Indian Journal of Agronomy **56** (3): 223–227 (September 2011)

Tillage and residue management for organic carbon sequestration in coconut (*Cocos nucifera*)-based cropping systems

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Received: April, 2011

ABSTRACT

A field experiment was carried out on a garden land clay loam soil at Vellayani, Kerala during 2004-06 to study the effect of cropping systems, residue management and tillage practices on organic carbon sequestration in soils and thereby improvement in soil properties for better growth and production of intercrops in a coconut garden. Among the different cropping systems, coconut (*Cocos nucifera)*+pineapple (*Ananas comosus*) cropping system maintained the highest organic carbon content of 1.30% at the end of two years, whereas the coconut + maize (*Zea mays* L.) system maintained only 1.21% soil organic carbon. Surface mulching with crop residues could maintain organic carbon up to 1.37% by the end of the study, but when the residues were incorporated to soil, the soil organic carbon (SOC) status was only 1.13%. Among tillage practices, reduced till maintained 1.29% organic carbon, whereas the conventional tillage could maintain only 1.22% SOC after two years of study. Improvement in soil properties, like aggregate stability, porosity, bulk density, water-holding capacity *etc* was observed with the maintenance of soil organic carbon. The improvement in soil properties reflected in better yield and returns. Coconut + pineapple cropping system registered the highest B:C ratio of 3.61. Coconut + banana (*Musa* spp.) system recorded a B:C ratio of 2.52, whereas coconut + maize recorded the lowest of 1.31. Benefit: cost ratios were better with reduced till practices (2.63) as well as surface mulching of crop residues (2.69).

Key words: Cropping systems, Organic carbon sequestration, Residue management, Soil organic carbon, Soil organic matter, Tillage, Yield.

The advent of intensive agriculture has led to dramatic losses of organic matter and hence organic carbon from cultivated soils. The lesser addition of organic carbonaceous inputs to soil coupled with oxidative losses associated with tillage (Lal *et al.*,1995) are the major reasons for loss of soil organic carbon. Soil organic matter improves the physical and chemical properties of soil (Kanojia and Kanawjia, 2004). The carbon in soil organic matter supports soil microbes by providing energy for their activities and thus keep the soil 'live'. Hence organic carbon sequestration, a management strategy which ensures the storage of carbon in soil sinks assumes much significance in the present day agricultural scenario. Among the various management options to conserve and sequester carbon in agricultural soils; cropping system approach, reduced tillage and residue management holds much importance. In Kerala, coconut-based cropping systems are prevalent in the uplands and they generate ample residue which could be recycled to soil. The conventional practice of ploughing and digging of land is followed here and this accelerates the oxidative losses of soil organic carbon.

With these views, an experiment was planned selecting intercrops belonging to C_3, C_4 and CAM categories for coconut garden. These three different systems generated residues of different quantity and quality for recycling to soil. Residues were added to soil either as surface mulch or incorporation. The conventional tillage practices were compared with less soil disturbing reduced till practices. The experiment aimed in evaluating the effects of these management practices on soil properties as well as on crop yield and economics.

MATERIALS AND METHODS

Field experiments were conducted from April 2004 to February 2006 at the College of Agriculture, Vellayani, Kerala, located at 8.5^0 N latitude and 76^0 9' E longitude, at an altitude of 29 m above mean sea level. The texture of soil was clay loam. The soil reaction was acidic (pH 5.8) and the organic carbon content in the upper 15 cm soil was 1.08%. It was low in available N (162 kg/ha) and available K (180 kg K_2O/ha) and high in available P (41 kg P_2O_5/ha). The bulk density (1.5 Mg/m^3), porosity (36.38%),

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water-holding capacity (36.5%) and particle density (2.3 Mg/m^{-3}) were analysed using the core method (Gupta and Dakshinamoorthy 1980). The per cent water stable aggregates before the start of the study, as per wet sieving method was 35.24% (Yoder, 1936). As per this method, the air dried soil aggregate of known weight was placed onto the top sieve of a net of sieves and immersed in water. Thereafter, mechanical wet sieving of soil was done in a column of water by raising and lowering of sieves at prescribed cycles per minute. The slurry passed through the net of sieves and finally the stable aggregates separated.

