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Carbon sequestration potential of coconut based cropping systems under integrated nutrient management practices

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Abstract

Carbon sequestration plays a major role in mitigating climate change by converting atmospheric carbon into long lived wood biomass and soil carbon pool. The present investigation emphasizes sequestration of above ground and soil carbon stock of coconut based cropping systems under integrated nutrient management (INM) practices. The experiment was conducted with three cropping sequences of vegetable crops as intercrops in coconut garden under four different integrated nutrient management practices in FRBD with five replications during 2012 to 2014 at Horticulture Research and Extension Station, Arasikere, Hassan District, Karnataka (India). The incremental increase in the carbon sequestration by palms after two years was to the tune of 3.01 t ha^{-1} under intercropping system compared to 2.31 t ha^{-1} recorded under the monocropping system. Baby corn-gherkin sequence recorded significantly the highest soil carbon stock *i.e.,* 19.17 Mg C ha^{-1} and 20.43 Mg C ha^{-1} at 0-30 cm depth during 2012-13 and 2013-14, respectively. Among the INM practices, soil carbon stock was significantly the highest in treatment with 5 tonne FYM + 50 per cent N as vermicompost + 50 per cent N as CCP + vermiwash spray + *Azotobacter* (21.16 Mg C ha^{-1} and 20.95 Mg C ha^{-1} at 0-30 cm, during 2012-13 and 2013-14, respectively) and the lowest was in inorganic fertilizer alone (17.94 Mg C ha^{-1} and 17.96 Mg C ha^{-1} at 0-30 cm, during 2012-13 and 2013-14, respectively). A significant difference was observed in the soil carbon pool potential due to interaction of the cropping sequence and INM practices and it was the highest under green manure–cucumber sequence coupled with application of 5 t FYM + 50 per cent N as Vermicompost + 50 per cent N as composted coir pith (CCP) + Vermiwash spray + Azotobacter at 0-30 cm depth (21.49 mg C ha^{-1} and 19.81 mg C ha^{-1} during 2012-13 and 2013-14, respectively).

Keywords: Carbon sequestration, coconut, cropping system, INM, vegetables

Introduction

Coconut based cropping system is a viable option for practicing the Integrated nutrient management package, which play a vital role in improving the soil properties and productivity of the system. It is well known fact that in the atmosphere, increase in the concentration of carbon dioxide (CO_2) and other greenhouse gases (GHGs) is recognized as the leading cause of global warming. The two key activities are relevant to bring down the global concentration of GHGs are; to reduce the anthropogenic emissions of CO_2 and create or promote carbon (C) sinks in the biosphere. The latter aspect proposes storing of atmospheric C in the biosphere, which could be achieved by promoting land-use practices such as agro-forestry and intensive cropping system (Montagnini and Nair, 2004). Soil organic matter (SOM) contains more reactive organic C than any other terrestrial pool. Consequently, SOM plays a major role in determining C storage in ecosystems and in regulating atmospheric CO_2 concentrations (Lal, 2004). Thus, soil C which traditionally has been a sustainability indicator of agricultural systems has now acquired the additional role as an indicator of environmental health. As agriculture is both a cause and victim of climate-change, the

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solution of climate-change caused by agriculture depends on selecting the Good Agriculture Practices (GAP) which provides the cost-effective agricultural production system with minimum adverse effects on the environment.

Coconut agro-ecosystem is one of the major agricultural systems in the country which provides food and shelter to the mankind. Trees contain nearly 75 per cent of the earth's biomass, so it is crucial to understand the role of plantations in carbon sequestration for longer duration as they play a pivotal role in combating climate change. Addition of soil amendments can increase the rate of plant growth and hence the amount of carbon sequestered in the soil ecosystem. Studies on carbon sequestration in coconut plantation coupled with vegetable intercropping and integrated nutrient management (INM) practice has not been attempted so far. Keeping in view of these facts, a field study was conducted to identify the suitable vegetable cropping sequence and INM practices in coconut garden and its impact on carbon sequestration potential in the system.

