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RESEARCH ARTICLE

Study on economics of biochar application in cotton – maize – cowpea cropping sequence under integrated nutrient management

■ **R. Elangovan, S.R. Shri Rangasami, R. Murugaragavan and N. Chandra Sekaran**

SUMMARY

The highest net return was found in continuous application (two times) especially in the treatment biochar @ 10 t + 100 % NPK + FYM with Rs.67,928 ha^{-1} followed by biochar @ 10 t + 75 % NPK + FYM treatment with Rs.67,172 ha^{-1}. The next higher net return was registered in biochar @ 10 t + 75 % NPK + FYM treatment under one time application with Rs. 62,970/-.Comparing the studies, the two times application (biochar @ 10 t ha^{-1} $time^{-1}$) recorded an addition of Rs. 5,565/- only over one time application. Therefore one time application (biochar @ 10 t ha^{-1}) considered to be an economically viable management technology than two times application in the cotton – maize – cowpea cropping sequence. One time conjoint application of biochar @ 10 t ha^{-1} along with 75 % recommended dose of NPK fertilizers and 12.5 t ha^{-1} of FYM *i.e.*, (biochar @ 10 t + 75 % NPK + FYM) to cotton and following the general recommended practices for maize and cowpea to be the best combination suited for enhancing higher benefit cost ratio of 1.45 under cotton – maize – cowpea cropping system in Inceptisol (Vertic Ustropept) of Periyanaickenpalayam series of Coimbatore District.

Key Words : Benefit cost ratio, Cotton, Maize, Cowpea, Biochar

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Management options to maintain soil health include amelioration of soil physical environment, enhancing soil chemical and biological qualities through Integrated Plant Nutrition System (IPNS), soil test based fertilizer recommendation, micronutrient application and management of industrial wastes and poor quality waters for agricultural use. Therefore, one has to take a wholesome view of the soil, plant and climate factors for obtaining sustainable productivity and high fertilizer use efficiency.

Agricultural ecosystem represents an estimated 11 per cent of the earth's land surface and include some of the most productive carbon rich soils. As a result, they play a significant role in the storage and release of C within the terrestrial carbon cycle (Lal *et al.,* 1995). The major considerations of the soil C balance and the emission of greenhouse gases from the soil are: (1) the potential increase of CO_2 emissions from soil contributing to the increase in the greenhouse effect, (2) the potential increase in other gas emissions (e.g., N_2O and CH_4) from soil as a consequence of land management practices and fertilizer use, and (3) the potential for increasing C (as CO_2) storage in to soils, which equals 1.3 - 2.4 3 x 10^9 metric tons of carbon per year, and to help reduce future increases of CO_2 in the atmosphere. Though the practice of biochar application for agriculture is prevalent in India, the noval and scientific approach on biochar – based soil management strategies are new and have not been evaluated in the content of Indian agriculture. For sustaining any agricultural crop, use of organic manures along with inorganic fertilisers is well established, thus revealing the complimentary effect of manures and fertilizers in improving the growth, yield and yield attributes. There is a need to further determine or explore the extent of this effect as well as the impact of increased frequency of application and response of crops to biochar application rate. To date, there has been insufficient experimental research to determine the longer-term effects of biochar addition on soil properties. The study was to test the hypothesis that soil productivity is improved through biochar amendments, but the extent of benefits is depends on its quantity and frequency of application and also application along with fertilizers. Hence, the subject of exploitation of biochar for cotton based cropping system was thought to be a vital nature and taken up for the study. In addition to work out economics for optimization of biochar with /without FYM and inorganic fertilizers for cotton – maize – cowpea cropping sequence.

