower pH compared to control soil sample over an area devoid of plants. Soil enzymatic activities and microbial communities were found higher in bamboo forests than in the soil from barren land. Maranon *et al.* (2015) [31] the chemical composition of five ecosystems i.e. leaves, forest floor, roots, topsoil and deep soil had variation in chemical concentration and were highest at the level of canopy leaves and lowest at deep soil. The identity of tree species significantly affected the composition of all elements in the canopies but none in the deep soil. Shukla *et al.* (2015) [45] the availability of micronutrients depends on soil pH, organic carbon content and absorptive surface like $CaCO_3$ and clay content and other physical, chemical and biological conditions of the rhizosphere Blonska *et al.* (2016) [6] and the effects of several tree species on dehydrogenase and urease activities in soils derived from two different parent materials (glaciofluvial sand and loess). The soil pH was lower under coniferous species than under broadleaf species in both parent materials. Ghagare (2017) [14] the soil fertility and availability of nutrients in rhizospheric soil of citrus orchards revealed that the soil pH was found within safe limits and available N (N) and phosphorus (P) were reported low while micronutrients like Fe, Mn and Cu were found in optimum and Zn in deficient limit.

Osobamiro *et al.* (2018) [34] significant seasonal variations were found in the soil properties like pH, organic carbon and N content. Higher CN ratio was recorded in some of the analysed soils which might lead to emission of CO_2 which is a greenhouse gas. Peng *et al.* (2018) [36] soil physicochemical properties in rhizospheric soils of eight common deciduous fruit trees in northern China where the available minerals, pH, microbial utilization of six types of carbon (C) substrates in the rhizosphere varied among tree species. Jiang *et al.* (2017) [20] the sampling site position and the main soil properties (pH, organic matter, available N, available K, available P, and moisture) affected the microbial community composition. Wang *et al.* (2018) [50] the composition and structure of soil bacterial communities were strongly impacted by the edaphic properties, especially the temperature, moisture, ammonical nitrogen, available P and total phosphorus which were the crucial factors to drive the temporal distribution of the soil bacterial community and diversity.

pH

The pH of soil is the expression of acidity or alkalinity of the soil and pH of orchard soil varied in different fruit tree orchards, seasons and sampling sites. Lakshmanan *et al.*, (2014) [25] soil properties are modified by range of processes occurring during tree growth and plant roots can influence the surrounding soil and inhabiting organisms and thereby, changing soil properties. Shilpkar *et al.* (2010) [43] the amount of water in rhizosphere soil was found to affect chemical properties of soil and reported maximum pH in monsoon than post monsoon season. Balota *et al.*, (2011) [5] pH under the tree canopy was lower than in the inter row because acidification processes are more intense near the edge of the tree canopy and Wong *et al.*, (2008) [53] the decrease in pH with the addition of organic residue and manure due to the production of organic acid in fertilized plot over control. Hinsinger *et al.* (2009) [18] the soil pH is important driver of soil microbial communities and can locally increase or decrease by up to two units in the rhizosphere.

Electrical Conductivity (EC)

Electrical conductivity is the measure of amount of salts present in soil i.e. salinity of soil and is an important indicator of soil health. In non-saline soils, determination of EC can be a convenient and economical way to estimate the amount of nitrogen (N) available for plant growth. Electrical conductivity (EC) of fruit orchards differed significantly Wemedo *et al.* (2012) [51] in the rhizosphere of mango, almond and control soil and the EC of the soil was less than 0.75 dS/cm but had variation in three studied soils having lowest in mango soil, increased in almond soil and peaked in control soil. Pal *et al.* (2013) [35] and Sharma *et al.* (2013) [42] found no significant difference in EC under different land use systems. Somasundaram *et al.* (2009) [48] found higher EC in agri-horticulture systems. Qingxia Fu *et al.* (2015) [37] the age of the kiwi fruit affected the EC in comparison to waste land. Root exudates from the plants have phenolic compounds; ferulic acid, HCN and benzoic acid have serious effect on soil EC. Shilpkar *et al.* (2010) [43] commented that amount of water in rhizosphere soil was found to affect chemical properties of soil and electrical conductivity was found maximum in post-monsoon.