Materials and methods

Investigations were carried out at Horticulture Research and Extension Station, University of Horticultural Sciences, Bagalkot, Arasikere, Hassan District, Karnataka (India) during 2012-13 and 2013-14. The experimental station is situated at 13^{o} 15' N latitude and 76^{o} 15' E longitude with an altitude of 808 m above mean sea level (MSL). The experimental site represents black soil situation of central dry zone of Karnataka with slightly alkaline pH (8.4), low OC content (0.43%), medium available N (315.8 kg ha^{-1}), and high P (35.3 kg^{-1} ha) and K content (325.6 kg ha^{-1}). The rainfall received during the experimental period of 2012-13 and 2013-14 was 302.6 mm and 518.8 mm, respectively which was less than the normal rainfall of the region (815.7 mm). The experiment consisting of two factors and four levels was laid out in a factorial randomized complete block design (FRBD) with five replications.

Factor 2: Nutrient management practices (Four practices)

S1: Inorganic fertilizer alone (100%)

S2: 5 t FYM + 75% NPK + 25% N by vermicompost

S3: 5 t FYM + 50% NPK + 25% N by vermicompost + 25 % N by composted coir pith (CCP) + IIHR vegetable special (micronutrient mixture) spray

S4: 5 t FYM + 50% N by vermicompost + 50 % N by composted coir pith (CCP) + Vermiwash spray + Azotobacter

The seeds/seedlings of okra, baby corn, cucumber and gherkin were sown and tomato seedlings were planted as intercrop in 45 years old coconut (Tiptur tall variety) garden of 10 m x 10 m spacing. For growing intercrops, plots were prepared by leaving 2 meters radius from the bole of the coconut and accordingly 60 per cent of the land was utilized to grow intercrops. Uniform quantity of farm yard manure was applied to each plot except S1 at the rate of 5 tons per hectare. Organic manures like vermicompost (VC) and composted coir pith (CCP) were applied as per the treatments to the respective plots two weeks before sowing/transplanting of vegetable crops and mixed well with the soil. The recommended dose of fertilizers (Package of Practices, University of Agricultural Sciences, Bengaluru) were applied in the form of urea, single super phosphate and muriate of potash and the fertilizer N was applied as

Treatment details

Factor 1: Intercropping sequences (Three sequences in existing coconut garden)

	Kharif (2012)	Summer (2013)	Kharif (2013)	Summer (2014)
M1	Okra	Fallow	Tomato	Fallow
M2	Green manure (Mucuna)	Cucumber	Green Manure (Mucuna)	Cucumber
M3	Baby corn	Gherkin	Baby corn	Gherkin
M4	Control: Coconut monocropping			

two equal splits as top dress at 30 days after sowing (DAS) and 60 DAS. Recommended dose of IIHR vegetable special (micronutrient mix which contains most of the micronutrients) was sprayed at 30 DAS and 60 DAS. Similarly, vermiwash was sprayed by diluting 1:10 ratio with water at 30 DAS and 60 DAS. Azotobacter was applied at the rate of 2 kg ha^{-1} after thoroughly mixing with FYM. Irrigation was provided during summer with drip irrigation system based on pan evaporation data of the region.

Above ground carbon sequestration in coconut (Naresh Kumar *et al.,* 2008);

Stem dry weight (SDW)(kg) = height x $(girth)^2$ x 41.14

Carbon stock (kg $palm^{-1}$) = SDW x 0.5 (50% of wood biomass is considered as the carbon stored)

h = height of the palm (m)

G = Girth = $2\pi r$

r = radius (m) at breast height

C (t ha^{-1}) = C kg ha^{-1} 1000^{-1}

CO_2 (t ha^{-1}) = C (t ha^{-1})/3.67

Note: 1 kg CO_2 = 0.27kg Carbon

1 kg C = 3.67 kg CO_2

1 Mega gram (Mg) = 1 t

Soil carbon stock (Srinivasan *et al.,* 2012);

C (Stock (Mg C ha^{-1}) = BD (g cc^{-1}) x OC (g kg^{-1}) x depth (m) x 10000/1000

BD – Bulk density of soil (g cc^{-1})

OC – Organic Carbon of soil (g kg^{-1})

The data were subjected to statistical analysis as per the standard procedure (Gomez and Gomez, 1984).