Biochar is term reserved for the plant biomass derived materials contained within the Black Carbon (BC) continuum (Lehmann *et al*., 2006). Biochar also known as charcoal, black carbon, soot, and char, is a broad class of materials produced from the incomplete combustion or pyrolysis of organic materials such as wood, wood by-products, plant residue, manure, petroleum, and petroleum by-products (Antal and Grønli. 2003). Bichar is a stable form of carbon and may last in the soil for the thousands of years. Thus it is possible, as part of a shift to organic farming practices, to use biochar to turn agriculture from a net emitter of carbon to a tool for drawing carbon back out of the atmosphere. Examples are char from forest fire and soot resulting from the incomplete combustion of fossil hydrocarbon (Baldock and Smernik, 2002). The range of carbon forms within a biochar particle may depend on the carbon properties (Lehmann, 2007). Novak *et al.* (2009).

The effect of biochar application on biological nitrogen fixation was studied by Rondon *et al*. (2007). Research indicates that both biological nitrogen fixation and beneficial mycorrhizal relationships in common beans (*Phaseolus vulgaris*) are enhanced by biochar applications (Rondon *et al*., 2007 and Warnock *et al*., 2007). Biochar can be applied and incorporated together with lime, since lime is often applied as a fine solid which must be well incorporated into soil **(**Julie Major, 2010). The majority of biochar field trials reported to date used this method for incorporating biochar into soil (Yamato *et al*., 2006; Steiner *et al*., 2007; Asai *et al*., 2009 and Major *et al*., 2010). Biochar could also be mixed with manure in holding ponds and could potentially reduce gaseous nitrogen losses as it does when applied to soil (Rondon *et al*., 2005; Yanai *et al*., 2007 and Spokas *et al*., 2009). Application of biochar to soil may be more desirable as it can increase soil organic carbon (SOC), improve the supply of nutrients to plants and there for enhance plant growth and soil physical, chemical, and biological properties (Glaser *et al.,* 2002; Lehmann *et al.,* 2003 and Rondon *et al.,* 2007).

The highest values of organic carbon at biochar treated soils indicate the recalcitrance of C-organic in biochar. High organic carbon in soils treated with biochar has been also been reported by Lehmann (2007), Solomon *et al.* (2007) and Liang *et al*. (2006). Increased net N mineralization in black carbon-treated forest soils has been attributed to declines in inhibitory phenolic compounds or due to increased sorption of available C (DeLuca *et al*., 2002, 2006 and Berglund *et al*., 2004).

Gaskin *et al*. (2007) investigated the influence of biochar additions (11 – 22 t ha^{-1}) to the loamy sand soils were found in crop yield. Lehmann *et al*. (2003a) used wood biochar at rates of 68-135 t C ha^{-1} and found an increase in rice biomass by 17% and cowpea by 43 per cent in pot experiment (in the absence of leaching). The increase in biomass is attributed to responses to improved P and K and possibly Cu nutrition provided by the biochar application. Lehmann *et al*, (2003) found that additions of biochar significantly increased rice biomass production by 38 per cent to 45 per cent.

Cotton - maize - pulse is a major cropping system practiced by farmers of the district of Coimbatore, Tamil Nadu, India. Cotton is considered as king of fiber in the world and India ranks first in its production with production of 33.40 million tonnes from an area 11.61 millions hectares with the productivity of 489 kg ha^{-1} during 2012-13. Maize, the third most important cereal crop next to wheat and rice in the world as well as in India. It is being cultivated to an extent of 8.67 million hectare with production and productivity of 21.60 million tonnes and 2492 kg ha^{-1}, respectively in the year 2012-13. Pulses play a vital role in human dietary and nutrition and it occupied 9.54 million hectares with the production of 5259.2'000 tonnes during the period 2011-12.

Economic analysis of biochar's application in agriculture is routinely disregarded. Additionally, only a small number of studies that looked at the economic viability of biochar performed thorough cost-benefit analysis (CBA) or life cycle evaluations (LCA) of utilising biochar as a soil amendment, for example (Dickinson *et al.,* 2005; Latawiec *et al.,* 2019; Homagain *et al.,* 2016; Pandit *et al.,* 2018). The highly variable yield effect of biochar soil amendment and the economic viability of using it in agriculture; second, the limited stability of C in freshly produced biochars incorporated in soils; and third, the ineffectiveness of using biochars for carbon sequestration in comparison to other carbon dioxide (CO_2) abatement technologies.

