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Residue-management practices using fly ash and various crop residues for productivity of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system under limited moisture conditions

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ABSTRACT

A field experiment was conducted at the Sher-e-Kashmir University of Agricultural Sciences and Technology, R.S. Pura, Jammu, during 2001–03, to evaluate the effect of fly ash and residue incorporation on the productivity and soil health in rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system under limited moisture conditions. Incorporation of residues of rice in wheat and wheat in rice not only increased the yield and yield components of rice and wheat but also increased the nutrient uptake besides improving the physico- chemical and biological properties of the soil which provide better soil environment for growth. Alternatively the incorporation of fly ash and left-over stubbles of previous crops as residues were found equally effective in increasing the productivity and soil environment in rice–wheat cropping system.For quick and better decomposition the application of *Trichoderma viride* + 20 kg N/ha as starter dose influenced the yield, available nutrients, microbial population and physical poperties of the soil significantly compared with no starter dose application.

Key words : Fly ash, Crop residues, *Trichoderma viride,* Rice–wheat sequence

Intensive agriculture and decreasing inputs of organic material have led to severe degradation of the soil resulting in a reduction on soil organic matter, soil fertility and productivity which is particularly more often in rice– wheat cropping system. Incorporation of residues as a means of nutrient recycling in the soil-plant ecosystem is an essential component of sustainable productivity in nutrient exhaustive rice–wheat cropping system, as it alters the soil environment which in turn influences the microbial population and activity in the soil and subsequent nutrient transformation (Kumar and Goh, 2000). Apart from rice and wheat crop residues, fly ash is also considered as the potential source of residue input. Crops sown immediately after the incorporation of residues suffered because of a deficiency of available N. To enhance the process of residue decomposition in the soil and to provide supplement N, the use of starter dose in the form of bio-inoculants and fertilizer N or any other such source to the decomposing residues could possibly partially offset the immobilization process. Since no single residue-management practices is superior under all conditions, it becomes imperative to determine the benefits and adverse effects of residue-management options in rice–wheat cropping system.

MATERIALS AND METHODS

The field experiment was conducted during 2001–02 to 2002–03 under limited moisture conditions at research farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, R.S. Pura. The experiment was conducted in split-plot design with the treatments comprising 4 sources of residues, viz. no residue, straw of previous crop @5 tonnes/ha/season each (wheat straw in rice and rice straw in wheat), left-over stubbles of previous crop and fly ash 2 tonnes/ha/season), in the main plot and 5 starter dose treatments (control, FYM 5 tonnes/ha/season, 20 kg N/ ha, *Trichoderma viride, Trichoderma viride*+20 kg N/ha) in the sub-plots applied to rice and wheat. The residues were incorporated immediately after the harvest of rice and wheat crop. The crop residues before incorporation into the plots were chopped by chaff cutter, each piece having about 5 cm length and spread across the plots incorporated by the power tiller to 8 cm depth. The starter dose mainly *Trichoderma viride* during first year was applied @ 10 g/ kg residue, whereas during the second year it was cultured separately with FYM (10 g/ kg FYM) for 14 days with constant moisture supply at regular intervals to maintain a sufficient multiplication of microorganism. This cultured FYM @ 1 kg/5 tonnes residue was applied.The soil was clay loam in texture with pH 6.7, EC 0.18 m mhos/cm, bulk density 1.38 g/cc, organic matter 0.51 %, and available N, P_2O_5 and K_2O was 191.0, 25.8 and 173.0 kg/ha respectively. A medium-duration rice variety 'PC 19' was transplanted in the third week of July in first year and second week of July in the second year. After the harvest of rice, wheat 'PBW 343'was sown in the third week of November with the addition of same treatment in the same plot. The total rainfall received during the whole crop season was 870.7 mm and 912 mm in 2001–02 and 2002–03, respectively, and distributed uniformly throughout the crop-growth period. However, during the wheat of 2001–02 and 2002–03, the rainfall received was 57.3 mm and 66.0 mm, respectively. For limited moisture situation, no irrigation was applied to rice and wheat during the crop growth expect during the field preparation, where 2 irrigations were applied to rice during transplanting and 1 pre-sowing irrigation to wheat, rest of the crop was left for rains to supplement irrigation needs.

