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Effect of rice residue management practices on weed density, wheat productivity and soil fertility in a swell-shrink soil

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ABSTRACT

Effect of rice residue management practices (removal, burning and incorporation), weed control measures (weedy check and herbicide) and nitrogen levels (60, 120 and 180 kg/ha) on the weed infestation, wheat yield and fertility status in a swell-shrink black cotton soil was studied during 2003-06. The herbicide treatment included application of isoproturon 1.0 kg/ha in the 1st year and tank mix of isoproturon 0.75 kg + 2,4-D 0.5 kg per hectare during the subsequent years. Residue incorporation reduced weed density, especially of *Phalaris minor*, resulting highest wheat yield during 2nd and 3rd year. Residue incorporation gave highest net monetary return of Rs. 57781 followed by Rs. 51440 and Rs. 48081 per hectare in the burning and straw removal treatments, respectively. The highest B:C of 6.79 was also recorded in the residue incorporation treatment followed by 6.19 and 3.86 in the burning and straw removal treatments, respectively. Herbicide application increased wheat yield and the net monetary return (B : C ratio). Irrespective of straw management practices, no increase in wheat yield was recorded beyond the N dose of 120 kg/ha. Compared to burning, the incorporation of rice straw significantly increased the organic C, and the bacterial and fungal population in soil. It was concluded that rice straw incorporation 5 t/ha was best among the given straw management practices in terms of weed density reduction, improved soil health, increased wheat yield, monetary return and B : C ratio.

Key words : Rice residue management, Wheat yield, Soil fertility, Net monetary return

The Indian soil, in general, and those of rice-wheat system in particular, are poor in organic matter. As evidenced from the long-term fertility experiments, soil organic matter declines further under intensive cropping with imbalanced fertilizer use (Swarup 1998). The recycling of crop residues is an important means to prevent the soil organic carbon decline. The organic matter in the form of crop residue serves as a major source for replenishing fertility status (Dhillon and Dhillon 1991) and provides beneficial effect on biological properties of soil (Mishra *et al.* 2001). Sharma *et al*. (2000) reported significant improvement in available nitrogen and phosphorus status of soil with addition of crop residues. However, many farmers believe that they obtain a positive response from burning of crop residues in terms of yield and reduced phytotoxicity (Lynch and Harper 1977). Rasmussen and Parton (1994) opined that burning is only a short-term option and in long run it may show adverse effect on crop yields, soil C and N. The burning of crop residues can also result in decline in the bacterial population involved in nitrification. However, the extent of reduction in microbial populations depends on the soil temperature rise during burning (Raison 1979). Increase in yield due to the incorporation of crop residues were usually achieved under the conditions of high-fertility soils without constraints or where long-term additions of crop residues have increased the amount of available N (Dick and Christ 1995). Burning of rice straw prior to sowing of wheat is still a common practice in central and northern part of India. Inorganic nitrogen application in the form of starter dose at the time of straw incorporation showed an increase in grain and straw yields of wheat at Palampur in Himachal Pradesh (Bali 1982). Besides supplementing the fertilizer need, crop management through residue retaining also had direct effect on the weed density in crop like wheat (Roder *et al*. 1998, Kim-Soon *et al*. 1994, Dastgheib 2006). Hardly any information is available on the impact of crop residue management on the black soils of central India. The present investigation was undertaken to study the effect of rice straw on the weed density, fertility status and wheat yield in a swell-shrink black cotton soil.

MATERIALS AND METHODS

A field experiment was conducted at National Research Centre for Weed Science, Jabalpur, during 2003-06. The soil of the experimental field belongs to Kheri series (very fine, montmorillonitic, hyperthermic family of Typic Chromustert) with pH 6.8, EC 0.33 dS/m, organic carbon 0.6% and available nitrogen, phosphorus and potassium content of 234, 30 and 270 kg/ha, respectively. The treatment combinations included three

crop residue management practices (removal, burning and incorporation of preceding rice straw prior to sowing of wheat) as main plot treatments, two weed management practices (no weed control and herbicide application) as sub-plot treatments and three N doses (60, 120 and 180 kg/ha) as sub-sub plot treatments. The herbicide treatments were post emergence application of isoproturon 1 kg/ha in 1st year, and a tank mix of isoproturon (0.75 kg/ha) + 2, 4-D (0.5 Kg/ha) during 2nd and 3rd year. The nitrogen was applied through urea in three splits of 50% as basal, 25% after one month and remaining 25% after two months of sowing. P and K were applied as basal 60 kg/ha through SSP and MOP, respectively. Each treatment was replicated thrice and the experiment was repeated for three years.