MATERIAL AND METHODS

Biochar refers to biomass-derived charcoal, obtained when biomass is "baked" under low or no oxygen conditions (pyrolysis). Biochar holds promise as a tool for improving soil fertility and sequestering carbon (C) in soil among other potential benefits. Research has shown that crop yields can be improved by biochar application but most data available to date is for single crops. Much interest exists for recommendation of biochar for cropping sequence rather than for mono cropping system. Brief review of literate indicates that, there are plenty of reports regarding the direct effect of biochar on soil fertility studies and crop growth. But only few attempts are made to study its continuous and residual effects in the soil. Hence, in the present investigation, biochar was produced, characterized and a series of laboratory and field experiments were conducted to study the effect of biochar with/without inorganic fertilizers and FYM on soil productivity and to examine the direct, cumulative and residual effects of biochar on soil fertility, crop productivity and crop quality of cotton – maize – cowpea based cropping sequence followed in Coimbatore, Western zone of Tamil Nadu.

Optimization of biochar application for cropping system :

Treatment details	
Main plot treatments (Recommended fertilizers kg ha^{-1})	Sub - Plot treatments (Biochar levels t ha^{-1})
F_1 .Control	B_1 . 0
F_2 -100% NPK (kg ha^{-1})	B_2 . 2.5 (t ha^{-1})
F_3 . 100% NPK (kg ha^{-1}) + FYM (12.5 t ha^{-1})	B_3 . 5.0 (t ha^{-1})
F_4 -75% NPK (kg ha^{-1}) + FYM (12.5 t ha^{-1})	B_4 . 7.5 (t ha^{-1})
	B_5 .10.0 (t ha^{-1})

Economic analysis (Table 1 to 6) :

Benefit cost ratio was worked out based on the cost of inputs and price output of cotton, maize and cowpea. From these, net income due to the application of biochar, fertilizers and FYM and net profit per rupee invested on biochar, fertilizers and FYM were calculated. The cost of inputs used in the experiment and the price for the produce of cotton, maize and cowpea used for arriving the B:C ratios are furnished in Table 1 to 6.

The benefit: cost ratio worked out as below :

$$\text{Benefit : cost ratio} = \frac{\text{Gross income (Rs. ha}^{-1})}{\text{Total cost of cultivation (Rs. ha}^{-1})}$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Economic analysis of biochar application for cropping sequence (Table 1 and 6) :

The highest total cost in the cultivation of cotton – maize – cowpea cropping system was Rs. 1,61,734 ha^{-1} in biochar @ 10 t + 100 % NPK + FYM treatment (when 100% recommended fertilizers to all the crops and two times application of biochar @10 t ha^{-1} and 12.5 t ha^{-1} of FYM) under cumulative study. The total cost involved for the same treatment under direct study was Rs. 1,41,734 ha^{-1} (when 100% recommended fertilizers to all the crops and one time application of biochar @10 t ha^{-1} and 12.5 t ha^{-1} of FYM). The total cost of production