RESULTS AND DISCUSSION

Effect of residues

Yield and productivity of rice and wheat: Incorporation of rice and wheat crop residues, left-over stubbles of previous crops and fly ash in both rice and wheat significantly increased the grain and straw yields of both these crops, particularly after the harvest of the first crop season (Tables 1, 2). Addition of residues and subsequent decomposition released nutrients particularly after the first crop (rice 2001) in a cycle that helped increase the yield attributing characters of both rice and wheat, which concomitantly resulted in realizing higher grain, and straw yields of both the crops compared to no-residue treatments. The grain and straw yields of both rice and wheat under rice straw, wheat straw and fly ash-treated plots were statistically at par. Similarly, the average total productivity was higher in the plots treated either with wheat residues in rice and rice residues in wheat or fly ash applied @ 2 tonnes/ha (Table 3).

Yield component of rice and wheat : Yield components of rice, *viz.* effective tillers and fertile grains/panicle, increased significantly with addition of residues (Tables 1, 2). Rice and wheat straw-incorporated plots showed the highest values of yield components of rice, being significantly higher than no-crop residue treatment and was at par with left-over stubbles of previous crop and fly ash-incorporated plots in both the years. Similarly, yield components of wheat like panicle-bearing tillers/m^2, ear length, grains/ear also increased significantly owing to application of straw residues of rice and wheat. Straw-incorporated plots showed the highest value of yield components of wheat and were at par with left-over stubbles of previous crops and fly ash-incorporated plots, but significantly superior to no-residue treatment. Application of residues and its subsequent decomposition in soil released plant nutrients slowly particularly after the first season of residue incorporation throughout the crop-growth period causing better uptake of nutrients by both rice and wheat crops; thus, it increased the values of yield-attributing characters of both rice and wheat. Similar results were also reported by Rajput and Warsi (1991).

Nutrient uptake by rice and wheat: Total NPK uptake

Table 1. Effect of residue management on growth, yield, its attributes and total uptake of NPK (kg/ha) of rice under limited moisture conditions

Treatment	Plant height (cm)		Effective tillers/ hill		Fertile grains/ panicle		Test weight (g)		Grain yield (q/ha)		Total N uptake		Total P uptake		Total K uptake	
	2001	2002	2001	2002	2001	2001	2002	2002	2001	2002	2001	2002	2001	2002	2001	2002
Crop residue																
No crop residue	79.4	77.5	4.8	5.1	63.8	57.3	60.3	21.81	29.3	32.9	53.1	60.4	7.2	8.6	58.8	67.2
Pre-crop residue 5 tonnes/ha	81.6	79.9	5.2	5.8	70.7	60.3	62.9	21.71	34.2	36.8	65.1	70.9	9.3	10.5	70.2	76.9
Left-over stubbles	82.0	81.2	5.0	5.7	65.2	60.1	62.3	21.89	31.2	36.5	59.0	69.8	8.2	10.0	63.7	75.0
Fly ash 2 tonnes/ha	80.3	79.8	5.2	5.8	70.3	61.2	64.2	21.91	33.9	39.5	64.1	75.2	9.2	11.2	69.3	81.6
CD (P=0.05)	NS	NS	NS	0.2	NS	NS	NS	NS	NS	3.1	5.9	6.9	1.2	1.6	4.9	5.6
Starter dose																
Control	79.4	76.5	4.8	5.0	65.8	56.2	57.3	21.88	30.4	32.4	55.1	59.5	6.9	8.1	58.8	63.9
FYM 5 tonnes/ha	80.4	81.8	5.1	5.9	69.8	60.7	65.4	21.81	33.4	39.1	63.5	75.2	9.4	11.5	69.9	8.27
N 20 kg /ha	81.4	77.5	5.1	5.6	68.5	60.2	61.5	21.82	32.2	35.7	61.2	68.3	8.4	9.7	65.4	73.4
Trichoderma viride (TV)	79.6	80.5	5.0	5.6	70.3	58.3	64.0	21.88	31.1	34.2	57.5	64.7	8.0	9.7	63.6	71.1
TV+ N 20 kg /ha	83.3	81.8	5.1	5.9	67.6	63.3	63.9	21.88	33.5	40.7	63.5	77.9	9.5	12.0	70.0	85.5
CD (P= 0.05)	NS	NS	NS	0.3	NS	3.6	4.4	NS	NS	1.8	3.9	5.8	0.9	1.1	3.8	4.1