Results and discussion

Above ground carbon sequestration in coconut

For estimating the above ground carbon sequestration, stem dry weight of the palms was assessed with the standard procedure. During the end of experimental period, the dry weight of the palms in the intercropping plot was more compared to the plot with monocrop. The incremental stem dry weight of coconut at the end of the experimental period was 60.28 kg $palm^{-1}$ under intercropping system as compared to 46.09 kg $palm^{-1}$ in monocropping system. The carbon sequestration of coconut during the course of post experimental period under intercropping system was 16.13 t ha^{-1}; whereas it was 14.48 t ha^{-1} in monocropping system. The incremental increase in the carbon sequestration after two years was to the tune of 3.01 t ha^{-1} under intercropping system compared to 2.31 t ha^{-1} recorded under the monocropping system. The same pattern was observed in respect to carbon dioxide sequestration also where the increase was 22.98 per cent in intercropping system compared to 18.88 per cent in monocropping system (Table 1). Increase in dry weight of the palms under intercropped plot was mainly attributed to cropping sequences adopted in the experimental plots with the vegetable crops coupled with adoption of integrated nutrient management practices, where in addition of organic manures and recycling of crop residue biomass were involved. The additional nutrient inputs and irrigation practice adopted for the intercrops was also utilized by the coconut palm which resulted in increased wood biomass due to more number of leaves, and height of the palm in intercropped plot. Studies conducted at ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod (Kerala) also revealed that the carbon sequestration potential was higher in coconut based fruit cropping system compared to monocropping system (Bhagya *et al*., 2017). Study on the effect of vegetable intercropping on root growth and development of coconut at ICAR-CPCRI (Dhanapal *et al*., 2013) revealed that the number of fresh roots was more in the intercropped zone compared to interspaces of monocrop. This was mainly due to the long term effect of vegetable cultivation in the interspaces which was managed with irrigation and manuring that resulted in continuous availability of water and nutrients which influenced the root growth. This facilitated the roots to remain alive and active in absorption, whereas in monocrop the roots in the interspace area remained dry and dark coloured and also the fine roots were less due to non-availability of water and nutrients.

Soil bulk density and organic carbon

The bulk density of the soil did not vary significantly due to cropping sequence, INM practices and their interaction at both the depths studied during the period. The organic carbon (OC) content differed significantly among the treatments at both the depths (Table 2). During the end of the experimental period, the OC recorded during 2013-14 at both the depths was significantly higher under M_3 (Baby corn-Gherkin) cropping sequence (0.49 and 0.40% at 0-15 cm and 15-30 cm depth respectively). Among the INM practices, soil OC content recorded at both the depths during 2013-14 was higher under S_3 (5 t FYM + 50% NPK + 25% N by Vermicompost + 25% N by composted coir pith (CCP) + IIHR micronutrient spray) (0.50% and 0.41% at 0-15 and 15-30 cm depth respectively) and S_4 (5 ton FYM +50% N by vermicompost+50% N by CCP+vermiwash spray+azotobacter) (0.50 % and 0.40% at 0-15 and 15-30 cm depth respectively) treatments. The S1 (Inorganic fertilizer alone) treatment recorded significantly the lowest OC content at 0-15 cm depth (0.40). In the interactions of both cropping sequence and INM practice, M3S3 and M3S4 treatments recorded significantly higher OC content (0.53% during 2013-14 at 0-15cm depth). M1S3, M1S4 and M3S3 interactions were also recorded significantly higher OC (0.42%) at 15-30 cm depth. The organic carbon content in the monocrop plot was significantly the lowest during the period. The impact of mixed farming experiment with coconut involving fodder crop cultivation, integrated with dairy and recycling the available organic manure on soil properties showed that there was an increase in maximum water holding capacity and porosity and decrease in bulk density along with buildup of organic carbon, N, P, K and Fe status and higher nut yield as reported by Maheswarappa *et al*. (1998). Study conducted in Sri Lanka confirmed the beneficial effect of manures, fertilizers and other management practices given to the intercrops on the palms (Liyanage *et al*., 1989).