Table 1 : Cost of cultivation of cotton/ha

Particulars	Inputs	Input rate/unit	Total Rs./ha
I Operational cost			
Human Labour			
Field Preparation	10 man days	165/lab/day	1650
FYM, Biochar Application and seed sowing	15woman days	165/lab/day	2475
Application of Fertilizer	10woman days	165/lab/day	1650
Application of fertilizer throughout crop period	16 woman days+ charges	165/lab/day	2470.5
Thinning and gap filling	6woman days	165/lab/day	990
Earthing Up	12 man days	165/lab/day	1980
1st weeding	25 woman days	165/lab/day	4125
2nd weeding	10 woman days	165/lab/day	1650
	16 woman days	165/lab/day	2640
3rd weeding	16 woman days	165/lab/day	2640
picking	15 woman days	165/lab/day	2475
Herbicide spray	3.3lit ha^{-1}	255 lit^{-1}	331.5
	2 woman days	165/lab/day	330
	16 woman days	165/lab/day	2640
Picking	15 woman days	165/lab/day	2475
Picking	15woman days	165/Lab/Day	2475
			33267
Animal Labour			
Rectification of field-Bullock	1 pair 2 lobour	800/day	800
Field -Cleaning charges	190/2 labour	extra charges	389
Total			1189
Machine Labour			
Disc	6 hrs	350/hr	2100
Tractor	1hrs	350/hr	350
Bund forming (1day)	8 hrs	200/ day	200
Rectification of bunds	12 man days	165/lab/day and @extra charge	2096
Final arrangement	3 hrs		100
			4746
Seed			3477
Fertilizers		2244	
Manures		5000	
Fertilizers and Manures			7244
Plant Protection			
Cost of Dimethoate	3lit (sprays)	250lit -1	750
Cost of Monochrotophos	2 lit (2sprays)	300 lit -1	600
Spraying charge			
	2 woman days	165/lab/day	330
	1 women 6 hrs	115/lab/day	115
			1795
Interest on working capital			905
II Fixed cost			4200
Sub Total (I &II)			56823
Managerial cost @ 10 %			
III Total cost			62,505

for 100 % NPK + FYM treatment was Rs.1,21,734 ha^{-1} (when 100% recommended fertilizers to all the crops and 12.5 t ha^{-1} of FYM) and for the control treatment Rs.1,09,523 ha^{-1} under both direct and cumulative studies. Use of biochar increased the total cost of production to the tune of Rs.20,000 and Rs. 40,000 ha^{-1} under single and cumulative studies respectively.

Among the treatments, application of biochar @ 10 t + 100 % NPK + FYM registered highest gross income of Rs. 2,29,662 ha^{-1} under cumulative study and

Table 2 : Cost of cultivation of maize/ha

Particulars	Inputs	Input rate/unit	Total Rs./ha
I Operational cost			
Human Labour			
Field Preparation	6 man days	165/lab/day	990
FYM, Biochar Application and Seed sowing	7woman days	165/lab/day	1155
Application of Fertilizer	5woman days	165/lab/day	825
Application of fertilizer throughout crop period	13woman days	165/lab/day	2145
Thinning and gap filling	3woman days	165/lab/day	495
Earthing Up	6 man days+half day	165/lab/day	1095
1st weeding	25 woman days	165/lab/day	4125
2nd weeding	10 woman days	165/lab/day	1650
	16 woman days	165/lab/day	2640
Herbicide spray	3 lit ha-1	255 lit-1	330
	2 woman days	165/lab/day	330
Harvest	14 woman days+charges	165/lab/day	2333
			18113
Animal Labour			
Field -Cleaning charges	190/labour+charges		230
Rectification of field-Bullock+	1 pair 1 lobour	400/day	400
			630
Machine Labour			
Field divided in to two half	4 hrs	350/hour	1400
Bund forming (2day)	12 hrs	200/ day	2400
Rectification of bunds	14 man days	165/lab/day +charges	2397
			6197
Seed			3394
Fertilizers		4048	
Manures		5000	
Fertilizers & Manures			9048
Plant Protection			
Herbicide	1 lit	252	252
Cost of Monochrotophos	2 lit (2sprays)	300 lit -1	600
Plant Protection			
			852
Interest on working capital			682
II Fixed cost			4815
Sub Total (I and II)			
Managerial cost @ 10 %			4059
III Total cost			44538

Rs.2,04,097 ha^{-1} under direct study. The gross income in 100 % NPK + FYM treatment was Rs.1,61,906 ha^{-1} and for the control treatment Rs.1,28,142 ha^{-1} under both direct and cumulative studies. An additional application of biochar @ 10 t ha^{-1} had increased the gross income to the tune of Rs.42,191 and Rs. 67,756 ha^{-1} over thecorresponding treatment without biochar (100 % NPK + FYM) under direct and cumulative studies respectively.

