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Assessment of carbon dynamics and available nutrients under citrus growing Vertisol's of Jalna Tahsil of Jalna district

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Abstract
The present investigation entitled "Assessment of carbon dynamics and available nutrients under citrus growing Vertisol of Jalna tahsil of Jalna District", was undertaken to know the fertility status of and carbon dynamics in citrus growing soils of Jalna tahsil during year, 2021-2022 For this purpose total 90 soil samples were collected from fifteen villages. Out of which 52 number of soil samples were identified and categorized under Vertisol soil order with respect to age group orchards and depth of soil sample. All soils from Vertisol order under study were neutral to alkaline in reaction and found no deleterious effect on crop. However, it was also noticed that most of the soil under study were non calcareous to calcareous in nature. Further it was concluded that pH, bulk density and calcium carbonate were increased with depth. The soils collected from different age groups of citrus orchards were noted in available content was noted in very low to moderate in available N, very low to low in available P and high to very high in available K. Soil sample under this study in respect of soil inorganic carbon, total carbon and carbon stock were showed increasing trend with respect to depth. However, SOC was decreased with increase in depth.

Keywords: Ph, EC, OC, $CaCO_3$ carbon dynamics, soil fertility

Introduction

Sweet Orange is considered as most important fruit crop of citrus group with their wholesome nature multifield nutrition and medicinal value have made them so important. Sweet Orange (*Citrus sinensis*) belongs to family Rutaceae. Sweet orange needs dry climate, arid weather and distinct summer and winter seasons with low rainfall. It is grown on wide range of soil ranging from clay to light sandy and sensitive to salt. Sweet orange is well grown on medium black, red, alluvial river bank loamy soil of Maharashtra state. In Maharashtra sweet orange is cultivated on an area of 35,500 ha with a production of 5.18 lakh tonnes of fruit. Maharashtra is in second placed both in area and production of Sweet Orange during the year 2019-20.

The physico-chemical properties such as soil pH, calcium carbonate ($CaCO_3$) and organic carbon are important as these affects the availability of nutrients in soil and there by on crop growth and production. Calcium is the secondary nutrient element required by all higher plants absorbed as Ca^{++} ion. It is constituent of cell wall, increases stiffness of plants and it plays an important role in cell. The macronutrients N, P and K are important soil elements that control the soil fertility. Nitrogen is available in inorganic forms to the plants. It is essential constituent of chlorophyll, protoplasm, protein and nucleic acid and imparts dark green colour required for photosynthesis. Phosphorus is the structural component of the plant cell. Phosphorus required for early root development and growth. Potassium is important for increasing disease resistance capacity of the plant. It plays catalytic role in activating enzymes and starch synthesis as well as it improves quality of the produce.

Carbon sequestration is a mechanism for removal of carbon from the atmosphere by storing it in biosphere (Chavan and Rasal, 2012) [6]. Carbon sequestration in the agriculture sector refers to the capacity of agriculture, horticulture and forests to remove carbon dioxide from the atmosphere. Carbon dioxide is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage and roots and soils (Patil and Kumar, 2017) [1]. Bhavya *et al.* (2017) [17] reported that, growing of perennial horticultural crops is one of the strategies to improve soil conditions which would result in enhancing soil attributes and contributing to the good soil health and helps to sequester more organic carbon and carbon dioxide in soil as compared to annual crops.

However, the benefits of perennial horticultural crops on soil in improving its chemical properties have been well known.

Soil chemical, physical and biological properties vary within a single field. The present study focused on soil organic carbon storage in citrus orchard and to study the available primary nutrient and micronutrient present in citrus orchard and to study the carbon dynamics and to find out the correlation between available nutrient and carbon present in citrus orchard. Jalna tahsil of Jalna district of Marathwada region of Maharashtra is selected for this study, as it has wide varieties of soil.

