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Crop Residue Recycling In Generating Nutrient Rich Organic Manures: Experiences from Rice Based Integrated Farming System

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***Abstract*:** Two different experiments on crop residue recycling were carried out at the Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala Agricultural University from 2018 to 2020. Paddy straw, the major crop residue from rice based cropping systems was utilised as resource base for both the experiments. Different paddy straw composts generated from the first experiment through vermicomposting, co - composting and microbial composting techniques were evaluated for use as potting media component in a pot culture trial with bhindi as test crop. Composts generated in the second experiment through co composting of paddy straw with cow dung and poultry manure in the ratio 8:1:1 and with goat manure and poultry manure in the ratio 4:1:1 (both on volume basis mixing of inputs) were rich in plant nutrients. These composts when substituted for the FYM component of potting media, recorded enhancement in the uptake of major nutrients,fruit yield and quality of okra. Use of these composts as ingredient of potting media recorded higher net returns and B: C ratio as well. In the second experiment, one month old partially withered paddy straw was bio recycled through co - composting strategies using nitrogen resources cow dung, poultry manure, goat manure and glyricidia leaves or their combinations. The different composts generated were evaluated in field culture for organic nutrition of fodder maize var. *African Tall.* Co - composting of paddy straw with goat manure and poultry manure (4:1:1 ratio on volume basis) produced nutrient rich compost and on substituting this compost for chemical fertilisers on N equivalent basis, higher fodder yield, net returns and B : C ratio were recorded comparable with the integrated nutrient management package for fodder maize recommended by KAU.

***Keywords*:** Crop residues, Integrated farming system, Paddy straw, Goat manure, Poultry manure

Crop residues are the leftover organic materials after harvesting or processing of crops and are valuable carbon inputs which could be recycled to soil to improve soil health. India generates around 500-550 million tons of crop residues annually (GOI 2016). Integrated Farming Systems (IFS) which promote sequential/multiple cropping for efficient utilisation of land resources generate substantial quantities of crop residues. Organic materials including dung and droppings are generated in IFS by dairy and poultry components. All these could be effectively utilised in generating quality organic manures within the farms (Athira et al 2021)

Rice based farming systems are characterized with the production of large quantities of crop residues mainly paddy straw. Straw though finds use as fodder for milch animals and as base material for mushroom production, largely goes as waste as a result of improper storage and drying. Mostly in double cropped conditions, at least one harvest falls during wet season which limits the chances of spreading and drying of straw resulting in mouldy growth considerably reducing the feed value of straw, which is then discarded as bio waste in fields. However in the present scenario, with the increasing trend towards organic farming, recycling of all possible organic resources assumes greater importance. However, there are limitations in recycling paddy straw as such to soil due to bulky volume, slow degradation and short term negative effect of nitrogen immobilization (Hu et al 2016). Composting of paddy straw is an alternate option to recycle the nutrients contained in it. Based on the above, studies were conducted as two different experiments in rice based integrated farming system at the Integrated Farming System Research Station (IFSRS), Karamana, Kerala Agricultural University in recycling paddy straw for crop production. Different composting strategies were tried out in the first experiment to generate paddy straw composts which were then utilised as potting media component for container cultivation of vegetable crop okra. Co - composting of partially withered paddy straw with different organic resources were also attempted and the composts generated were used for organic nutrition of summer crop fodder maize raised in rice fallows.

MATERIAL AND METHODS

Experiment I on bio recycling of paddy straw using different technologies was carried out at IFSRS during the period from March to August, 2018. Different treatments followed for composting of paddy straw (Table 1) and the composition of paddy straw (Table 2). The statistical design followed was completely randomised design with eight treatments and three replications. One week old straw of medium duration rice variety *Uma* was used for composting. Paddy straw sprinkled with water and stalked overnight was mixed with cow dung, poultry manure or both in different ratios on volume basis for co-composting and was filled in concrete pits of size 1 m^3. For vermicomposting treatments, earthworms (*Eudrillus euginea*) were introduced @ 1000 nos per 1 m^3 pit after 10 days of initial degradation when the heat in composting piles was reduced. Sufficient moisture levels were maintained in the composting material by periodic sprinkling of water. The materials were turned twice a week to ensure aeration and uniform decomposition. Mushroom species *Pleurotus sajor-caju* was utilised for enhancing decomposition of paddy straw in microbial composting. The nutrient content of the different composts are detailed in Table 3.

