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Effect of rice (*Oryza sativa*) straw management on growth and yield of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted at Jorhat, Assam during 2004-05 and 2005-06 to find out an effective practice of rice (*Oryza sativa* L.) straw management in wheat (*Triticum aestivum* L. emend. Fiori & Paol.) as a component of integrated nutrient management. Straw was incorporated @ 5 t/ha with different decomposers, viz. starter N (one-third recommended dose of N), cellulose-decomposing microorganisms (CDM), earthworms culture (EC), EC + FYM, CDM + EC, FYM and starter N+ CDM + EC + lime. These decomposers significantly improved the yield and yield components in wheat compared with straw removal. Incorporation of rice straw @ 5 t/ha under dual inoculation of cellulose-decomposing microorganisms and earthworms improved the grain yield by 2.46 t/ha. These also increased the nutrient uptake, available N, P, K in soil at harvest and benefit : cost ratio. Straw incorporation increased the organic C in the soil by 2-11% compared with straw removal. It also increased the microbial population in soil substantially irrespective of the decomposer used. Inoculation with CDM led to build-up of microbial population in the soil. Thus, rice straw incorporation with cellulose decomposing micro-organisms and earthworms resulted in higher yield, increased nutrient uptake, improved residual soil fertility and soil microorganism status and ultimately higher benefit : cost ratio of wheat.

Key words: Cellulose-decomposing microorganisms, Earthworm culture, Rice straw, Wheat

Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system is one of the predominant cropping systems of India, followed on 10.5 million ha. The stagnation in the productivity of rice and wheat in this system is a serious concern which is mainly attributed to decline in soil fertility, particularly soil organic matter. It is well recognized that for sustaining the productivity of this system, integrated use of organic and inorganic sources of nutrients is inevitable. Crop residue is one of the major sources of organic matter and plant nutrients if managed properly. Recycling of such crop residues also reduces soil erosion vis-a-vis nutrient loss and improves the physico-chemical and biological properties of the soil, playing an important role in energy flow and nutrient cycling (Singh and Ganguly, 2005). Verma and Bhagat (1992) reported increase in soil organic matter and improvement of rice and wheat yield following incorporation of residues. Burning of crop residues in the field, a common practice followed by the farmers, can cause up to 80% loss of tissue N, besides it is a significant source of air pollution. Incorporation of residues into the soil after harvest through conventional tillage decreased the yield of subsequent crops due to N immobilization (Sidhu and Beri, 1989). In Assam, with the expansion of irrigation facilities the area under wheat following rice is increasing progressively. Rice is harvested with top one-third portion of the straw, which after threshing is used as animal feed, and the major portion (two-third) of the straw left in the field after harvest of rice causes enormous problem in the establishment and growth of the succeeding wheat due to wider C: N ratio and slow rate of its decomposition. Information related to rice straw management in Assam is very much limited. Ali *et al.* (1995) found increase in rice yield and improvement in residual soil fertility with rice straw incorporation. Development of appropriate straw management practice is, therefore, very important for its successful use as a component of integrated nutrient management. In cognizance of the above facts the present study was undertaken.

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MATERIALS AND METHODS

An experiment was conducted at the research farm of the University at Jorhat during 2004-05 and 2005-06. The soil was acidic in reaction (pH 5.4), low in organic C (0.42%), and had available N (160 kg/ha), P (13.7 kg/ha) and K (92 kg/ha). The initial microbial population of the soil was 9.69 log cfu/g soil. Eight treatments were tested in randomized block design with three replications. The treatments were: control (rice straw removal), rice straw incorporation (RSI) + starter N (one-third of recommended dose of wheat), RSI + cellulose decomposing micro-organisms (CDM), RSI + earthworm culture (EC), RSI + EC + FYM, RSI + CDM + EC, RSI + FYM and RSI + starter N + CDM + EC + lime. In the control plot straw was cut at ground level and removed; whereas in straw-incorporated plots rice straw was incorporated @ 5 t/ha. The CDM used was the mixture of *Bacillus polymyxa* and *Trichoderma viridi.* The population of the applied broth was 10^8–10^9 cfu/ml. The broth culture was applied @ 2 ml/kg of straw as per treatment. Earthworm culture (*Amyanthas diffringens* Baired) was inoculated @ 2 kg earthworm per t of rice straw. Lime was applied @ 1 t/ha at the time of straw incorporation only in the treatment involving lime application along with starter N, CDM and EC. Farm yard manure was applied @ 2.5 t/ha as per treatments. The rice straw used contained 40.4% C, 0.65% N, 0.12% P and 0.96% K with C : N ratio 62 : 1 and was incorporated 20 days before sowing of wheat. Fertilizer was applied @ 80 kg N, 19.8 kg P and 34.8 kg K/ha. Half the N and full dose of P and K were applied as basal and the remaining N was top-dressed in two equal splits, half at crown–root initiation stage and half at spike initiation stage. In the treatment receiving rice straw incorporation with starter N, one-third of the recommended N (26.6 kg N/ha) was applied at the time of straw incorporation. The wheat variety 'Sonalika' was sown in lines 20 cm apart on 10 November 2004 and 15 November 2005, and harvested on 14 April 2005 and 20 April 2006 respectively.

