The Pharma Innovation Journal 2023; SP-12(6): 465-471

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(6): 465-471

www.thepharmajournal.com
Received: 29-04-2023
Accepted: 02-06-2023

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Impact of different land use on depth wise soil physical properties of shrink swell soil series of Western Maharashtra

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Abstract
A field and laboratory studies were conducted to assess the physical properties of different land-use of Rahuri, Pather and Babulgaon soil series. The depth wise soils samples from above mentioned soil series were collected under fallow land, conventionally cultivated land and guava orchards in farmers field at Rahata, Ahmednagar and further processed and analysed in the Division of Soil Science and Agricultural Chemistry, Rahuri. From the study, it was revealed that the Rahuri soil series exhibited a silty clay texture, while the Pather and Babulgaon soil series exhibited a clay textural class and the data regarding bulk showed wide variation among different soils ranging from 1.08 Mg m^{-3} in surface soils of guava orchards of Babulgaon to 1.57 Mg m^{-3} in lower depth of fallow land of Pather series. Further, tabulated values of soil hydraulic conductivity revealed that the Rahuri series of Guava orchards exhibited the highest values for soil hydraulic conductivity. (1.98 cm h^{-1}) and the lowest under D_4 depth (Bwss2 horizon) of Babulgaon series of fallow land (0.59 cm h^{-1}). In surface horizon, the soil porosity of Rahuri series ranged from 41.76 to 49.90 percent with mean value of 46.01, in Pather series, it ranged from 45.39 to 54.49 percent with the mean value of 50.12 and in Babulgaon series, it ranged from 48.14 to 57.95 percent with the mean value of 52.76 percent. It was found that the continuous addition of organic matter via leaf litter under perennial crops helps to increase the physical properties of the soil and maintain the soil health as compared to annual crops.

Keywords: Rahuri, Pather, babulgaon, guava, depth, texture, bulk density, porosity, hydraulic conductivity

Introduction
Physical properties of the soil that determines its quality include, bulk density, porosity, texture and hydraulic conductivity. These properties, in turn, determine the water and nutrient-holding capacity of the soil. Soil physical properties also influence water and nutrient movement to rhizosphere and soil organisms' activity. Soil porosity is the most important soil physical attribute that influences water infiltration and movement. Soil bulk density determines the infiltration, available water capacity, soil porosity, rooting depth/restrictions, soil microorganism activity, root proliferation, and nutrient availability. Researchers use hydraulic conductivity to determine soil health or to predict how water will flow through soil at different field sites. Agricultural decisions are based on hydraulic conductivity for determining irrigation rates or to predict erosion or nutrient leaching. Physical properties such as soil texture are usually used to indicate the size distribution of mineral particles, and are considered as crucial factors affecting the soil organic matter accumulation (Dexter, 2004) [5]. For instance, silt and clay particles can protect soil organic matter against microbial mineralization by stabilizing them on mineral surface (Six *et al*. 2002) [25]. The fruit trees including guava are perennial in nature and incorporating perennial crops into agroecosystems has been shown *to* mitigate soil degradation and improve soil health by enhancing soil physico-chemical properties.

Material and method
The present investigation was carried out in the guava orchards of farmer's field at Rahata, Ahmednagar district. The age of guava orchards was around 15-25 years. Guava orchards, conventionally cultivated land and fallow land of three major soil series of Rahuri, Pather and Babulgaon were selected to conduct this experiment. The soils of the farm belong to the broad group of black soils with variation in depth, colour, texture and other morphological characteristics.

The vegetation in study area was categorized on the basis of varied land use in different soil order of Entisol, Inceptisol and Vertisol. In this study, three different land use patterns in three different soil series were selected as 1) Fallow land 2) Conventionally cultivated land 3) Perennial horticulture land (guava orchard). The composite soil samples from specified horizons *viz.*, A_p horizon in Rahuri series, A_p, Bw_1 and B_{w2} horizons in Pather soil series, A_P, B_{w1}, B_{wss1}, B_{wss2} horizons in Babulgaon soil series were collected from soil profiles from each soil series in each land use system. The soil samples thus obtained were subjected to various physical analyses, and the results obtained have been presented in table 1 and 2.

