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Carbon Sequestration and Productivity Potential of Coconut (*Cocos nucifera* L.) Hybrids and Varieties under Coastal Eco-System of Maharashtra

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Authors' contributions

This work was carried out in collaboration among all the authors. Authors SLG and VVS designed the study. All authors conducted the experiment. Author SLG wrote the manuscript with support from authors HPM and VVS. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was carried out at All India Coordinated Research Project on Palms, Regional Coconut Research Station, Bhatye (DBSKKV, Dapoli), Maharashtra, (India) during the period of 2004-2016 to assess the carbon sequestration and productivity potential of twelve coconut hybrids and three varieties which was laid out in a randomized block design with three replications. Results showed that the two hybrids *viz*, GBGD x ECT (127.6 nuts/palm/year) and COD x LCT (108.0 nuts/palm/year) are superior with respect to nut production followed by WCT x MYD (107.6 nuts), ECT x GBGD (106.9 nuts) and the standard variety 'Pratap'. Furthermore, the coconut orchard substantially contributed towards improving the above and below ground carbon stock. The above ground standing biomass and carbon stock recorded was the highest in the variety East Coast Tall (312 kg/plant and 27.32 t/ha, respectively) followed by hybrid WCT x GBGD (308.69 kg/plant and

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27.01 t/ha, respectively) and the lowest was in hybrid MYD x ECT (138.71 kg/plant and 12.14 t/ha, respectively). The highest soil carbon stock 39.12 t/ha and 37.16 t/ha at 0-30 and 31-60 cm depth was recorded in the rhizosphere of hybrid ECT x MYD and the lowest soil carbon stock (35.52 t/ha and 34.71 t/ha) was observed in hybrid PHOT x GBGD.

Keywords: Coconut hybrids; carbon sequestration; nut yield; standing biomass; soil carbon stock.

1. INTRODUCTION

Coconut (*Cocos nucifera* L.) is grown in about 95 countries in the tropical belt of world with an area of about 11,906 thousand hectares with production of 67,128 million nuts and productivity of 5,638 nuts/ha. India, Indonesia and Philippines together accounts for more than 74% of total world production. In India, coconut is one of the major plantation crops grown in 19 states and union territories mostly along the coastal region of the country with a total cultivated area of 2.15 million hectares with a production of 21,384 million nuts. Maharashtra occupied 7th place in area and 9th place in production with the annual production of 208.9 million nuts [1]. It is estimated that about 12 million people in India are dependent on the coconut sector in the areas of cultivation, processing and trading activities [2]. Perennial nature of palms, higher level of heterozygosity, long gestation phase, need for larger area and longer time for experimentation and lack of technologies for mass propagation of palms with targeted traits are the major constraints in successful breeding efforts [3]. Tall cultivars are commonly grown for copra and oil purpose while dwarfs are preferred for tender nut water. Development of high yielding hybrids/varieties is very important to achieve higher production and productivity in coconut. The discovery of hybrid vigour in coconut, first from India in 1937 [4], received considerable attention in the production of coconut hybrids, which usually express hybrid vigour in growth, precocity and higher yield. Hybrid varieties have been developed by combining the early flowering trait of dwarf cultivar and hardiness and high yielding characters of tall cultivar [5].

In recent past, it is well known fact that due to climate change, there is increase in the concentration of carbon dioxide and other greenhouse gases leading to global warming. The key activities involved to bring down the global concentrations of greenhouses are; to reduce the anthropogenic emissions of CO_2 and create or promote carbon sinks in the biosphere which could be achieved by promoting land-use practices such intensive cropping system [6]. The carbon sequestration is a mechanism for removal of carbon from atmosphere and storing in the biosphere [7]. By keeping in view of these facts, the present study was undertaken in a long term experiment and their potential with respect to yield was reported by Shinde et al. [8] and in this paper the study on their carbon sequestration potential and yield which will act as a ecological service has been described.