Materials and Methods

Jalna district, which is one of the districts of Marathwada region, lies between 19 Degree & 15 minutes and 20 Degrees & 32 minutes north latitude and 75 Degree & 45 minutes east longitude approximately. (dsmsce.gov.in). The northern part of the district is occupied by the Ajanta and Satmala hill range. The general slope of the district is towards the southeast, and the average altitude above mean sea-level is 534 metres. Average Rainfall ranges between 600 to 700 mm. The mean annual rainfall of district is 890.34 mm and mostly received during June to September. The annual maximum temperature range between 410 to 45 °C and minimum temperature range between 11.20 to 35 °C.

Forty-five sweet orange orchards growing belt of Jalna taluka of Jalna district having cultivation of more than of one hectare and having plant population more than 100 plants. The information about the GPS location orchards (GPS Map Camera.apk), name of cultivar, mobile no, survey no. area of orchards and age of orchards. In order to know the nutrient status of soil citrus orchards were selected by different age group i.e. (0-5 years), (5-10 years), and (10-15 years) at different depth of (0-30 cm) and (0-60 cm) surface soil and subsoil respectively. Surface soil sample (0-30 cm) and subsoil sample (30-60 cm) were collected avoiding any metallic contamination with the help wooden khurapi and scoop. Soil samples from 0-30 cm and 0-60 cm depth were collected from sweet orange orchards of Jalna taluka of Jalna district. Four citrus plants selected and centre of four plant selected for soil sampling. Soil clod from surface soil and subsoil were collected.

Soil samples collected from the study area were dried and crushed with the help of wooden rod and passed through 2 mm sieve and then used for the determination of Physico chemical properties and available nutrient content by adopting standard laboratory method. Soil pH and Electrical conductivity (E.C.) in 1:2.5 soil water suspension was determined by Jackson (1973) [6]. Modified method of Walkley and Black (1934) [17] was used for determination of organic carbon. The free calcium carbonate was determined by rapid titration method as outlined by Piper (1966), available nitrogen was estimated by alkaline $KMnO_4$ method given by Subbiah and Asija (1956) [13], available phosphorus was extracted by 0.5M $NaHCO_3$ solution buffer at pH 8.5 given by Olsen *et al*. (1954) [18] whereas available potassium was extracted shaking with ammonium acetate and determined by flame photometer given by Jackson (1973) [6] respectively. Estimation of total carbon will be carried out by modified Walkley and Black method as developed by Chan *et.al*. (2001) [19]. soil Carbon stock was estimated by mass, volume and density relationship soil inorganic carbon (SIC) the calculation was carried out by using 12% Carbon value in $CaCo_3$. Correlation study was undertaken to find out the relation between physical chemical properties of soil with carbon dynamics by Panse & Sukhatme (1985) [20], (opstat.com).

Results and Discussion

The results obtained from the present investigation and from laboratory and satisfied analysis were presented with table and figures.

Status of Physico-chemical properties of citrus growing soil from Jalna Tahsil

pH

The data from Table 1 pH of soils from 0-5 age group of citrus orchards was varied from 6.36 to 8.53 with a mean of 7.68 at 0-30 cm depth, whereas, it was ranged from 7.13 to 8.45 with a mean of 7.82 at 0-30 cm at 30-60 cm depth. Further data on pH of soils from 5–10-year, age group of citrus orchards was ranged from 7.40 to 8.60 and 7.57 to 8.28 with an average value 7.92 and 7.73 at 0-30 and 30-60 cm depth respectively. However, it was also noticed from the data presented table from 10-15-year, age group of citrus orchards soils the pH was varied from 7.03 to 8.04 and 7.03 to 8.80 with a mean value 7.71 and 7.74, at 0-30 and 30-45 cm depth respectively. The higher pH was noticed in the sub-surface region of these soils, this might be attributed to low organic matter content and leaching of exchangeable bases lower horizons. The higher pH values in orchard soils could be attributed to comparatively less leaching of bases in fine textured soils like sandy clay and sandy clay loam. Similar results were reported by Chetna and Prasad (2011) [21].

