



Variation in physico-chemical properties of soil under different agri-horti system in Vindhyan region

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Abstract: Adoption of unsuitable production system may lead to deterioration of soil physico-chemical properties. Hence, it becomes important to assess the impact of various production systems. For this purpose, a study was carried out to find out variation in physico-chemical properties of soil in agri-horti system based four orchards of Rajiv Gandhi South Campus, Banaras Hindu University, Mirzapur, India. Soil samples were collected from the orchards of custard apple (*Annona reticulata*), guava (*Psidium guajava*), bael (*Aegle marmelos*) and crane berry (*Carissa carandas*) from two depths (0-15 and 15-30 cm) separately within canopy and out of canopy of different plants. The results of the study revealed that all the agri-horti systems were effective in bringing gradual improvement in the physico-chemical properties of the soil. Among different orchards tried, the custard apple system resulted in the highest improvement in temperature (27.16 °C), moisture (24.53 %) and water-holding capacity (41.80 %), whereas crane berry based system recorded better result in case of bulk density, porosity, electrical conductivity, pH, organic carbon, available N (187.55 kg ha⁻¹) and K (193.46 kg ha⁻¹). Custard apple based system recorded highest DTPA extractable micronutrients (Zn 0.54, Fe 17.23, Cu 0.88 and Mn 14.72 mg ka⁻¹).

Keywords: Agri-horti based orchard, Depth of soil, Physico-chemical properties of soil, Plant canopy

INTRODUCTION

Degradation of soil quality is one such issue which is often attributed to improper use of chemical fertilizers and pesticides. In India orchards are usually planted in low fertile soil, a number of reports highlighted the deficiency of major (nitrogen, phosphorous and potassium) and minor (zinc, copper, iron, manganese and boron) nutrients in the citrus orchards in different parts of the world (Sharif *et al.*, 1998; Zia *et al.*, 2006). According to Nair (1984), different systems like, agri-horticultural, agro-forestry and agri-pastoral systems have very much potential to minimize the loss of soil through erosion and runoff, and to sustain soil organic matter, improve soil physical properties and promote efficient nutrient cycling. The land use systems comprising of tree, crops and pastures play a vital role in improving soil fertility and its quality. Trees have capacity to change the properties of soil (Young, 1991). Past few decade there has been rising international interest in studies on the influence of trees on their surrounding environment (Eldridge and Wong 2005; Obrador and Moreno 2006). Orchard ground floor management systems are actually impacting the nutrient dynamics, hydraulic properties and productivity under short or long-term conditions (Rodrigues *et al.*,

2011). The Vindhyan soil of district Mirzapur in eastern Uttar Pradesh of India exhibit catenary's relationship with increase in drainage intensity down the slope, changes in colour from yellowish brown to reddish grey and texture from loam to clay or silt clay are observed. The C/N ratio of the soil in the low lying areas was higher than in upland and terrace soils of sand stone-shale topo-sequences (Yadav *et al.*, 1977). As one of the oldest geological formation of the country, Vindhyan system covers about 80-90 % portion of the Mirzapur district of Uttar Pradesh. The Rajiv Gandhi South Campus, Banaras Hindu University has cultivable and non cultivable land. In this region, intercropping of cereal crops with custard apple, guava, crane berry, bael and aonla etc are more suitable under the agri-horti system. The present study was planned to identify the agri-horti system which could promote efficient nutrient recycling to achieve higher improvement in properties of red soils of Vindhyan region in Mirzapur district of India.

MATERIALS AND METHODS

Study area: Experiment was carried out at Rajiv Gandhi South Campus, of the Banaras Hindu University, India to evaluate the variations in physico-chemical

properties of soil caused by four agri-horti systems which are six years old. The campus is occupying over an area of more than 1000 ha and it situated in Vindhyan region of district Mirzapur, India (25° 10' latitude and 82° 37' longitude). This vindhyan region comes under agro-climatic zone III A (semi-arid eastern plain zone), rainfed condition and invariably poor fertility status of the soils. The climate is typically semi-arid, with low rainfall and moderate humidity.