Cation exchange capacity (CEC)

Cation exchange capacity (CEC) is a useful indicator of soil fertility it shows the soil's ability to supply three important plant nutrients: calcium, magnesium and potassium. Cation exchange capacity (CEC) differed in fruit orchards, the reason behind this may be higher organic carbon content in the horticultural land use system and CEC is positively correlated to organic matter content which increases the surface area of soil and thus exchange capacity is increased. Somasundaram *et al.* (2009) [48] and Sharma *et al.* (2013) [42] found higher CEC in cultivated soils, agri-horticulture system than barren lands. Osobamiro *et al.* (2018) [34] stated that temperature gives a significant negative correlation with organic carbon, orgamic matter, CEC and % silt. As decreased rainfall predicted in climate change will lead to decrease in soil properties like CEC, % clay and silt (Fatubarin and Olojugba, 2014) [13]. Higher clay content is directly proportional to CEC in soil. Balota *et al.* (2011) [5] as CEC under the canopy was found higher than inter row in different tree species. Shiowatana *et al*., (2001) [44] stated that increase in the rate of decomposition of organic materials leads to high CEC.

Organic Carbon (%)

Soil organic carbon is a measureable component of soil organic matter. Addition of organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, and carbon sequestration. Organic carbon content in orchard soils of different fruit tree species differed significantly. Higher organic carbon in horticultural crops may be accounted to continuous addition of organic waste or matter through litter fall and addition of FYM in the orchard soil. Somasundaram *et al.* (2009) [48]; Liding *et al.* (2011) [26] and Sofi *et al*. (2012) [47]. Higher organic carbon content in apple orchards was due to lower ambient temperature in the higher altitude Sofi *et al.* (2012) [47] and Carter *et al*. (1998) [8] concluded that in summer season increased soil temperature made soil susceptible to soil erosion and thereby reducing soil organic carbon. Osobamiro *et al*. (2018) [34] reported that rainfall and percent relative humidity showed significant positive correlation with organic carbon, similar findings were given by Shilpkar *et al*. (2010) [43] that OC content increase in monsoon season.

Sadana *et al*. (2002) [41] reported that the factors supporting the differential capacities of plants or genotypes to access nutrients in soil include differences in the surface area of contact between soil and root system. Russell *et al*. (2007) [40] reported that soil organic carbon significantly differed among plant species in the surface (0–15-cm) layer, when compared with abandoned pasture and mature forest. The change in soil organic carbon over 15 yr ranged from 0.03 to 0.66 Mg C ha^{-1} yr^{-1}. The species differed in chemical composition and quantity with their difference in production. Nanganoa *et al*. (2019) [32] reported that secondary forests produced more organic matter and higher number of macrofauna. However, the organic matter of the other land uses was not low; hence, it could be beneficial to return plant residues to the field for maintaining soil quality.

CN ratio

Carbon to Nitrogen ratio (CN) is a ratio of the mass of carbon to the mass of nitrogen in a substance or soil. CN ratio observed in rhizospheric and non rhizospheric soils of different fruit tree species varied significantly Osobamiro *et al*. (2018) [34] reported that arable soils have the highest CN ratio though the maximum value for oil palm soil is higher than that of arable soil. Excess C may be released in form of CO_2 when CN ratio is low; organisms make use of the available carbon and excess N loss as ammonia. Shilpkar *et al*. (2010) [43] commented that CN ratio in soil was highest during monsoon season and Osobamiro *et al*. (2018) [34] found that C/N ratio in rainy season is higher than in dry season in all the sampled soils. The more the CN ratio i.e. above 10-12; the greater are the chances of these nutrient being immobilized by micro-organisms which render them unavailable to plants (Brady and Weil, 2008) [7]. Higher CN ratios greater than 23, have been shown to favor slow degradation of residues by the associated microorganisms (Eiland *et al.*, 2001) [12], higher mineralization effects (Goma, 2003) [15] and limited N in the soil which may lead to reduced crop yields (Uriyo *et al.*, 1979) [49].

Available Nitrogen

Plant available forms of nitrogen (N) are inorganic and include nitrate (NO3), and ammonium, (NH4). Fruit tree orchards had significantly higher available nitrogen Usha (2016) the amount of nitrogen found higher (26.98%) under cultivated soils as compared to uncultivated soils. The possible reason identified for this may be due to higher addition of fertilizers and manures under the canopy in cultivated or orchard soil and also has better physical condition of soil Singh *et al*. (2011) [46]. The increase in available N in soils of Haryana under different cropping system is with the application of fertilizers and manures (Antil and Singh, 2007; Devraj *et al*. 2013 and Kaur and Singh, 2014) [3, 22]. The available nitrogen in soil was minimum in post monsoon and maximum during monsoon season Shilpkar *et al.* (2010) [43]. Available nitrogen under the canopy was found higher than inter row in different tree species. Kreyling *et al.* (2012) [23] reported the concentration of soil organic matter changed seasonally due to litter input and the microbial degradation activity, as well as other nutrients, such as N and P cycling. Guntinas (2012) [16] investigated that changes in temperature and moisture content affected net nitrogen mineralization. Temperature sensitivity was maximal at 25^0C and optimum soil moisture for nitrogen mineralization was 80% to 100% when three different soils were studied.

