Indian Journal of Weed Science (2022) **54**(3): 233–239
http://dx.doi.org/10.5958/0974-8164.2022.00043.0

RESEARCH ARTICLE

Effect of tillage and weed management on weed dynamics and yield of rice in rice-wheat-greengram cropping system in vertisols of central India

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Received: 31 August 2021 | Revised: 24 August 2022 | Accepted: 27 August 2022

ABSTRACT

A field experiment on effect of tillage and weed management on weed dynamics and yield of rice in rice-wheat-greengram cropping system in vertisols of central India was conducted during *Kharif* 2014 to 2015 at ICAR-DWR, Jabalpur. The experiment consisted of total 15 treatments. A split plot design having three replications was used with five tillage practices in main plots and three weed control treatments in subplots. The maximum weed density and biomass were found when zero tillage was done in rice in the presence of *Sesbania* (S) and greengram residues (ZT+S+GG); under zero tillage in rice in the presence of *Sesbania* and green gram residues-zero tillage in wheat in the presence of rice residues- zero tillage in greengram in the presence of wheat residues system [ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG)] followed by zero tillage done in rice in the presence of only *Sesbania* residues (ZT+S) under ZT+S(R)-ZT(W)-ZT(GG) system. Whereas the minimum was recorded when conventional tillage was done in transplanted rice under CT(TPR)-CT(W)-fallow system which also recorded higher grain and straw yields as well as gross monetary returns but had higher cost of cultivation followed by (ZT+S) under ZT+S(R)-ZT(W)-ZT(GG) system. This system also has the maximum net monetary returns and B:C along with the reduced cost of cultivation. Rotational application of chlorimuron + metsulfuron-methyl 4 g /ha during previous year and post-emergence application (PoE) of bispyribac-sodium 25 g/ha during next year in rice as well as regular application of bispyribac-sodium 25 g/ha PoE in rice during both the years gave similar weed control and recorded the higher crop yield, net monetary returns and B:C. Among different treatment combinations, rotational application of chlorimuron + metsulfuron-methyl 4 g/ha PoE during previous year and bispyribac-sodium 25 g/ha PoE during next year after conventional tillage in transplanted rice under CT(TPR)-CT(W)-fallow system and ZT+S in rice under ZT+S(R)-ZT(W)-ZT(GG) system has resulted lower weed density and biomass along with higher weed control efficiency, higher grain and straw yields and economic returns than other combinations.

Keywords: Bispyribac-sodium, Chlorimuron + metsulfuron-methyl, Conventional tillage, Economics, Productivity, Weed management, Rice, Zero tillage

INTRODUCTION

Rice is a major food crop in India and rice-wheat is one of the valuable and popular cropping system in India as well as most of the regions in the world. It occupies about 13.5 million ha (Mha) of cultivable land in South Asia (Nawaz *et al*. 2019), particularly in India, Bangladesh, Pakistan and Nepal. In most of the part of central India, rice is grown by transplanting method in puddled conditions. This type of cultivation requires a large quantity of water, huge labour and energy; declines crop productivity; causes ill effects on soil health as well as increases cost of cultivation and ultimately lowers the net income. Sowing direct-seeded rice (DSR) is a better choice to overcome the problem of water scarcity and labour shortage (Weerakoon *et al.* 2011). Similarly, sowing of DSR with zero or minimum tillage conserves the soil and water and ensures sustainable crop production. It also abridges the cost of cultivation as well as energy consumption to sustain productivity and secure good earnings for the farmers (Singh *et al*. 2006). Hence, conservation agriculture (CA) become popular among many countries and they are shifting from conventional agriculture to CA. About 157 Mha area has come under CA in which 15 Mha occupied in India during, 2013 (FAO 2014). Sowing of DSR gives almost equal yield to transplanted rice and it has higher net monetary returns due to lower cost of cultivation (Singh *et al.* 2005). Weeds are the major constraint in DSR it causes yield reduction. Uncontrolled weeds in DSR cause 85 to 98% yield loss especially in zero tillage system (Chauhan and Johnsos 2011). It was assessed that 10 to 32 days after sowing (DAS) in wet-seeding and up to 83 DAS in dry-seeding were more critical for weed control (Sharma *et al.* 2006). In DSR, weed management is a very difficult task as weeds and crop plants emerge at the same time (Khaliq and

