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Carbon sequestration under asana (*Bridelia retusa*) based agroforestry systems in red ferruginous Alfisols

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ABSTRACT: *An experimental study was conducted at the Research Farm of AICRP on Agroforestry, Dr. BSKKV, Dapoli, Maharashtra during 2019 and 2020. The experiment was laid out in a randomized block design (RBD) with eight treatment and three replications. The results emerged out indicated that significantly high carbon sequestration, growth performance of Asana based agroforestry were recorded by T6>T4>T5 than other. The carbon sequestration was found highest in T6 this may due to high availability of plant biomass addition in soil. The above ground biomass (AGB) (153.58 t ha^{-1}) and (166.25 t ha^{-1}) and below ground biomass (BGB) (38.40 t ha^{-1}) and (40.90 t ha^{-1}) were highly recorded by T6 in the year of 2019 and 2020. However, plant leaves C % (38.03%) and (39.00%), woody branches C % (42.47%) and (42.97%), branches C % (38.02%) and (39.04%) were highly recorded by T6 in the year of 2019 and 2020. Similarly, carbon (%) (8.12%) and (8.42%), plant carbon stock (75.83 t ha^{-1}) and (83.83 t ha^{-1}), soil carbon stock (33.20 t ha^{-1}) and (34.76 t ha^{-1}), plant carbon sequestration (95.99 t ha^{-1}) and (103.91 t ha^{-1}) as well as soil carbon sequestration (3.197 t ha^{-1}) and total carbon sequestration rate (7.32 t ha^{-1}) were highly recorded by T6 in both the year. The study showed that the T6-Asana + Jam agroforestry system sequestered more carbon than other treatments; it may be due to presence of high amount biomass and addition organic matter of that system. Overall, it can be concluded that the higher growth performance and more carbon sequestration were recorded significantly by (T6) Asana + Jam (Syzygium samarangense) followed by Asana + Morus alba (T4) than other. Thus, Asana + Jam agroforestry system was sequestered more carbon in lateritic soils of Konkan.*

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1. INTRODUCTION

Agroforestry, the practice of introducing trees in farming system has played a significant role in enhancing land productivity and improving livelihood in both developed and developing countries. The planting of tree along with crops improves soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of stream and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock (Mukundi and Sathaye, 2004). in which trees are planted among agricultural crops with the intention of enhancing the sequestration of atmospheric CO_2 in biomass and stable reservoirs, such as wood and soil (Barreto *et al.* 2009, Shibu and Sougata 2012, Atangana *et al.* 2014).Forest around the world play an important role in storing significant amount of carbon in their biomass and soil, which helps mitigate climate change (Canadell and Raupach, 2008). *Bridelia retusa* (L.) A. Juss., locally known as Asana belongs to Euphorbiaceae family. Normally asana was found in Konkan region of Maharashtra. It is an indigenous species in Konkan widely use farmers as a fodder and multipurpose tree species. It is found throughout India up to an altitude of 1000 m, except in very dry regions. Bark is grey to brown exfoliating in irregular flakes. By Asana based agroforestry systems removing carbon from the atmosphere and developing soil fertility and also helps to improved productivity of plants and crops. In contrast to selected forest tree along with some crop species for carbon sequestration and soil improvement naturally in the bio-diverse condition. This system used for bund plantation, block plantation, as a source of nutrient *etc.* easily in Konkan region. The present study focuses on "Carbon Sequestration and Soil Fertility under Asana based Agroforestry Systems in Rainfed Lateritic Soil. "Arial yam (*Dioscorea bulbifera*), Pineapple (*Ananas comosus*), Elephant foot yam (*Amorphophallus paeonifolins*), Mulberry (*Morus alba*), Karonda (*Carissa carandas*), Jam (*Syzygium samarangense*), Seedless lemon (*Citrus latifolia*), are being selected as intercrops in agroforestry system.