Soil carbon stock

Depth at 0-15 cm

The soil carbon stock was not influenced by the cropping sequence during both the years of experiment, whereas it was significantly influenced by the INM practices and interactions of both. During both the years, S4 (5 ton FYM +50% N by vermicompost+50% N by CCP+vermiwash spray+azotobacter) treatment recorded significantly higher soil carbon stock (10.30 Mg Cha^{-1} and 10.74 Mg C ha^{-1}) and S1 (Inorganic fertilizers alone 100%) treatment recorded the lowest soil carbon stock (9.08 Mg C ha^{-1} and 9.03 Mg C ha^{-1}). In the interactions of the treatments,

Table 1. Influence of cropping sequence and integrated nutrient management practices on above ground carbon sequestration of coconut palms

Period	Cropping system	Year	Stem dry weight of coconut palm (kg $palm^{-1}$)	Carbon sequestration (t ha^{-1}) (100 palms ha^{-1})	CO_2 sequestration (t ha^{-1}) (100 palms ha^{-1})
Pre-experimental period	Coconut monocropping	2011-12	243.51	12.18	44.68
	Coconut intercropping	2011-12	262.33	13.12	48.14
Post-experimental period	Coconut monocropping	2013-14	289.59	14.48	53.14
	Coconut intercropping	2013-14	322.61	16.13	59.20

Table 2. Effect of cropping sequence and integrated nutrient management practices on soil bulk density (g cc^{-1}) and organic carbon (%)

Treatments	BD (g cc^{-1})				OC (%)			
	0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
M1	1.46	1.45	1.62	1.63	0.44	0.44	0.38	0.38
M2	1.45	1.39	1.62	1.64	0.40	0.45	0.36	0.37
M3	1.43	1.42	1.64	1.64	0.45	0.49	0.39	0.40
S.Em ±	0.006	0.006	0.013	0.009	0.007	0.009	0.0061	0.0060
CD@5%	NS	NS	NS	NS	0.019	0.026	0.0179	0.0176
S1	1.54	1.43	1.62	1.65	0.39	0.40	0.35	0.37
S2	1.41	1.40	1.57	1.63	0.42	0.44	0.36	0.36
S3	1.39	1.41	1.65	1.66	0.45	0.50	0.41	0.41
S4	1.44	1.44	1.67	1.65	0.46	0.50	0.37	0.40
S.Em ±	0.007	0.007	0.015	0.010	0.007	0.010	0.0070	0.0069
CD@5%	NS	NS	NS	NS	0.022	0.030	0.0207	0.0204
M1S1	1.52	1.47	1.60	1.60	0.40	0.38	0.38	0.34
M1S2	1.44	1.42	1.57	1.64	0.44	0.39	0.37	0.35
M1S3	1.40	1.41	1.63	1.64	0.47	0.52	0.40	0.42
M1S4	1.49	1.50	1.68	1.70	0.43	0.46	0.35	0.42
M2S1	1.55	1.38	1.64	1.62	0.39	0.41	0.33	0.37
M2S2	1.41	1.37	1.56	1.62	0.38	0.41	0.35	0.35
M2S3	1.39	1.41	1.62	1.64	0.39	0.46	0.39	0.39
M2S4	1.43	1.39	1.64	1.62	0.45	0.52	0.36	0.37
M3S1	1.54	1.42	1.61	1.66	0.39	0.46	0.34	0.39
M3S2	1.37	1.42	1.59	1.65	0.43	0.45	0.35	0.40
M3S3	1.37	1.40	1.69	1.64	0.48	0.53	0.44	0.42
M3S4	1.42	1.44	1.68	1.70	0.49	0.53	0.41	0.41
S.Em ±	0.012	0.013	0.026	0.018	0.013	0.018	0.0122	0.0120
CD@5%	NS	NS	NS	NS	0.038	NS	0.0359	0.0353
Control	1.43	1.39	1.56	1.67	0.34	0.35	0.35	0.34
S.Em ±	0.013	0.013	0.0265	0.0187	0.013	0.018	0.0124	0.0122
CD@5%	NS	NS	NS	NS	0.027	0.037	NS	0.0247

NS: Non significant

M1: Okra -fallow, Tomato –fallow
M2: Green manure (Mucuna)–Cucumber
M3: Babycorn –Gherkin
Control: Coconut mono cropping