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Matloob2011). On the flip side after the harvesting of rice with a combiner huge quantity of residues remain left over the soil surface and create problem in tillage operation as well as application of pre-emergence herbicides. Hence patchy emergence of weeds and crops has been shown due to improper distribution and absorption of herbicides which results in lower crop yield. Hence, timely weed management in DSR especially under CA is very necessary for getting higher productivity, economic returns and effective weed control (Jaya-Suria *et al.* 2011).

Different weed control methods are available for rice crop such as differential tillage practices (Mohler and Galford 1997, Chauhan *et al.* 2006), mechanical, manual, chemical, competitive cultivars, seeding density, water management, fertilizer management, seed invigoration and straw mulching and all these weed control strategies are proved to increase rice yield (Sana *et al.* 2017). The weed flora also shifts with change from conventional to conservation tillage practices, which require a suitable weed management method that involves proper tillage practices, use of crop residues as mulch, inclusion of pulse crop in cropping system, use of suitable broad-spectrum herbicides *etc*. Chemical weed management has appeared as a promising approach for weed control in rice under CA because it is easy, effective and economically feasible method. Through proper time and a combination of pre- and post-emergence applications of herbicides, weeds can be effectively suppressed and allow a competition-free environment for the direct-seeded fine rice (Khaliq *et al.* 2012). Because of the importance of rice and losses due to weeds in DSR, the present study was taken to see the effect of tillage and weed management on weed dynamics and yield of rice in rice-wheat-greengram cropping system in vertisols of central India

MATERIALS AND METHODS

This experiment was conducted at Research Farm, ICAR-Directorate of Weed Research, Maharajpur, Jabalpur (M.P.) during *kharif* 2014 to 2015. The experimental site is situated at 23^o 11' 9.1824" North latitude and 79^o 58' 27.7680" East longitude with an altitude of 411.78 meters above the mean sea level. It is classified under “Kymore Plateau and Satpura Hills” agro- climatic zone as per norms of National Agricultural Research Project (NARP), New Delhi. The soil of the experimental field was clay (27% sand, 29% silt and 44% clay), neutral in reaction (pH 7.18), normal in EC (0.40 ds/m), medium in organic carbon content (0.60%), medium in available nitrogen (250.56 kg/ha), medium in available phosphorus (17.83 kg/ha) and potassium (280.16 kg/ha) with 1.37 Mg/m^3 bulk density. During the *Kharif* 2014 about 1290 mm rainfall was received on 56 rainy days. But in the next year (2015), the rainfall was quite low (1029 mm) which was received in 44 rainy days.

Experiment was conducted using split-plot design with three replications. The experiment consisted of fifteen treatments comprising of five tillage practices as main plot treatments, *viz*. conventional tillage (CT) in rice (R)+ Sesbania (S)-conventional tillage in wheat (W)-zero tillage (ZT) in greengram (GG) [CT+S(R)-CT(W)-ZT(GG)], conventional tillage in rice+ Sesbania+ greengram residues-conventional tillage in wheat + rice residues (RR)-zero tillage in greengram+ wheat residues (WR) [CT+S+GG (R)-CT+RR(W)-ZT+WR(GG)], zero tillage in rice+ Sesbania -zero tillage in wheat-zero tillage in greengram, [ZT +S(R)-ZT+S(W)-ZT(GG)], zero tillage in rice + Sesbania + greengram residues [GG(R)]-zero tillage in wheat + rice residue-zero tillage in greengram + wheat residues (WR)-[ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG)], conventional tillage in transplanted rice (TPR)-conventional tillage in wheat fallow [CT(TRP)-CT(W)-fallow] and sub plot treatments, *viz.* weedy check, bispyribac-sodium 25 g/ha in rice as post-emergence application (PoE) in both the years and rotational application of chlorimuron + metsulfuron-methyl (ready mix) 4 g/ha PoE during (2014) and bispyribac-sodium 25 g/ha PoE during 2015 in rice. Weed count, for estimating weed density at 60 days after sowing/transplanting was recorded with the help of a quadrat (0.5 x 0.5 m) placed randomly at four spots in each plot. To record weed biomass weeds were cut at ground level, washed with tap water, sun-dried in hot air oven at 70^{o}C for 48 hrs and then weighed. For the statistical analysis weed density and biomass were converted to 1 m^2 and imposed square root transformation to normalize their distribution. Further weed control efficiency (WCE) was calculated by using the formulae given by Mani *et al.* 1973. The grain yield was taken from 10 m^2 area in the center of each plot and expressed in t/ha at 14% moisture content. Economic analysis was done as per the prevailing cost of inputs and selling price of output as per the concerning years.