The data on growth parameters, yield attributes and yield were recorded. The soil samples were analysed for organic C, available N, P, and K; and the plant samples were analysed for N, P and K by standard methods. Microbial population in soil was determined at harvest of wheat.

RESULTS AND DISCUSSION

Growth and yield

Plant height and spike length of wheat did not vary significantly due to different straw management practices (Table 1). Irrespective of the decomposer used, straw incorporation significantly increased the effective tillers/m and grains/spike over straw removal during both the years of study. Effective tillers/m were more during 2005-06 than 2004-05. Incorporation of straw with CDM and earthworm culture resulted in highest effective tillers/m and grains/spike. Effective tillers/m were, however, statistically similar with the treatments where straw was incorporated with CDM or earthworm culture alone. Faster decomposition of rice straw in the presence of different decomposers, particularly CDM and earthworm culture, improved the status of soil organic matter, leading to higher uptake of available nutrients from the soil and ultimately increased the yield components (Singh and Yadav, 2006). The efficiency of CDM was almost similar to that of earthworm culture in decomposing rice straw, as evident from similar increase in yield components and yield. Similarly, straw incorporation with different decomposers recorded statistically similar grains/spike. Incorporation of rice straw significantly increased the grain and straw yields of wheat compared with straw removal. The increase in grain yield was attributed to improvement in different yield components. Our results corroborate the findings of Singh *et al.* (2005). The highest grain yield was recorded when straw was incorporated along with CDM and earthworm culture, followed by straw incorporation with CDM alone during 2004-05, whereas both the treatments were statistically at par during 2005-06. The highest pooled grain yield was also obtained from the treatment receiving straw

Table 1. Growth, yield components and yield of wheat as influenced by straw-management practices

Treatment	Plant height (cm)		Effective tillers/m		Grains/ spike		Grain yield (t/ha)			Straw yield (t/ha)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	Pooled	2004-05	2005-06
Control	86.2	86.7	54.7	53.7	33.3	33.0	1.48	1.40	1.44	2.80	3.53
RSI + starter N	85.0	84.2	58.7	71.2	40.2	39.6	1.54	1.50	1.52	2.87	3.58
RSI + CDM	89.2	86.0	74.8	84.0	40.6	38.9	2.21	2.00	2.11	4.02	4.50
RSI + EC	82.6	79.3	60.6	88.5	40.2	39.3	1.71	1.90	1.81	3.83	4.23
RSI + EC + FYM	90.6	89.6	65.7	76.9	42.5	38.0	1.86	1.90	1.88	3.02	4.13
RSI + CDM + EC	91.0	92.9	76.0	91.6	42.8	38.2	2.64	2.27	2.46	4.30	3.51
RSI + FYM	86.1	85.0	69.1	75.2	41.3	39.8	1.69	1.87	1.78	3.30	3.60
RSI + starter N + CDM + EC + liming	84.8	83.0	66.1	73.2	38.7	39.0	1.79	1.80	1.79	3.58	3.67
SEm±	3.5	4.2	5.2	5.8	1.2	0.9	0.10	0.10	0.10	0.20	0.20
CD (P=0.05)	NS	NS	12.5	13.9	2.8	2.1	0.20	0.30	0.20	0.40	4.30

RSI - rice straw incorporation, CDM – cellulose-decomposing micro-organisms; EC – earthworm culture, FYM – farmyard manure incorporation with CDM and earthworm culture. Straw yield followed a trend similar to that of grain yield. Cumulative activity of CDM and earthworm might have resulted in faster decomposition of straw and consequently released the nutrients throughout the growth period and improved the organic matter status, which ultimately resulted in better growth and yield (Kavimandan *et al.*, 1987). Periodical analysis of soil revealed an increase in soil available N, P and K from 30 days after sowing.

Nutrient uptake

Straw incorporation increased the nutrient uptake by wheat, irrespective of the use of decomposers (Table 2). The lowest uptake of N, P and K was recorded when straw was removed. Nitrogen uptake varied significantly among different straw management practices, perhaps due to variation in dry matter yield. During 2005-06, the N, P and K uptake were comparatively higher than during 2004-05, perhaps due to higher dry matter yield. Incorporation of rice straw with CDM and earthworm culture resulted in the highest N uptake during both the years of study. Faster decomposition and rapid mineralization of nitrogen due to cumulative action of CDM and earthworms might have resulted in increased availability of nitrogen and its uptake. The treatment where straw was incorporated with either CDM or earthworm + FYM registered statistically similar uptake of N. Though there was substantial increase in N uptake due to straw incorporation with starter N, it was not comparable to the rest of the straw management practices. Straw incorporation significantly increased the P uptake, and the trend was similar to that of N. The increase in P uptake was 9.2 and 5.4 kg more with rice straw incorporation under dual inoculation of CDM and earthworms during 2004-05 and 2005-06 respectively compared with straw removal. The increased availability of P in the presence of straw incorporation might have increased the P uptake. The increase in available P due to incorporation of rice straw with decomposers might be due to the inactivation of Fe and Al as well as hydroxyl Al ions, which reduced the fixation of P (Subehia *et al.*, 2005). Straw incorporation increased the K uptake significantly, being highest with the treatment receiving straw incorporation with dual inoculation of CDM and earthworm, but on a par with the treatment where straw was incorporated with CDM alone. During 2005-06 straw incorporation with earthworm culture also resulted in uptake of K statistically similar to that obtained under dual inoculation of CDM and earthworms, perhaps due to increase in the earthworm population and their activity in the soil compared with that in 2004-05. The increased availability of nutrients and improvement in organic C status of soil due to faster decomposition of rice straw with combined activity of CDM and earthworm might have increased the uptake of nutrients (Surekha *et al.*, 2004).