Table 1. Different treatments on paddy straw composting followed in Experiment I

Vermicomposting
T_1 - Paddy straw + cowdung (8:1) + earthworms
T_2 - Paddy straw + cowdung (6:1) + earthworms
T_3- Paddy straw + cowdung (4:1) + earthworms
Co - composting
T_4 - Paddy straw + poultry manure (8:1)
T_5 - Paddy straw + poultry manure (6:1)
T_6 - Paddy straw + poultry manure (4:1)
T_7 - Paddy straw + cowdung + poultry manure (8:1:1)
Microbial composting
T_8 - Paddy straw + Urea + Pleurotus (For 100 kg straw, 500 g urea and 150 g Pleurotus)

Table 2. Composition of paddy straw used in Experiment I and II

Parameters	Expt. I	Expt. II
Lignin (%)	26	19
Cellulose (%)	54	30
Major nutrients (%)		
N	0.68	0.22
P	0.12	0.15
K	1.35	1.38
Micro and beneficial nutrients (mg kg^{-1})		
Fe	544.2	262.75
Cu	23.88	27.03
Mn	144.19	637.5
Zn	36.31	31.05
B	3.24	4,24
C: N ratio	60:1	39:1

Pot culture study was conducted to evaluate the different composts with KAU hybrid okra var. *Manjima* as the test crop. These composts were used as component of potting media (Soil, rock sand, coir pith compost and paddy straw compost well mixed in the ratio 1: 0.5: 0.5: 1 on volume basis and filled @ 13 kg media per grow bag. For the control treatment, FYM was used instead of paddy straw compost in the same proportion. In treatments T_1 to T_8, the 8 different composts generated were substituted for the FYM portion of potting media. In T_9, conventional potting media i.e., soil, sand and FYM (1:1:1 on volume basis) was used. The crop was nourished as per the recommendations of KAU Package of Practices (KAU, 2016). Basal organic manure was supplied through FYM @ 130 g per plant. The basal dose of chemical fertilizers was supplied as urea, rock phosphate and muriate of potash @ 0.78, 1.26 and 0.76 g per plant, respectively. Top dressing with 0.78 g of urea per plant was done one month after planting. Data on the nutrient uptake, yield, quality and economics of okra as influenced by different potting media.

The different treatments followed in Experiment II are given in Table 6. Partially degraded, one month old straw of medium duration rice variety *Uma* was made used in the experiment II. The composition of the straw and the nutrient status of composts were estimated (Table 2, 6). The

Table 3. Nutrient content of different composts in Experiment I

Treatments	Major nutrients (%)			Micro nutrients (mg kg^{-1})				
	N	P	K	Fe	Cu	Mn	Zn	B
T_1	1.83	0.48	2.18	1189.67	28.15	158.57	174.27	12.92
T_2	1.90	0.51	2.22	1244.33	33.72	159.93	186.10	13.16
T_3	2.12	0.58	2.58	2001.33	37.80	162.03	187.77	13.50
T_4	2.06	0.63	2.70	2251.33	27.32	170.30	180.23	14.61
T_5	2.22	0.79	2.78	2998.67	32.30	184.07	191.83	16.55
T_6	2.67	0.93	3.15	3586.67	34.21	187.60	217.37	19.74
T_7	2.40	0.85	3.03	2358.67	28.45	190.57	170.90	17.90
T_8	1.57	0.27	1.71	1084.33	26.61	154.80	163.20	11.28
CD (p = 0.05)	0.317	0.129	0.591	619.975	-	-	-	2.749

composts generated were used in organic nutrition of fodder crop maize var. *African Tall* raised in summer rice fallows. The field experiment was laid out in randomised block design with eight treatments and three replications. In treatments T_1 to T_7, organic crop nutrition was followed using composts 1 to 7 respectively. T_8 followed an integrated nutrient management package as per KAU recommendation. FYM @ 10 t ha^{-1} was applied as basal organic dose uniformly for all the treatments. For treatments 1 to 7, organic crop nutrition was followed and the respective composts were applied on N equivalent basis to substitute inorganic N requirement avoiding chemical fertilizers.

RESULTS AND DISCUSSION

Experiment I

Nutrient content of composts: Treatment T_6 had the highest content of major and micronutrients followed by T_7 (Table 3). The micronutrient content of different composts were statistically similar except for Fe and B. Treatment T_6 recorded higher contents of both Fe and B. Higher N content of T_6 could be related with the higher N content of poultry manure (2.3%) used for composting, compared to cow dung (1.21%). Furthermore, the improved N content of poultry manure might have accelerated the growth of nitrifying bacteria, contributing to increased level of N in final compost. Abdelhamid *et al.* (2004) observed that as the quantity of poultry manure added to the initial material increases, total N content of paddy straw compost also increases. Poultry manure used for the experiment was rich in P (1.4 %) over cow dung (0.4 %) and hence the composts produced using poultry manure as an ingredient naturally had higher P content. Similarly, the higher K content registered in T_6 and T_7 could be due to the increased amount of K supplied by poultry manure (1.35%) compared to cow dung (0.6%).