RESULTS AND DISCUSSION

Weed density and biomass

The higher density and biomass of *Echinochloa colona* and *Dinebra retroflexa* were observed with ZT+S in rice under ZT+S(R)-ZT(W)-ZT(GG) system, followed by ZT+S+GG under ZT+S+GG

(R)-ZT+RR(W)-ZT+WR(GG) system (**Table 1**). However, a reverse trend was observed in case of *Cyperus iria* and *Caesulia axillaris*. Whereas, all the weeds have minimum density and biomass when conventional tillage was done in transplanted rice under CT (TPR)-CT(W)-fallow system. The higher density and biomass of *Echinochloa colona* and *Dinebra retroflexa* in ZT+S in rice under ZT+S(R)-ZT(W)-ZT(GG) system may be attributed to minimum disturbance, which left a large number of weed seeds on upper soil layer. These weed seeds germinated just after the sowing of rice and consequently acquired more density and biomass than the high soil disturbance (conventional tillage) system (Feldman *et al.*1997). Mishra and Singh (2012) also observed more emergence of above weeds under zero tillage in rice but the presence of rice residues up to 6 t/ha can suppress the emergence and growth of *E. colona* (Chauhan, 2012). Similarly, *Cyperus iria* is a prolific seed producer, and produces more than 5000 seeds out of which 60% of seeds germinate after 75 days of shedding in moist soil at 20 to 30°C temperature under optimum dryland condition (Das 2008). This species also reproduces from underground plant storage structure (rhizomes), which were not killed or removed in minimum or zero tillage (Sharma *et al.* 2015). The previous crop residues were present on the soil surface under conservation tillage system which influences soil temperature and moisture regimes and affects the weed germination and emergence patterns throughout the growing season (Bullied *et al.* 2003). *Caesulia axillaris* also produces a huge number of seeds and plant develops abundant adventitious roots at the base of the stem (Srivastava *et al.*1983) and their propagation is also facilitated by more available moisture regime throughout the season. Seed germination of *Caesulia axillaris* was manifested by absolute light requirement. As a consequence, more population and biomass of *C. axillaris* was exhibited with ZT+S+GG in rice under ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG) system. Further, the lower density and biomass of these weeds in conventional tillage might be due to the region that light can penetrate only in the weeds that are commenced on surface layer of soil but most of the seeds were deeply buried which could not germinate due to insufficient supply of oxygen to the deeper soil layer (Egley 1986). The minimum weed density and biomass in CT (TPR) might be because of a reduction in oxygen diffusion rate below 20 x10^{-8} g O_2/cm^2/minute in puddled soil against normal value 40 x 10^{-8} g O_2 /cm^2/ minute. Hence, seeds failed to germinate due to lack of oxygen under puddled condition in transplanted rice (Benech *et al.* 2000). Chauhan *et al.* (2010) also reported lower emergence and growth of *Cyperus iria* due to continuous shallow flooding. Ismail *et al.* (1995) reported no emergence of *E. colona* when rice was flooded for 5 days after seedling/transplanting. It was noticed that long-term cropping of DSR followed

Table 1. Weed density (no./m^2) and biomass (g/m^2) in rice as affected by tillage and weed control practices at 60 DAS (mean of two years)