Analysis of soil samples for physical properties

Soil texture was analysed with the help of International Pipette method given by Piper (1966) [19]. Bulk density of soil sample was determined by using core sampler technique given by Blake and Hartage (1986) [3]. Hilgard dish method suggested by Keen Raczkowski (1921) [10] was used for measurement of soil porosity and the soil hydraulic conductivity was determined by constant head method given by Klute and Dirksen (1986) [12].

Result and Discussion

Effect of different land use on depth wise soil physical properties of Rahuri, Pather and Babulgaon soil series.

1. Soil texture (Particle size distribution of soil)

Data pertaining to particle size distribution (clay, silt and sand %) of soil as influenced by different soil series is presented in table 1 and shown in fig 1.

1.1 Soil series and Depth

The Rahuri soil series exhibited a silty clay texture, while the Pather and Babulgaon soil series exhibited a clay textural class. In the Rahuri series, the sand fraction exhibited an average range of 16.34 to 18.39 percent, while the silt fraction ranged from 50.67 to 51.20 percent, and the clay fraction ranged from 30.76 to 32.36 percent. While, across the Pather soil series, the average sand fraction ranged from 14.14 to 18.32 percent, silt fraction ranged from 29.17 to 30.95 percent, clay fraction ranged from 51.35 to 55.64 percent. In Babulgaon series, the average sand fraction ranged from 11.20 to 14.77 percent, silt fraction ranged from 28.97 to 31.81 percent, clay fraction ranged from 53.14 to 59.19 percent (Table 1). The higher sand content was associated with Rahuri series in fallow land (18.39%). Regarding the subsurface horizons observed in the Pather and Babulgaon soil series, it was noted that the sand content exhibited a higher concentration in the uppermost soil layer, with a gradual decrease in concentration observed in the lower depths. Conversely, a contrasting pattern was observed with regards to the proportion of clay particles present within the soil. According to Jaiyeoba's (2003) [9] findings, an increase in clay content at deeper soil depths resulting from cultivation may be attributed to either clay translocation from the surface horizon or clay removal via surface runoff. The obtained outcomes are consistent with the discoveries reported by Gul *et al.* (2011) [7].

1.2 Land use

Table 1 presents the impact of various land use systems on the sand, silt, and clay fractions of soils. The effect of various land use patterns i.e., fallow land, agricultural land, and guava orchards, on soil particle size distribution exhibited numerical variations, regardless of the soil series. However, soil texture is a slowly changing property and cannot be modified due to change in land use systems as well as cultural practices. Similar results were observed by Saglam (2012) [24] that interaction effect between land use and texture did not have significant effect.

Land use did not have much effect on the particle distribution of soil. However, the effect of depth was prominent. The soil profile exhibited a decrease in sand content and an increase in clay content as the depth increased. Based on the standard deviations for the mean of series, depth, and land use, the observed variations may not be considered major. However, a slight variation in the percentage composition of sand, silt, and clay can significantly impact the soil's permeability and nutrient leaching. Textural class seldom changes with land use, however variability within soil series and with depth in a profile is well known. The clay contents increased whereas, the sand contents decreased with depths in all land use systems. This could be due to the smaller soil particle move more easily through soil. An increase in clay and decrease in sand particle with depth in hill soil has been reported by several workers (Brammer 1971; Rahman 2005) [4, 21]. The outcomes are corroborated by the findings of Naeem (1998) [17].

2. Bulk density

The data regarding bulk density (Table 2 and fig. 2) showed wide variation among different soils ranging from 1.08 Mg m^{-3} in surface soils of guava orchards of Babulgaon to 1.57 Mg m^{-3} in lower depth of fallow land of Pather series.