The treatments included three different cropping systems, i.e. coconut + banana 'Robusta', coconut + maize 'Co 1' and coconut + pineapple 'Mauritius', two types of residue management, i.e. surface mulching , residue incorporation and two different methods of tillage, i.e. conventional practice and less soil manipulating reduced tillage . Altogether, there was 13 treatments of which 12 comprised of different combination of coconut+intercrops, residue recycling and tillage and sole coconut as control. Partially wilted crop residues of maize, banana and pineapple were chopped and applied to respective plots either as mulch or soil incorporation of 40 kg/plot, prior to planting of crops. This quantity was sufficient to supply organic material of 25 t/ha. During the course of the experiment, two crops of maize and one crop each of pineapple and banana were raised. Further the crop residues after the harvest of crops also were recycled to soil either as mulch or incorporation in respective plots and the changes in soil properties were observed for two years. Application of manures and fertilizers were done as per the recommendations given by KAU (2007).

The design was factorial randomized block design (RBD) with 3 replications. The gross plot size was 4 X 4 m^2. The plots were taken between two rows of coconut spaced at 7.5 X 7.5 m after leaving a basin radius of 1.75 m around each coconut tree. The plots requiring normal conventional tillage practices were ploughed, dug and levelled. Weeds and stubbles were removed and thereafter pits were taken for banana and channels for maize and pineapple. For plots requiring reduced tillage, non selective translocated herbicide glyphosate was applied @ 0.8 kg a.i./ha to clear off weedy growth. Stubbles were hand removed and the very minimum tillage requirement to plant the crop was undertaken without much soil disturbance.

RESULTS AND DISCUSSION

Soil organic carbon status

The results of the investigation revealed that there was improvement in the organic carbon status of soil with the progress of experiment and by second year, significantly high organic carbon was seen in coconut + pineapple system (Table 1). Surface mulching of crop residues (m_1) could maintain more organic carbon in soil. Reduced tillage resulted in high organic carbon content in soil by the end of second year of study. Among the crop residues under study, higher lignin content was noticed for pineapple residue (43%). Lignin resists easy decomposition contributing to slow build up of organic matter. Humus is a ligno protein complex. The enhanced production of soil organic matter (SOM) in coconut + pineapple cropping systems, where pineapple residue was recycled into soil could be attributed to this lignin rich nature of pineapple residue. More SOM essentially means a high status of soil organic carbon (SOC). This is in agreement with the findings of Paustian *et al*. (1992) who noticed that grass litter with low lignin content (6%) contributed to low SOM status while saw dust (30% lignin) recorded high SOM status.

In surface mulched plots, the crop residue decomposition was slow compared to the practice of incorporation. Residue incorporation resulted in enhanced biological and chemical reaction leading to increased rate of organic matter mineralization. By the time of second year of experiment, reduced till seemed superior to the conventional way of soil till in enhancing both SOC and SOM. This is attributed to the less oxidative loses of soil organic matter. When soil is deeply tilled, more of oxygen reaches the inner layers enhancing oxidative processes. Tillage mixes and incorporates organic debris to soil. Enhanced respiration and hence faster decomposition of SOM is observed soon after tillage. Chatskikh and Olesen (2007) studied the CO_2 emissions from soils and identified that soil tillage intensified the emission of CO_2 from soils.

Soil properties

Observations made on bulk density, particle density, water holding capacity and aggregate stability of soil after first and second year are presented in Table 1. The percentage of water stable aggregates were significantly improved under coconut + pineapple cropping system, surface mulching of residues and reduced till methods. This could be related to the maintenance of more organic matter. Soil aggregation is attributed to the action of gum components of organic matter. Jacob *et al.* (2010) observed that the minimum till systems maintained more organic matter and the gum action of organic matter well improved soil aggregation in these systems. Neelam *et al.* (2010) found that soil aggregation was well improved in zero till system and the aggregates in turn protected the organic carbon within them.

