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Effect of planting method, tillage and weed management on productivity and physico-chemical properties of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during 2002-03 and 2003-04 at Raipur in Chhattisgarh to assess the productivity of rice (*Oryza sativa* L.) – wheat [*Triticum aestivum* L. emend. Fiori & Paol.] cropping system and changes in soil-nutrient status due to different planting methods of rice and tillage and weed-management practices of wheat. Transplanting of rice after *Sesbania aculeata* (green manure, GM) incorporation ($Rice_{GM-TP}$) produced significantly higher grain yield of rice (19.5-25.3%) and increased the organic C, available N and K over transplanting of rice ($Rice_{TP}$) and *beushening* system without GM ($Rice_{BS}$). The residual effect of $Rice_{GM-TP}$ gave 11.1% higher grain yield of wheat, increased the available N, P and K content in the soil and reduced the bulk density in 0-7 and 10-17 cm soil depths. Conventional tillage ($Wheat_{CT}$) in wheat produced 19.1% higher grain yield than zero tillage ($Wheat_{ZT}$). Zero-tilled wheat gave 10.7% higher organic C in the soil than $Wheat_{CT}$. Infiltration rate was the highest under $Wheat_{CT}$ and observed to be 20.5% higher at harvest. Post-emergence application of sulfosulfuron @ 25 g/ha and metsulfuron-methyl @ 4 g/ha reduced the dry weight of weeds significantly over the weedy check and increased the grain yield of wheat. Transplanting of rice after GM incorporation followed by conventional tillage and post-emergence application of sulfosulfuron in wheat improved the soil physico-chemical properties and gave the maximum total productivity (12.45 t/ha) and net returns (Rs 52,104/ha).

Key words: Grain yield, Rice-planting methods, Tillage, Total productivity, Rice – wheat system, Weed management

Rice (*Oryza sativa* L.) - wheat [*Triticum aestivum* L. emend. Fiori & Paol.] system is emerging as popular cropping system in irrigated ecology of south-eastern region of the country. But the poor yield of wheat limits the system productivity. The conventional method of land preparation for wheat after rice takes long time and delays the seeding. This accompanied by short winter reduces the time for proper growth and development and thus adversely affect the seed yield. Puddling done prior to transplanting of rice alters the physical conditions of the soil, so that it is not conducive for the succeeding crops (Bajpai and Tripathi, 2000). The *beushening* system of rice cultivation is common in the eastern region, which includes shallow ploughing, redistribution of seedlings and burying of weeds simultaneously well before the nodal differentiation of rice plants and creates the soil structure similar to that of the puddled field (Urkurkar *et al.*, 2000). Incorporation of green-manure increases grain yield, besides improving the organic matter and other soil physical conditions of the soil (Aggarwal *et al.*, 1997). But its effects on tillage practices for seeding of wheat needs to be assessed in rice - wheat system. Tillage practices also contribute greatly for the occurrence of weeds, which pose serious limitations to achieve yield potential and bring down the wheat yield up to 53% (Singh *et al.*, 2002). New herbicides of phenoxy groups are safe, effective and economical for controlling both the grassy and broad-leaved weeds. A study was therefore undertaken to find out suitable tillage and weed-management practices for wheat under different methods of planting rice.

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MATERIALS AND METHODS

A field experiment was conducted on rice - wheat cropping system during 2002-03 and 2003-04 at Indira Gandhi Krishi Vishwavidyalaya, Raipur in Chhattisgarh. The soil was silty clay (Alfisols) and neutral in reaction with medium organic C (5.6 g/kg), low available N (240 kg/ha), medium available P (8.3 kg/ha) and high available K (274 kg/ha). The bulk density of the soil before seeding green-manure crop was 1.54 and 1.57 Mg/cm^3 (0-7 cm and 10-17 cm, soil depths) with hydraulic conductivity of 0.818