2.1 Soil series and depth

Among surface soils, the bulk density was higher in fallow land of Rahuri series (1.55 Mg m^{-3}). The bulk density was higher in coarse soils because of wider, but fewer macropores and occupies more volume than the clay soil. Babulgaon and Pather series contents higher clay which is responsible for more total pore space which leads to lower bulk density of soil. The soil's bulk density exhibited a positive correlation with depth, as observed. It is a common observation that the bulk density of soil tends to increase with increasing soil depth. The subsoil exhibits greater compaction and reduced porosity due to lower levels of organic matter, weaker aggregation, and less root penetration compared to the topsoil layer. These results were similar with the findings of Nayak *et al.* (2009) [18] who reported the soil bulk density to be ranging from 1.35 Mg m^{-3} at surface to 1.42 Mg m^{-3} at sub-surface under *Prosopis juliflora* and was found significantly higher than under *Terminalia arjuna*. Similarly, Logsdon *et al.* (2000) [14] studied the changes in depth-incremental soil bulk density.

2.2 Land use

The data pertaining to soil bulk density as influenced by land use system are presented in table 2. The soil under guava orchard recorded lower mean bulk density (1.25 Mg m^{-3}) as compared to the mean values of conventionally cultivated land and fallow land (1.38 and 1.48 Mg m^{-3}, respectively). In general, the conventionally cultivated soil observed the higher bulk density than guava cultivated land and this might be due to intensive cultivation practices which enhance the compaction of soil. The lower bulk density was recorded in soils under guava orchards might be due to high availability of organic matter in the form of litter fall. The results of this study are in consent with the findings of other studies (Lee *et al*. 2009; Gupta *et al*. 2010) [13, 8] Similarly, Thakur *et al.* (2011) [26] observed that applying organic manure on a regular basis significantly reduced bulk density.

Table 1: Effect of different land use on depth wise soil separates (%) in different soil series

Order (Soil series)	Land Use	Tr no.	Treatments (Horizons)	Sand	Silt	Clay	Textural class
Entisol (Rahuri)	Fallow	1	EFD$_1$ (A$_p$)	**18.39**	50.67	**30.76**	Silty clay
	Agriculture	2	EAD$_1$ (A$_p$)	17.10	50.93	31.91	
	Guava	3	EGD$_1$(A$_p$)	16.34	**51.20**	32.36	
Inceptisol (Pather)	Fallow	4	IFD$_1$ (A$_p$)	18.32	29.84	51.35	Clay
		5	IFD$_2$ (B$_{w1}$)	17.59	29.43	52.56	
		6	IFD$_3$ (B$_{w2}$)	17.16	29.17	53.13	
	Agriculture	7	IAD$_1$ (A$_p$)	16.70	30.95	52.20	
		8	IAD$_2$ (B$_{w2}$)	16.17	30.08	53.41	
		9	IAD$_3$ (B$_{w2}$)	15.38	29.88	54.17	
	Guava	10	IGD$_1$ (A$_p$)	15.10	30.35	54.09	
		11	IGD$_2$ (B$_{w2}$)	14.52	30.40	54.99	
		12	IGD$_3$ (B$_{w2}$)	14.14	30.14	55.64	
Vertisol (Babulgaon)	Fallow	13	VFD$_1$ (A$_p$)	14.77	31.81	53.14	Clay
		14	VFD$_2$ (B$_{w1}$)	14.71	31.30	53.58	
		15	VFD$_3$ (B$_{wss1}$)	14.54	30.56	54.57	
		16	VFD$_4$ (B$_{wss2}$)	14.30	30.21	54.98	
	Agriculture	17	VAD$_1$ (A$_p$)	14.04	30.63	54.75	
		18	VAD$_2$ (B$_{w1}$)	13.76	30.20	55.56	
		19	VAD$_3$ (B$_{wss1}$)	13.34	30.11	56.30	
		20	VAD$_4$ (B$_{wss2}$)	12.89	29.53	57.18	
	Guava	21	VGD$_1$ (A$_p$)	12.63	30.25	56.43	
		22	VGD$_2$ (B$_{w1}$)	12.11	29.72	57.57	
		23	VGD$_3$ (B$_{wss1}$)	11.65	29.05	58.73	
		24	VGD$_4$ (B$_{wss2}$)	11.20	28.97	59.19	
			Max	18.39	51.20	59.19	
			Min	11.20	28.97	30.76	
			Mean	14.87	32.72	52.02	
			SD	2.03	7.06	8.10	
			CV	13.69	21.58	15.57	