The rice residue was incorporated two weeks prior to wheat sowing. The soil was irrigated following incorporation of the rice residue. Keeping in view the short interval between harvesting of rice and sowing of subsequent wheat crop, the starter dose of nitrogen @ 25 kg/ha was given to fasten the decomposition process of rice residue in the residue incorporated plots, and this amount was subsequently subtracted from the basal dose. Soil samples were analyzed for chemical and biological properties by following the standard methods (Page *et al*. 1982). The economic parameters, *viz.,* net monetary return and benefit:cost ratio (B:C) were calculated by averaging the cost of production and gross monetary return over the three year period. The net monetary return was calculated by deducting the cost of cultivation from gross monetary return. The B:C ratio was calculated by dividing the gross monetary return by the total cost of cultivation.

RESULTS AND DISCUSSION

Weed density

The residue management practices showed significant effect on total weed density and weed dry weight (Table 1). The significant reduction in weed density during 1st and 2nd year and that of weed dry weight during 2nd and 3rd year of wheat was recorded due to rice residue incorporation as compared to its removal. The toxic effect of rice residue on weeds in wheat was also reported by Chou and Lin (1976) which is linked to the longer duration of toxicity as 8 weeks as reorted by Guenzi *et al*. (1967). Similarly, significant reduction in total weed density during all the three years and that of total weed dry weight during 1st and 3rd years of wheat was noticed under burning than rice residue incorporation treatment. The data showed that both burning and residue incorporation treatments were equally in decreasing the weed infestation in wheat as compared to removal of rice residue. Application of herbicides significantly reduced the weed infestation as compared to weedy plots. Total weed dry matter production increased significantly with the N dose in two out of three years of wheat. The effect of N application on weed growth was earlier reported by Das and Yaduraju (1999).

Phalaris minor and *Medicago denticulata* were the dominant weed flora in the experimental field. The effects of the residue management practices, herbicide

Table 1. Effect of residue management on total weed dry weight and weed density in wheat

Treatment	Weed dry weight (g/m^2)			Weed density (no./m^2)		
	2003-04	2004-05	2005-06	2003-04	2004-05	2005-06
Management						
Removal	5.82* (34.9)	2.64 (10.6)	7.48 (58.3)	5.5 (30.7)	6.1 (24.4)	9.0 (81.0)
Burning	4.61 (22.2)	2.29 (9.2)	5.69 (35.2)	4.6 (22.2)	4.7 (8.9)	8.3 (70.4)
Incorporation	5.57 (32.0)	2.01 (8.0)	6.18 (39.6)	4.8 (24.0)	4.6 (8.5)	7.8 (62.0)
LSD (P=0.05)	0.43	0.49	1.37	0.5	1.2	0.4
Weed control						
Weedy	5.77 (34.2)	2.94 (11.8)	7.24 (54.3)	5.3 (29.6)	6.1 (4.5)	9.0 (81.8)
IPU+2,4-D**	4.89 (24.9)	1.69 (6.8)	5.66 (34.5)	4.6 (21.6)	4.2 (6.7)	7.7 (60.5)
LSD (P=0.05)	0.51	0.59	1.25	0.4	1.3	0.9
N levels						
N60	4.38 (20.2)	2.11 (8.4)	6.31 (42.6)	4.6 (20.6)	4.9 (9.5)	8.0m (71.6)
N120	5.67 (33.1)	2.28 (9.1)	6.64 (47.5)	4.9 (26.2)	5.1 (20.6)	8.7 (77.2)
N180	5.95 (36.4)	2.54 (10.2)	6.41 (43.1)	5.3 (30.0)	5.4 (21.8)	8.3 (69.5)
LSD (P=0.05)	0.49	0.35	NS	NS	NS	NS

* Weed data were subjected to square root transformation (figures in the parenthesis are the original values), ** 1st year isoproturon alone 1 kg/ha was applied as post

