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Carbon sequestration assessment in sapota orchard at regional fruit research station, Ganeshkhind, Pune, Maharashtra

Murodiye Kishor Ramchandra, Deepak Dulaji Sawale, Abhay Vijay Patil and Marella Rahul Reddy

Abstract
The present research experiment was studied at Regional Fruit Research Station, Ganeshkhind, Pune and Division of Soil Science and Agricultural Chemistry, College of Agriculture, Pune during 2020-2021. An 18-year-old Sapota orchard that had been planted on Inceptisol was used for the experiment. Eight alternate bearing Sapota genotypes were delineated for research along with traditionally cultivated soil. Biometric observations recorded during the study *viz.* diameter at breast height, tree height, volume of tree, below ground biomass, above ground biomass, total plant biomass and plant carbon were taken uniformly for the estimation of carbon stock from Sapota genotypes. Estimates were made for the soil organic carbon stock at two depths and carbon sequestration per tree during an 18-year period. Among the Sapota 8 genotypes, CO-2 recorded higher tree height (540 cm), diameter at breast height (57 cm), volume of tree (1377251.10 cm^3), above ground biomass (1115.57 kg $tree^{-1}$), below ground biomass (290.04 kg $tree^{-1}$) and total plant biomass (1405.62 kg $tree^{-1}$) which resulted into higher accumulation of plant carbon (702.81 kg $tree^{-1}$) followed by PKM-1 and PKM-Hy-7/1. Significantly higher soil organic carbon stock was recorded from CO-2 (36.94 and 35.64 Mg ha^{-1}) followed by PKM-1 (36.70, 35.08 Mg ha^{-1}) while lower soil organic carbon stock was observed in Cricket ball (32.56 and 31.46 Mg ha^{-1}).

Keywords: Sapota genotypes, soil carbon stock, carbon sequestration

Introduction
Carbon is a significant element found in all living species, mostly in the form of plant biomass, soil organic matter, and the gas carbon dioxide, which is dissolved in soil water. Carbon sequestration refers to the long term storage of carbon in the oceans, soils, vegetation (particularly forests), and geologic formations (William, 1999 and Dharmesh *et al*., 2014) [14, 4]. Carbon sequestration is the process through which CO_2 from the atmosphere is taken by trees, plants and crops and stored as carbon in biomass such as tree trunks, branches, foliage, roots, and soils through photosynthesis (EPA, 2011) [6]. Carbon dioxide is emitted by a range of human activities, which are referred to as sources of CO_2, while it is is removed by sinks of CO_2. Forests and soils, on the other hand, have a significant impact on CO_2 levels in the atmosphere since forest vegetation is a major component of the global carbon cycle, storing at least 350 pg of carbon (Dixon *et al*., 1994) [5]. Despite the forest's ability to store large amounts of CO_2, its projected carbon storage is vulnerable to change due to variables such as conversion of forest areas to other land uses, timber harvesting, mining, and other activities that result in changes in carbon fluxes to the atmosphere. Tree species, soil type, regional climate, terrain, and management practises all affect carbon sequestration rates (EPA, 2011) [6]. Until a tree develops, the quantity of carbon stored by it continues to increase significantly over time and age. Different parameters, such as tree age, leaf area, and photosynthetic efficiency, influence the carbon capture process in photosynthesis. Increased carbon emissions are a big source of concern around the world, and the Kyoto Protocol does a good job of addressing it (Ravindranath *et al.*, 1997; Chavan and Rasal, 2010) [11, 1]. Above ground biomass (AGB) of tree includes all living biomass of all its parts above the soil, while below ground biomass (BGB) includes all the plant biomass of live roots excluding the fine roots of sizes < 2 mm diameter (Ravindranath and Ostwald, 2008) [12].
Sapota (*Achras zapota* L.) is a delicious fruit introduced from tropical America and first planted at Gholrad near Mumbai in 1898. The country that produces the most sapota is India. Gujarat, Karnataka, Maharashtra and Tamil Nadu are among the states where it is grown.

Gujrat is the largest producer of sapota in India, followed by Karnataka. In India, sapota farming covers over 97 thousand hectares. Much less work has been carried out on carbon sequestration potential of sapota trees. Keeping the above facts in view, the present investigation was under taken to study the soil organic carbon sequestration under sapota plantation.

Materials and Methods

Sapota orchard with 8 genotypes (more than 18 years old) at Regional Fruit Research Station, Ganeshkhind, Pune was selected for present study. The research station is having light to medium and well drained soil. The mean annual rainfall varies between 650-750 mm and normally distributed from June to October. The average maximum and minimum temperature recorded during the experiment was 40.0 °C and 11.6 °C, respectively.