Residual soil fertility

Organic C in the soil increased substantially due to straw incorporation compared with straw removal (Table 3). The increase was higher (11%) when straw was incorporated with CDM and earthworm culture. Singh *et al.* (2006) also reported increased organic C in the soil following straw incorporation. Similarly, irrespective of the decomposers used, straw incorporation significantly increased the available N, P and K, whose values were the highest under straw incorporation with dual inoculation of CDM and earthworm. The available N, P and K in the soil were higher during 2005-06 than during 2004-05, perhaps due to the cumulative effect of straw incorporation. Decomposition of rice straw might have improved the microbial activity leading to increased N_2 fixation, and reduced the N losses in residue-incorporated plots by forming organo-mineral complexes (Becker *et al.*, 1994). The increase in available P following straw incorporation with decomposers might be due to solubilizing action of certain

Table 2. Effect of straw management practices on nutrient uptake by wheat (grain + straw)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Control	30.6	32.7	9.6	10.2	47.6	55.2
RSI + starter N	38.6	44.9	10.2	11.2	48.8	58.3
RSI + CDM	60.5	62.5	15.1	16.2	69.4	76.3
RSI + EC	48.2	55.1	11.1	13.1	63.1	68.6
RSI + EC + FYM	55.6	64.3	12.2	13.9	55.8	69.8
RSI + CDM + EC	76.7	70.8	18.8	15.6	76.3	73.9
RSI + FYM	41.3	46.3	11.1	12.4	54.9	60.5
RSI + starter N + CDM + EC + lime	44.1	46.1	12.0	11.9	59.7	56.7
SEm±	3.5	3.2	1.0	0.8	3.4	4.0
CD (P=0.05)	8.5	7.5	2.4	1.9	8.1	9.5

Table 3. Organic C, available nutrients, microbial population in soil and benefit : cost ratio as influenced by straw management practices

Treatment	Organic C (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)		Microbial population (log cfu/g soil)		Benefit : cost ratio	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Control	0.53	0.54	136	138	10.3	10.3	88	89	9.70	9.71	1.72	1.69
RSI + starter N	0.54	0.55	142	143	10.8	11.2	90	91	9.67	9.72	2.06	1.87
RSI + CDM	0.59	0.59	185	186	12.5	12.5	98	98	9.90	9.91	2.49	2.37
RSI + EC	0.58	0.59	183	182	11.6	12.0	90	92	9.70	9.72	2.19	2.13
RSI + EC + FYM	0.57	0.58	187	191	12.0	12.5	97	97	9.71	9.74	2.16	2.17
RSI + CDM + EC	0.59	0.60	196	197	12.9	12.5	99	99	9.92	9.94	2.76	2.49
RSI + FYM	0.57	0.59	190	191	12.0	12.0	95	97	9.87	9.85	2.09	2.11
RSI + starter N + CDM + EC +lime	0.55	0.57	189	190	11.6	12.0	90	92	9.80	9.80	1.85	1.88
SEm±	0.01	0.01	2.1	2.5	0.2	0.2	2.1	0.8				
CD (P= 0.05)	0.02	0.02	5.0	6.0	0.5	0.4	5.0	2.0				

acids and displacement of phosphate by organic anions formed during the decomposition of organic residues. Our results corroborate the findings of Kachroo *et al.* (2006). Thus, incorporation of rice straw with CDM or earthworms improves the soil fertility through increased N, P and K. The straw incorporation improved the microbial population in the soil substantially, being highest with the treatment receiving straw incorporation with dual inoculation of CDM and earthworm culture. The increase in microbial population in the soil was higher in 2005-06 than in 2004-05. Straw incorporation provides a stable supply of C and energy for micro-organisms, and increases the microbial population (Dobermann and Fairhurst, 2002).

Economics

The benefit : cost ratio as influenced by different treatments (Table 3) revealed that straw incorporation increased the benefit : cost ratio of wheat compared with straw removal. The highest benefit : cost ratio was recorded with straw incorporation along with dual inoculation of CDM and earthworms, followed by the treatment where straw was incorporated along with CDM alone during both the years of experimentation. The benefit : cost ratio due to straw incorporation with earthworms was comparable to straw incorporation with FYM.

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