The higher net return Rs.67,928 ha^{-1} was recorded by application of biochar @ 10 t + 100 % NPK + FYM followed by Rs.67,172 ha^{-1} in biochar @ 10 t + 75 % NPK + FYM treatments under cumulative study and Rs.62,970 ha^{-1} in biochar @ 10 t + 75 % NPK + FYM treatment under direct study. The net return of Rs.40,172 ha^{-1} and Rs.18,619 ha^{-1} was recorded in 100 % NPK + FYM and control treatments under direct and cumulative studies respectively. Application of biochar @ 10 t ha^{-1} had increased the net income to the tune of Rs.22,191 and Rs.27,756 ha^{-1} over the corresponding treatment without biochar (100 % NPK + FYM) under direct and

Table 3 : Cost of cultivation of cowpea/ha

Particulars	Inputs	Input rate/unit	Total Rs./ha
I Operational cost			
Human Labour			
Field Preparation	8 man days	165/lab/day	1320
Rectifying bund	10 man days	165/lab/day	1650
FYM, Biochar Application and Seed sowing+ management fee	10woman days	165/lab/day	1650
Application of Fertilizer	7woman days	165/lab/day	1221
Application of fertilizer throughout crop period	13woman days	165/lab/day	2145
Thinning and gap filling	3woman days	165/lab/day	495
Earthing Up	6 man days	165/lab/day	990
1st weeding	20 woman days	165/lab/day	3300
2nd weeding	11 woman days	165/lab/day	1815
	16 woman days	165/lab/day	2640
Herbicide spray	3 lit ha-1	255 lit-1	765
	2 woman days	165/lab/day	330
			18321
Animal Labour			-
Machine Labour			
Rectification of bunds	14 man days	165/lab/day +charges	2397
Bund forming (2day)	5.5 hrs	200/day+charges	1115
			3512
Seed			1920
Fertilizers		922	
Manures		1922	
Fertilizers and Manures			2844
Plant Protection			
Herbicide	1 lit+tax		252
Cost of Monochrotophos	1.5 lit (2sprays)	300 lit -1	450
			702
Interest on working capital			476
II Fixed cost			1340
Sub Total (I and II)			19661
Managerial cost @ 10 %			1966
III Total cost			21627

Table 4 : Effect of biochar on economics of cotton –maize- cowpea cropping sequence-(B : C ratio)-(Biochar one time application – Direct Study)

Treatments	Cotton yield (kg ha^{-1})		Residue Maize yield		Residue cowpea yield (kg ha^{-1})	
	Seed cotton yield	Stalk yield	Stover	Grain	Grain yield	Haulm yield
F_1B_1	1051	2228	7660	4345	385.5	462.6
F_2B_1	1570	3328	9364	5542	488.2	585.9
F_3B_1	1626	3447	9680	5828	542.8	651.4
F_4B_1	1605	3403	9604	5752	528.3	634
F_1B_2	1218	2582	7844	4475	409.3	491.2
F_2B_2	1643	3483	9542	5675	515.3	618.4
F_3B_2	1720	3646	9863	5954	570.6	684.8
F_4B_2	1686	3574	9784	5887	557.2	668.6
F_1B_3	1298	2751	8022	4608	432.9	519.5
F_2B_3	1751	3712	9722	5806	542.8	651.4
F_3B_3	1841	3902	10047	6084	599.5	719.4
F_4B_3	1778	3769	9965	6019	586.6	703.9
F_1B_4	1443	3059	8206	4732	458.7	550.5
F_2B_4	1912	4053	9906	5934	571.1	685.4
F_3B_4	2009	4259	10226	6217	631.1	757.3
F_4B_4	1960	4155	10146	6143	617.2	740.6
F_1B_5	1495	3169	8385	4867	485.1	582.1
F_2B_5	2000	4240	10080	6068	599.9	719.8
F_3B_5	2058	4372	10407	6348	662.5	795
F_4B_5	2011	4263	10322	6278	644.1	772.9