EC

The EC of Vertisol soils from 0-5 age group of citrus orchards was varied from 0.18 to 0.34 dSm^{-1} and 0.18 to 0.33 dSm^{-1} with a mean of 0.26 dSm^{-1} and 0.26 dSm^{-1} at 0-30 and 30-60 cm depth respectively. Further, in 5–10-year, age group of citrus orchards EC of soils was ranged from 0.18 to 0.32 dSm^{-1} and 0.17 to 0.34 dSm^{-1} with an average values 0.26 dSm^{-1} and 0.25dSm^{-1} at 0-30 and 30-60 cm depth respectively. Whereas, it also seen from data (Table 1) that in 10-15-year, age group of citrus orchards grown under Vertisol soils, the EC of these soils was varied from 0.19 to 0.39 dSm^{-1} and 0.19 to 0.38 dSm^{-1} with a mean value 0.28 dSm^{-1} and 0.28 dSm^{-1} at 0-30 cm depth and 30-45 cm depth generally, EC decreased with increased in depth. It is found that there was no remarkable accumulation of soluble salt in soils because of sufficient leaching of soluble salt from upper zone to lower zone. Thombe *et al* (2020) [14], Ajagaonkar and Patil (2017) [1].

Table 1: Physico-chemical properties of Vertisol soil from citrus growing orchards

Depth of soil (cm)	Parameter	pH	EC (dSm^{-1})	Organic Carbon (g kg^{-1})	$CaCO_3$ (%)
Age- 0-5 year					
0-30 cm	Range	6.36-8.53	0.18- 0.34	2.99-6.98	2.90 - 22.4
	Mean	7.68	0.26	5.30	8.96
30-60 cm	Range	7.13-8.45	0.17-0.33	2.19-6.18	4-23.4
	Mean	7.82	0.26	4.23	12.73
Age 5-10 years					
0-30 cm	Range	7.4-8.60	0.18-0.32	3.59-8.17	4.5 - 24.5
	Mean	7.92	0.26	5.69333	11.1889

30-60 cm	Range	7.57-8.28	0.17-0.34	2.59-4.19	6-25
	Mean	7.73	0.25	4.19222	13.2444
Age 10-15 years					
0-30 cm	Range	7.13-8.4	0.19-0.39	3.99-7.99	4.5-23.1
	Mean	7.71556	0.28889	5.90444	11.1222
30-60 cm	Range	7.03-8.8	0.19-0.38	3.19-6.18	5.5-24
	Mean	7.74889	0.28	4.47333	12.5444

Organic Carbon

The data from Table 1 indicated that the organic carbon content in soils from 0-5 age group of citrus orchards was varied from 2.99 to 6.98 g kg^{-1} and 1.19 to 6.18 g kg^{-1} with a mean of 5.30 g kg^{-1} and 4.23 g kg^{-1} at 0-30 and 30-60 cm depth respectively. Whereas, in 5–10-year, age group of citrus orchards organic carbon content in soils were ranged from 3.59 to 8.17 g $kg^{-1}$and 2.59 to 6.98g kg^{-1} with a mean value 5.69 g kg^{-1} and 4.19 g kg^{-1} at 0-30 and 30-60 cm depth respectively. However, the values of soil organic carbon content in 10-15-year, age group of citrus orchards were varied from 3.99 to 7.99 g $kg^{-1}$with a mean value 5.90 g kg^{-1} at 0-30 cm depth. While, it was ranges from 3.19 to 6.18 g kg^{-1} with a mean value 4.47 g kg^{-1} at 30-60 cm depth. The high organic carbon content in surface soil was due to natural vegetation and addition of organic matter by farmers. The low organic carbon content was recorded in subsurface region of these soils because of reduced the decomposition rate at lower depth is the lack of fresh organic carbon in lower soil layers and decreasing input of surface litter (Datta *et al*, 2015) [2]. Zade *et al* (2020) [16], Ajagaonkar and Patil (2017) [1].