cm/hr and infiltration rate of 0.542 cm/hr. In rainy season (*kharif*), the treatments comprising three planting methods in rice, viz. *beushening* system of planting rice without GM ($Rice_{BS}$), transplanting rice without GM ($Rice_{TP}$) and transplanting rice after GM incorporation ($Rice_{GM-TP}$) were laid out in randomized block design with three replications having plot size of 21.5 x 10.0 m. During winter season (*rabi*) 36 treatments comprising three residuals of rice-planting methods, four tillage practices for wheat, viz. conventional tillage ($Wheat_{CT}$), reduced tillage ($Wheat_{RT}$), zero tillage ($Wheat_{ZT}$) and one harrowing followed by planking ($Wheat_{HP}$) and three weed-management practices, viz. sulfosulfuron @ 25 g/ha ($Wheat_{SS}$), metsulfuron methyl @ 4 g/ha ($Wheat_{MM}$) and one weedy check ($Wheat_{UW}$) were studied in split-split plot design with three replications. The three residuals of rice-planting methods were studied as main plot treatment having plot size of 21.5 x 10.0 m. These plots were divided into four subplots (10.0 x 5.0 m) to accommodate tillage treatments. The plots were further subdivided into the size of 3.0 x 5.0 m to accommodate the three weed-control treatments.

The experiment was laid out 45 days before transplanting rice to grow the green-manure crop of *Sesbania aculeata* (1.6 t /ha dry weight having 2.5% N)) *in situ* and apply the treatment of $Rice_{GM-TP}$. Rice cv 'Mahamaya' was sown in nursery ($Rice_{GM-TP}$ and $Rice_{TP}$) as well as in experimental field ($Rice_{BS}$) on the same day i.e. 29 June 2002 and 17 June 2003, respectively. The seed rate of 80 kg/ha was used for *beushening* and 50 kg/ha for transplanting rice. The seedlings at 28 days were transplanted under the treatments of $Rice_{TP}$ and $Rice_{GM-TP}$. Similarly, *beushening* (direct dry seeding with activation of monsoon rains and shallow ploughing of flooded rice field well before the nodal differentiation stage of rice seedlings having height of 25-30 cm) was also done on the same day, i.e. 28 days after direct seeding, under the treatment $Rice_{BS}$. Wheat cv 'GW 273' was sown with seed rate of 125 kg/ha after different tillage practices (as per treatment) on 11 November 2002 and 13 November 2003 respectively. Among tillage treatments of wheat, four ploughings were done by cultivator followed by planking under $Wheat_{CT}$ and two ploughings by cultivator followed by planking was performed under $Wheat_{RT}$. Direct seeding was done with modified Pantnagar-type zero-till seed drill under $Wheat_{ZT}$, whereas, tillage was limited to only single pass of harrow across the field followed by planking in $Wheat_{HP}$. Two herbicides, i.e. sulfosulfuron and metsulfuron-methyl, were applied at 30 days after sowing (DAS) wheat. Fertilizer dose of 100 kg N + 26.2 kg P + 33.3 kg K/ha was applied to both the crops of rice and wheat. The whole amount of P and K was applied as basal dressing, whereas, N was applied 50% basal, 25% at tillering or crown-root-initiation stage and the remaining 25% at panicle initiation or flowering stage of rice and wheat respectively.

Organic C and available N, P and K content in the soil were determined before seeding and at harvest of the crops, N, P and K content in the grain and straw of wheat was also analysed to calculate the uptake of these nutrients. Core sampler was used for determining the bulk density from 0–7 cm and 10–17 cm soil depths at harvest of rice and wheat. The hydraulic conductivity was determined at 25 DAS and at harvest of wheat by steady-state constant head using soil samples as collected earlier by core sampler for measuring the bulk density. The infiltration rate was measured by using a double-ring infiltrometer. Total dry weight of weeds was recorded at 60 DAS in wheat crop. The yield of wheat was converted into rice-equivalent yield by multiplying the yield with the prevailing farm-gate price of wheat and divided by price of rice in different years to get the total productivity of the system.

RESULTS AND DISCUSSION

Planting method of rice

Planting of rice after green-manure incorporation ($Rice_{GM-TP}$) significantly increased the grain yield (Table 1). The increase was 19.5% and 25.3% higher compared with transplanting without green-manure ($Rice_{TP}$) and *beushening* without green-manure ($Rice_{BS}$) respectively. Further, $Rice_{TP}$ produced 21.8% higher grain yield than $Rice_{BS}$. Victor and Swarnakar (2002) also reported reduction in grain yield of rice due to *beushening*. $Rice_{GM-TP}$ significantly increased the organic C and the available N and K content in the soil compared with *beushening* or transplanting alone and improved the grain yield. Sharma and Jain (1997) also reported improvement in physical properties of the soil and nutrient availability due to addition of green-manure in rice. The bulk density of 0-7 and 10-17 cm soil depth was reduced under $Rice_{BS}$ compared with that under $Rice_{TP}$ at harvest of rice. The incorporation of weeds in the soil under $Rice_{BS}$ added organic matter and reduced the bulk density of surface (0-7 cm) and subsurface (10-17 cm) soil layers due to dispersion of finer soil separates during *beushening* operation and later on reconsolidation of soil mass with time. Purohit (2003) also reported decrease in bulk density due to *beushening*.