Table 5 : Effect of biochar on economics of cotton –maize- cowpea cropping sequence (B : C ratio)-(Biochar two time application – Cumulative study)

Treatments	Cotton yield (kg ha^{-1})		Cumulative maize yield		Second residue cowpea yield (kg ha^{-1})	
	Seed cotton yield	Stalk yield	Stover	Grain	Grain yield	Haulm yield
F_1B_1	1051	2228	7664	4346	385.5	462.6
F_2B_1	1570	3328	9365	5545	488.2	585.9
F_3B_1	1626	3447	9682	5825	542.8	651.4
F_4B_1	1605	3403	9600	5750	528.3	634
F_1B_2	1218	2582	7986	4574	422.3	506.8
F_2B_2	1643	3483	9684	5772	529.6	635.5
F_3B_2	1720	3646	10000	6055	586.5	703.8
F_4B_2	1686	3574	9927	5984	573.3	688
F_1B_3	1298	2751	8305	4804	439.5	527.3
F_2B_3	1751	3712	10005	6004	558.4	670
F_3B_3	1841	3902	10324	6284	615.6	738.7
F_4B_3	1778	3769	10248	6211	603.3	724
F_1B_4	1443	3059	8624	5035	472.1	566.6
F_2B_4	1912	4053	10327	6234	587.6	705.1
F_3B_4	2009	4259	10648	6514	645	773.9
F_4B_4	1960	4155	10561	6443	635.9	763.1
F_1B_5	1495	3169	8946	5267	500.6	600.7
F_2B_5	2000	4240	10644	6461	616.5	739.8
F_3B_5	2058	4372	10969	6748	680.9	817.1
F_4B_5	2011	4263	10885	6674	662.4	794.8

Table 6 : Economic analysis – Benefit cost ratio of cotton –maize- cowpea cropping sequence (Biochar one time application – Direct Study)

Treatments	Details	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
F_1B_1	$F_{0+}B_{0t}$	109523	128142	18619	1.17
F_2B_1	$F_{100\%}$ + B_{0t}	116734	151754	35020	1.30
F_3B_1	$F_{100\%}$ + B_{0t} + M	121734	161906	40172	1.33
F_4B_1	$F_{75\%}$ + B_{0t} + M	119934	154715	34781	1.29
F_1B_2	F_{0+} $B_{2.5t}$	114523	135137	20614	1.18
F_2B_2	$F_{100\% + B2.5 t}$	121734	161906	40172	1.33
F_3B_2	$F_{100\%}$ + $B_{2.5 t}$ + M	126734	172358	45624	1.36
F_4B_2	$F_{75\%}$ + $B_{2.5 t}$ + M	124934	168661	43727	1.35
F_1B_3	F_0 + B_{5t}	119523	142232	22709	1.19
F_2B_3	$F_{100\% +}$ $B_{5 t}$	126734	172358	45624	1.36
F_3B_3	$F_{100\%}$ + $B_{5 t}$ + M	131734	181793	50059	1.38
F_4B_3	$F_{75\%}$ + $B_{5 t}$ + M	129934	178010	48076	1.37
F_1B_4	$F_{0 +}$ $B_{7.5t}$	124523	149428	24905	1.20
F_2B_4	$F_{100\% +}$ $B_{7.5t}$	131734	183110	51376	1.39
F_3B_4	$F_{100\%}$ + $B_{7.5t}$ + M	136734	192795	56061	1.41
F_4B_4	$F_{75\%}$ + $B_{7.5t}$ + M	134934	188908	53974	1.40
F_1B_5	F_{0+} B_{10t}	129523	156723	27200	1.21
F_2B_5	$F_{100\%}$ + B_{10t}	136734	194162	57428	1.42
F_3B_5	$F_{100\%}$ + B_{10t} + M	141734	204097	62363	1.44
F_4B_5	$F_{75\%}$ + B_{10t} + M	139934	202904	62970	1.45