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2. MATERIAL AND METHODS

An experiment was conducted at Research Farm of All India Co-ordinated Research Project on Agroforestry, Dr. BSKKV, Dapoli, Dist. Ratnagiri, MS during the year 2019 and 2020. The 15 years old block plantation of Asana tree species and framed in a randomized block design (RBD) with eight treatments and three replication. The treatment comprises *viz.* T_1- Asana + Arial yam (*Dioscorea bulbifera*), T_2- Asana + Pine apple (*Ananas comosus*), T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*), T_4- Asana + Mulberry (Morus alba), T_5- Asana + Karonda (*Carissa carandas*), T_6- Asana + Jam (*Syzygium samarangense*), T_7- Asana + Seedless Lemon (*Citrus latifolia*) and T_8- Only Asana (*Bridelia retusa*). Non-destructive method used for estimating carbon sequestration. Treatment (Tree species) wise plant parts (leaf, stem, Branches) sample were collected for estimation of total biomass of tree and carbon analysis. Treatment wise plants observation recorded such as growth parameters, above ground biomass, below ground biomass, carbon percent, carbon stock, carbon sequestration and carbon sequestration rate.

a) Growth parameters: DBH and Height of plants measured by clinometer and meter tape. Diameter of plants was randomly selected at breast height of 1.3 m measured from the ground surface using a measuring tape.

b) Tree above ground biomass (t ha^{-1}): The above ground biomass was calculated by Non-distructive method with help of allometric equation by Dimobe *et al.* (2018).

$$AGB=\alpha+\beta \{(DBH)\ 2 \times Ht\}+ r$$

Where AGB is the Above ground biomass, α is the alpha, β is the beta DBH is the Diameter at breast height, Ht is the Height and r is the Regression coefficient.

c) Below ground biomass (t ha^{-1}): Below ground biomass of tree was calculated by multiplying above ground biomass with a factor of 0.25 for all tree species using the guidelines of IPCC (1996) and Carins and Meganck, (1994).

Below ground biomass = above ground biomass X 0.25

d) Carbon estimation (%): The leaves, stems and branches of each species were separated to estimate carbon by Ash method. Fresh part of each species wash with distilled water and dried in sunlight. 5 gm of each dried sample was taken in crucible and weight it. The crucibles were placed in the muffle furnace adjusted at 400 ^{o}C; it was carried out for 2.30 hours. The crucibles were cooled slowly inside the desiccators. After cooling the crucible, taken the weight of ash of samples with crucible and calculated the carbon percentage by Allen *et al.* (1986).

$$\text{Ash \%} = \frac{W3 - W1}{W2 - W1} \times 100$$

$$C\ \% = (100 - \text{Ash \%}) \times 0.58$$

Where, C is Organic carbon, W1 is weight of crucibles, W_2 is weight of grind samples with crucibles, and W_3 is the weight of ash with crucibles. 0.58 is the content of carbon in dry organic matter.

e) Plant carbon stock: Carbon stock was calculated by biomass of tree multiplying with carbon percent by Rajput (2010).

Carbon stock = Biomass x carbon content

f) Soil carbon stock: It was determine by using Total soil carbon, Bulk density and depth of soil layer. For calculated Soil carbon stock formula is given by Datta (2015)

SCS = TSC x BD x Depth

Where, SCS is the Soil carbon stock (t ha^{-1}), TSC is the Total soil carbon (g kg^{-1}), BD is the Bulk density (Mg m^{-3}) and depth of soil is in meter.

g) Plant carbon sequestration: Carbon sequestration is the amount 50% of total biomass. Carbon sequestration was calculated by Total biomass multiplying with 0.5 (Mac Dicken, 1997).

Carbon Sequestration (CSe) = Total biomass x 0.5

h) Soil carbon sequestration: It was determine by using the difference of Final and initial year Soil carbon stock. Formula given by Mandal *et al.* (2020)

C sequestration (t C ha^{-1}) = SCS Current – SCS initial

Where, SCS is the soil carbon stock of current year and SCS is the Soil Carbon stock of initial year.

i) Total carbon sequestration rate (t ha^{-1}): It was determine by using the difference of Final and initial year Soil carbon sequestration divided by number of years by Adhikari *et al.* (2019).

$$\frac{\text{CSR = Final year Cse- Initial year Cse}}{\text{No. of years}}$$

3. RESULTS AND DISCUSSION

Growth parameters: the growth attributes like DBH and height of plants measured by clinometer and meter tape. DBH and Height was useful to calculate above ground biomass. DBH was ranged from 16.06m to 18.99cm in 2019, 16.96 cm to 20.10 cm in 2020 (Table 1). Litton Creighton and Boone Kauffman (2008) studied that the allometric models are important for quantifying biomass and carbon storage in terrestrial ecosystems on the basis of DBH and height estimating biomass. However, Luoma *et al.* (2017) studied that the forest resource information has a hierarchical structure: individual tree attributes are summed at the plot level and then in turn, plot-level estimates are used to derive stand or large-area estimates of forest resources.