Treatment	*Echinochloa colona*		*Cyperus iria*		*Dinebra retroflexa*		*Caesulia axillaris*		Total	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Weed density	Weed biomass
Tillage										
CT+S(R)-CT(W)-ZT(GG)	3.14 (9.36)	4.90 (23.61)	2.26 (4.59)	2.25 (4.57)	1.59 (2.03)	1.85 (2.93)	0.92 (0.35)	1.08 (0.67)	4.14 (16.64)	5.46 (32.64)
CT+S+GG(R)-CT+RR(W)-ZT+WR(GG)	2.72 (6.87)	4.01 (15.60)	2.76 (7.11)	2.62 (6.39)	1.42 (1.52)	1.60 (2.06)	1.02 (0.54)	1.05 (0.61)	4.13 (16.52)	5.07 (25.25)
ZT+S(R)-ZT(W)-ZT(GG)	3.89 (14.66)	5.30 (27.62)	2.95 (8.21)	2.98 (8.41)	2.18 (4.24)	2.15 (4.12)	1.80 (2.75)	1.82 (2.82)	5.57 (30.55)	6.76 (45.24)
ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG)	3.52 (11.90)	5.55 (30.36)	4.25 (17.56)	3.99 (15.39)	2.00 (3.51)	2.04 (3.66)	2.07 (3.77)	2.64 (6.46)	6.28 (38.93)	7.65 (57.98)
CT(TPR)-CT(W)	2.24 (4.51)	2.88 (7.77)	1.96 (3.33)	1.98 (3.41)	1.31 (1.22)	1.43 (1.55)	0.74 (0.05)	0.75 (0.07)	3.16 (9.50)	3.70 (13.17)
LSD (p=0.05)	0.56	0.50	0.42	0.52	0.61	0.25	0.31	0.77	0.69	0.47
Weed management										
Weedy check	4.73 (21.88)	7.71 (58.95)	5.31 (27.60)	5.31 (27.74)	2.21 (4.39)	2.30 (4.78)	1.86 (2.95)	2.21 (4.38)	7.69 (58.06)	9.95 (98.44)
Bispyribac-sodium 25 g/ha (in both the years)	2.07 (3.80)	2.65 (6.50)	1.78 (2.67)	1.68 (2.33)	1.48 (1.69)	1.67 (2.28)	1.24 (1.05)	1.33 (1.26)	3.16 (9.50)	3.68 (13.08)
Chlorimuron + metsulfuron-methyl in 2014 and bispyribac-sodium 25 g/ha in 2015	2.50 (5.76)	3.23 (9.94)	1.41 (1.49)	1.30 (1.18)	1.41 (1.50)	1.48 (1.69)	0.83 (0.18)	0.90 (0.31)	3.11 (9.18)	3.73 (13.42)
LSD (p=0.05)	0.27	0.60	0.34	0.34	0.47	0.15	0.19	0.54	0.36	0.59

*Value presented in the parentheses are original by zero-till sown wheat provided an excellent opportunity for severe weed infestation. The present findings are in close conformity with Jha (2010).