Calcium Carbonate

The data on Calcium carbonate percentage in soils from 0-5 age group (Table 1) of citrus orchards was presented in the data showed that calcium carbonate content in these soils was varied from 2.90 to 22.40 per cent and 4.00 to 23.40 per cent with a mean value of 8.96 per cent and 12.73 per cent at 0-30 and 30-60 cm depth respectively. Further data showed that calcium carbonate percentage in 5–10-year, age group of citrus orchards soils was ranged from 4.50 to 24.50 per cent and 6.0 to 25.0 with a mean value 11.18 per cent and 13.24 per cent at 0-30 and 30-45 cm depth respectively. However, soil samples collected 10-15-year-old age group of citrus orchards showed that calcium carbonate content in these soils was varied between 4.50 to 23.10 per cent with a mean value 11.12 per cent at 0-30 cm depth. While, it was ranged from 5.50 to 24.0 per cent with a mean value12.54 per cent at 30-45 cm depth. Generally, calcium carbonate range were increased with increased in depth this might be due to leaching of bicarbonates and bases during rainy season from upper layer

Macro nutrient status of Vertisol soil from citrus growing orchards

Available nitrogen

Status of available nitrogen (Table 2) of Vertisol soils in 0-5 age group of citrus orchards varied from 104.65 to 231.29 kg ha^{-1} and 103.76 to 149.76 kg ha^{-1} with a mean of 168.40 kg ha^{-1} with and 131.19 kg ha^{-1} at 0-30 cm depth and 30-60 cm depth respectively. Whereas, in 5–10-year, age group of citrus orchards available N ranged from 112.12 to 215.61 kg ha^{-1} and 103.31 to 165.44kg ha^{-1} with a mean value 168.28 kg ha^{-1} and 129.91 kg ha^{-1} at 0-30 cm depth and 30-60 cm depth respectively. It is also seen from data Table 2 in 10-15-year, age group of citrus orchards grown under Vertisol order available N of these soils was varied from 105.85 to 253.24 kg ha^{-1} and 102.72 to 190.52 kg ha^{-1} with a mean value 164.11 kg ha^{-1} and 128.78 kg ha^{-1} at 0-30 cm depth and 30-45 cm depth. Nitrogen content in surface was higher as compared to the lower depths of soil, which might be due to presence of more organic matter in surface than sub-surface soil. Marathe *et al*.., (2015) [8].

Available Phosphorous

Status of available P in soils from 0-5 age group of citrus orchards are presented in Table 2 shows that, available P in soils were varied from 8.19 to 12.76 kg $ha^{-1}$and 8.019 to 12.85 kg ha^{-1} with a mean of 10.95 kg ha^{-1} and 11.27 kg ha^{-1} at 0-30 cm depth and 30-60 cm depth respectively. Whereas, in 5–10-year, age group of citrus orchards available P content in these soils were ranged from 7.30 to 13.26 kg ha^{-1} and 7.03 to 13.20 kg ha^{-1} with an average value of 10.85kg ha^{-1} and 10.73 kg ha^{-1} at 0-30 and 30-60 cm depth respectively. However, It is also seen from data that in 10-15-year, age group of citrus orchards grown under Vertisol order, available P content in these soils were varied from 7.07 to 12.94 kg ha^{-1} and 7.03 to 12.81 kg $ha^{-1}$with a mean value 10.90 kg ha^{-1} and 10.74 kg ha^{-1} at 0-30 and 30-60 cm depth respectively. Available P content was decreased with increase in depth, this might be attributed to the fact that the availability of P in subsurface region decreased by more P -fixation in the form of tri-calcium phosphate. Kadam *et al.* (2021) [1].

Table 2: Available nutrient status of Vertisol from citrus growing orchards

Depth of soil (cm) Parameter		N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Age- 0-5 year				
0-30 cm	Range	104.65-231.29	11.37-11.91	436.8-806.4
	Mean	168.4	10.9525	557.65
30-60 cm	Range	103.76-149.76	11.87-11.69	392-806.4
	Mean	131.19	11.2799	564.125
Age 5-10 years				
0-30 cm	Range	112.12-215.61	9.4-10.58	436.8-1254.4
	Mean	168.28	10.85	630
30-60 cm	Range	103.31-165.44	9.36-13.2	403.2-1187
	Mean	129.91	10.73	625.75
Age 10-15 years				