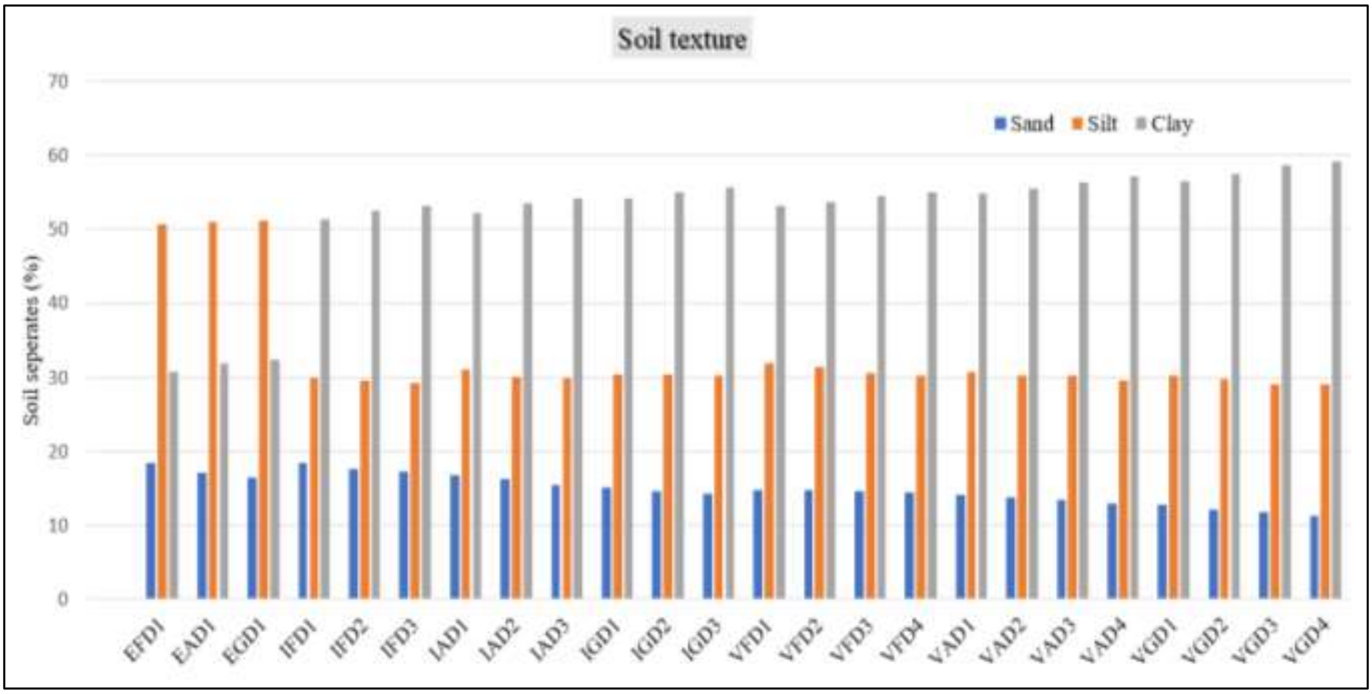

Fig 1: Effect of different land use on depth wise soil separates (%) in Rahuri, Pather and Babulgaon soil series