Soil analysis: Soil samples were collected from the agri-horti based orchards of custard apple, guava, bael and crane berry from two depths (0-15 and 15-30 cm) separately within canopy and out of canopy of different orchards. Green gram, mustard and pearl millet are taken as an inter cropping in different orchards. Collected soil sample were brought into laboratory, dried in shade at room temperature and processed to pass through 2-mm sieve. Soil temperature was recorded using mercury-in-glass thermometer capable of measuring temperature in the range of 0 to 50 °C. (Nwankwo and Ogagarue, 2012). Water holding capacity of the soil samples was determined by Keen-Rozzkowski box as described by Chopra and Kanwar (1988). The soil samples were analysed for pH and EC in a 1:2.5 soil: water mixture (Jackson, 1973); organic carbon by a modified Walkley-Black method (Jackson, 1973); mineralizable N by potassium permanganate method (Subbiah and Asija, 1956); available P by Bray and Kurtz 1954; available K in soil with flame photometer (Hanway and Heidal, 1969); available sulphur by the turbidimetric method (Chesnin and Yien, 1951) and DTPA extractable micronutrients (Zn, Fe, Mn and Cu) with AAS (Lindsay and Norvell, 1978).

Statistical analysis: The statistical analysis of the data was done by the analysis of variance (ANOVA) of factorial randomized block design. The means were tested for significance at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect on physical properties of soil

Soil temperature: The temperature in custard apple, guava, bael, and crane berry soils were 27.16, 26.48, 27.12 and 26.18 °C, respectively. The highest temperature (27.16 °C) was observed in custard apple orchard and lowest (26.18 °C) in crane berry orchard. The mean value of soil temperature was observed to be 26.69 °C within canopy and 26.66 °C out of canopy. The temperature within canopy and out of canopy did not vary significantly. Differences in soil temperature are expected due to direct inhibition of incoming solar radiation by the tree canopy and also due to surface residues. Similar finding was also observed by Sharma, 2015. Further, the temperature was recorded in morning hours which was probably the reason behind non significant difference in soil temperature of within and outside of canopy. Fortin (1993) observed that

surface residue cover can affect soil temperature by insulating the soil surface. The temperature observed at 15 cm depth was 26.27 °C and at 30 cm depth, it was 27.20 °C.

Soil moisture: The value of soil moisture content that observed in custard apple, guava, bael and crane berry orchard were 24.53, 20.90, 21.27, 21.83 % respectively, and presented in Table 1. The highest soil moisture was observed in custard apple whereas lowest in guava orchard. Soil moisture within canopy was significantly higher (23.66 %) as compared to out of canopy (20.33 %). The higher soil moisture within canopy may be due to surface cover and shading effect of trees. Soil moisture content of 0-15 cm was recorded in lower value (20.72 %) as compared to 0- 30 cm depth (23.54 %). This observation clearly shows that the soil moisture is increasing with increasing depth. Brady and Weil (2002) also reported that soil moisture increases with increase in depth. The greater soil moisture-retention capacity of different agri-horti systems were attributed to incorporation of crop residues into the soil, which helped conserve the soil moisture and reduce the evaporation losses due to structural improvement (Kumar and Pandey 2004). Aulakh, and Baidwan (2004) reported that the soil moisture content variation was greater in fallow than in intercropping treatments, which is in conformity with the results of the present study.

Water holding capacity: The water-holding capacity of soil influences the availability of nutrients to the plants and promotes the root activities. Water holding capacity of soil samples collected from custard apple, guava, bael, and crane berry orchards were found to be 41.00, 41.81, 39.22 and 40.76 %, respectively. Water holding capacity within canopy was observed to be 41.04 % which was higher than that of out of canopy (40.30 %). Odewumi *et al.* (2013) also observed that the soil under teak canopy had relatively higher water holding capacity than soil outside teak soil canopy. However, it was of interest to observe that with the increase in the soil depths the water-holding capacity was found to decrease. Water holding capacity at 0-15 cm depth was 41.39 % and at 15-30 cm depth it was 40.01 %. Gang *et al.* (2007) also observed that water holding capacity decreased with depth. The addition and recycling of biomass under intercropping systems help improve organic C, soil structure, and soil aeration, thereby improving the physical, chemical, and biological environments of soil (Maheswarappa, 1998), which might be responsible for increase in the water-holding capacity of the soil. This is in accordance with the works of Aulakh and Baidwan (2004) and Kumar and Pandey (2004). According to Gupta (1983), continuous intercropping also reduces the bulk density of the soil and thereby improves the water-holding capacity of soil by reducing the percentage pore space, which is in the line of the present study.