2. MATERIALS AND METHODS

Evaluation of twelve hybrids and three varieties (Table 1) developed by different centers of All India Coordinated Research Project on Palms (AICRPP) was undertaken at Regional Coconut Research Station, Bhatye, Ratnagiri, (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra, India) during the period of 2004-2016.

The hybrids and varieties were planted during 1992 at a distance of 7.5 m × 7.5 m in a square system which was laid out in a randomized block design having fifteen treatments and three replications. In each treatment eight plants were maintained and the total area per treatment was 0.135 hectare including three replications. The total plot size were 2.03 hectare which was accommodated 360 number of plant population. The experimental station is situated on the coast of the Arabian Sea on the western outskirts of village Bhatye and linked with the southern - borders of Ratnagiri city, (M.S.), India by the Bhatye Creek- Bridge on the mouth of river Kajali. Its height from mean sea level (MSL) is 3.2 M and located at 16° 58’N Latitude and 73° 17’ E Longitude. The experimental site represents red sandy loam soil with acidic pH (5.8), medium organic carbon content (0.62%) and medium fertility status. The average annual rainfall received is 3500 mm, of which 82 percent is received during the four monsoon months (June-September). The mean temperature ranges from 21°C (minimum) to 36°C (maximum), and the average relative humidity varies between 60 and 95%. The standard

Table 1. List of hybrids/varieties and parents included in the experiment

Hybrids/varieties	Name of the center	Parents
GBGD x ECT	Ambajipeta (A.P.)	COD (Chowghat Orange Dwarf)
ECT x GBGD	Ambajipeta (A.P.)	MYD (Malayan Yellow Dwarf)
PHOT x GBGD	Ambajipeta (A.P.)	PHOT (Philippine Ordinary Tall)
GBGD x PHOT	Ambajipeta (A.P.)	LCT (Laccadive Ordinary Tall)
LCT x COD	Kasaragod (Kerala)	GBGD (Gangabondam Green Dwarf)
COD x LCT	Kasaragod (Kerala)	ECT (East Coast Tall)
ECT x MYD	Veppankulam (TN)	WCT (West Coast Tall)
MYD x ECT	Veppankulam (TN)	
COD x WCT	Kasaragod (Kerala)	
WCT x MYD	Kasaragod (Kerala)	
LCT x GBGD	Kasaragod (Kerala)	
WCT x GBGD	Kasaragod (Kerala)	
ECT	Veppankulam (TN)	
LCT	Kasaragod (Kerala)	
Pratap	Ratnagiri (Maharashtra)	

package of practice as per recommendations were adopted including manuring and fertilization, weed control, irrigation during summer month, mulching, insect and pest control and disease management were followed. The observations on height (m), girth (cm), number of leaves on the crown were recorded during October 2016 (at the age of 24 years). In coconut, the palm height was measured from base of trunk to the crown region and which was measured with the help of bamboo pole. The coconut palm girth was measured at 1 meter height from the base of the trunk with help of measuring tape. The matured nuts were harvested at right time and nut yield was recorded periodically during harvest and pooled to get the yield per palm per year.

2.1 Above Ground Carbon Sequestration in Coconut

For estimating the above ground carbon sequestration, the above ground standing biomass estimation was carried out by adopting the method developed by Naresh Kumar et al. [9].

Accordingly,

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

Carbon stock generally for any plant species is considered as 50% of its biomass (Pearson et al. [10]).

Hence, Carbon stock (kg/palm) = Biomass (SDW) × 0.5 (50% of wood biomass is considered as the carbon stored).

For estimation of CO_2 (t/ha) sequestered: Multiplying carbon stock (t/ha) with 3.67 as factor [11].

C (t/ha) = C (kg/ha) x1000^{-1}
CO_2 (t/ha) = C (t/ha) x 3.67

Note:

1 kg CO_2 = 0.27 kg Carbon
1 kg C = 3.67 kg CO_2
1 Mega gram (Mg) = 1 t

2.2 Below Ground Carbon Stock/Soil Carbon Stock in Coconut

For soil carbon stock estimation, soil samples were collected during the year 2016 from the basin of the crops as per the standard procedures. Organic carbon content of soil was estimated by adopting Walky-Black's method and bulk density of the field was estimated by using core sampler at 0-30 and 31-60 cm depth described by Jackson [4]. Soil carbon stock was estimated by following standard formula (Srinivasan et al. [12]).