0-30 cm	Range	105.85-235.34	10.39-12.94	358-851.2
	Mean	164.11	10.9013	627.125
30-60 cm	Range	102.72-190.52	10.3-12.81	414.4-806.4
	Mean	128.78	10.7488	583.325

Available Potassium

Status of available potassium (Table 2) in Vertisol soils in 0-5 age group of citrus orchards were varied from 324 to 806.4 kg ha^{-1} and 246 to 806.4 kg ha^{-1} with a mean of 557.65 kg ha^{-1} and 564.15kg ha^{-1}at 0-30 cm depth and 30-60 cm depth respectively. Whereas, In 5–10-year, age group of citrus orchards available K was ranged from 313.6 to 1254.4 kg ha^{-1} and 280 to 1187kg ha^{-1}with an average value 630 kg ha^{-1} and 625 kg ha^{-1} at 0-30 and 30-60 cm depth respectively. However, available K content was decresed with increase in depth this might be due to availability K- rich mineral in parent material, with presence of high clay content like Feldspars, mica and Illite etc. Bachewar and Pathan (2018) [3].

Carbon dynamics of Vertisol soil from citrus growing orchards

Soil organic Carbon (SOC)

The data from Table 3 indicated that soil organic carbon content in soils from 0-5 age group of citrus orchards was varied from 2.99 to 6.98 g kg^{-1} and 1.19 to 6.18 g kg^{-1} with a mean of 5.30 g kg^{-1} and 4.23 g kg^{-1} at 0-30 and 30-60 cm depth respectively. Moreover, from 5–10-year, age group of citrus orchards soil organic carbon content in soils were ranged from 3.59 to 8.17 g kg^{-1}and 2.59 to 6.98g kg^{-1} with a mean value 5.69 g kg^{-1} and 4.19 g kg^{-1} at 0-30 and 30-60 cm depth respectively Whereas, values of soil organic carbon content in 10-15-year, age group of citrus orchards were varied from 3.99 to 7.99 g kg^{-1}with a mean value 5.90 g kg^{-1} at 0-30 cm depth. While, it was ranges from 3.19 to 6.18 g kg^{-1} with a mean value 4.47 g kg^{-1} at 30-60 cm depth. The high organic carbon content in surface soil was due to natural vegetation and addition of organic matter by farmers. The low organic carbon content was recorded in subsurface region of these soils because of reduced the decomposition rate at lower depth is the lack of fresh organic carbon in lower soil layers and decreasing input of surface litter (Datta *et al*, 2015) [2]. Zade *et al* (2020) [16], Ajagaonkar and Patil (2017) [1].

Soil inorganic Carbon (SIC)

The data from Table 3 in 0 –5-year, age group of citrus orchards inorganic carbon ranged between 3.48 to 26.88 g kg^{-1} with a mean 10.71 g kg^{-1} at 0-30 cm depth. Whereas, it was varied from 4.8 to 28.08 g kg^{-1} at 30-60 cm depth. It is also seen from the data in table inorganic carbon in soils of citrus orchards from 5–10-year, age group varied from 5.4 to 29.4 g kg^{-1} and 7.2 to 30 g kg^{-1} with a mean 13.76, g kg^{-1} and 16.45g kg^{-1} at 0-30 cm depth and 30-60 cm depth respectively. However, in 10–15-year, age group of citrus orchards, inorganic carbon was varied from 5.4 to 27.72 g kg^{-1} with a mean value 14.59 g kg^{-1} at 0-30 cm depth and was ranged from 1.57 to 28.8 g kg^{-1} with an average 15.01g kg^{-1} at 30-60 cm depth respectively. However, SIC recorded in increasing trend with increase in depth. This might be due to presence of lithogenic inorganic carbon or secondary carbonate under semi-arid climate where evapotranspiration far exceeds precipitation (Zade, *et al*., 2020) [16].