Nutrient uptake and crop yield of okra: Nutrient uptake (Table 4) was high for T_6 and T_7 which could be attributed to the nutrient richness of these composts (Table 3) and hence more availability for uptake. Crop yields were also higher for these two treatments attributing to higher nutrient uptake which lead to improved crop nutrition.

Quality parameters of okra: Higher and comparable crude protein content were recorded by treatments T_6 and T_7 (Table 5). The crude fibre ranged from 1 to 17.90 per cent in okra fruits grown in different media. T_7 recorded lower crude fibre content. Vitamin C content ranged from 10.53 to 21.05 mg 100 g^{-1} and T_7 recorded higher content of vitamin C. The enhancement in quality parameters could be well related with better crop nourishment. Singh *et al.* (2020) reported better quality aspects in okra with an integrated nutrient supply which well nourished the crop.

Economics of cultivation: Net return was higher and comparable for treatments T_7 (Rs.7.04 bag^{-1}) and T_6 (Rs. 6.01 bag^{-1}) (Table 6). Lowest net return was for T_1 (Rs. -19.99 bag^{-1}), wherein paddy straw vermicomposted with cow dung in the ratio 8:1 (volume basis) was used as the potting media component. B: C ratio followed the same trend as net return. The treatment T_7 had the highest BCR of 1.23, comparable to T_6 (1.20). The lowest BCR of 0.51 was for T_1.

Experiment II

Nutrient content of composts: Nutrient status of different composts generated by different co-composting methods are given (Table 8). Co-composting methods using, different organic manures as nitrogen source could significantly influence the total N, P and K content of rice straw composts. Rice straw co - composted with goat manure and poultry manure in the ratio 4:1:1 on volume basis (T_6) had higher N (3.30%), P (0.98%) and K (3.22%) contents. Treatments T_4, T_5 and T_7 recorded comparable values and closely followed T_6

Table 4. Nutrient uptake and yield of bhindi as influenced by different potting media

Treatments	Nutrient uptake (kg per plant)			Fruit yield (kg per plant)	Number of fruits per plant	Average weight of fruit per plant (g)
	N	P	K			
T_1	1.17	0.14	1.61	0.345	17.33	22.93
T_2	1.56	0.28	2.13	0.482	23.00	23.78
T_3	1.74	0.31	2.36	0.508	23.67	24.21
T_4	2.11	0.32	2.45	0.515	25.67	24.71
T_5	2.52	0.33	2.50	0.534	26.00	25.21
T_6	2.73	0.42	2.96	0.590	26.67	26.26
T_7	2.92	0.48	2.88	0.619	27.67	27.05
T_8	1.24	0.15	1.91	0.382	19.00	22.59
T_9	1.28	0.23	1.81	0.361	18.33	21.07
CD (p = 0.05)	0.350	0.124	0.353	0.0390	3.734	2.272

with regard to content of major nutrients. Co-composting methods had a significant influence on the content of Fe, Cu, Mn, Zn and B micronutrients. Treatment T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 on volume basis) recorded significantly higher contents of Fe (3201.66 mg kg^{-1}), Cu (45.58 mg kg^{-1}), Mn (1096.17 mg kg^{-1}, Zn (280.40 mg kg^{-1}) and B (19.97 mg kg^{-1}). T_8 (natural composting of rice straw) had lower content of micronutrients and was comparable to T_1 and T_2 mostly.

Nutrient uptake and crop yield: The nutrient uptake data are given in. Uptake of N was higher (179.25 kg ha^{-1}) for the INM treatment T_8 (basal FYM + soil test based application of chemical fertilizers) and was on par with T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 as nutrient source) (Table 9). The lower N uptake was with T_1 (126.83kg ha^{-1}) comparable to T_3 and T_2. T_8 registered higher P uptake of 21.28 kg ha^{-1} which was on par with treatment T_6. Higher uptake of K (198.04 kg ha^{-1}) was for T_8 and comparable to T_6. The results suggest the comparable performance of organic nutrition using paddy straw compost

Quality parameters of test crop: Among different treatments, T_8 (KAU POP recommendation combining organic and inorganic nutrients) recorded a higher crude protein content (8.26 per cent) and was comparable to T_6 and T_4 followed by T_5 *i.e.* plants nourished under organic nutrition using rice straw composts. The treatments T_1, T_3, T_2 and T_7 recorded lower and comparable crude protein content.