Bulk density: Among the different orchards of the agri-horti base systems, crane berry orchard recorded significantly better bulk density over custard apple, guava and bael orchards. It might be due to higher organic matter accumulation (Narain and Singh 1985). Significantly lower bulk density was also recorded under within canopy when compared to the samples collected from soil out of canopy. Odewumi *et al.* (2013) reported that the value of bulk density was slightly higher in soil outside tree canopy than in soil under tree canopy. The improvement in bulk density might be attributed to increase in the soil organic-matter content (Maheswarappa *et al.*, 1998) brought about by the incorporation of the huge amount of biomass of the agri-horti based cropping system, which resulted in better aggregation properties of the soil. The bulk density of soil samples was found to be significantly lower at 0-15 cm depth than soil samples collected from 15-30 cm depth. According to Ahmed (2002), the bulk density increases with increasing depth. This might be due to more compaction of soil at lower depths.

Porosity: Significant variations were occurred in the porosity under various orchards. The highest porosity (51.09 %) of soil was recorded in custard apple orchards 50.01 % whereas lowest (50.01 %) under crane berry orchard. The porosity of soil samples drawn from within canopy was 49.71 % which was significantly higher under out of canopy. It was also observed that porosity at 15-30 cm (51.07 %) which was significantly higher than 0-15 cm depth (50.15 %). However, Lipiec *et al.* (2005) reported that tillage practices decreased the soil porosity with increasing depth. Brady and Weil (2002) also observed that the decrease in organic matter shifts macro-pores to micro pores, thus the porosity was higher at 15-30 cm depth and at out of canopy.

Effect on chemical properties of soil

Soil pH and EC: The soil pH values of custard apple, guava, bael and crane berry orchards were 5.5, 5.6, 5.7 and 5.3, respectively. The soil pH within canopy was recorded in lower than out of canopy. With increase the depth of soil from 0-15 to 15- 30 cm increased value of pH. This might be due to leached down of soluble salts. Generally pH did not show any specific trend with depth but Kumar *et al.* (2012) reported an increase in soil pH with increasing depth of profiles which was due to prevention of leaching of soluble bases to the deeper zones of the soil. This is definitely an interesting development in soil reaction because soil pH was increased toward neutrality, which is a desirable factor for improvement of soil condition. This was due to the nitrification process in the soil, and addition of biomass of intercrops might have influenced the ionic exchange capacity of the soil, thus resulting in a slow increase in the soil pH toward the intermediate favorable range.

Higher electrical conductivity was recorded within canopy as compared to out of canopy. The electrical conductivity was also found higher under 15 cm of depth as compared to 30 cm depth. Fida *et al.* (2011) also reported higher electrical conductivity at sub-surface. It might be due to leaching of salt from upper surface to lower surface. This shows that salinity did not have any harmful effect on crop growth. The increase in the soil organic-matter content and favorable changes in the soil physical, chemical, and biological environment increase the soil microorganism activities, which might have been favored to increase the electrical conductivity of the soil as reported by Maheswarappa *et al.* (1998) and Manna and Singh (2001). Aulakh and Baidwan (2004) also reported that inter-cropping systems resulted in greater electrical conduc-

Table 1. Physical properties of different orchards soils of Rajiv Gandhi South Campus, Mirzapur.