Soil Organic Carbon Stock$_{(0\text{-}30,\ 31\text{-}60)}$ (Mg ha^{-1}) = [(C concentration $_{layer}$ (kg Mg^{-1}) × (Bulk density) $_{layer}$ (Mg m^{-3}) × Depth (m) × 10^{-3} Mg kg^{-1} × 10^4 (m^2 ha^{-1})].

2.3 Statistical Analysis

Experiment was laid out in a randomized block design with three replications and the data were subjected to statistical analysis as per the standard procedures (Panse and Sukhatme

[13]). The statistical analysis for below ground carbon stock was performed using Statistical analysis system 9.3 computer software (SAS Institute Inc., [14]). DMRT procedure (Duncan's Multiple Range Test) was used at P=0.05 level to determine the significance among the treatments. DMRT is more useful than the LSD (Least significant differences) test when larger pairs of means are being compared. DMRT tends to require larger differences between means compared to the LSD, which guards against Type I error. For example, while the LSD might say a difference of means of 6 is significant, the DMRT value might be double that, guarding against the possibility of marking differences significant when they are not.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The observations recorded on 24 years old coconut palms with respect to height, girth and total number of leaves on the crown during October 2016, indicated that there were no significant differences in the growth parameters among the hybrids/varieties. Whereas, significantly higher stem girth was observed in ECT (126 cm), which was at par with ECT x MYD (121 cm) and WCT x GBGD (116.2 cm) (Table 2). The girth was significantly lower in COD x WCT hybrid (91.8 cm), which might be due to dwarf female parent. Similar results were also recorded by Nagwekar et al. [15] in the same hybrids and Ramanandam et al. [16] in the hybrids ECT x MGD, GBGD x ECT, GBGD x FJT, GBGD x PHOT, GBGD x LCOT and ECT x GBGD.

3.2 Nut Yield

The twelve years average yield data presented in Table 2 indicated that the hybrid, GBGD x ECT recorded significantly higher yield (127.6 nuts/palm/year) and was at par with COD x LCT (108 nuts), WCT x MYD (107.6 nuts) and ECT x GBGD (106.9 nuts). Among the hybrids, LCT x COD recorded significantly the lowest yield (54.3 nuts/palm/year) and was at par with MYD x WCT (59.3 nuts/palm/year) and ECT x MYD (62.1 nuts/palm/year). The variation in fruit setting percentage among coconut hybrids was earlier reported by Nair et al. [17] and Thomas et al. [18] in WCT, CGD and COD and they have reported the maximum fruit set (39.54%) in COD (self) followed by WCT (self) and COD x WCT.

3.3 Above Ground Carbon Sequestration

As illustrated in the Fig. 1 and Fig. 2, it was observed that among the different hybrids and varieties, the above ground standing biomass (SDW) and above ground carbon stock (312 kg/plant and 27.32 t/ha, respectively) was significantly the highest in the variety East Coast Tall followed by hybrid WCT x GBGD (308.69 kg/plant and 27.01 t/ha, respectively). The lowest above ground biomass and carbon stock were observed in coconut hybrid MYD x ECT (138.71 kg/plant and 12.14 t/ha, respectively). This is attributed to the highest plant girth and plant height among the different hybrids and varieties. Furthermore, the CO_2 sequestered also followed the same trend and accordingly, the highest CO_2 sequestration was recorded in the variety East Coast Tall (100.26 t/ha) followed by hybrid WCT x GBGD (99.13 t/ha) and which was on par with each other (Fig. 2). The lowest CO_2 sequestration was noticed in coconut hybrid MYD x ECT (44.54 t/ha). These results are in accordance with the research findings of Bhagya et al. [19] who opined that, coconut based cropping system sequestered more carbon as compared to coconut alone. Trees contain nearly 75 per cent of the earth's biomass, so it is of the greatest importance 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 eco-system [20].