S1: Inorganic fertilizer alone 100%
S2: 5 ton FYM + 75% NPK + 25% N by vermicompost
S3: 5 ton FYM + 50% NPK + 25% N by vermicompost + 25 % N by CCP + IIHR micronutrient spray
S4: 5 ton FYM + 50% N by vermicompost + 50 % N by CCP + vermiwash spray + Azotobacter

M2S4 recorded significantly the highest soil carbon stock (11.56 Mg C ha^{-1}) whereas M3S2 recorded the lowest soil carbon stock (8.74 Mg C ha^{-1}) during 2012-13. Whereas M3S4 treatment recorded significantly the highest soil carbon stock (10.94 Mg C ha^{-1}) and M1S1 treatment recorded the lowest soil carbon stock (8.17 Mg C ha^{-1}) during 2013-14 (Table 2). The carbon stock was the lowest under monocropping plot (7.36 Mg C ha^{-1} during 2013-14).

Depth at 15-30cm

During the experimental periods, cropping sequence influenced the soil carbon stock significantly. M3 (Baby corn-gherkin) sequence recorded significantly the highest soil carbon stock (9.84 Mg C ha^{-1} and 10.18 Mg C ha^{-1}) and M2 (Green manure - cucumber) sequence recorded the lowest soil carbon stock (9.19 Mg C ha^{-1} and 9.00 Mg C ha^{-1}) (Table 3). Among the INM practices, S4 (5 ton FYM +50% N by vermicompost+50% N by CCP+vermiwash spray + azotobacter) treatment recorded significantly higher soil carbon stock (10.86 Mg C ha^{-1} and 10.21 Mg C ha^{-1}) during both the years. S2 (5t FYM +75%NPK+25% N by vermicompost) recorded the lowest soil carbon stock (8.53 Mg C ha^{-1}) during 2012-13 and S1 (inorganic fertilizers alone 100%) treatment recorded the significantly the lowest soil carbon stock (8.93 Mg C ha^{-1}) during 2013-14. Among the interactions, M_3S_4 recorded significantly the higher soil carbon stock (12.37 Mg C ha^{-1} and 10.97 Mg C ha^{-1}), whereas, M3S2 recorded the lowest SOC (8.29 Mg C ha^{-1}) during 2012-13 and M1S1 recorded the lowest SOC (8.26 Mg C ha^{-1}) during 2013-14.

Total soil carbon pool

Total carbon pool at 0-30 cm soil profile during 2013-14 under intercropped area was higher with M3 sequence (20.43 Mg C ha^{-1} $year^{-1}$), S4-INM practice (20.91 Mg C ha^{-1} $year^{-1}$) and M3S4 interaction (21.92 Mg C ha^{-1} $year^{-1}$) (Fig. 1). The monocrop garden had the lowest carbon stock during the period. Increase in soil carbon stock under the intercropping and INM treatments may be attributed to recycling organic biomass and external addition of organic manures. Buildup of soil organic carbon with the application of 50 per cent N or more in the form of vermicompost or composted coir pith as compared to the inorganic treatments in coconut has been reported by other workers in coconut plantation (Liyanage *et al.*, 1989, Maheswarappa *et al.*, 2014; Upadhyay *et al.*, 2009). Soil carbon stock was the highest under the treatment, M3 (baby corn-gherkin), which added the highest crop residual biomass to the soil and S4 (5 ton FYM +50% N by vermicompost +50% N by CCP+vermiwash spray+azotobacter) which received organic manures as nutrient source and interactions of both. This is in line with intensive cropping system, recommended dose of inorganic NPK and NPK+FYM maintained soil quality