Treatment	Temperature (°C)	Moisture (%)	Water holding capacity (%)	Bulk density (Mg m ⁻³)	Particle density (Mg m ⁻³)	Porosity (%)
Factor I Orchards						
Custard Apple	27.16	24.53	41.81	1.37	2.68	51.09
Guava	26.48	20.90	41.00	1.35	2.67	50.75
Bael	27.12	21.27	39.22	1.35	2.66	50.60
Crane berry	26.18	21.83	40.76	1.33	2.65	50.01
SEm±	0.39	1.00	0.70	0.01	0.003	0.23
LSD (P=0.05)	NS	NS	NS	0.02	0.01	0.66
Factor II Canopy						
Within canopy	26.69	23.66	41.04	1.31	2.64	49.71
Out of canopy	26.66	20.33	40.30	1.38	2.68	51.41
SEm±	0.28	0.71	0.49	0.005	0.002	0.16
LSD (P=0.05)	NS	2.04	NS	0.01	0.01	0.47
Factor III Depth of soil sampling						
0-15 cm	26.27	20.72	41.39	1.33	2.65	50.15
15-30 cm	27.20	23.54	40.01	1.37	2.67	51.07
SEm±	0.28	0.71	0.49	0.005	0.002	0.16
LSD (P=0.05)	0.80	2.04	NS	0.01	0.01	0.47
Interaction						
Orchard × Canopy	NS	S	NS	S	S	S

Table 2. Chemical properties of different orchards soils of Rajiv Gandhi South Campus, Mirzapur.

Treatment	pH	EC (dS m ⁻¹)	OC (%)	Nitrogen (kg ha ⁻¹)	Phosphorous (kg ha ⁻¹)	Potassium (kg ha ⁻¹)
Factor I Orchards						
Custard Apple	5.5	0.380	0.44	171.44	9.60	191.04
Guava	5.6	0.400	0.47	180.51	9.57	184.94
Bael	5.7	0.440	0.49	182.76	10.38	180.31
Crane berry	5.3	0.410	0.54	187.55	9.49	193.46
SEm±	0.13	0.020	0.01	2.66	0.36	1.70
LSD (P=0.05)	NS	NS	0.02	7.67	NS	4.89
Factor II Canopy						
Within canopy	5.5	0.430	0.54	191.75	9.80	191.28
Out of canopy	5.6	0.390	0.44	170.52	9.78	183.35
SEm±	0.09	0.020	0.01	1.88	0.25	1.20
LSD (P=0.05)	NS	NS	0.01	5.42	NS	3.46
Factor III Depth of soil sampling						
0-15 cm	5.3	0.400	0.50	186.12	11.20	189.50
15-30 cm	5.7	0.420	0.46	175.01	8.32	185.38
SEm±	0.09	0.020	0.01	1.88	0.25	1.20
LSD (P=0.05)	0.27	NS	0.01	5.42	0.73	3.46
Interaction						
Orchard × Canopy	NS	NS	S	S	NS	S

tivity.

Soil organic carbon: Organic carbon content of the soil samples collected from orchards of custard apple, guava, bael, and crane berry was 0.44, 0.47, 0.49 and 0.54 %, respectively. The highest organic carbon was found in crane berry orchard and least in guava orchard. Within canopy, organic carbon was high due to plant leaf residues as compared to out of canopy. The organic carbon was found to be higher at 0-15 cm depth (0.50 %) which was significantly lower at 15-30 cm depth. Similar result was reported by Gregorich *et al.* (1995). The existence of low to medium organic carbon content of soil was might be due to reviling climatic condition-(high temperature) and poor management (Ghugre *et al.*, 2002). The increase in organic C content of soil under these agri-horti systems might be due to the decomposition of biomass of different inter crops. Similar findings on increase in organic C contents of orchard soil due to intercropping practices

in mango orchard have been reported by Nath *et al.* (2003), Aulakh and Baidwan (2004), and Swain and Patro (2007).

Available nitrogen: Significantly highest available nitrogen content in soil (187.55 kg ha⁻¹) was observed in crane berry orchard whereas lowest under custard apple orchard (171.44 kg ha⁻¹). Nitrogen content within canopy was significantly higher (191.75 kg ha⁻¹) as compared to out of canopy (170.52 kg ha⁻¹). It might be due to higher accumulation of organic carbon within the canopy. The improvement in available N content of the soil under canopy might also be due to fixation of atmospheric N through increased enzymatic and microbial activity in the rhizosphere by the inter crops and release of bound nutrient after their decomposition in the soil. Similar results of increased available N content of the soil through intercropping in mango orchard have been reported by Kumar and Pandey (2004) and Swain and Patro (2007). Mengel and Kirkby (1987);

Table 3. Chemical properties of different orchards soils of Rajiv Gandhi South Campus, Mirzapur.