Table 2. Effect of residue management on some major weed species in wheat

Treatment	*Phalaris minor* (no./m^2)				*Medicago denticulata* (no./m^2)			
	2003	2004	2005	Pooled	2003	2004	2005	Pooled
Management								
Removal	2.7*	2.5	4.2	3.2	3.8	4.4	7.4	5.1
	(7.3)	(7.0)	(19.2)	(11.2)	(11.5)	(17.5)	(61.3)	(30.7)
Burning	2.3	2.2	3.3	2.6	3.1	3.4	5.4	4.1
	(5.0)	(4.6)	(11.5)	(7.0)	(10.2)	(13.6)	(33.5)	(19.0)
Incorporation	1.7	1.9	3.0	2.3	3.2	3.2	5.2	4.1
	(2.7)	(3.3)	(9.8)	(5.3)	(10.8)	(12.7)	(33.2)	(19.1)
LSD (P=0.05)	0.5	NS	NS	0.4	NS	NS	1.8	NS
Weed control								
Weedy	2.5	2.5	3.7	2.9	3.4	4.7	7.8	5.4
	(6.2)	(6.4)	(13.2)	(8.6)	(11.1)	(18.8)	(67.0)	(33.6)
IPU+2,4 -D**	2.0	2.0	3.3	2.5	3.4	2.6	4.2	3.5
	(3.8)	(3.5)	(13.0)	(7.0)	(10.6)	(10.4)	(18.4)	(12.2)
LSD (P=0.05)	0.3	0.4	NS	NS	NS	1.3	1.2	1.5
N levels								
N60	2.1	2.0	3.1	2.5	3. 5	3.1	5.2	4.0
	(4.3)	(3.9)	(10.0)	(6.1)	(11.3)	(12.5)	(29.6)	(17.6)
N120	2.4	2.2	3.3	2.7	3.2	3.7	6.2	4.4
	(6.0)	(5.0)	(12.2)	(7.7)	(9.9)	(14.9)	(44.4)	(22.9)
N180	2.2	2.4	4.1	3.0	3.4	4.1	6.7	4.9
	(4.7)	(6.1)	(18.2)	(9.7)	(11.4)	(16.3)	(54.0)	(28.3)
LSD (P=0.05)	NS	NS	0.8	0.4	NS	0.6	NS	0.5

* Weed data were subjected to square root transformation (figures in the parenthesis are the original values)

application and N dose on the population density of these weeds are given in Table 2. The data pooled over the three years of experimentation showed the significant decrease in *Phalaris minor* population in wheat due to incorporation than removal of preceding rice residue, however no effect of residue treatments was observed on the density of *Medicago denticulata*. The sole application of isoproturon in the first year was found effective on *Phalaris minor* but not on *M. denticulata*. However, the post emergence application of mixture of isoproturon at 0.75 kg/ha + 2,4-D at 0.5 kg/ha during the subsequent years was effective in controlling *M. denticulata.* The pooled data indicated that the density of these weeds increased with the applied N level.

Wheat productivity

There was no significant effect of residue management practices on wheat yield in the first year. However, during subsequent years significant effect of residue management practices was noticed in terms of wheat yield (Table 3). During both 2nd and 3rd year, the highest wheat yield was recorded in the residue-incorporated plots. The residue burning and residue removal treatments were found at par in terms of wheat yield throughout the period of study. Similar to wheat yield, the residue incorporation treatment showed highest net monetary return among the given practices of crop residue management. Compared to the residue incorporation treatment, the net monetary return was lower by 11.0 and 16.8% in residue burning and residue removal treatments, respectively. Similar trend was recorded in terms of benefit:cost ratio (B:C). The difference in the B:C ratio between removal and incorporation treatments was 3.03, whereas it was only 0.60 between burning and incorporation treatments. In spite of similarity between the residue burning and residue removal treatments in terms of wheat yield, both the economic parameters that is the net monetary return and the B:C ratio were higher in the former than in the latter treatment. Relatively lower values of both these economic indicators as recorded in removal than remaining two treatments was due to very high cost incurred towards the labour requirement for residue removal operation. Thus on the basis of the given observations it may be noted that the