Different weed control practices caused significant variation in density and biomass of weeds in rice. All weeds had higher density and biomass in weedy check plots where no weed control practices were done. But, weed infestation appreciably declined due to herbicides application. Hoffman *et al.* (1998) reported a reduction in density and biomass of weeds due to application of herbicides. It was noticed that *C. iria, D. retroflexa* and *C. axillaries* were effectively controlled by rotational application of chlorimuron + metsulfuron-methyl 4 g/ha during 2014 and bispyribac-sodium 25 g/ha PoE during 2015 than continuous application of bispyribac-sodium 25 g/ha PoE in rice during both the years. On the contrary, *E. colona* had minimum density and biomass in plots receiving regular application of bispyribac-sodium during both the years as compared to rotational application of herbicides. Effective control of *C. iria, D. retroflexa* and *C. axillaris* due to rotational application of herbicides might be because chlorimuron + metsulfuron-methyl showed better efficacy against these weeds and rotational application of herbicides also prevented early development of resistance in weeds (Das 2008). Singh *et al.* (2003) reported that chlorimuron + metsulfuron-methyl was more capable to kill the broad-leaved weeds and sedges as compared to other herbicides. The above results are in line with Sreelakshmi *et al.* (2016). *E. colona* had taller and more vigorous plants as compared to other weeds and crop. If the targeted plants are taller than the other non-targeted plants, a greater amount of herbicide was intercepted by these plants. In addition, bispyribac-sodium is absorbed by both roots as well as shoots and it is translocated in the plant simultaneously through apoplast and simplast movement (Antralina *et al.* 2015). As a result of more absorption and faster translocation of bispyribac-sodium to the site of action in lethal concentration, density and biomass of *E. colona* were reduced when regular application of bispyribac-sodium was done in rice during both years. Chauhan (2012) also reported 97% reduction in of population of *E. colona* with application of bispyribac-sodium 25 g/ha at four leaf stage.

Density and biomass of weeds were affected due to the interaction of tillage and weed control practices. The total weed density and biomass were the maximum when no weed control was done in ZT+S or ZT+S+GG in rice under ZT+S(R)-ZT(W)-ZT(GG) or ZT+S+GG(R)-ZT+RR(W)-ZT+WR (GG) being minimum in no weeding was done after conventional tillage in transplanted rice and proved superior to other tillage practices. It might be due to poor germination and emergence of weeds in transplanted rice due to anaerobic conditions. However, in case of zero tillage old as well as newly dropped weed seeds were left over on or uppermost layer of the soil, which germinated and emerged out due to zero soil disturbances. Besides this, no herbicidal or other weed control practices were adopted for weed control. Therefore, all weeds had higher density and biomass under zero tillage system. Further, higher weed density and biomass were recorded when the regular application of bispyribac-sodium was done during both years after zero tillage in rice in the presence or absence of greengram and *Sesbania* residues as compared to other combinations. Because 15-80% of applied herbicides are intercepted by anchored crop residues, the herbicides were not absorbed and translocated at site of action in lethal concentration so that higher density and biomass of weeds were recorded under above treatment combinations. Even so greater reduction in weed density and biomass was observed in plots receiving rotational application of chlorimuron + metsulfuron-methyl during previous year and bispyribac-sodium during next year in transplanted rice. Poor emergence of weeds took place in transplanted rice due to anaerobic conditions and the late-emerged weeds were effectively controlled by rotational application of herbicides.

Weed control efficiency in rice

Weed control efficiency (WCE) was significantly influenced due to different tillage practices and weed management practices in rice. The minimum WCE was recorded in ZTR under ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG). However, the maximum WCE was recorded when conventional tillage was done in transplanted rice under CT (TPR)-CT (W)-fallow system (Table 2.). When rice was sown as direct on zero tillage in presence of greengram and *Sesbania* residues under ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG) system, the weeds produced higher dry matter. When rice was transplanted after conventional tillage in puddled conditions weeds shows poor germination and result in lower density and biomass. Thus, lower WCE was exhibited under ZT+S+GG(R)-ZT+RR(W)-ZT+WR (GG) system but higher in CT(TPR)-CT(W) system. Numerically the higher WCE was recorded with rotational application of herbicides as compared to the regular application of the same herbicides during both the years of experimentation, but statistically, it was at par. All the weeds except *E. colona* attained lower density and biomass with rotational application of herbicides. Consequently, both herbicides had almost similar WCE but lower than weedy check plots. The results are in close conformity with Teja *et al.* (2015). The WCE was also affected due to the interaction of tillage and weed control practices. The minimum WCE was recorded when weed control was not done after zero tillage in rice in the presence of greengram and *Sesbania* residues, which was higher when no weed control was done after conventional tillage in transplanted rice. It might be attributed to decrease in weed biomass production in conventional tillage contrary to zero tillage when weed biomass production was not checked appreciably. From the foregoing observations we can say that transplanting could check weed growth without adoption of any weed management practice. However, WCE was enhanced with bispyribac-sodium 25 g/ha PoE after zero as well as conventional tillage. The maximum WCE was registered in case of rotational application of chlorimuron + metsulfuron-methyl 4 g/ha during 2014 and bispyribac-sodium 25 g/ha during 2015 in conventional tillage in transplanted rice due to lower dry matter production of weeds.