Total 36 soil samples were collected from all the eighteen quadrats at different depth i.e. 0-30 cm and 30-60 cm. Then the samples were dried under shade to remove the moisture content and crushed with the help of wooden mortar and pestle. After that the soil was sieved through 2 mm sieve to obtain a uniform sample. The pH and Electrical conductivity were recorded by using pH meter and conductivity method respectively. For estimation of calcium carbonate ($CaCO_3$), “Acid Neutralization method” was used. For estimation of Nitrogen and Phosphorous, alkaline permanganate and Ammonium acetate extract method was followed respectively whereas in case of Potassium, flame photometer was used for estimation. For the study, micronutrient estimation (Fe, Mn, Zn, Cu) was done using Atomic Absorption Spectrophotometer. Total carbon content of soils is determined by Nelson and Somner method (1982) [15]. Estimated effect of different Sapota genotypes and depth on soil chemical properties of soil after eighteen years of plantation before taking biometric observations (Table 1).

Table 1: Soil chemical properties:

Sr. no.	Properties	Range
1.	pH (1:2.5)	7.71 - 8.35
2.	EC (dS m-1)	0.14 - 0.18
3.	Calcium carbonate (%)	6.54- 7.16
4.	Available N (kg ha-1)	135.30 - 162.91
5.	Available P (kg ha-1)	11.52- 20.71
6.	Available K (kg ha-1)	445.52- 587.41
7	DTPA-Fe (mg kg-1)	6.21 - 8.36
8	DTPA-Mn (mg kg-1)	10.41 - 11.77
9	DTPA-Zn (mg kg-1)	2.08- 2.87
10	DTPA-Cu (mg kg-1)	12.54- 23.25

The biometric observations *viz.*, tree height, diameter at breast height (1.3 meter from ground), volume of tree, above ground biomass, below ground biomass, total plant biomass and plant carbon for Sapota garden were estimated.

Details of Genotypes

Sr. no.	Genotypes	Sr. no.	Genotypes
1.	Kalipatti	6.	CO-2
2.	CO-1	7.	PKM-Hy-7/1
3.	Cricket Ball	8.	PKM-2
4.	Kirti harti	9.	Conventionally cultivated soil (without Sapota tree)
5.	PKM-1		

The height and diameter at breast height (DBH) are two main biophysical measurements which measured for each tree sample. The Sapota tree height measured by measuring tape and bamboo stick. The tree diameter was measured at breast height (DBH) by using measuring tape (at 1.3 meters height from ground).

Estimation of above and below ground biomass

Above ground biomass includes all living biomass above the soil. The above ground biomass (ABG) has been calculated by multiplying volume of tree and wood density (Ravindranath and Ostwald, 2008) [12]. The volume was calculated based on diameter and height.

AGB (g) = Volume of tree (cm^3) x wood density (g cm^{-3})

The below ground biomass (BGB) has been calculated by multiplying above ground biomass taking 0.26 as the root to shoot ratio (Ravindranath and Ostwald, 2008) [12].

BGB (kg) = AGB (kg) x 0.26

Volume of tree was estimated by using diameter at breast height (DBH) of tree and computed as per the standard formula (Ravindranath and Ostwald, 2008) [12].

Volume of tree (V) (cm3) = π x r2 x H

Where,
V = volume of tree in cubic centimetres or cubic metre
r = radius of the tree 1.3 m above ground = DBH / 2
H = height of the tree in centimetres or metres
Total plant biomass is the sum of the above and below ground biomass (Chavan and Rasal 2011) [2].

TPB=AGB+BGB (All values are in kilogram)

Generally, for any plant species 50% of its biomass is considered as carbon (Chavan and Rasal 2011) [2].
Plant Carbon = total plant biomass x 50% or Biomass / 2

Estimation of Soil organic carbon stock

Soil organic carbon stock at two depths i.e. 0-30 and 30-60 cm were estimated by using following standard formula (Jasmine, Wagner and Abbott 2021) [9].

SOC Stock= TOC x BD x D

Where,
TOC = Total organic carbon
BD = Bulk density of soil
D = Depth of soil layer

Soil Carbon sequestration

Soil carbon sequestration (kg tree-1) = SOC stock / Number of plants per hector

Result and Discussion

Biometric observations

The effect of the different Sapota genotypes on total plant biomass and plant carbon is presented in [Table-2]. The Sapota genotype CO-2 recorded higher above ground biomass (ABG) (1115.57 kg $tree^{-1}$) and below ground biomass (BGB)

(290.04 kg tree^{-1}) as compared to all other genotypes. However, lower ABG (417.82 kg tree -1) and BGB (108.63 kg tree^{-1}) were observed in Cricket ball genotype. Further genotype CO-2 recorded higher total plant biomass (1405.62 kg tree^{-1}) and plant carbon (702.81 kg tree^{-1}) as compared to other genotypes followed by PKM-1 and PKM-Hy-7/1.