(B – Biochar; F- NPK fertilizers and M- FYM)

Table 7: Economic analysis – Benefit Cost Ratio of cotton –maize- cowpea cropping sequence (Biochar two time application – Cumulative study)

Treatments	Details	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
F_1B_1	$F_{0+}B_{0t}$	109523	128142	18619	1.17
F_2B_1	$F_{100\%}$ + B_{0t}	116734	151754	35020	1.30
F_3B_1	$F_{100\%}$ + B_{0t} + M	121734	161906	40172	1.33
F_4B_1	$F_{75\%}$ + B_{0t} + M	119934	154715	34781	1.29
F_1B_2	F_{0+} $B_{2.5t}$	119523	141037	21514	1.18
F_2B_2	$F_{100\% + B2.5 t}$	126734	164754	38020	1.30
F_3B_2	$F_{100\%}$ + $B_{2.5 t}$ + M	131734	176524	44790	1.34
F_4B_2	$F_{75\%}$ + $B_{2.5 t}$ + M	129934	171513	41579	1.32
F_1B_3	F_0 + B_{5t}	129523	152837	23314	1.18
F_2B_3	$F_{100\% +}$ $B_{5 t}$	136734	181856	45122	1.33
F_3B_3	$F_{100\%}$ + $B_{5 t}$ + M	141734	192758	51024	1.36
F_4B_3	$F_{75\%}$ + $B_{5 t}$ + M	139934	187512	47578	1.34
F_1B_4	$F_{0 +}$ $B_{7.5t}$	139523	166032	26509	1.19
F_2B_4	$F_{100\% +}$ $B_{7.5t}$	146734	199558	52824	1.36
F_3B_4	$F_{100\%}$ + $B_{7.5t}$ + M	151734	210910	59176	1.39
F_4B_4	$F_{75\%}$ + $B_{7.5t}$ + M	149934	205410	55476	1.37
F_1B_5	F_{0+} B_{10t}	149523	179428	29905	1.20
F_2B_5	$F_{100\%}$ + B_{10t}	156734	217860	61126	1.39
F_3B_5	$F_{100\%}$ + B_{10t} + M	161734	229662	67928	1.42
F_4B_5	$F_{75\%}$ + B_{10t} + M	159934	227106	67172	1.42

(B – Biochar; F- NPK fertilizers and M- FYM) cumulative studies respectively. Comparing the studies, the application of biochar @ 10 t ha^{-1} at two times application under cumulative study had recorded an additional income of Rs. 5,565 ha^{-1} only over one time application under direct study.

The benefit cost ratio (BCR) was higher under direct study than cumulative study. However, the highest B : C ratio was recorded with application of biochar @ 10 t + 75 % NPK + FYM with benefit cost ratio of 1.45 followed by biochar @ 10 t + 100 % NPK + FYM (1.44) and next in the order was by biochar @ 10 t + 100 % NPK (1.42) under one time application (direct study) and the treatments biochar @ 10 t + 100 % NPK + FYM and biochar @ 10 t + 75 % NPK + FYM with benefit cost ratio each of 1.42 under two time application (cumulative study).

To select the cost effective dose of biochar with fertilizers and with or without FYM, the economic analysis (Benefit Cost Ratio) has been worked out for cotton – maize – cowpea cropping system in Inceptisol (Vertic Ustropept) of Periyanaickenpalayam series of Coimbatore District of Tamil Nadu.