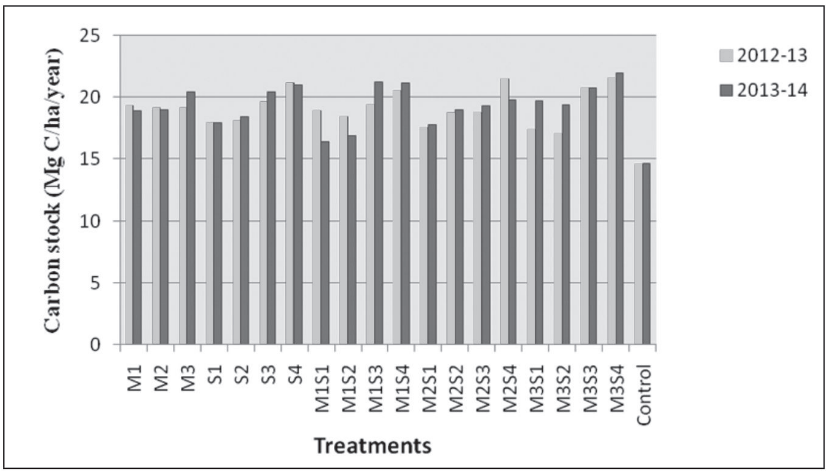

Fig. 1. Total soil carbon stock at 0-30 cm depth as influenced by different treatments

Table 3. Effect of cropping sequence and integrated nutrient management practices on soil carbon stock under coconut based cropping system (Mg C ha^{-1})

Treatments	0-15 cm depth		15-30 cm depth	
	2012-13	2013-14	2012-13	2013-14
M1	9.69	9.45	9.59	9.47
M2	9.93	9.96	9.19	9.00
M3	9.33	10.25	9.84	10.18
S.Em ±	0.180	0.227	0.152	0.159
CD@5%	NS	NS	0.448	0.4684
S1	9.08	9.03	8.86	8.93
S2	9.52	9.46	8.53	8.96
S3	9.71	10.30	9.91	10.10
S4	10.30	10.74	10.86	10.21
S.Em ±	0.210	0.262	0.176	0.184
CD@5%	0.618	0.668	0.518	0.541
M1S1	9.14	8.17	9.76	8.26
M1S2	9.60	8.38	8.81	8.54
M1S3	9.82	10.90	9.53	10.30
M1S4	10.19	10.36	10.27	10.77
M2S1	9.09	8.83	8.44	8.90
M2S2	10.22	10.46	8.49	8.53
M2S3	8.86	9.63	9.91	9.70
M2S4	11.56	10.92	9.93	8.89
M3S1	9.01	10.11	8.39	9.61
M3S2	8.74	9.56	8.29	9.82
M3S3	10.44	10.39	10.29	10.31
M3S4	9.14	10.95	12.37	10.97
S.Em ±	0.364	0.454	0.305	0.318
CD@5%	1.07	0.454	0.897	0.936
Control	7.22	7.36	7.33	7.24
S.Em ±	0.370	0.460	0.309	0.323
CD@5%	0.751	0.935	0.628	0.656

NS: Non significant

M1: Okra -fallow, Tomato –fallow
M2: Green manure (Mucuna)–Cucumber
M3: Babycorn –Gherkin
Control: Coconut mono cropping

S1: Inorganic fertilizer alone 100%
S2: 5 ton FYM + 75% NPK + 25% N by vermicompost
S3: 5 ton FYM + 50% NPK + 25% N by vermicompost + 25 % N by CCP+IIHR micronutrient spray
S4: 5 ton FYM + 50% N by vermicompost + 50 % N by CCP + vermiwash spray + Azotobacter

productivity and C-sequestration (Srinivasan *et al.*, 2012; Manna *et al.*, 2012). As per the report of Manna *et al*. (2012), the long-term C sequestration in soil is dependent on both organic C inputs and its stability in soil organic sources of nutrients such as FYM that decompose slowly resulting in more SOC accumulation in soil. Apart from a direct contribution to soil organic C, organic manures applied to soil may also improve C accumulation indirectly through enhancing microbial biomass and activity as reported by Liang and Balser (2011).

Conclusion

Present study on coconut based cropping system with different vegetable crops under integrated nutrient management system in central dry zone of Karnataka have substantially contributed towards improving the above and below ground carbon stock of the system. In respect of the soil carbon stock, it was the highest under M3-sequence (baby corn-gherkin) (20.43 Mg C ha^{-1} $year^{-1}$), in S4-INM practice (5 tonne FYM+50% N by Vermicompost +50 % N by CCP+vermiwash spray+Azotobacter) (20.91 Mg C ha^{-1} $year^{-1}$) and interaction of M3S4-treatment (21.92 Mg C ha^{-1} $year^{-1}$).

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