Table 3. Effect of residue management on wheat yield and economic parameters

Treatments	Wheat yield (kg/ha)			Economic parameters (mean)		
	2003	2004	2005	Production cost (Rs/ha/yr)	Net return (Rs/ha/yr)	B:C ratio
Residue management practices						
Removal	5217	5297	3800	37308	48081	3.86
Burning	5128	4819	4150	24918	51440	6.19
Incorporation	5150	5916	4550	25518	57781	6.79
LSD (0.05)	NS	771	258	-	-	-
Weed control measures						
Weedy	5185	4967	3929	24708	51445	6.24
Iso+2,4 -D	5144	5721	4351	26028	55792	6.43
LSD (0.05)	NS	751	449	-	-	-
N levels						
N_{60}	4600	4486	3770	26805	45300	5.06
N_{120}	5588	5590	4410	28761	56598	5.90
N_{180}	5305	5956	4900	30717	58192	5.68
LSD (P= 0.05)	730	597	504	-	-	-

residue removal is the most inferior and residue incorporation is the most superior among the residue management practices.

Although compared to the burning the net monetary return and B:C ratio were higher in the incorporation treatment, the cost of cultivation was substantially higher in the latter than in the former practice. The data showed that compared to burning there was an increase of 2.4% in the cost of cultivation in incorporation practice which in turn resulted in an increase in 12.3 and 9.7% in terms of net monetary return and B:C ratio, respectively. It may be noted that most of the Indian farmers are not economically affluent enough to bear the additional expenditure at the time of land preparation, which could be a constraint towards adoption of the residue incorporation practice.

The application of isoproturon alone had no significant effect on wheat yield during 1st year because in this year the most dominant weed growth was of *Medicago denticulata*, which was not controlled by isoproturon (Table 1). The uncontrolled weed growth could have nullified the effect of residue management practices as observed during the first year. However, the application of mix of two herbicides (isoproturon + 2,4-D) was found effective in controlling the weeds during the subsequent years resulting in significantly higher grain yield.

The data also showed that there was a significant increase in wheat yield with increase in the N application rate from 60 to 120 kg/ha in all the three years. However, no significant improvement in wheat yield was noticed due to further increase in N dose.

Soil fertility

The soil samples analysed prior to sowing of 3rd year wheat showed that there was no effect of the crop residue management treatments on soil pH and EC (Table 4). However, significant increase in organic carbon in the residue-incorporated plots was noticed over both burning and residue removal plots. Dhiman *et al.* (2000) also reported increased organic carbon content of soil with the incorporation of crop residue. There was no difference between the burning and residue removal treatments in terms of soil organic matter content. Marcos *et al.* (1994) also noticed that there was no decline in soil organic carbon content due to residue burning. Both available P and K were significantly higher in the residue-incorporated plots than the residue-removal plots. The significant effect of residue management practices was also noticed on the soil microbial population, especially during the early stage of crop growth. The highest bacterial as well as fungal population was recorded in the residue incorporated plots at 6 DAS. However, there was no difference between burning and residue removal treatments in this regard and this was in tune with the results reported by Goh and Phillips (1991). The result thus showed that the overall chemical and biological health of the residue-incorporated plots were relatively better than the plots receiving removal and burning treatments. This

could probably explain why the better wheat yield was recorded in former than the latter plots.

Overall the data showed that rice straw incorporation was best among the given straw management practices in terms of improved weed reduction, soil health, increased wheat yield, monetary return and B:C ratio; and there was no need of any additional fertilizer N over its recommended level of 120 kg/ha in the straw incorporated plots. It was concluded that rice straw incorporation @ 5 t/ha was best among the given straw management practices (removal, burning and incorporation) in terms of weed suppression, improved soil health and increased wheat yield.

Table 4. Effect of crop residue management on soil properties in rice-wheat sequence

Residue management	pH*	EC* (dS/m)	Organic C* (%)	Available nutrients*		Bacteria** (cfu/g x10 ^{5})		Fungi** (cfu/g x10 ^{5})	
				P (kg/ha)	K (kg/ha)	6 DAS	90 DAS	6 DAS	90 DAS
Removal	6.8	0.30	0.61	29.8	267	18.0	8.6	10.5	8.1
Burning	6.9	0.34	0.61	32.2	316	16.1	9.0	9.1	6.5
Incorporation	6.8	0.28	0.65	36.9	304	19.9	8.6	14.1	7.4
LSD (P=0.05)	NS	NS	0.03	5.4	32	2.1	NS	2.3	NS

* After harvest of rice, ** After sowing of wheat, DAS- Days after sowing, Cfu - Colony forming unit

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