Grain and straw yields of rice

Grain and straw yields were lower in ZT+S+GG in DSR under ZT+S+GG(R)-ZT+RR(W)-ZT+WR (GG). However, both were increased in conventional tillage in DSR under CT+S(R)-CT(W)-ZT(GG) and CT+S+GG(R)-T+RR(W)-ZT+WR(GG) being maximum in conventional tillage in transplanted rice under CT(TPR)-CT(W)-fallow system. Plots receiving zero tillage in rice in presence of greengram and *Sesbania* residues had more weed density and biomass compared to other tillage practices. This affected the yield attributing traits adversely and finally had poor values of yield attributes, grain and straw yields. However, further increment in grain and straw yields was observed in conventional tilled DRS because of better yield attributes as compared to zero tillage in DSR under ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG) system. Whereas maximum grain and straw yields was obtained in conventional tilled transplanted rice under CT(TPR)-CT(W)-fallow system since, transplanted rice had sufficient space for each plant/hill for better growth and development under weed-free environment. Henceforth, lower inter and intra species competition under transplanted rice had superior yield attributing traits, which ultimately resulted in the maximum grain and straw yields.

The minimum grain and straw yields were obtained in weedy check plots, due to inferior yield attributes. However, a slight increment in grain and straw yields was recorded in case of regular application of same herbicides being maximum in rotational application of herbicides. This might be due to better weed-free environment provided to crop for optimum growth and under rotational application of herbicides from early stage of crop. Higher yield attributes and yields were recorded because of better weed control by the application of chlorimuron +metsulfuron-methyl was also reported by Heisnam *et al*. (2015). The results are also agreement with Kaikkhura *et al.* (2015). The interaction of tillage and weed control practices caused significant effects on grain and straw yields of rice. All the plots in which weeds were not controlled after each tillage practice had long and thin plants. Other growth and yield attributes were also poor in this situation. It might be attributed to higher density and biomass of weeds in these plots, which suppressed the growth of crop plants and led to inferior yield attributes. Finally, lower yields were recorded in weedy plots under each tillage practice as compared to other combinations of tillage and weed management practices. The values of above parameters were enhanced with the regular application of bispyribac-sodium in all tillage practices. Thus, yields were also increased due to the positive effect of weed control on yield attributes. Further, the maximum value of growth and yield attributes were registered when rotational application of herbicides was done in transplanted rice. In case of transplanting plants were properly spaced, as well as weeds were also very less and post emerged weeds were effectively controlled by rotational application of herbicides. Thus, plants got sufficient space, light and nutrients for their optimum growth and development on accounts of zero inter and intra species competition. This led to superior yield attributes, which ultimately resulted in the maximum grain as well as straw yields in these treatment combinations.

Economics

The minimum cost of cultivation was recorded in ZT+S in DRS under ZT+S(R)-ZT+(W)-ZT+(GG) system. It was gradually increased in conventional tillage in DSR being maximum when rice was transplanted after conventional tillage in puddled condition under CT(TPR)-CT(W)-fallow system. Transplanting of rice after conventional tillage was more costly because it involved use of several implements including puddling to obtain suitable sowing condition and also involve manual transplanting which increases the cost of cultivation. But in case of sowing of DSR under zero tillage systems, the establishment costs reduced considerably. Consequently, it had lower cost of

Table 2. Weed control efficiency, grain and straw yields and economics of rice as affected by tillage and weed control practices (mean of two years)