3.4 Soil Bulk Density and Organic Carbon

The data presented in Table 3 represents soil organic carbon (%) and bulk density of soil (g/cm^3) at 0-30 and 31-60 cm depth in the rhizosphere of different hybrids and varieties of coconut. With respect to bulk density, there was no significant difference found among the different hybrids and varieties in coconut at both the depths during the course of study. Whereas, the organic carbon (OC) content differed significantly in the rhizosphere of different hybrids and varieties in coconut at both the depths. Significantly the highest soil organic carbon (0.81% and 0.76%) was recorded in coconut basin at 0-30 and 31-60 cm depth in the coconut hybrid ECT x MYD which was on par with hybrid COD x LCT and variety East Coast Tall. The coconut basin in the hybrid PHOT x GBGD recorded significantly the lowest organic carbon at both the depths (0.74 and 0.71%). The rhizosphere in the interspace of coconut hybrids and varieties recorded significantly the lowest organic carbon content (0.46% and 0.44%). The rhizosphere of coconut hybrids and varieties were resulted in improvement in the organic carbon content and which has reflected in higher yield and biomass. The present findings are in accordance with the report of Naveen Kumar and Maheswarappa, [20] in coconut based cropping system with INM.

Table 2. Growth performance and nut yields of different coconut hybrids and varieties

Hybrids/ varieties	Plant height (m)	Plant girth (m)	No. of leaves on crown	Av. nut yield/palm/year (2004-2016)*
GBGD x ECT	4.45	1.01	28.2	127.6
ECT x GBGD	4.26	1.03	30.2	106.9
PHOT x GBGD	4.17	1.12	29.2	90.3
GBGD x PHOT	4.03	1.01	29.2	81.1
LCT x COD	4.3	1.10	27.0	54.3
COD x LCT	4.62	1.01	26.8	108.0
ECT x MYD	3.47	1.21	26.2	62.1
MYD x ECT	3.44	0.99	27.5	59.3
COD x WCT	4.2	0.92	26.3	80.4
WCT x MYD	5.34	1.01	28.0	107.6
LCT x GBGD	4.11	1.02	26.7	82.9
WCT x GBGD	5.56	1.16	28.5	74.7
ECT	4.78	1.26	29.7	81.8
LCT	5.26	1.06	27.0	83.1
Pratap	4.73	1.04	27.7	96.0
Mean	4.45	1.06	27.9	86.41
SE d±	N.S	4.08	N.S	12.7
CD (P=0.05)	-	12.64	-	30.8