Estimation of above ground biomass: The most popular and non-destructive method of above ground biomass on the basis of DBH and height are used for estimating above ground biomass under asana-based agroforestry systems by using allometric equation (Dimobe *et al.* 2018). The above ground biomass was recorded in (Table 2). The highest value of above ground biomass was found in T_6– Asana + Jam (*Bridelia retusa* + *Syzygium samarangense*) , 153.58 t ha^{-1} in 2019 and increased up to166.25 t ha^{-1} in 2020, whereas lowest in T8– Only Asana (*Bridelia retusa*), 113.11 t ha^{-1} in 2019 and 119.46 t ha^{-1} in 2020. The biomass of T_6- Asana based + Jam in AS system was higher than other treatments of asana based agroforestry systems because T_6- Asana + Jam has more branches and dark and thick leaves as compared to other intercrops. Dimobe *et al.* (2018) studied that the above ground biomass was estimated by allometric question by using DBH and height. Chave *et al.* (2005) recorded that the above ground biomass measurement of each tree was subsequently converted into estimates of above ground biomass using allometric equations for moist deciduous forest stands that related tree diameter to biomass. Mac Dicken (1997) observed that the above ground biomass tree was estimated

Table 1. DBH and height under asana based agroforestry systems.

Treatments	DBH (cm)		Height (m)	
	2019	2020	2019	2020
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	16.63	17.68	6.32	6.68
T_2- Asana + Pine apple (*Ananas comosus*)	16.07	17.21	6.03	6.45
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	16.81	17.97	6.95	7.50
T_4- Asana + Mulberry (*Morus alba*)	17.80	18.36	6.80	7.03
T_5- Asana + Karonda (*Carissa carandas*)	17.44	18.03	6.61	7.12
T_6- Asana + Jam (*Syzygium samarangense*)	18.99	20.10	8.12	8.98
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	16.84	18.64	6.70	7.32
T_8- Only Asana (*Bridelia retusa*)	16.06	16.96	5.62	5.99
Mean	17.08	18.12	6.80	7.14
S.Em.±	0.17	0.21	0.15	0.08
C.D. at 5%	0.50	0.64	0.44	0.23
CV%	1.67	2.01	3.78	1.82

Table 2. Above and below ground biomass (t ha^{-1}) under asana based agroforestry systems.

Treatments	Above Ground Biomass (t ha^{-1})		Below Ground Biomass (t ha^{-1})	
	2019	2020	2019	2020
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	124.96	135.41	30.80	35.60
T_2- Asana + Pine apple (*Ananas comosus*)	121.42	128.10	30.91	32.03
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	127.91	136.17	33.18	36.03
T_4- Asana + Mulberry (*Morus alba*)	146.42	152.44	36.61	38.11
T_5- Asana + Karonda (*Carissa carandas*)	135.73	142.97	33.94	36.92
T_6- Asana + Jam (*Syzygium samarangense*)	153.58	166.25	38.40	40.90
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	128.98	142.07	32.25	35.52
T_8- Only Asana (*Bridelia retusa*)	113.11	119.46	28.28	29.86
Mean	131.52	140.36	33.04	35.62
S.Em.±	3.92	4.82	0.95	1.13
C.D. at 5%	11.88	14.61	2.88	3.43
CV%	5.16	5.94	4.98	5.50

using non- destructive sampling technique using DBH and Height.

Estimation of below ground biomass: The value of below ground biomass was highest in T_6- Asana + Jam (*Bridelia retusa + Syzygium samarangense*) 38.40 t ha^{-1} in the year of 2019 and increased to the level of 40.90 t ha^{-1} in 2020,whereas lowest in T_8 – Only Asana (*Bridelia retusa*) 28.28 t ha^{-1} in 2019 and 29.86 t ha^{-1} in 2020. The below ground biomass given in (Table 2). Biomass of tree roots, which is a large proportion of the below ground productivity, consists of coarse roots (>2 mm diameter) (Albrecht *et al.* 2004 and Akinnifesi *et al.* 2004). Fine roots of both trees and crops have a relatively fast turnover (days to weeks) (Van Noordwijk *et al.* 1998), but the lignified coarse roots decompose much more slowly and may thus contribute substantially to below ground C stocks (Vanlauwe *et al.* 1996). Similarly, Inamati and Patil (2019) and Bhalawe *et al.* (2019) observed that the below ground biomass of trees was calculated by multiplying above ground biomass with factor of 0.25 for all tree species using the guidelines of IPCC (1996) and Carins and Megnck (1994).