NS, Non-significant

Table 2. Effect of residue management on growth, yield, its attributes and total uptake of NPK (kg/ha) of wheat under limited moisture conditions

Treatment	Plant height (cm)		Panicle bearing tillers/m^2		Ear length (cm)		Grains/ ear		Test weight (g)		Grain yield (q/ha)		Total N uptake		Total P uptake		Total K uptake	
	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002 03	2001–02	2002–03
Crop residue																		
No crop residue	57.3	60.3	167	173	5.5	5.4	29.7	30.1	39.4	38.8	18.7	19.6	49.7	52.6	8.2	8.9	51.4	54.1
Pre-crop residue 5 tonnes/ha	60.3	62.9	198	194	6.3	6.2	32.6	32.6	39.9	39.7	23.3	22.9	63.6	63.1	11.0	11.5	66.6	66.4
Left over stubbles	60.1	62.3	191	193	6.1	5.8	32.3	31.5	40.0	39.0	22.5	22.1	60.8	60.6	10.6	10.8	63.6	63.4
Fly ash 2 tonnes/ha	61.2	64.2	197	199	6.2	6.0	35.5	34.3	39.7	39.4	23.7	24.2	64.7	66.3	11.0	11.7	67.3	69.9
CD (P=0.05)	NS	NS	26	20	0.4	0.4	2.3	2.4	NS	NS	2.2	1.6	5.0	2.5	0.6	0.4	4.9	3.1
Starter dose																		
Control	56.2	57.3	170	178	5.4	5.3	30.4	29.3	40.3	38.8	19.3	19.4	51.0	51.5	8.3	8.8	52.7	53.0
FYM 5 tonnes/ha	60.7	65.4	195	193	6.3	6.0	33.0	32.0	38.8	40.3	23.5	23.7	63.8	65.3	11.2	11.9	67.0	68.5
N 20 kg/ha	60.2	61.5	187	196	6.1	6.0	32.5	31.4	39.7	38.6	21.5	22.6	57.9	61.7	9.8	10.7	60.7	64.8
Trichoderma viride (TV)	58.3	64.0	190	189	5.9	5.8	32.2	33.4	39.1	39.3	21.9	20.9	59.2	57.1	10.1	10.0	61.9	59.9
TV+ N 20 kg/ha	63.3	63.9	197	194	6.3	6.1	34.4	33.6	39.9	39.0	24.0	24.5	66.0	67.5	11.6	12.2	68.8	70.8
CD (P=0.05)	3.6	4.4	16	17	0.3	0.4	1.9	2.2	NS	NS	1.9	1.8	4.7	2.9	0.7	0.6	4.7	4.6

NS, Non-significant

by rice and wheat was significantly influenced by residue treatments. The highest uptake of nutrients was recorded in rice and wheat straw-incorporated plot and were at par with left-over stubbles and fly ash incorporation (Tables 1, 2). Higher total NPK uptake at harvest due to residue-incorporated treatments might be attributed to higher NPK content in grain and straw over the control treatment coupled with higher dry-matter yields. Mitra and Sharma (1991) also reported that higher nutrient concentration in plant part under the residue incorporation.

Physico-chemical and biological changes in soil : Incorporation of residues like rice straw in wheat, and wheat straw in rice before transplanting of rice and sowing of wheat in rice–wheat ecosystem though at par with FYM application showed that after harvest of the second year wheat crop, the bulk density of the soil decreased, whereas organic matter content and microbial population increased significantly compared with the initial values, no-residue treatments, left-over stubbles of previous crop and fly ash (Table 3). This may due to the fact that addition of residues on decomposition added humus to the soil and thus mass per unit volume of soil decreased, resulting in decrease in bulk density and increase in organic carbon content. Panda *et al.* (1999) reported the similar findings.