Residual effect on wheat

The residual of rice-planting methods significantly influenced the grain yield of wheat during 2003-04 (Table 2). The residual of $Rice_{GM-TP}$ or $Rice_{BS}$ produced significantly higher grain yield of wheat than of $Rice_{TP}$. The residual of $Rice_{TP}$ reduced the wheat yield by 11.1% compared with residual of $Rice_{GM-TP}$ and $Rice_{BS}$. The organic

C and the available N, P and K were more under Rice $_{GM-TP}$ and Rice $_{BS}$ than under Rice$_{TP,}$ which benefited the wheat crop and increased the grain yield. At wheat harvest, the residual of Rice$_{GM-TP}$ gave significantly higher organic C and the available N, P and K in the soil compared with other two methods (Table 3). Addition of green-manure might have resulted in higher organic C by conditioning the soil, increasing the nutrient-holding capacity and preventing the loss of applied nutrients. Bajpai *et al.* (2004) also reported increased N status in the soil even after harvest of non-legume *rabi* crop due to incorporation of *Sesbania aculeata* as green-manure. Moreover, the residual of rice$_{BS}$ did not alter the soil properties as of Rice $_{TP}$ and gave significantly higher values of organic C, hydraulic conductivity and infiltration rate at the harvest of wheat. The hydraulic conductivity and infiltration rate under residual of Rice$_{GM-TP}$ was 9.5 and 13.8% higher than residual of Rice $_{TP}$ respectively (Table 2). The residual of rice $_{GM-TP}$ also lowered the bulk density of soil at harvest of wheat compared with that of Rice $_{BS}$ or Rice $_{TP}$. Incorporation of green-manure before puddling under Rice $_{GM-TP}$ increased the hydraulic conductivity compared with that under Rice$_{TP}$.

Tillage practices in wheat

Grain yield of wheat increased by 19.1 and 23.7% under conventional tillage (Wheat$_{CT}$) over zero tillage (Wheat$_{ZT}$) and seeding after one harrowing and planking (Wheat$_{HP}$) respectively (Table 2). The uptake of N, P and K also increased under wheat $_{CT}$ compared with that under Wheat$_{ZT}$ or Wheat$_{HP}$. The decrease in yield and nutrient uptake may be ascribed to tillage practices under Wheat$_{ZT}$

Table 1. Effect of rice planting methods on grain yield, organic C, available nutrient status and bulk density of soil at harvest of rice

Treatment	Grain yield (t/ha)		Organic C (g/kg soil)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)		Bulk density (Mg/m^3)			
											0-7 cm		10-17cm	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Rice$_{BS}$	4.49	4.86	5.65	5.76	253	256	10.76	10.15	276	280	1.44	1.45	1.48	1.48
Rice$_{TP}$	5.59	6.03	5.40	5.54	249	249	10.04	9.19	278	279	1.49	1.49	1.51	1.52
Rice$_{GM-TP}$	6.14	6.38	6.01	6.23	260	265	10.99	11.33	285	289	1.47	1.48	1.50	1.50
SEm±	0.11	0.08	0.09	0.04	1	1.2	0.15	0.26	2	2	0.002	0.002	0.005	0.003
CD (P=0.05)	0.42	0.32	0.35	0.16	4	5	0.61	0.99	7	8	0.01	0.01	0.02	0.01

Table 2. Grain yield of wheat, dry weight of weeds, and soil physical properties as influenced by residual of rice-planting method, tillage and weed-management practices