The porosity of soil was found affected only by tillage. Reduction in tillage brought about increase in porosity

Table 1. Effect of cropping systems, residue management and tillage practices on the organic carbon and organic matter status of 0-15 cm soil, water stable aggregates, porosity, bulk density and water holding capacity.

Treatment	Organic carbon (%)		Org. matter (%)		Water stable aggregates (%)		Porosity (%)		BD (Mg/m^3)		Water holding capacity (%)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Cropping system												
Coconut + banana	1.23	1.25	2.12	2.15	38.72	42.30	39.21	41.31	1.40	1.34	39.34	40.43
Coconut + maize	1.18	1.21	2.03	2.08	38.45	41.00	39.07	40.77	1.40	1.35	38.27	39.01
Coconut + pineapple	1.25	1.30	2.15	2.24	39.52	43.15	39.37	41.21	1.38	1.31	39.78	41.18
SEm±	0.022	0.021	0.031	0.031	0.30	0.252	0.271	0.293	0.010	0.011	0.391	0.343
CD (P=0.05)	0.051	0.042	0.082	0.082	0.881	0.735	NS	NS	NS	0.022	1.144	1.008
Residue management												
Surface mulching	1.31	1.37	2.25	2.37	39.64	42.69	39.19	41.22	1.39	1.33	39.66	40.94
Residue incorporation	1.13	1.13	1.95	1.94	38.16	41.60	39.24	40.98	1.40	1.35	38.60	39.47
Sem±	0.011	0.011	0.022	0.021	0.250	0.201	0.223	0.232	0.010	0.001	0.322	0.281
CD (P = 0.05)	0.042	0.042	0.073	0.065	0.720	0.592	NS	NS	NS	0.010	0.934	0.822
Tillage												
Conventional tillage	1.22	1.22	2.00	2.03	38.24	41.62	38.69	40.58	1.40	1.35	39.11	40.09
Reduced tillage	1.22	1.29	2.11	2.23	39.56	42.68	39.74	41.62	1.38	1.32	39.15	40.37
SEm±	0.010	0.011	0.021	0.020	0.250	0.201	0.223	0.232	0.010	0.001	0.322	0.280
CD (P = 0.05)	NS	0.042	0.053	0.061	0.720	0.592	0.651	0.684	NS	0.011	NS	NS

Initial values for SOC content – 1.08%, SOM -1.86% , WSA,-35.24% , Porosity- 36.38%. , Bulk density- 1.50Mg/m^3 ,Water holding capacity- 36.5%

because of buildup of more organic matter. Clifford *et al.* (2003) noticed that while cultivation decrease soil porosity, conservation tillage systems increases porosity. Bulk density was found favourably decreased in coconut + pineapple cropping system, surface mulched and reduced tilled plots. The accumulation of SOM in these treatment plots favourably and significantly lowered the bulk density of soil. With the addition of humus to soil the mass per unit volume of soil decreased resulting in decreased bulk density.

Water holding capacity was found higher in coconut- + pineapple cropping systems and in surface mulched plots and could be related to the organic matter build up in these treatments. Organic matter can imbibe large quantities of water thereby increasing the water holding capacity of soil. Though not significant statistically, an increasing trend in water holding capacity observed in reduced till plots could also be related to the increase in organic matter content. SOM promotes cohesion of soil particles and thereby it's capacity to hold and retain moisture is increased. Khan and Parvej (2010) studied soil properties and concluded that the water retentive capacity of mulched soils under zero till condition was the highest at all stages of crop growth. This was attributed to the maintenance of SOM.