Effect of starter dose

Yield and productivity of rice and wheat: Application of *Trichoderma viride* + 20 kg N/ha as a starter dose both in rice and wheat crops (Tables 1, 2) being at par with FYM application @ 5 tonnes/ha/season increased the grain and straw yields significantly of both the crops compared with 20 kg N/ha, *Trichoderma viride* alone and no starter dose application. However, application of 20 kg N/ha and *Trichoderma viride* alone though at par with each other increased the grain and straw yields of both the crops significantly over no-residue application. This may be owing to rapid decomposition of residues with the bio-oinoculant, as it acts to decompose the cellulose part faster and application of additional N at initial stage of crop growth might have increased the availability of nutrients in the root zone more often after 1 crop season of residue incorporation, thus more uptake of nutrient by plants resulted in higher values of yield. However, the average overall productivity of rice and wheat followed the similar trend (Table 3).

Yield attributes of rice and wheat: Trichoderma viride coupled with 20 kg N/ha as a starter dose applied both in rice and wheat crops (Tables 1, 2) increased the values of yield-attributing characters, mainly of effective tillers/hill and fertile grains/panicle in rice; and plant height, panicle tillers/m^2, ear length, grains/ear in wheat during both the years significantly over the control, but were at par with

Table 3. Soil physico-chemical and biological changes after 2 cycles as affected by recycling of residues and its management in rice–wheat cropping system

Treatment	Organic carbon (%)	pH	Bulk density (g/cc)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Microbial count ($\times 10^5$ cfu/g)*	Average total productivity (tonnes/ha)
Crop residues								
No crop residue	0.48	6.6	1.38	185	25.0	170	3.43	5.03
Pre- crop residue 5 tonnes/ha	0.65	6.4	1.31	210	36.2	184	5.76	5.86
Left-over stubbles	0.61	6.5	1.35	203	33.0	183	5.42	5.62
Fly ash 2 tonnes/ha	0.54	6.4	1.34	204	33.3	176	4.74	6.05
CD (P=0.05)	0.10	NS	0.01	12	3.0	6.7	0.29	0.29
Starter dose								
Control	0.49	6.6	1.38	185	23.7	170	3.30	5.08
FYM 5 tonnes/ha	0.68	6.5	1.31	210	37.8	187	5.20	5.99
N 20 kg /ha	0.54	6.5	1.35	203	31.1	174	4.90	5.60
Trichoderma viride (TV)	0.56	6.5	1.35	201	32.7	180	5.40	5.41
TV+ N 20 kg /ha	0.58	6.4	1.34	203	34.1	184	5.40	6.14
CD (P=0.05)	0.09	NS	0.02	9	2.4	5	0.12	0.15
Initial values	0.51	6.7	1.39	191	25.8	173	3.50	

rest of the starter dose treatments. These results corroborate with the findings of Sharma and Mittra (1992).

Nutrient uptake by rice and wheat: Application of *Trichoderma viride* coupled with 20 kg N/ha as a starter dose (Tables 1, 2) influenced the total NPK uptake at harvest of both rice and wheat significantly over no starter dose application and alone application of either 20 kg N/ha or *Trichoderma viride* but were statistically at par with the application of FYM 5 tonness/ha. The increase is attributed to the fact that combined application of *Trichoderma viride* +20 kg N/ha at the time of residue incorporation might have enhanced the decomposing process of incorporated residue, thereby releasing the nutrients in quicker possible time on one hand and supplemented N as starter dose which reduced the immobilization effect of N on crop growth on the other hand (Malik and Jaiswal, 1998).

Physico-chemical and biological changes in soil : Application of starter dose improved the physical condition of the soil significantly than no starter dose application owing to enhanced rate of decomposition and more microbial population (Table 3). Available N, P_2O_5 and K_2O in soil after 2 years increased significantly due to application of residues over no-residue treatment and initial values. The increse is owing to better soil health and more organic matter in the soil due to residue incorporation and partly due to application of recommended does of NPK both in rice and wheat, which might have balanced the nutrient removal by these crops.

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