Treatment	Grain yield (t/ha)		Dry weight of weeds (g/m^2)		Bulk density at harvest (Mg/m^3)				Infiltration rate at harvest (cm/hr)		Hydraulic conductivity at harvest (cm/hr)	
					0-7 cm depth		10-17 cm depth					
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Residual of rice-planting method												
Rice$_{BS}$	2.71	2.82	55	81	1.54	1.52	1.57	1.56	0.83	0.83	0.60	0.64
Rice$_{TP}$	2.40	2.51	72	71	1.54	1.56	1.58	1.57	0.77	0.75	0.56	0.56
Rice$_{GM-TP}$	2.68	2.93	58	76	1.52	1.52	1.55	1.56	0.83	0.84	0.62	0.67
SEm±	0.11	0.05	4.7	4.9	0.004	0.004	0.003	0.004	0.007	0.008	0.005	0.01
CD (P= 0.05)	NS	0.22	NS	NS	0.02	0.02	0.01	0.02	0.03	0.03	0.02	0.03
Tillage practice												
Wheat$_{CT}$	3.08	3.06	62	91	1.53	1.52	1.57	1.55	0.88	0.89	0.72	0.75
Wheat$_{RT}$	2.88	2.77	65	71	1.53	1.54	1.57	1.57	0.86	0.86	0.59	0.63
Wheat$_{ZT}$	2.24	2.73	75	75	1.52	1.53	1.55	1.55	0.74	0.72	0.56	0.59
Wheat$_{HP}$	2.20	2.48	75	74	1.55	1.55	1.57	1.56	0.75	0.75	0.50	0.52
SEm±	0.09	0.06	6	7.0	0.006	0.005	0.007	0.006	0.009	0.01	0.01	0.01
CD (P= 0.05)	0.26	0.18	NS	NS	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Weed management												
Wheat$_{UV}$	1.48	1.72	103	182	1.53	1.54	1.57	1.57	0.81	0.80	0.59	0.62
Wheat$_{SS}$	3.30	3.29	46	24	1.53	1.54	1.57	1.57	0.81	0.81	0.59	0.62
Wheat$_{MM}$	3.02	3.27	33	22	1.53	1.53	1.57	1.56	0.80	0.80	0.59	0.62
SEm±	0.06	0.05	4	6	0.001	0.005	0.001	0.001	0.004	0.004	0.001	0.002
CD (P= 0.05)	0.18	0.15	11	17	NS	NS	NS	NS	NS	NS	NS	NS

and $Wheat_{HP,}$ which failed to provide favourable seed-bed for the seeding of wheat and might have also reduced the root growth and nutrient absorption of wheat due to compacted soil layer. These findings are in agreement with the results of Parihar (2004). Organic C content under $Wheat_{ZT}$ was more (10.3 and 11.2%) than under $Wheat_{CT}$ at wheat harvest. The N, P and K content in the soil at harvest also increased under $Wheat_{ZT}$ (Table 3). The residues under $Wheat_{ZT}$ remained in the upper soil layers and concentrated the organic matter content and plant nutrients in the surface layer, thus improved the organic C in the soil. But the plough-based tillage under $Wheat_{CT}$ incorporated the residues of rice and distributed the organic matter evenly throughout the ploughed layer and regulated the biological activity. These results are in close conformity with the findings of Kumar *et al.* (2004).

Tillage practices did not show consistent effect on bulk density after wheat harvest (Table 2). The hydraulic conductivity (17.9%) and infiltration rate (31.1%) increased under $Wheat_{CT}$ compared with relatively undisturbed soil under $Wheat_{ZT}$. The higher soil compaction under zero-tillage plots kept the water confined in the upper soil layers, resulting in lower infiltrability, as also reported by Ray and Gupta (2001).

Interaction between residual of rice-planting methods and tillage practices opted for seeding of wheat revealed that grain yield under conventional tillage was significantly higher than other tillage practice after residual of *beushening* system ($Rice_{BS}$) during 2002-03 and of rice transplanting after GM incorporation ($Rice_{GM-TP}$) during 2003-04 (Table 4). Lowest yield was recorded under $Wheat_{ZT}$ during 2002-03 and under $Wheat_{HP}$ during 2003-04 after residual of rice transplanting without GM. Different tillage practices and weed-management treatments also showed their interaction effect on grain yield of wheat during both the years. The wheat sown through conventional or reduced tillage practices produced significantly higher grain yield compared with zero tillage at the same level of weed management during 2002-03. However, during 2003-04 zero tillage gave comparable grain yield with conventional and reduced tillage practices and was significantly superior to $Wheat_{HP}$ at the same level of both the herbicides.