Estimation of plant carbon (%): The value of C % was highest in T_6 – Asana + Jam (*Bridelia retusa + Syzygium samarangense*) 38.03% in leaves, 42.47% in Woody branches, 38.02% in branches in the year of 2019 and increased up to 39.00% in leaves, 42.97% in

Table 3. Plant parts C (%) under asana based agroforestry systems.

Treatments	Leave C (%)		Woody branch C (%)		Branch C (%)	
	2019	2020	2019	2020	2019	2020
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	33.20	33.54	38.04	38.36	34.77	36.12
T_2- Asana + Pine apple (*Ananas comosus*)	33.08	33.53	37.80	38.14	34.83	34.79
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	33.09	33.80	38.18	38.46	34.88	35.20
T_4- Asana + Mulberry (*Morus alba*)	35.91	36.36	40.98	41.31	35.60	36.01
T_5- Asana + Karonda (*Carissa carandas*)	34.64	35.07	40.05	40.08	35.04	35.42
T_6- Asana + Jam (*Syzygium samarangense*)	38.03	39.00	42.47	42.97	38.02	39.04
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	33.75	34.097	39.50	39.81	34.94	35.28
T_8- Only Asana (*Bridelia retusa*)	31.39	32.27	37.29	37.66	34.03	34.66
Mean	34.14	34.71	39.29	39.60	35.26	35.82
S.Em.±	0.39	0.29	0.51	0.55	0.29	0.48
C.D. at 5%	1.20	0.91	1.51	1.67	0.91	1.46
C.V. %	2.02	1.47	2.22	2.41	1.47	2.33

Table 4. Total soil carbon under asana based agroforestry systems.

Treatments	Total soil carbon (%)	
	2019	2020
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	6.34	6.67
T_2- Asana + Pine apple (*Ananas comosus*)	6.15	6.51
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	6.56	6.84
T_4- Asana + Mulberry (*Morus alba*)	6.20	6.46
T_5- Asana + Karonda (*Carissa carandas*)	7.04	7.44
T_6- Asana + Jam (*Syzygium samarangense*)	8.12	8.42
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	6.92	7.27
T_8- Only Asana (*Bridelia retusa*)	5.36	5.52
Mean	6.59	6.89
S.Em.±	0.18	0.18
C.D. at 5%	0.57	0.55
C.V. %	4.94	4.56

Woody branches and 39.04% in branches in the year of 2020. While C% was lowest in T_8 – Only Asana (*Bridelia retusa*) 31.39% in leaves, 37.29% in Woody branches and 34.03% in branches in 2019 and 32.27% in leaves, 37.66% in woody branches, 34.66% in branches in the year of 2020 (Table 3). Carbon content of tree components was dependent on the ash content. Accordingly, Kraenzel *et al.* (2003) reported that woody tissues of trunk, roots, branches, and twigs were higher carbon content pools than soft tissue of leaves, flowers and fine roots. Wani and Qaisar (2014) recorded an average carbon content of 46.39% in the stem wood of Cerdrus deodara against 46.05% and 42.81% in its branches and leaves.

Estimation of total soil carbon (%): Data of total soil carbon (%) was statistically significant and it is given in (Table 4). The total soil carbon was found highest in T6–Asana+ Jam (*Bridelia retusa* + *Syzygium samarangense*) 8.12% in 2019 and increased up to 8.42% in 2020, whereas lowest in T_8 – Only Asana (*Bridelia retusa*) 5.36% in 2019 and 5.52% in 2020. The high value of total soil carbon % may be due to addition of high amount of organic matter decomposed in that treatment (T_6) as compare to others. Zaro *et al.*, (2019) observed that the addition, plant restudies of weeds, leaves and branches of coffee trees naturally fallen or detached during harvest, organic compounds released by the roots and decomposition of dead roots and microorganisms added to the soil, it increased the level of soil carbon. Benbi *et al.* (2011) recorded that the soil carbon under poplar-based agroforestry system and he observed the soil carbon pool in an ecosystem is controlled by the balance between the carbon inputs derived from litter fall, root biomass and root exudates and the outputs through heterotrophic respiration.