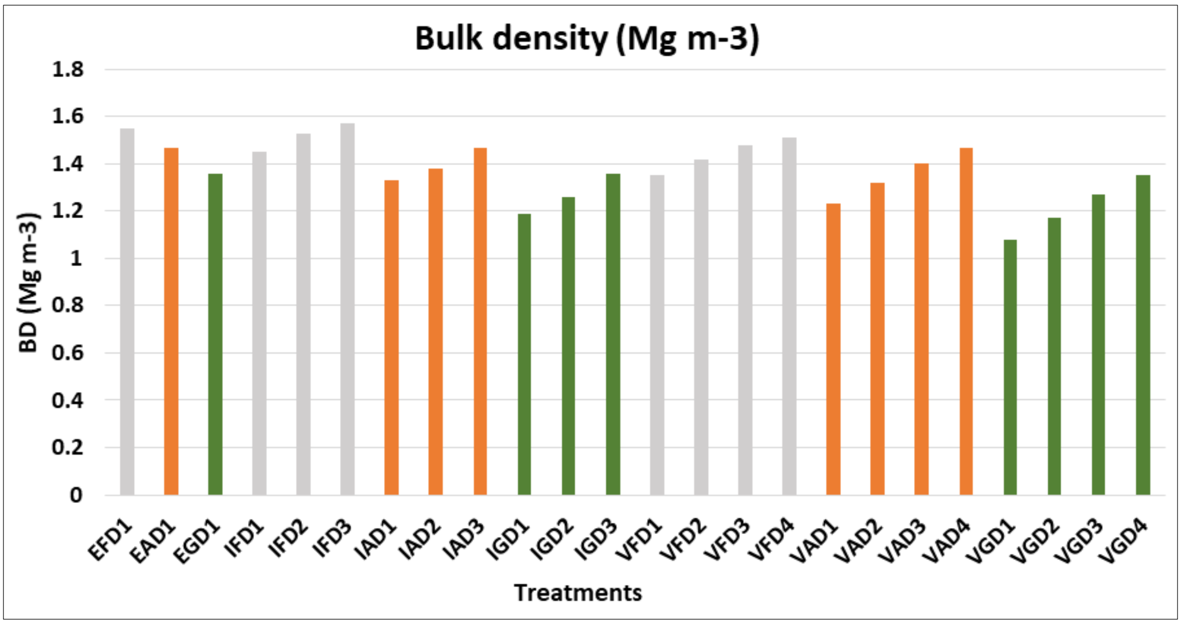

Fig 2: Effect of different land use on depth wise soil bulk density in Rahuri, Pather and Babulgaon soil series