Yield

The yields of the three different intercrops are presented in Table 2. In general, the yield of crops showed an increasing trend with surface mulching and reduced till. Among intercrops, banana and pineapple yielded better. The reduced yield of maize could be attributed to the partially shaded condition of coconut garden. The coconut yield obtained in different treatments by the second year are given in Table 3. The coconut yields didn't vary significantly. Any how, the sole cropped coconut recorded lower yields in comparison to intercropped. In coconut, it takes almost 44 months for the spadix primordia to develop into coconut. Hence it could be assumed that the treatment effects may take more period so as to significantly influence coconut yields. However it could be noticed that intercropping could improve the performance of coconut when compared to sole crop. Manna and Singh (2001) reported that biolitter recycling in intercropped systems could improve the SOC status and soil properties so as to improve yields.

The coconut equivalent yields for different treatments also were worked out (Table 3). Coconut + banana system recorded significantly higher values for coconut equivalent yield when compared to coconut +

Table 2. Effect of residue management and tillage practices on yield of intercrops

Treatment	Maize Grain yield (t/ha)		Banana Bunch yield (t/ha)	Pineapple Fruit yield (t/ha)
	1st crop	2nd crop		
Residue management				
Surface mulching	0.67	0.72	40.29	11.67
Residue incorporation	0.56	0.58	36.44	10.15
SEm±	0.024	0.026	1.721	0.405
CD (P = 0.05)	0.086	0.092	NS	1.373
Tillage				
Conventional tillage	0.58	0.62	37.04	10.60
Reduced tillage	0.65	0.68	39.69	11.22
SEm±	0.025	0.026	1.721	0.403
CD (P = 0.05)	NS	NS	NS	NS

maize or coconut + pineapple. Coconut + banana under surface mulched and reduced till conditions recorded the highest coconut equivalent yield of ₹ 24,676 nuts/ha. The equivalent yields were significantly lower for other cropping systems. The equivalent yield for the control treatment, i.e. coconut alone without any intercrops was the lowest at 6,565 nuts/ha.

Economics

The net returns from coconut as well as that from different cropping systems were worked out (Table 3). Net returns from coconut recorded the lowest value of ₹53,650/ha in sole cropped coconut plots. On studying the net returns from the system as a whole, it was found that the net returns were higher from coconut + banana cropping system. The surface mulched and reduced tilled coconut + banana system could achieve net returns as high as ₹3,30,766/ha, which was significantly superior to all other treatments. Coconut + pineapple system when surface mulched and reduced tilled, could give a net return of ₹1,47,476/ha. The average values for net returns from intercrops are presented in Table 3. The B:C ratios were also analysed and it was noticed that among the different systems under study, the coconut + pineapple system gave the highest B: C ratio of 3.61. Coconut + banana cropping system recorded a B:C ratio of 2.52, whereas the B:C ratio recorded by the coconut + maize system was at the lowest of 1.31. The less labour requirement for surface mulching of residues compared to residue incorporation and for reduced till in comparison to conventional tillage reduced the cost for these treatments. The cost of cultivation including the cost of fertilizers and plant protection chemicals was much low for pineapple. This coupled with high yields of pineapple resulted in higher B:C ratio for pineapple crop. For banana, the fertilizer requirement and plant protection costs were far more and there were additional expenses on propping. The cost of cultivation was high and therefore the B:C ratio went down, though the returns were high. Regarding maize, the lower yields registered under partial shade resulted in the lower B:C ratio. In residue management, surface mulching recorded higher B:C ratio (2.69) than residue incorporation (2.27). Re-

Table 3. Coconut yield for the second year of study, coconut equivalent yield and net return for different treatments