Table 3: Carbon dynamics of Vertisol soil from citrus growing orchards

Depth of soil (cm)	Parameter	SOC (g kg^{-1})	SIC (g kg^{-1})	Total Carbon (g kg^{-1})	Carbon Stock (t ha^{-1})
Age- 0-5 year					
0-30 cm	Range	2.99-6.98	6.66-26.88	11.06-36.20	49.45-215.05
	Mean	5.3	10.71	17.17	105.54
30-60 cm	Range	1.19-6.18	6.58-28.08	12.40-34.36	104.65-379.33
	Mean	4.23	13.6625	20.94	216.47
Age 5-10 years					
0-30 cm	Range	3.59-8.17	5.4-16.10	12.05-23.85	56.28-252.74
	Mean	5.69	13.76	21.32	105.97
30-60 cm	Range	1.19-4.19	8.4-16.30	12.60-37.72	104.99-551.64
	Mean	4.19222	16.455	22.1	245.9517
Age 10-15 years					
0-30 cm	Range	3.99-7.99	5.52-17.72	12.52-36.77	67.25-210.74
	Mean	5.90444	14.595	22.39	121.93
30-60 cm	Range	3.19-6.18	9-18.8	13.26-32.90	160.31-491.54
	Mean	4.47333	15.01625	22.95423	256.39

Total Carbon (TC)

In 0–5-year, age group of citrus orchards total carbon ranged between 14.85 to 16.09 g kg^{-1} with a mean 15.42 g kg^{-1} at 0-30 cm depth. Whereas, it was varied from 13.73 to 15.00 at 30-60 cm depth. It is also seen from the data in Table 3 total carbon in soils of citrus orchards from 5–10-year, age group varied from 12.05 to 35.85 g kg^{-1} and 9.99 to 37.72 g kg^{-1} with a mean 21.32 g kg^{-1} and 22.10g kg^{-1} at 0-30 cm depth and 30-60 cm depth respectively. Whereas, in 10–15-year, age group of citrus orchards, total carbon was varied from 12.52 to 36.77 g kg^{-1} with a mean value 22.39 g kg^{-1} at 0-30 cm depth while it was ranged between 13.26 to 32.90 g kg^{-1} with an average 22.95 g kg^{-1} at 30-60 cm depth. In general, maximum total carbon content in soils was noted at subsurface region as compare to surface region. This might be correlated to soil inorganic carbon content in subsurface region. Singh *et al* (2007) [12], Gupta and Sharma (2011) [7] and Zade *et al.* (2000) [16].

Carbon Stock (CS)

The data from Table 3 carbon stock in soils of citrus orchards 0–5-year, age group of ranged from 49.4 to 215.05 t ha^{-1}and 104.65 to 379.33 t ha^{-1} with a mean value 99.54 t ha^{-1} and 216.4 t ha^{-1} at 0-30 cm depth and 30-60 cm depth respectively.

Moreover, in 5–10-year, age group of citrus orchards carbon stock varied from 56.28 to 252.74 t $ha^{-1}$and 104.99 to 551.64 t ha^{-1} with a mean value 105.97 t ha^{-1} and 245.95 t ha^{-1} at 0-30 cm depth and 30-60 cm depth respectively. Whereas, in 10–15-year, age group of citrus orchards carbon stock ranged between 67.25 to 210.74 t ha^{-1} with a mean value 121.93 at 30 cm depth. Whereas, it was varied from 160.31 to 491.54 with an average 256.39 t ha^{-1} at 30-60 cm depth. Carbon stock in subsurface layer were showed increasing trend with respect to depth. This could be attributed to continuous addition farm yard manure and organic matter in orchards which leads to continuous decomposition of accumulated organic matter. Shinde *et al.* (2020) [9].

Conclusion

Vertisol soil under study were neutral to alkaline in reaction and found no deleterious effect on crop. pH, EC and Calcium carbonate were increased with depth. The available nitrogen content was low and available P_2O_5 low in range and available potassium showed highest ratings in availability. However, it was also concluded that available nutrients decreased with increase in depth. Vertisol under study carbon dynamics soil inorganic carbon, Total carbon and carbon stock were showed increasing trend with respect to depth.

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