Among the different genotypes, CO-2 recorded higher tree height (540cm), trunk diameter at breast height (57 cm), volume of tree (1377251.10 cm^3), above ground biomass, below ground biomass, total plant biomass than rest of the treatments and on the base of these biometric observations higher plant carbon were reported after calculation than rest of the treatments and on the base of these biometric observations higher plant carbon were reported after calculation than rest of the treatments. It might be due to higher leaf fall or litter fall consistently for the period of eighteen years, it's genetic character and well adoption to climatic conditions. Similar observations were also be recorded by Kaur *et al.* (2002) [10] and Chavan and Rasal (2012) [3].

The study was conducted on appraisal of carbon capture, storage and utilization through fruit crops and concluded that various fruit crops and concluded that various fruit crops like apple, mango, citrus and grapes have shown their potential roles in sequestering carbon. Further, they also reported calculation of C biomass gives an idea about the quantity and quality of carbon available in the area. Further, they have also stressed on necessity of estimation of carbon sequestration potential of various fruit crops in India (Sharma *et al.* 2021) [13].

Carbon Sequestration

Soil carbon sequestration was significantly influenced by sapota genotypes and with two depths (0-30 and 30-60 cm). Significantly higher carbon sequestration was recorded in the soil at two depths collected beneath the sapota genotype CO-2 (369.42 and 356.40 kg tree^{-1}) which was at par with CO-1 (367.20 and 341.94 kg tree^{-1}), PKM-1 (367.08 and 350.88 kg tree^{-1}) and PKM-Hy-7/1 (364.30 and 344.20 kg tree^{-1}) at 0-30 cm and 30-60 cm depth. This increased in SOC stock and carbon sequestration under sapota genotypes might be due the different quantities and qualities of organic matter input through fresh litterfall, living organisms and root activity. Similar results have been reported by Gupta and Sharma (2011) [7] and Gupta and Negi (2012) [8].

Table 2: Effect of sapota genotype on total plant biomass and plant carbon after eighteen years of plantation

Sr. No.	Genotypes	Tree height (cm)	Diameter at breast height (cm)	Volume of tree (cm^3)	Above ground biomass (kg tree^{-1})	Below ground biomass (kg tree^{-1})	Total plant biomass (kg tree^{-1})	Plant carbon (kg tree^{-1})
1.	Kalipatti	490	47.50	867866.56	702.97	182.77	885.74	442.87
2.	CO-1	510	52.00	1082546.40	876.86	227.98	1104.84	552.42
3.	Cricket ball	480	37.00	515839.20	417.82	108.63	526.46	263.23
4.	Kirti Bharti	510	51.50	1061828.30	860.08	223.62	1083.70	541.85
5.	PKM-1	520	55.50	1257358.10	1018.46	264.80	1283.26	641.62
6.	CO-2	540	57.00	1377251.10	1115.57	290.04	1405.62	702.81
7.	PKM-Hy-7/1	510	55.00	1211058.80	980.95	255.04	1236.00	618.00
8.	PKM-2	520	50.00	1020500.00	826.60	214.91	1041.52	520.76

Table 3: Effect of sapota genotype and depth on soil organic carbon stock and carbon sequestration after eighteen years of plantation

Sr. No.	Genotype	SOC (Mg ha^{-1})			Carbon sequestration per plant (kg tree^{-1})	
		Depth (cm)			Depth (cm)	
		0-30	30-60	Mean	0-30	30-60
1.	Kalipatti	34.17	32.05	33.11	341.70	320.58
2.	CO-1	36.72	34.19	35.46	367.20	341.94
3.	Cricket ball	32.56	31.46	32.01	325.62	314.64
4.	Kirti Bharti	35.91	34.61	35.26	359.10	346.11
5.	PKM-1	36.70	35.08	35.89	367.08	350.88
6.	CO-2	36.94	35.64	36.29	369.42	356.40
7.	PKM-Hy-7/1	36.43	34.42	35.43	364.30	344.20
8.	PKM-2	35.11	33.29	34.20	351.12	332.91
9.	Conventionally Cultivated soil	29.78	27.93	28.86	297.84	279.39
	Mean	34.92	33.19		---	---
		Genotype	Depth	G × D	---	---
	S.E.(m) ±	0.37	0.78	1.11	---	---
	CD at 5%	1.10	2.33	NS	---	---

Conclusion

It is concluded that the CO-2 sapota genotype was found most suitable for improving carbon fractions, carbon stock, carbon sequestration and fertility status of soil at 0-30 and 30-60 cm depth during eighteen years of sapota plantation in Inceptisol. The second most effective genotype is PKM-1 for improving carbon sequestration.

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