Available Phosphorus

The orthophosphates, $H_2PO_4^-$ and HPO_4^{2-}, are the primary forms of phosphorus taken up by plants. When the soil pH is less than 7.0, $H_2PO_4^-$ is the predominate form in the soil. Although less common, certain organic phosphorus forms can also be directly taken up by plants. Singh *et al.* (2011) [46] and Somasundaram *et al.* (2013) reported higher phosphorus in cultivated land or kitchen garden than barren land because of addition of fertilizers and manures in cultivated land and replenishment of nutrients which reduces losses due to erosion and fixation. Wekha *et al.* (2016) [52] indicated higher phosphorus levels in soil during rainy season. Shilpkar *et al*. (2010) [43] found that after application of mono-calcium phosphate fertilizer, it reacts with moisture to form phosphoric acid which progressively releases hydrogen ions to the soil leading to an acidifying effect, decreasing soil pH and increasing availability and uptake of phosphorus. Balota *et al*., (2011) [5] studied that soil P concentration was higher under the tree canopy than in the inter row where P fertilizer is applied onto soil surface and organic matter is high due to litter fall. Augustine and Joseph (1992) [4] found higher level of P under the canopy of trees than open grasslands Wemedo *et al*. (2012) [51] reported to have higher available P in control than mango and almond orchard. Gururaj (1975) [17] studied that cold temperature during winter reduces nutrient availability however, in summer very high temperature fixes the added P. shading, irrigation and agronomic practices favorably lower the soil temperature.

Available Potassium

Potassium is a natural plant food and fertilizers such as potassium chloride and potassium sulfate are widely found in nature. Potassium is essential for plant health and there must be an adequate supply in the soil to maintain good growth. Singh *et al*. (2011) [46] and Mandal and Jayaprakash (2012) they reported higher available K in citrus orchards compared to maize soil. Higher amount of K in horticulture orchards is due to higher and frequent use of potassic fertilizers and moreover, continuous litter fall replenish the uptake pool of K. Peng *et al*. (2018) [36] reported that available K content of peach soil was much higher than of the other samples, while the lowest available K content was found in the grape and cherry soils. Singh *et al*. (2011) [46] reported higher K content in barren land than cultivated ones.

Available Micronutrients (Fe, Mn, Zn and B)

The DTPA extractable micronutrients (Fe, Mn and Zn) along with boron content in rhizospheric and non-rhizospheric soils showed wide variation in different fruit tree species and during different seasons under the canopy and in inter rows of fruit orchards. Usha (2016) and Singh *et al*. (2011) [46] found that highest content of micronutrients like zinc in citrus orchard in comparison to guava orchard and vegetable cropping system. Ajayi (2014) found that mineral elements (Fe, Cu, Ca and Pb) found under the pepper and plantain rhizosphere soils are in close range. So, no difference of crop species was reflected on micro-elements. Shukla *et al*. (2015) [45] reported that current status of Fe, Mn, Zn and B in soils of Haryana was 21.6%, 6.2%, 15.3% and 3.3% deficient, respectively. It may be because of improper management in orchard soils and response varies with crop, season and genotypes.

Higher amount of iron, manganese and boron are found in the soils having higher organic matter. Litter fall further enhances organic carbon under the canopy of fruit trees and so is the micronutrient content. Cheng *et al*. 2017 [9] reported that Fe and Mn contents in orchard soils were higher than those in cropland soil and unused soil. Debnath *et al*. (2015) [10] reported that iron and manganese content was found higher in apricot orchard and other fruit tree species over the control, zinc content was found higher in control Lindsay and Norvell, (1978) [28].

Conclusions

It is evident from this study that fruit tree species, seasons and sampling sites significantly affected all the soil chemical properties, soil enzyme activities, microbial population and nutrient availability. The composition and structure of microbial communities and soil nutrient status were strongly impacted by the edaphic factors especially the temperature and moisture. These factors also play a crucial role in shaping the rhizosphere of the fruit tree species. Nutrients P, K, Fe, Zn, Mn and Cu are transported to roots by diffusion, which is a slow process in spite of their large quantity present in rhizospheric soil but the plant available fraction, are insufficient to satisfy plant requirements. The availability of nutrients in the rhizosphere is controlled by the combined effect of soil properties, plant characteristics and the interaction of roots with microorganisms.

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