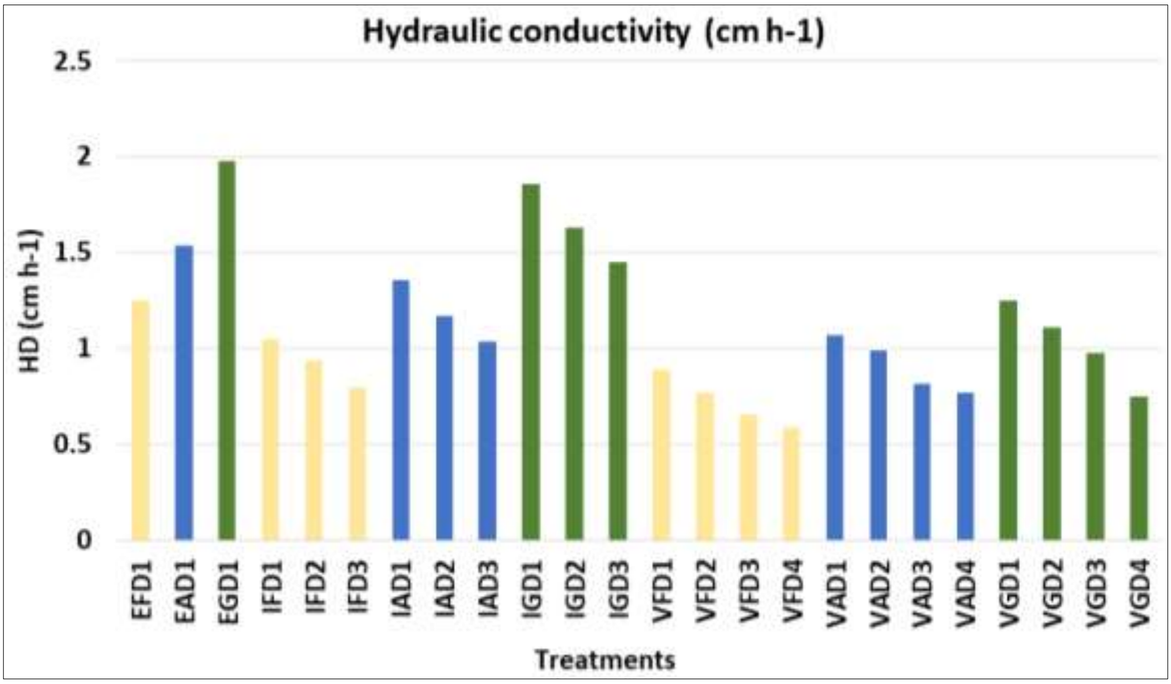

Fig 3: Effect of different land use on depth wise hydraulic conductivity in Rahuri, Pather and Babulgaon soil series

3. Hydraulic Conductivity

The hydraulic conductivity of soil is a significant indicator of water movement and pore structure. Consequently, it is essential to ascertain the physical and hydraulic properties of soils under various land use conditions. Based on the tabulated values of soil hydraulic conductivity on table 2 and fig. 3, the Rahuri series of Guava orchards exhibited the highest values for soil hydraulic conductivity. (1.98 cm h^{-1}) and the lowest under D_4 depth (Bwss2 horizon) of Babulgaon series of fallow land (0.59 cm h^{-1}).

3.1 Soil series and depth

Reviewing the information in table 2, we see that with respect to soil series, the hydraulic conductivity followed the following trend Rahuri>Pather>Babulgaon; Large sand particle-dominated soils tend to have comparatively large pore spaces and, consequently, high values of saturated hydraulic conductivity. Small clay particle-dominated soils typically have small pore spaces and low saturated hydraulic conductivity values. Babulgaon and Pather soil series consist of high swelling clay content and this fine fraction of soil tend to have relatively small pore spaces and minimum values of saturated hydraulic conductivity. Reynolds *et al.* (2000) [23] determined the saturated hydraulic conductivity of a sand, loam, and clay loam soil to be 29 cm h^{-1}, 4.1 cm h^{-1}, and 0.091 cm h^{-1}, respectively.

The highest hydraulic conductivity was noticed in surface horizons and gradually decreased with an increase in soil depth. This might be due to higher organic matter accumulation at surface layer which has resulted in reduction in bulk density, increase in porosity and subsequently increase in hydraulic conductivity. Similar results were also reported by Biswas *et al.* (2003) [2], Malik *et al.* (1996) [16] and Rathod and Devar (2003) [22].

Table 2: Effect of different land use on depth wise soil bulk density, hydraulic conductivity and porosity of Rahuri, Pather and Babulgaon soil series