Plant carbon stock under asana –based agroforestry systems: Plant carbon stock was found significantly highest in T_6–Asana + Jam (*Bridelia retusa* + *Syzygium samarangense*) 75.83 t ha^{-1} in 2019 and increased up to 83.83 t ha^{-1} in the year of 2020,whereas lowest in T_8- Only Asana (*Bridelia retusa*) 48.40 t ha^{-1} in 2019 and 52.06 t ha^{-1} in 2020. It is given in (Table 5).The high value of carbon stock in T_6 – Asana + Jam, this may be due to thick and dark leaves of Jam, the plant species characteristics structure, patterns of branches in trees and genetic makeup of T_6 – Asana + Jam which accumulated highest carbon from atmosphere, thus carbon stock depends on age, structure and genetic makeup. Similarly, Baker *et al.* (2002), Pambudi (2011) and Andre *et al.* (2005) reported that plant biomass increases with tree age with increases carbon stock in tree. Hairiah (2007) showed that natural forest possessed the highest amount of stored carbon as compared to other land use system and it depends on biomass.

Soil carbon stock under asana–based agroforestry systems: The whole soil carbon stock data of asana trees and crops indicated that the treatments were found statistically significant and presented in (Tables 5) Soil carbon stock was highest in T_6– Asana + Jam (*Bridelia retusa*+ *Syzygium samarangense*) 33.20 t ha^{-1} in 2019 and increased up to 34.76 t ha^{-1} in 2020, whereas lowest in T_8 – Only Asana 23.80 t ha^{-1} in 2019 and 24.86 t ha^{-1} in the year of 2020. The high value of soil carbon stock recorded in T_6 – Asana + Jam, it may be due to continuous decomposition of plant and root biomass, root exudates. It increased the level of

Table 5. Plant and soil carbon stock (t ha^{-1}) under asana based agroforestry systems.

Treatments	Plant Carbon stock (t ha^{-1})		Soil Carbon stock (t ha^{-1})	
	2019	2020	2019	2020
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	55.05	61.04	27.32	29.09
T_2- Asana+Pineapple (*Ananas comosus*)	53.68	56.82	27.17	28.77
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	56.99	61.73	27.60	29.07
T_4- Asana+Mulberry (*Morus alba*)	68.62	72.96	26.48	27.86
T_5- Asana+Karonda (*Carissa carandas*)	62.08	68.04	29.35	31.38
T_6- Asana + Jam (*Syzygium samarangense*)	75.83	83.83	33.20	34.76
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	58.14	64.67	29.22	31.05
T_8- Only Asana (*Bridelia retusa*)	48.40	52.06	23.80	24.86
Mean	59.85	65.14	28.02	29.60
S.Em.±	1.86	2.02	0.83	0.74
C.D. at 5%	5.64	6.12	2.50	2.25
C.V. %	5.38	5.37	5.1	4.34

organic carbon in soil. While low in T_8– Only Asana, this may be due to low availability of organic matter in this treatment. The higher amount of organic matter in combine crops like tree with agri-crop than in only crop or plant system (Benbi *et al.* 2011). Carbon stock is intricately liked with soil quality, nature of land use, choice of species and the management practices adopted (Swamy *et al.*, 2003) which explains the varying carbon stock in different land use management and also at different land uses (Singh *et al.*, 2004).

Plant carbon sequestration under asana based agroforestry System: The plant C sequestration among various land use systems were presented in (Table 6). The plant carbon sequestration was noted maximum in T_6–Asana+ Jam (*Bridelia retusa* + *Syzygium samarangense*) 95.99 t ha^{-1} in 2019 and 103.91 t ha^{-1} in 2020, whereas lowest in T_8 – Only Asana 70.70 t ha^{-1} in 2019 and 74.67 t ha^{-1} in the final year. The high C sequestration in T_6- Asana + Jam (*Bridelia retusa*+ *Syzygium samarangense*), this might be due to fast carbon capturing potential from atmosphere by photosynthesis process, age, spacing, genetic makeup and tree growth habit. Carbon sequestration was depended on the biomass of the plants. It was significantly lowest in T_8- Only asana may be due to availability of biomass was less as compared to others and this was cause of sole tree present in this treatment. Similarly, Sharma *et al.* (2015) stated that the agroforestry system was better than traditional agriculture systems and providing better land use option for the carbon sequestration. Adhikari *et al.* (2019) observed that the carbon sequestration increased due to the fast growing tree species and availability of biomass under agroforestry systems. Bhalawe *et al.* (2019) reported that the C sequestration was highest in agroforestry land used system than other systems; this may be due to faster carbon capturing potential, age, structure, and intensity of management and soil types.