The higher B: C ratio was registered in one time application of biochar (direct study) than two times application (cumulative study). However, the highest net return was found in two times application (cumulative study) particularly the treatments biochar @ 10 t + 100 % NPK + FYM with Rs.67,928 ha^{-1} followed by biochar @ 10 t + 75 % NPK + FYM treatments with Rs.67,172 ha^{-1}. Application of biochar @ 10 t ha^{-1} had increased the net income to the tune of Rs.22,191 and Rs. 27,756 ha^{-1} over the corresponding treatment without biochar *viz.,* (100 % NPK + FYM) in direct and cumulative studies respectively. Comparing the studies, biochar @ 10 t ha^{-1} at two times application (cumulative study) in the cotton – maize – cowpea cropping system had recorded an additional income of Rs. 5,565 ha^{-1} only over one time application (direct study) because of higher cost of biochar. For realizing Rs. 5,565 ha^{-1}, an additional expenditure of Rs. 20,000 ha^{-1} has to be incurred for the application of biochar @ 10 t ha^{-1}. Therefore in cotton-maize-cowpea cropping system biochar one time application is considered to be an economically viable management technology than two times application. However, considering intrinsic potential of biochar in improving the soil nutrient status, crop yield and sequestration of large amounts of C in soil an additional investment on biochar is considered to be an environmentally viable technology.

With respect to Benefit Cost Ratio (BCR), biochar one time application (direct study) was found better with higher B : C ratio than two times application (cumulative study) in the cotton – maize – cowpea cropping system. Among the treatments, the treatment biochar @ 10 t + 75 % NPK + FYM in one time application recorded the net return of Rs. 62,970 ha^{-1} and highest benefit cost ratio of 1.45 in cotton – maize – cowpea cropping system suggesting that the onetime conjoint application of biochar @ 10 t ha^{-1} along with 75 % recommended dose of NPK fertilizers and 12.5 t ha^{-1} of FYM to cotton and adopting general recommended practices for maize and cowpea to be the best combination suited for enhancing higher benefit cost ratio under cotton – maize – cowpea cropping system in Inceptisol (Vertic Ustropept), Periyanaickenpalayam series of Coimbatore district of Tamil Nadu. The next best treatments were biochar @ 10 t + 100 % NPK + FYM with benefit cost ratio of 1.44 followed by biochar @ 10 t + 100 % NPK (1.42) under one time application and the treatments biochar @ 10 t + 100 % NPK + FYM and biochar @ 10 t + 75 % NPK + FYM with benefit cost ratio each of 1.42 under two times application.

Conclusion :

Addition of biochar @ 10 t ha^{-1} had increased the net income to the tune of Rs.22,191 and Rs. 27,756 ha^{-1} over the general recommended practice of 100 % NPK + FYM (12.5 t ha^{-1}) under one time and continuous (two times) application respectively. The highest net return was found in continuous application (two times) especially in the treatment biochar @ 10 t + 100 % NPK + FYM with Rs.67,928 ha^{-1} followed by biochar @ 10 t + 75 % NPK + FYM treatment with Rs.67,172 ha^{-1}. The next higher net return was registered in biochar @ 10 t + 75 % NPK + FYM treatment under one time application with Rs. 62,970/-.

Comparing the studies, the two times application (biochar @ 10 t ha^{-1} $time^{-1}$) recorded an addition of Rs. 5,565/- only over one time application. Therefore one time application (biochar @ 10 t ha^{-1}) considered to be an economically viable management technology than two times application in the cotton – maize – cowpea cropping sequence.One time conjoint application of biochar @ 10 t ha^{-1} along with 75 % recommended dose of NPK fertilizers and 12.5 t ha^{-1} of FYM *i.e.*, (biochar @ 10 t + 75 % NPK + FYM) to cotton and following the general recommended practices for maize and cowpea to be the best combination suited for enhancing higher benefit cost ratio of 1.45 under cotton – maize – cowpea cropping system in Inceptisol (Vertic Ustropept) of Periyanaickenpalayam series of Coimbatore District.

Biochars from different biological materials and it has become clear that prosopis wood biochar as superior one that can act as a soil conditioner and has the capacity to enhance plant growth by supplying and retaining nutrients and by providing other benefits such as improving soil physical properties. The study also reveals that the biochar is a potentially valuable resource, when applied to soil; it increased the physical properties, enhanced fertility and increased soil nutrients and also ability to sustain the soil fertility status over long run to fetch highest yield and returns.

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