Treatment	WCE (%)	Grain yield (t/ha)			Straw yield (t/ha)			Cost of cultivation (x10^3 `/ha)	GMR (x10^3 `/ha)	NMR (x10^3 `/ha)	B:C
		2014	2015	Pooled	2014	2015	Pooled				
Tillage											
CT+S(R)-CT(W)-ZT(GG)	78.65	4.11	3.89	4.01	7.04	6.34	6.69	28.26	57.43	26.284	1.84
CT+S+GG(R)-CT+RR(W)-ZT+WR(GG)	82.88	4.35	3.94	4.14	7.00	6.56	6.78	28.46	59.32	27.971	1.89
ZT+S(R)-ZT(W)-ZT(GG)	71.46	4.66	4.08	4.37	7.96	6.48	7.22	27.81	62.56	31.858	2.04
ZT+S+GG(R)-ZT+RR(W)-ZT+WR(GG)	59.76	3.70	3.69	3.69	7.77	5.17	6.47	28.01	53.09	22.192	1.72
CT(TPR)-CT(W)	92.04	4.81	4.61	4.71	8.31	7.77	8.04	35.77	67.65	31.746	1.88
LSD (p=0.05)	-	0.23	0.16	0.10	0.48	1.21	0.51	-	-	-	-
Weed management											
Weedy check	45.25	2.79	2.75	2.77	6.84	5.11	5.97	28.55	40.38	9.498	1.31
Bispyribac-sodium 25 g/ha (in both the years)	92.77	4.93	4.79	4.86	7.52	7.36	7.44	30.51	69.33	36.485	2.11
Chlorimuron + metsulfuron-methyl in 2014 and bispyribac-sodium 25 g/ha in 2015	92.85	5.26	4.59	4.92	8.48	6.92	7.70	29.94	70.33	38.048	2.18
LSD (p=0.05)	-	0.10	0.14	0.07	0.28	0.63	0.32	-	-	-	-

cultivation (Bullock 2004). Sowing of DSR (ZT+S+GG) under ZT+S+GG (R)-ZT+RR(W)-ZT+WR(GG) system had minimum gross monetary returns (GMRs) and net monetary returns (NMRs) as well as B:C. However, conventional tillage in transplanted rice under CT(TPR)-CT(W)-fallow system recorded the highest GMRs but NMRs and B:C were higher in ZT+S in rice under ZT+S(R)-ZT-(W)-ZT(GG) system followed by CT(TPR)-CT(W)-fallow system. Economic returns were influenced by the yields of crop and cost of cultivation. Due to higher yields of rice in transplanting under CT(TPR)-CT(W)-fallow system gets higher GMRs but due to lower cost of cultivation in ZT+S(R)-ZT-(W)-ZT(GG) system as compared to transplanted rice fetched higher NMRs and B:C. No weed control in rice fetched the minimum cost of cultivation GMRs, NMRs and B:C. The higher cost of cultivation was recorded with regular application of bispyribac-sodium 25 g/ha in rice during both the years it was at par with rotational application of chlorimuron + metsulfuron-methyl 4 g /ha during 2014 and bispyribac-sodium 25 g/ha PoE during 2015 in rice. However reverse trend was observed in case of GMRs, NMRs and B:C due to a proportionate increment in profit in per rupee investment in weed control. Interaction between tillage and weed control practices also caused marked influence on economics of rice. The GMRs, NMRs and B:C were lower in plots where weed control practices were not adopted after each tillage. However, cost of cultivation was higher when regular application of bispyribac-sodium 25 g/ha in rice during both the years after conventional tillage in transplanted rice. GMRs and NMRs were higher when rotational application of chlorimuron + metsulfuron-methyl 4g/ha during 2014 and bispyribac-sodium 25 g/ha PoE during 2015 was done after conventional tillage in transplanted rice and B:C was higher in rotational application of chlorimuron + metsulfuron-methyl 4 g/ha during 2014 and bispyribac-sodium 25g/ha PoE during 2015 was done after zero tillage was done in rice in presence of *Sesbania*.

Thus, it was concluded that zero tillage in presence of *Sesbania* residues as well as conventional tillage in transplanted rice along with rotational application of chlorimuron + metsulfuron-methyl 4g/ha during 2014 and bispyribac-sodium 25g/ha PoE during 2015 found effective for weed control in rice and attained higher productivity and profitability of rice.

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