Soil carbon sequestration under asana-based agroforestry systems: The data of soil carbon sequestration was found to be statistically significant under asana-based agroforestry systems and given in (Table 6). The highest soil C sequestration was found in T_6-AsanaJam (*Bridelia retusa+Syzygium samarangense*) 3.20 t ha^{-1}, followed by T_5– Asana + Karonda (*Bridelia retusa* + *Carissa carandas*) 2.90 t ha^{-1}, whereas the lowest in T_8 - only Asana (*Bridelia retusa*) 1.86 t ha^{-1}. Soil carbon sequestration was recorded maximum in T_6- Asana + Jam, this may be due high availability of plant biomass potential in soil and soil could sequester organic carbon through balanced application of NPK. Whereas, C sequestration was noted lowest in T_8 - only Asana (*Bridelia retusa*), this may be due to low availability of biomass and residue organic carbon. Similarly, Zaro *et al.* (2019) observed that the addition of plant restudies of weeds, leaves and branches of coffee trees naturally fallen or detached during harvest, organic compounds released by the roots and decomposition of dead roots and microorganisms

Table 6. Plant and soil carbon sequestration and total carbon sequestration rate (t ha^{-1}) under asana based agroforestry systems.

Treatments	Plant Carbon Sequestration (t ha^{-1})		Soil Carbon Sequestration (t ha^{-1})	Total CSe Rate (t ha^{-1})
	2019	2020		
T_1- Asana + Arial yam (*Dioscorea bulbifera*)	77.88	85.48	2.15	5.35
T_2- Asana + Pine apple (*Ananas comosus*)	76.16	80.07	2.11	4.68
T_3- Asana + Elephant foot yam (*Amorphophallus paeonifolins*)	80.55	86.03	2.517	5.25
T_4- Asana + Mulberry (*Morus alba*)	91.503	95.27	1.93	5.59
T_5- Asana + Karonda (*Carissa carandas*)	84.837	92.30	2.90	5.76
T_6- Asana + Jam (*Syzygium samarangense*)	95.993	103.91	3.19	7.32
T_7- Asana + Seedless Lemon (*Citrus latifolia*)	80.617	88.79	2.83	5.75
T_8- Only Asana (*Bridelia retusa*)	70.697	74.66	1.86	3.83
Mean	82.28	88.32	2.44	5.44
S.Em.±	2.3993	2.5007	0.3102	0.62
C.D. at 5%	7.2782	7.5858	0.941	1.88
C.V. %	5.05	4.9	22.03	19.72

added to the soil, it increased the level of soil carbon sequestration. Mandal *et al.* (2020) observed that the soil carbon sequestration was increased by root biomass, shoot biomass, amount of root exudates and application of manure in soil.

Total carbon sequestration rate under asana-based agroforestry systems: The total carbon sequestration rate was recorded maximum in T_6–Asana + Jam (*Bridelia retusa*+ *Syzygium samarangense*) 7.32 t ha^{-1} fallowed by T_5 – Asana + Karonda (*Bridelia retusa* + *Carissa carandas*) 5.76 t ha^{-1}, whereas least in T_8–Only Asana (*Bridelia retusa*) 3.83 t ha^{-1}. It was statistically significant and given in (Table 6). In a forest ecosystem, the CSR is closely related to climatic conditions, soil properties, tree species, stand age and the forest rotation length (Graham *et al.* 1992, Niu and Duiker 2006). Carbon sequestration rate is depended on the biomass of plants potential. Total carbon sequestration rate is based on the carbon sequestration of plants and soil. Where carbon sequestration increased total carbon sequestration rate also increased. Jana *et al.* (2009) studies that the annual carbon sequestration rate from ambient air estimated for all young species of 6 years ago by considering annual mean duration of effective sunlight for photosynthesis at the rate of the forest stand. Adhikari *et al.* (2019) estimated annual carbon sequestration rate in agroforestry systems by difference of final and initial year of carbon sequestration divided by numbers of year.

4. CONCLUSION

It can be concluded that the higher growth performance and carbon sequestration were recorded significantly by T6-Asana + Jam (Syzygium samarangense) followed by T4- Asana + Mulberry (Morus alba) than other. Regarding to growth performance of agroforestry system, higher DBH and height were recorded under T6 – Asana + Jam system may be high contribution of soil carbon sink and reflects healthy soil improves plant health. The higher growth performance and carbon sequestrations were recorded significantly by T6-Asana + Jam (Syzygium samarangense) followed by T4- Asana + Mulberry (Morus alba) than other. Thus, T6 – Asana + Jam agroforestry system was sequestered more carbon in in lateritic soils of Konkan.

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