Order (Soil series)	Land Use	Tr no.	Treatments (Horizons)	Bulk density (Mg m^{-3})	Hydraulic conductivity (cm h^{-1})	Soil Porosity (%)
Entisol (Rahuri)	Fallow	1	EFD_1 (A_p)	1.55	1.25	41.76
	Agriculture	2	EAD_1 (A_p)	1.47	1.54	46.37
	Guava	3	EGD_1(A_p)	1.36	1.98	49.90
Inceptisol (Pather)	Fallow	4	IFD_1 (A_p)	1.45	1.05	45.39
		5	IFD_2 (B_{w1})	1.53	0.94	42.84
		6	IFD_3 (B_{w2})	1.57	0.80	39.94
	Agriculture	7	IAD_1 (A_p)	1.33	1.36	50.49
		8	IAD_2 (B_{w2})	1.38	1.17	48.49
		9	IAD_3 (B_{w2})	1.47	1.04	45.21
	Guava	10	IGD_1 (A_p)	1.19	1.86	54.49
		11	IGD_2 (B_{w2})	1.26	1.63	51.98
		12	IGD_3 (B_{w2})	1.36	1.45	50.13
Vertisol (Babulgaon)	Fallow	13	VFD_1 (A_p)	1.35	0.89	48.14
		14	VFD_2 (B_{w1})	1.42	0.77	45.84
		15	VFD_3 (B_{wss1})	1.48	0.66	43.78
		16	VFD_4 (B_{wss2})	1.51	0.59	42.06
	Agriculture	17	VAD_1 (A_p)	1.23	1.07	52.18
		18	VAD_2 (B_{w1})	1.32	0.99	49.65
		19	VAD_3 (B_{wss1})	1.40	0.82	46.15
		20	VAD_4 (B_{wss2})	1.47	0.77	43.54
	Guava	21	VGD_1 (A_p)	1.08	1.25	57.95
		22	VGD_2 (B_{w1})	1.17	1.11	56.60
		23	VGD_3 (B_{wss1})	1.27	0.98	53.86
		24	VGD_4 (B_{wss2})	1.35	0.75	51.17
			Max	1.57	1.98	57.95
			Min	1.08	0.59	39.94
			Mean	1.37	1.11	48.24
			SD	0.13	0.37	4.83
			CV	9.27	33.20	10.02

3.2 Land use

It is also evidenced from the table 2 that the hydraulic conductivity was higher in tree plantation system than in the open field condition, this could be due to the addition of organic material, which allows the bulk density of the soil to decrease. So, raising the amount of organic matter in the local soils will make a big difference in managing soils in a healthy way. Similarly, Meek *et al.* (1992) [15] concluded that the channels formed by decayed roots subsequently form the macro-pores which create conducive environment to high water hydraulic conductivity. Through these pores water can easily enter and have high infiltration rate compare to soils without these buffers (Rachman *et al*. 2004) [20].

4. Soil Porosity

The porosity of soil refers to the amount of space within the soil matrix that is not occupied by solid particles and can potentially be filled with either air or water. The soil porosity and organic matter content exhibit a decreasing trend with increasing depth from the soil surface. Soil porosity is strongly linked to soil organic matter concentration. The data pertaining to soil porosity is presented in table 2 and depicted in fig. 4.

4.1 Soil series and depth

In surface horizon, the soil porosity of Rahuri series ranged from 41.76 to 49.90 percent with mean value of 46.01, in Pather series, it ranged from 45.39 to 54.49 percent with the mean value of 50.12 and in Babulgaon series, it ranged from 48.14 to 57.95 percent with the mean value of 52.76 percent (Table 2). The results revealed that the Babulgaon soil series recorded maximum soil porosity followed by Pather soil series. The minimum soil porosity was recorded in Rahuri series. The soil's texture exerts a significant influence on its physical and chemical attributes. Sandy soils are characterised by their coarse texture and high degree of macroporosity, owing to the relatively large size of their constituent particles and pore spaces. The soil texture of clay soils is characterized by a high proportion of fine particles, resulting in a high density of micro pores. Despite their small size, the abundance of these micro pores contributes to a relatively large total pore space in clay soils, surpassing that of sandy soils.

In Pather soil series, the average soil porosity for subsurface horizons *viz.,* B_{w1} and B_{w2} horizon was 47.77 percent and 45.09 percent respectively. In Babulgaon series, the average soil porosity for B_{w1}, B_{wss1} and B_{wss2} was 50.70, 47.93 and 45.59 percent respectively. The porosity of the soil exhibited an inverse relationship with the bulk density, whereby it demonstrated a consistent decline with the progression of soil depth. These findings are consistent with those of Franzluebbers (2011) [6].