Cropping systems	Coconut yield (nuts/ha)	Coconut equivalent yield (nuts/ha)	Net returns coconut (₹/ha)	Net returns intercrop (₹/ha)	Net returns cropping system (₹/ha)
Coconut + banana					
Surface mulch + conventional tillage	6946	24,004	57,466	235,367	2,92,833
Surface mulch + reduced tillage	7033	24,676	58,333	272,433	3,30,766
Residue incorporation + conventional tillage	7053	23,262	58,533	187,433	2,45,966
Residue incorporation + reduced tillage	6883	23,676	56,833	227,366	2,84,199
Coconut + maize					
Surface mulch + conventional tillage	6843	7223	56,433	3,927	60,360
Surface mulch + reduced tillage	6906	7304	57,066	5,557	62,623
Residue incorporation + conventional tillage	6776	7247	55,766	1,520	57,286
Residue incorporation + reduced tillage	6800	7163	56,000	2,233	58,233
Coconut + pineapple					
Surface mulch + conventional tillage	6941	12,509	57,416	84,250	1,41.666
Surface mulch + reduced tillage	7010	12,733	58,100	89,376	1,47,476
Residue incorporation + conventional tillage	6785	11,973	55,853	65,976	1,21,829
Residue incorporation + reduced tillage	6743	12,086	55,433	75,440	1,30,873
Coconut alone	6565	6565	53,650		53,650
SEm+	204.73	208.7	2047		2047
CD (P=0.05)	NS	606.8	1879		1879

duced tillage found superior to conventional tillage with respect to B : C ratio (2.63 and 2.33 respectively).

It is summarized that pineapple + coconut cropping system is more economical than other systems. With the recycling of pineapple residue to soil as surface mulch and with reduction in tillage practices, there is considerable enrichment of SOC. Coconut gardens could be well utilized for organic carbon sequestration. Suitable intercrops like pineapple could be raised in coconut gardens both for improving farmer's income and for sustaining soil health.

REFERENCES

Chatskikh, D. and Olesen, J.E. 2007. Soil tillage enhanced CO_2 and N_2O emissions from loamy sand soil under spring barley. *Soil and Tillage Research* **97**(1): 5–18

Clifford, R.B., Anthony, S.R.J., Franzluebbers, K. 2003. *Tropical Soils - Properties and Management for Sustainable Agriculture,* pp 292 Oxford University Press, New York

Gupta, R.P. and Dakshinamoorthy, C. 1980. *Procedures for Physical Analysis of Soil and Collection of Agrometeorological Data,* IARI, New Delhi, p 116

Jacob, A., Helfrich, M., Hanisch, S., Quendt, U, Rauber, R. and Ludwig, B. 2010. Effect of conventional and minimum tillage on physical and biochemical stabilization of soil organic matter. *Biology and Fertility of Soils* **46**: 671–80

KAU. 2007. *Package of Practices Recommendations: Crops,* pp 278 Kerala Agricultural University, Thrissur.

Kanojia, R.K. and Kanawjia, S.K. 2004. Soil degradation and use of agricultural and industrial organic byproducts. *Indian Farming* **54**(4): 18–21

Khan, M.A.H. and Parvej, M.R. 2010. Impact of conservation tillage under organic mulches on the reproductive efficacy and yield of quality protein maize. *The Journal of Agricultural Sciences* **5**(2): 52–63

Lal, R., Kimble, J. and Stewart, B.A. 1995. World soils as a source or sink for radiatively active gases. (*In:*) *Advances in Soil Science - Soil management and green house effect.* Lal, R., Kimble, J., Levine, E. and Stewart, B.A. (Eds.) pp 1–2, CRC press, London

Manna, M.C., Singh, M.V. 2001. Long term effects of intercropping and bio-litter recycling on soil biological activities and fertility status of subtropical soils. *Bioresource Technology* **76**(2): 143–50

Neelam, A., Gaur, A., Bhalla, E., Gupta, S.R. 2010. Soil aggregate carbon and diversity of mycorrhiza as affected by tillage practices in a rice-wheat cropping system in Northern India. *International Journal of Ecology and Environmental Sciences* **36**(4): 233–43

Yoder, R.E. 1936. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. *Journal of American Society of Agronomy* **28**: 337–51