Table 5. Quality parameters of bhindi fruit as influenced by different potting media

Treatments	Crude protein (%)	Crude fibre (%)	Ascorbic acid (mg 100 g^{-1})
T_1	11.55	17.90	10.53
T_2	12.72	16.70	12.28
T_3	13.65	15.23	14.04
T_4	17.62	15.47	12.28
T_5	17.97	14.93	17.54
T_6	19.25	14.37	19.30
T_7	21.12	11.10	21.05
T_8	12.25	16.7	12.28
T_9	12.37	19.3	10.53
CD (p = 0.05)	1.622	0.978	4.286

Table 6. Different treatments followed in Experiment II

Treatment	Co- composting techniques (Volume basis)
T_1	Rice straw + cow dung (4:1)
T_2	Rice straw + goat manure (4:1)
T_3	Rice straw + poultry manure (4:1)
T_4	Rice straw + cow dung + goat manure (4:1:1)
T_5	Rice straw + cow dung + poultry manure (4:1:1)
T_6	Rice straw + goat manure + poultry manure (4:1:1)
T_7	Rice straw + cow dung + glyricidia leaves (4:1:1)
T_8	Natural composting (Rice straw alone as control)

Table 7. Economics of bhindi and fodder maize as influenced by different treatments

Treatments	Net returns (Rs ha^{-1})	B : C ratio	Net returns (Rs ha^{-1})	B : C ratio
T_1	-19.99	0.51	4320	1.03
T_2	-9.10	0.76	12349	1.09
T_3	-4.72	0.87	10823	1.08
T_4	0.58	1.01	20510	1.14
T_5	2.51	1.09	21246	1.15
T_6	6.01	1.20	27661	1.20
T_7	7.04	1.23	20665	1.15
T_8	-15.92	0.59	39814	1.31
T_9	-7.32	0.75	513.43	0.02
CD (p = 0.05)	2.394	0.073	4320	1.03

Table 8. Nutrient status of composts generated from Experiment II

Treatments	Major nutrients (%)			Micro nutrients (mg kg^{-1})				
	N	P	K	Fe	Cu	Mn	Zn	B
T_1	2.59	0.55	2.39	1239.83	18.17	447.08	148.47	14.10
T_2	2.88	0.73	2.60	1299.50	19.62	645.73	161.50	16.83
T_3	2.78	0.79	2.45	1875.17	22.52	834.17	177.40	17.63
T_4	3.04	0.89	2.94	3031.83	31.90	908.75	244.85	17.93
T_5	2.99	0.93	2.86	3187.00	35.25	1053.75	244.67	18.77
T_6	3.30	0.98	3.22	3201.66	45.58	1096.17	280.40	19.97
T_7	2.93	0.82	3.00	1788.33	24.48	900.00	211.85	17.53
T_8	1.2	0.35	1.95	807.16	12.65	413.75	43.10	12.97
CD (p = 0.05)	0.230	0.090	0.160	778.873	8.452	177.160	71.190	0.904

Table 9. Nutrient uptake, yield and quality of fodder maize as influenced by different composts

Treatments	Nutrient uptake (kg per ha)			Green fodder yield ($t\ ha^{-1}$)	Crude protein (%)
	N	P	K		
T_1	126.83	11.99	142.17	29.89	7.94
T_2	130.85	13.14	145.32	31.05	8.08
T_3	128.45	12.37	143.48	29.94	8.00
T_4	171.29	18.78	190.56	32.67	8.17
T_5	169.29	17.38	189.26	32.23	8.11
T_6	174.34	20.41	195.19	33.11	8.19
T_7	142.75	15.46	163.68	32.20	8.08
T_8	179.25	21.28	198.04	33.56	8.26
CD (p = 0.05)	5.160	1.153	6.346	2.030	7.94

Economics of cultivation: The net returns and B: C ratio of okra cultivation are presented in Table 6. Net return was highest for treatment T_8 and T_6 (Table 6). This could be attributed to the higher yield obtained under these treatments. The lowest net returns were in T_1 (Rs. 4320 ha^{-1}), where rice straw co-composted with cow dung in the ratio 4:1 was used as organic manure for fodder maize. The treatment T_8 registered the highest BCR of 1.31, followed by T_6. Lower BCR of 1.03 was in T_1 comparable to T_3.

CONCLUSION

Co - composting of paddy straw with poultry manure in the ratio 4:1 or with cow dung and poultry manure in the ratio 8:1:1 were the best methods for production of nutrient rich compost with high recovery in a short period, compared to vermicomposting and microbial composting. Substituting the above composts for FYM in potting medium could result in better growth, yield attributes, yield and net income of bhindi grown in pot culture. With respect to the quality parameters of okra, paddy straw co - composted with cow dung and poultry manure in the ratio 8:1:1(volume basis) was superior. Co - composting in the ratio 4:1:1 (volume basis) also generated composts rich in plant nutrients . When utilized for organic crop nutrition of fodder maize African Tall, these composts could result in comparable yield and economics as that obtained with the integrated nutrient management package recommended by KAU. Thus the superiority of paddy straw composts both as component of potting media and as quality organic manure were established.

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