Note: ** indicates 177palms ha^{-1} in coconut*

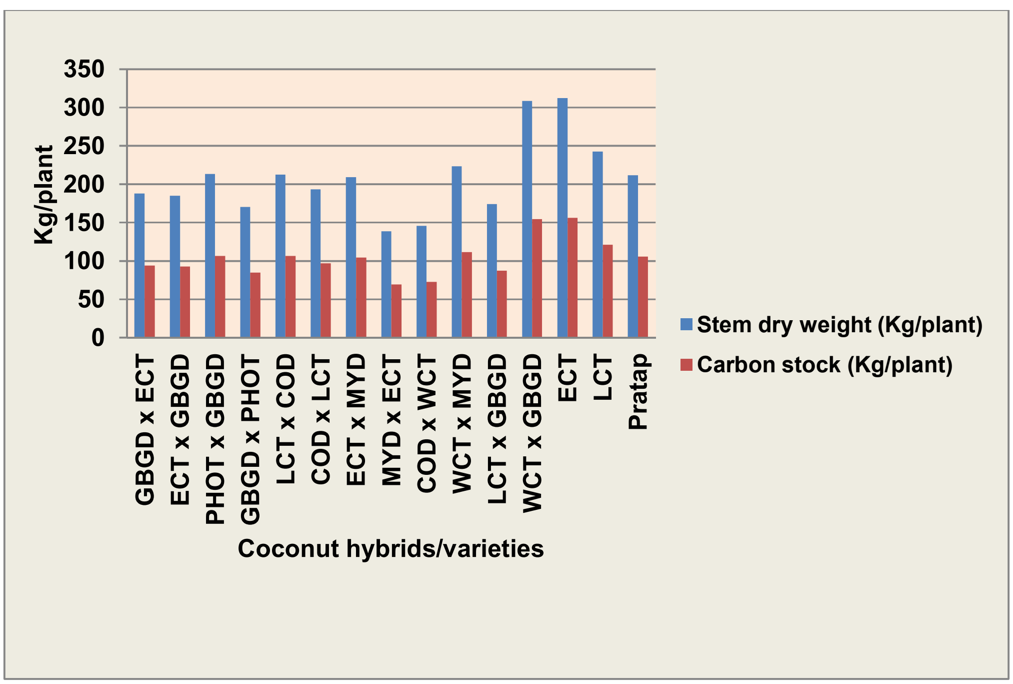

Fig. 1. Above ground standing biomass and carbon stock of different hybrids/varieties in coconut

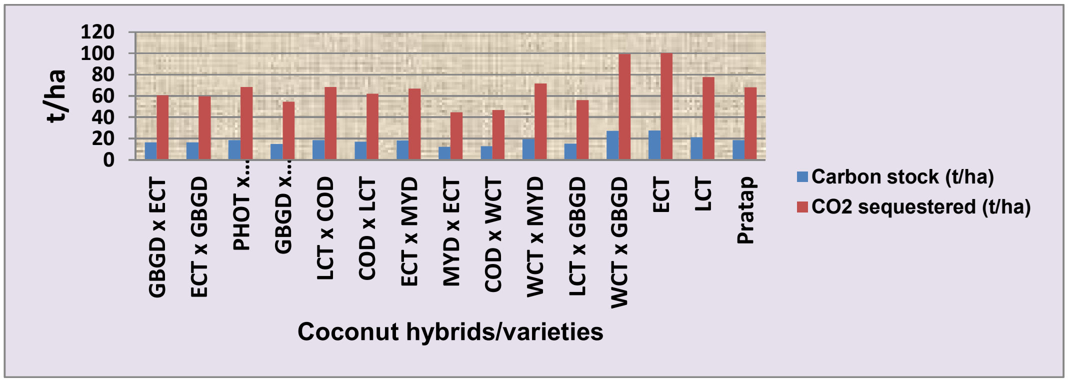

Fig. 2. Above ground carbon stock and amount of CO_2 sequestered by different coconut hybrids and varieties

Table 3. Organic carbon and soil bulk density in the rhizosphere of different coconut hybrids and varieties

Hybrids/	Organic carbon (%)		Bulk density (gcm^{-3})	
varieties	0-30 cm	31-60 cm	0-30 cm	31-60 cm
GBGD x ECT	0.77ab	0.74b	1.61	1.63
ECT x GBGD	0.76b	0.73b	1.60	1.62
PHOT x GBGD	0.74c	0.71c	1.60	1.63
GBGD x PHOT	0.76b	0.72c	1.61	1.63
LCT x COD	0.77ab	0.73b	1.60	1.63
COD x LCT	0.78ab	0.74b	1.60	1.62
ECT x MYD	0.81a	0.76a	1.61	1.63
MYD x ECT	0.78ab	0.73b	1.61	1.63
COD x WCT	0.77ab	0.73b	1.61	1.62
WCT x MYD	0.76b	0.72bc	1.61	1.62
LCT x GBGD	0.76b	0.72bc	1.60	1.63
WCT x GBGD	0.77ab	0.73b	1.60	1.63
ECT	0.78ab	0.74b	1.61	1.63
LCT	0.77ab	0.74b	1.62	1.64
Pratap	0.76b	0.73b	1.62	1.64
Interspace	0.46c	0.44d	1.60	1.58
CD (P=0.05)	0.041	0.68	NS	NS