Treatment	Sulphur (mg kg ⁻¹)	Zinc (mg kg ⁻¹)	Iron (mg kg ⁻¹)	Copper (mg kg ⁻¹)	Manganese (mg kg ⁻¹)
Factor I Orchards					
Custard Apple	7.37	0.54	17.23	0.88	14.72
Guava	8.03	0.51	14.76	0.57	14.10
Bael	8.09	0.47	13.20	0.64	13.61
Crane berry	7.86	0.53	13.88	0.55	13.52
SEm±	0.25	0.02	0.99	0.08	1.08
LSD (P=0.05)	NS	NS	2.86	0.24	NS
Factor II Canopy					
Within canopy	8.02	0.51	15.37	0.73	14.65
Out of canopy	7.72	0.52	13.64	0.55	13.37
SEm±	0.17	0.02	0.70	0.06	0.77
LSD (P=0.05)	NS	NS	2.02	0.17	NS
Factor III Depth of soil sampling					
0-15 cm	8.02	0.53	17.07	0.72	16.16
15-30 cm	7.66	0.49	12.46	0.60	11.81
SEm±	0.17	0.02	0.70	0.06	0.77
LSD (P=0.05)	NS	NS	2.02	NS	2.21

and Tisdale *et al.* (1995) also reported that total N content of a soil is directly associated with its organic carbon content. In the present study it was interesting to observe that the N content of each intercropped plot decreased with the soil depth. Nitrogen content at 0-15 and 15- 30 cm depth was 186.12 kg ha⁻¹ and 175.01 kg ha⁻¹, respectively, which might be due to lower leaching losses as reported by Sharma and Choudhury (2007).

Available phosphorus: The available phosphorous content in soil samples of custard apple, bael, guava and crane berry orchard was 9.60, 9.57, 10.38 and 9.49 kg ha⁻¹, respectively. The Significant Highest value of available phosphorus (10.38 kg ha⁻¹) was observed in bael orchard whereas lowest (9.49 kg ha⁻¹) in crane berry orchard. The increase in the availability of P content in the soil by different agri-horti based orchard might be due to increase in the total microflora population, particularly P solublizers in the rhizosphere of plant, which is in line with the findings of Varghese and Balakrishnan (1978). Phosphorus content is soil of within canopy and out of canopy did not vary significantly. Watanab and Olsen (1965) also reported that P in soil was high in surface soil, which could be attributed to the applied phosphatic fertilizers or higher organic matter. Phosphorus content at 0-15 cm depth was 11.20 kg ha⁻¹ and at 15-30 cm depth it was 8.32 kg ha⁻¹ but the effect was non significant. Mehvish *et al.* (2011) also observed higher P concentration in the surface soils which decreased gradually with increasing soil depth.

Available potassium: The average potassium content of custard apple, bael, guava and crane berry orchards soil were 191.04, 184.94, 180.31 and 193.46 kg ha⁻¹ respectively. Significantly highest potassium was recorded in crane berry orchard (193.46 kg ha⁻¹) whereas lowest potassium content in soil was under bael orchard (180.31 kg ha⁻¹). This corroborates with the findings of Swain and Patro (2007). The increase in availability of K contents in the soil might be due to increase in humus content of soil after decomposition of biomass of intercrops that builds up total population of beneficial microbes in the orchard soil. Similar results of improvement in nutrient status of soil due to intercropping have been reported by Maheswarappa *et al.* (1998), Kumar and Pandey (2004), and Swain and Patro (2006). The higher potassium content was observed from sample drawn from within canopy (191.28 kg ha⁻¹) and lower in out of canopy (183.35 kg ha⁻¹). High potassium within canopy may be due to high organic carbon. Padmaja and Singh (1999) also observed a significant positive correlation between available forms of potassium and organic carbon and silt content of soil. The potassium in 15 cm depth of soil was significantly higher than 30 cm depth. Higher available K in surface soils could be attributed to more intensive weathering, release of labile-K from organic

residues of cultivated crop plants and upward translocation of K from depths along with capillary rise of ground water which is stated by Pulakeshi *et al.* 2012.