4.2 Land use

The soil porosity was influenced by different land use system (Table 2), Across the different land use type, the relatively maximum mean soil porosity was recorded in the soils of guava orchard (53.26%) followed by conventionally cultivated land (47.76%) and the lowest was recorded in fallow land (43.72%). The higher porosity at both surface and subsoils of guava orchards could be explained by the presence of higher amount of organic matter and clay in in these soils. Gupta *et al.* (2010) [8] observed the same results and reported a positive correlation between porosity with organic carbon and clay content. For cultivated land, the lower porosity was mainly attributed to cultivation. Kizilkaya and Dengiz (2010) [11] reported that long-term cultivation without appropriate soil management enhances rapid organic matter degradation and finally results in soil compaction and lower porosity. These results were in conformity with the findings of Akhtaruzzaman *et al.* (2015) [1]. Similarly, Wubie and Assen (2020) [27] found that highest total porosity (50.87%) was recorded in the forest land compared to grazing land (48%) which caused a 7 percent decline in soil porosity.

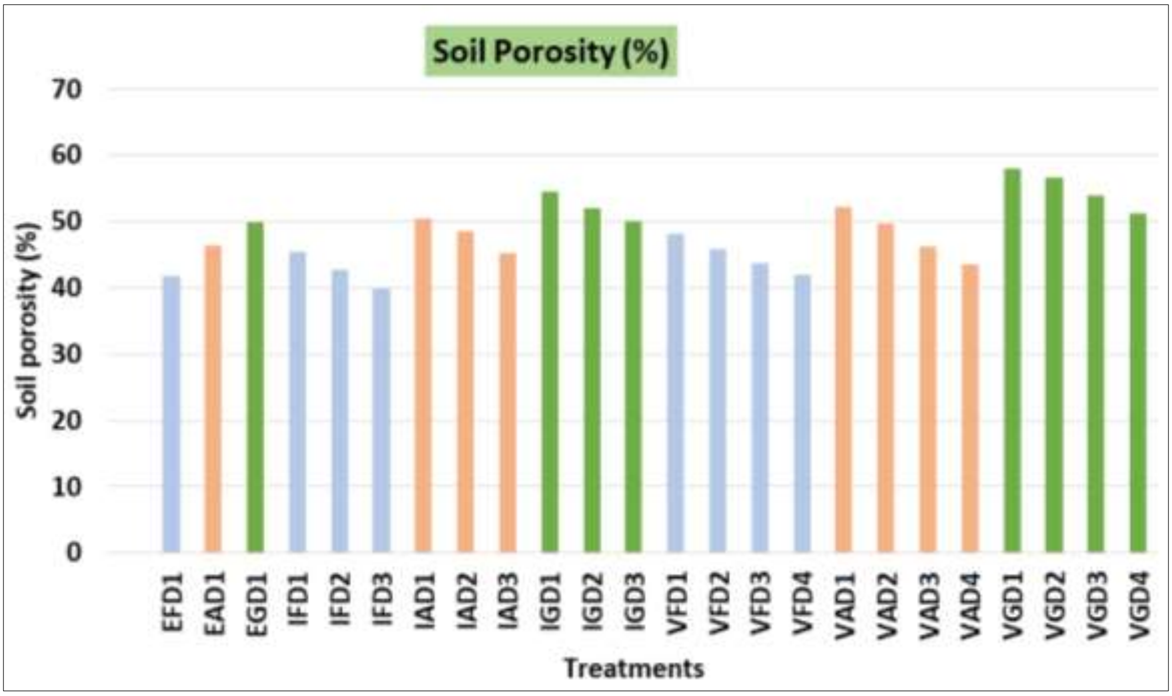

Fig 4: Effect of different land use on depth wise soil porosity in Rahuri, Pather and Babulgaon soil series

Conclusions

The guava-based horticulture land use system was better than conventionally cultivated and fallow land for all the soil attributes studied. It was estimated that soil physical properties *viz.*, sand percent, silt percent, hydraulic conductivity, porosity showed decreasing trend with successive increase in soil depths. However, other soil properties, including clay content and soil bulk density, followed an increasing trend concerning soil depths.

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