3.5 Soil Carbon Stock

The soil carbon stock was significantly varied in the rhizosphere of different hybrids and varieties in coconut during the course of study. As illustrated in Fig. 3, it was shown that, among the different coconut hybrids and varieties under investigation, the rhizosphere of hybrid ECT x MYD had significantly higher soil carbon stock (39.12 t/ha and 37.16 t/ha) in the depths of 0-30 and 31-60 cm. The lowest soil carbon stock 35.52 t/ha and 34.71 t/ha at 0-30 and 30-60 cm depth was noticed in the hybrid PHOT x GBGD. Also the lowest soil carbon stock of 22.08 t/ha and 20.85 t/ha at 0-30 and 30-60 cm depth was observed in the coconut interspace. Furthermore, the higher carbon stock at both depths (0-30 and 31-60 cm) in the rhizosphere of coconut might be due to increase in organic carbon in the soil owing to decomposition of root system over a period of time and organic manure incorporation to the coconut crop as compared to the interspace and interaction effect of organic manure and green manure incorporation. Similar findings were observed in orchard wherein, the beneficial effects of sustainable practices (Residue incorporation, cover crop retention and compost application) on yield which was improved as compared with conventionally managed orchards [19,20].

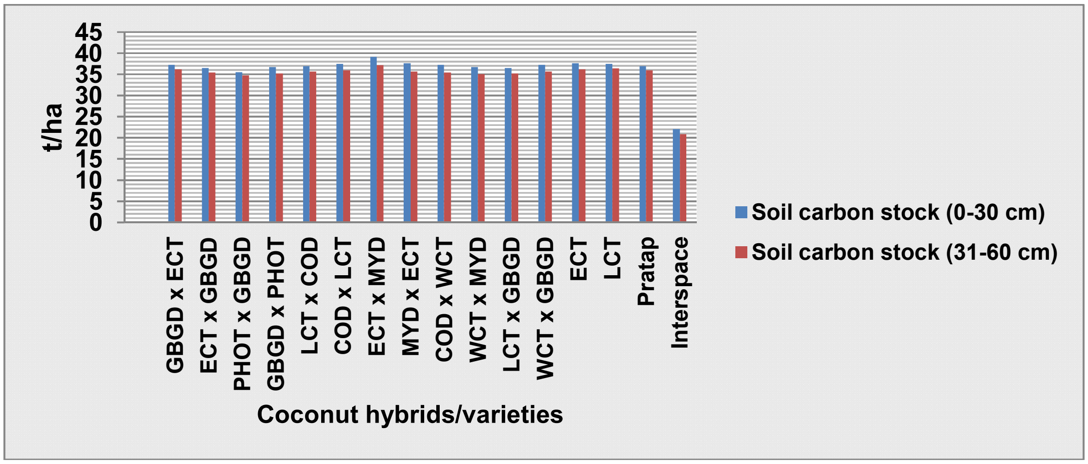

Fig. 3. Soil carbon stock in the rhizosphere of different coconut hybrids and varieties

4. CONCLUSION

From the present study, it can be concluded that the hybrids *viz*, GBGD x ECT and COD x LCT are superior with respect to nut production followed by WCT x MYD, ECT x GBGD and the standard variety 'Pratap'. Furthermore, the coconut orchard substantially contributed towards improving the above and below ground carbon stock. The above ground standing biomass and carbon stock recorded was the highest (312 kg/plant and 27.32 t/ha, respectively) in the variety East Coast Tall followed by hybrid WCT x GBGD (308.69 kg/plant and 27.01 t/ha, respectively) and the lowest in hybrid MYD x ECT (138.71 kg/plant and 12.14 t/ha, respectively). The highest sequestration of soil carbon stock (39.12 t/ha and 37.16 t/ha at 0-30 and 31-60 cm depth) was recorded in the rhizosphere of hybrid ECT x MYD and the lowest soil carbon stock (35.52 t/ha and 34.71 t/ha) was noticed the rhizosphere of hybrid PHOT x GBGD.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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