Weed management in wheat

Wheat field was dominated by *Melilotus indica* and *Chenopodium album* among broad-leaved weeds, and *Echinochloa colona* and *Cynodon dactylon* among grassy weeds. Other weed species were: *Achyranthus aspera*, *Physalis minima*, *Anagallis arvensis* and *Alternanthera triandra*. In weedy check, *Melilotus indica* was the most dominant weed species, contributing 65.5% and 80.1% of the total weed density, and 66.5 and 82.1% of total dry weight of weeds during 2002-03 and 2003-04 respectively.

Table 3. Nutrient uptake (grain and straw) by wheat and soil nutrient status as influenced by residual of rice planting methods, tillage and weed management

Treatment	Nutrient uptake by wheat (kg/ha)						Available nutrient status at harvest of wheat (kg/ha)						Organic C (g/kg soil)	
	N		P		K		N		P		K			
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Residual of rice-planting method														
$Rice_{BS}$	81.4	82.0	10.5	11.0	130.8	134.9	242	246	10.0	10.4	275	277	5.63	5.77
$Rice_{TP}$	71.4	71.5	9.0	9.4	115.8	117.7	236	242	10.0	10.3	277	275	5.21	5.21
$Rice_{GM-TP}$	79.8	86.3	11.0	12.0	131.1	142.9	252	251	10.6	11.2	285	288	6.08	6.13
SEm±	2.7	2.4	0.3	0.2	1.7	1.2	2.1	0.7	0.1	0.1	1.8	2.1	0.05	0.09
CD (P= 0.05)	NS	9.2	1.2	1.0	7.1	4.8	8.2	2.8	0.5	0.4	7.4	8.6	0.18	0.36
Tillage practice														
$Wheat_{CT}$	91.3	83.8	11.7	11.7	90.6	146.4	242	245	10.0	10.5	284	284	5.54	5.53
$Wheat_{RT}$	86.2	80.8	11.0	10.8	89.5	139.0	247	245	10.3	10.7	275	279	5.80	5.88
$Wheat_{ZT}$	66.6	77.3	9.3	11.2	80.5	127.7	242	253	10.6	11.1	285	288	6.18	6.22
$Wheat_{HP}$	66.1	72.8	8.5	9.1	72.8	114.2	250	244	10.2	10.2	272	275	5.04	5.18
SEm±	1.2	1.2	1.1	0.3	1.9	1.4	3.0	1.1	0.2	0.2	3.2	2.4	0.16	0.15
CD (P= 0.05)	3.7	3.6	3.1	1.0	5.6	4.3	NS	3.2	0.6	0.6	9.8	7.3	0.51	0.46
Weed management														
$Wheat_{UV}$	43.9	46.3	7.7	6.6	42.1	71.9	242	245	10.3	10.7	279	281	5.61	5.65
$Wheat_{SS}$	99.0	95.1	12.6	12.8	109.0	158.8	244	247	10.2	10.6	279	281	5.68	5.71
$Wheat_{MM}$	89.5	94.7	10.1	12.7	98.3	156.8	245	246	10.2	10.6	280	282	5.62	5.75
SEm±	1.2	1.2	1.4	0.2	2.3	1.2	1.2	0.9	0.04	0.04	0.8	0.9	0.02	0.03
CD (P= 0.05)	3.3	3.5	4.2	0.6	6.8	3.5	NS	NS	NS	NS	NS	NS	NS	0.07

Table 4. Interaction effect of tillage practices with residual of rice-planting methods and weed management on grain yield (t/ha) of wheat

Treatment	Tillage practice							
	$Wheat_{CT}$		$Wheat_{RT}$		$Wheat_{ZT}$		$Wheat_{HP}$	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Residual of rice-planting method								
$Rice_{BS}$	3.26	3.09	2.76	2.82	2.33	2.71	2.48	2.67
$Rice_{TP}$	2.93	2.69	2.99	2.56	1.79	2.77	1.88	2.22
$Rice_{GM-TP}$	3.02	3.40	2.87	2.92	2.60	2.88	2.24	2.53
Weed management								
$Wheat_{UW}$	1.75	1.88	1.56	1.77	1.13	1.38	1.46	1.82
$Wheat_{SS}$	3.85	3.72	3.73	3.23	2.90	3.33	2.72	2.87
$Wheat_{MM}$	3.62	3.58	3.33	3.30	2.69	3.45	2.42	2.74
			SEm±		CD (P=0.05)			
			2002-03	2003-04	2002-03	2003-04		
Residual of rice-planting method x tillage			0.15	0.10	0.45	0.30		
Weed management x tillage			0.12	0.10	0.30	0.10		