Available sulphur: Sulphur content in soil of custard apple, bael, guava and crane berry orchards are 7.37, 8.09, 8.03 and, 7.86 mg kg⁻¹, respectively. The highest S content was recorded in bale orchard. The sulphur content within canopy was higher than out of canopy. It was also noticed that available sulphur content at 15 cm depth was higher than 30 cm depth. Among the all treatments the effect was found to be non significant. Kumar *et al.* (2009) also reported that available sulphur content in red soil decreased with increased soil depth.

Available iron: The average available iron in custard apple, guava, bael and crane berry orchards soil was 17.23, 14.76, 13.20 and 13.88 mg kg⁻¹ respectively. Among the different orchards, custard apple recorded significantly highest iron content over rest of the orchards. The iron content was significantly higher within canopy (15.37 mg kg⁻¹) with compare to out of canopy; it may be due to presence organic matter in soil. Sarkar *et al.* (2000) also found that the availability of iron increased significantly with increase in organic carbon. Iron content in soil at 15 cm depth was also found significantly higher (17.07 mg kg⁻¹) than in 30 cm depth of soil (12.46 mg kg⁻¹). These dynamisms indicated the fact that optimum soil moisture levels have immense impact on the availability of micronutrients within soil profile. The iron content in all the soil samples collected from orchard lies under high range. This might be due to presence of iron oxide in red soil of the region.

Available zinc: Average zinc content in orchards of custard apple, guava, bael and crane berry was recorded 0.51, 0.54, 0.47 and 0.53 mg kg⁻¹ respectively. The highest Zn content in soil was found under custard apple orchard. It has been observed that zinc content in soil within canopy was found less than out of canopy but the difference found to be non significant. Sample collected from different depth of soil also recorded non significant difference in Zn content in soil. The highest Zn content in soil (0.53 mg kg⁻¹) was observed at 15 cm depth of soil as compare to 30 cm depth of soil (0.49 mg kg⁻¹). Bassirani *et al.* (2011) also observed that available Zn content in soil was found in decreasing trend with increasing depth. Zinc concentration in all the orchards was found to under deficiencies range. The main reasons for the deficiencies of zinc may be attributed to nature of parent material, coarse soil texture, low use of organic matter and micronutrient fertilizers of our soils.

Available copper: The mean value of copper content in soil of custard apple, guava, bael and crane berry orchard was observed 0.88, 0.75, 0.64 and 0.55 mg kg⁻¹, respectively. The highest copper content was observed in custard apple orchard whereas the lowest in

crane berry orchard. Within canopy, copper content was significantly higher (0.73 mg kg^{-1}) than out of canopy (0.55 mg kg^{-1}). High values of Cu might be due to relatively high organic matter content of soil. Within the vertical depth distributions, higher Cu concentrations were recorded at 15 cm depth of soil (0.72 mg kg^{-1}) as compared to 30 cm depth of soil (0.60 mg kg^{-1}) but the difference was found to be non significant. Sharma and Chaudhary (2007) also reported that surface horizons found higher copper content in soil and decreased with depth of soils.

Available manganese: Average available manganese content in the soil of the four orchards custard apple, guava, bael and crane berry was 14.10, 14.72, 13.61 and 13.52 mg kg^{-1} respectively. The manganese content within canopy (14.65 mg kg^{-1}) was higher than that of out of canopy (13.37 mg kg^{-1}). The manganese content at 0-15 cm depth was also found to be significant higher (16.16 mg kg^{-1}) than 15-30 cm. depth (11.81 mg kg^{-1}). Sharma *et al.* (2003) also observed that DTPA extractable Mn was positively and significantly influenced by the organic carbon.

Conclusion

Among four orchards, custer apple system produced the most improvement in temperature ($27.16 \text{ }^{\circ}\text{C}$), moisture (24.53 %) and water-holding capacity (41.80 %) whereas crane berry based system recorded better result in bulk density, particle density, porosity, electrical conductivity, pH and organic carbon content, The nutrients status under different orchards was also enhanced availability of major and micronutrients (Zn 0.54, Fe 17.23, Cu 0.88 and Mn 14.72 mg ka^{-1}) in soil. Hence, use of different agri-horti based models could be best options to overcome the problems of ecological imbalance for sustainable crop production.

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