Application of sulfosulfuron @ 25 g/ha and metsulfuron-methyl @ 4 g/ha increased the grain yield and the uptake of N, P and K by wheat over weedy check due to reduced dry weight of weeds compared with that of weedy check (Table 2 & 3). The higher grain yield of weed-control plots was owing to the lower weed population as reflected through dry weight of weeds and better crop-canopy development, which resulted in more efficient utilization of solar energy and nutrients by the wheat crop. Malik *et al.* (2003) also reported the lowest dry weight of weeds and maximum control of major broad-leaved weeds with metsulfuron-methyl. The crop-weed competition greatly reduced the wheat yield under weedy check. Singh *et al.* (2005) also reported similar results.

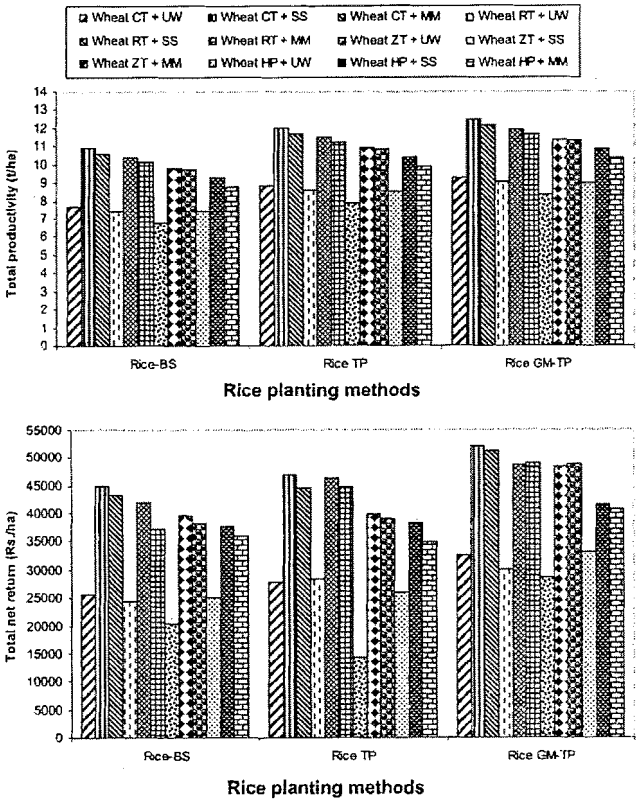

Fig. 1. Total productivity in terms of rice equivalent yield and total net returns of rice–wheat system as influenced by rice planting methods (direct + residual), tillage and weed management in wheat (mean of 2002-03 and 2003-04)

Economics and system productivity

For total productivity (TP) of the system in terms of rice-equivalent yield (REY) and total net returns, $Rice_{GM-TP}$ + $Wheat_{CT}$ and post-emergence application of sulfosulfuron was found to be the best combination, which produced the highest TP (12.45 t/ha) and total net returns of the system, (Rs 52,104/ha), which was closely followed by the same set of planting methods of rice and wheat combined with post-emergence application of metsulfuron methyl in wheat, giving 12.14 t/ha total productivity and Rs. 51,124/ha returns (Fig. 1). Further, $Rice_{GM-TP}$ followed by $Wheat_{ZT}$ either with sulfosulfuron or with metsulfuron methyl gave net returns comparable to that of $Wheat_{RT}$ due to reduced cost of cultivation. The lowest net returns were recorded under the combination $Rice_{TP}$ + $Wheat_{HP}$ with unweeded check.

It is concluded that transplanting of rice after green-manure incorporation followed by seeding of wheat through conventional tillage and post-emergence application of sulfosulfuron for weed control in wheat produced the higher grain yield of individual crop, total productivity and net returns as well as nutrient status of the soil in rice - wheat system.

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