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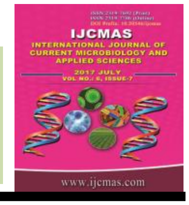

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Impact of Different Tillage Practices with Weed Management Methods on Growth, Yield and Economics of Rice (*Oryza sativa* L.) in South Eastern Part of Bihar

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A B S T R A C T

A farmer's participatory trail was conducted during Kharif season of 2014 and 2015 on farmers' field at Kumar village (Sikandra) of Jamui district (Bihar) under CSISA project. The experiment was laid out in the factorial randomized block design using three way ANOVA table. The experiment consisted of four tillage practices *viz.* T_1-Stale bed direct seeded rice, T_2-ZT direct seeded rice, T_3-Mechanical transplanted rice, T_4-Conventional puddle transplanted rice and six weed management practices *viz.* W_1-Weedy check (control), W_2-Weed free, W_3-Pyrazosulfuron at 20 g ha^{-1} as pre emergence, W_4-Oxadarzil at 18 g ai ha^{-1} as pre emergence, W_5-Pyrazosulfuron at 20 g ha^{-1} as pre emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS and W_6- Oxadarzil at 18 g ai ha^{-1} as pre emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS. Treatment T_3 mechanically transplanted rice recorded highest plant height (94.20 cm), number of effective tillers (250.64), dry matter m^{-2} (1369.7 g), length of panicle (24.12 cm), weight of panicle (2.72 g), no. of grains (115.47), test weight (25.62 g) grain and straw yield 3778 kg and 6105 kg ha^{-1} respectively. Lowest Weed density (26.34 and 6.02) and weed dry weight (3.03 and 6.04 g) were recorded with stale bed direct seeded rice at 30 and 60 DAS. Under weed management practices lowest weed density (9.34 and 3.03) and weed dry weight (0.88 and 2.82 g) at 30 and 60 DAS. Maximum Grain (3847 kg ha^{-1}) and Straw yield (6184 kg ha-1) was recorded under treatment W_5 Pyrazosulfuron at 0.20 kg ha^{-1} as pre emergence fb bispyribac sodium at 0.20 kg ai ha^{-1} at 22 DAS. The maximum net return was obtained with treatment W_5 (Rs. 28,631) and B: C ratio of 2.05.

Introduction

Rice is one of the most important cereal crops and provides food security and livelihood for millions of people across the globe. It is the main staple food of India, covering an area of about 43.97 m ha with the total production and productivity of 104.32 mt and 2.37 t/ha respectively during 2011-12 (Annonymous 2013 a). In India, rice plays an important role in the economy aswell as in rural livelihoods and is the staple food crop, second only to wheat. Major rice cultivation method used is manual transplanting of nursery grown seedlings into puddled soil. Puddling is a process of cultivating soil in standing water which consumes large amount of water. Moreover, as water resources are depleting due to intensive use of toxic pesticides and also resulting in scarcity of water in many part of the world, as there is competition between industrial and agricultural consumption of water resources (Mahajan *et al.,* 2011, 2012). There is a great concern that Indian rice growers will probably have inadequate access to irrigation water in the future (Mahajan *et al.,* 2013). Hence, shortage of irrigation water, threatens the sustainability of rice production in irrigated conditions (Chauhan *et al.,* 2012, 2014). Rice is mainly cultivated in 38 district of Bihar. Out of this 25 districts are falling under low productivity group which accounts for 63% of 36.57 lakh hectares of total area under rice in the state. Rice is one of the major crops of Bihar but its productivity is very poor. More than 60% rice area is concentrated in Bihar in low productivity zone and this zone contributes more than 50% of rice production of the state. Area coverage under rice with high yielding varieties is about 65% and irrigation facility is available for about 40% rice area in the state, if the productivity of low productivity zone is increased, the rice production can be increased considerably without increasing the area under rice. Transplanting is the major method of rice cultivation in Bihar. However, transplanting is becoming increasingly difficult due to shortage and high cost of labour, scarcity of water, uneven distribution of rainfall and less profit. The transplanting of rice under puddle conditions requires more irrigation water and creates a hard pan below the surface. The conventional tillage, puddling and long duration varieties further delay the transplanting of rice. Direct seeding and mechanically transplanted rice have gained significance to reduce the cost of production, saving of water, fuel, energy, time and wear and tear of tractor, which can be achieved by omitting the repeated tillage operations for land preparation. Directed-seeded rice (DSR) needs only 34% of the total labour requirement and saves 27% of the total cost of transplanted crop (Mishra and Singh, 2011). Herbicide (pendimethalin @ 1.00 kg ai ha^{-1}) as pre-emergence supplemented with two hand weedings were needed to reduce weed growth in zero till dry-seeded rice (Singh *et al.,* 2005a). Tillage influences weed infestation, as under zero tillage seeds of most of the seasonal weeds remain on the soil surface, while under conventional tillage the weed seeds are inverted by plough and buried beneath the soil, thus under zero tillage the infestation of weeds are more. However, the crop establishment under zero tillage in rice-wheat system is gaining momentum in recent days as a pathway to address rising water and labour scarcity, increasing cost of fuel energy and to enhance resource-use efficiency and system sustainability. Zero tillage sowing in standing crop resides along with application of herbicides in proper combination or sequence leads to lower weed population and higher yield than conventional planting (Sharma and Singh, 2012). However, direct seeded rice is subjected to greater weed competition than transplanted rice. Weeds offer intense competition with the rice crop for all critical growth factors, *viz.* space, sunlight, water and nutrients, thus considerable yield loss. Manna (1991) reported a yield reduction of 25% in transplanted rice, 32% in puddle broadcasted rice and 52% in direct seeded rice due to weeds. Direct seeded rice (DSR) has the potential of saving water through earlier establishment of plants and thus it facilities early seeding of wheat in rice-wheat cropping system (Ladha *et al.,* 2003). Zero tillage or reduce tillage establishment is used widely for many crops around the world and this technology has potential to allow saving in time, energy, water and labour during rice establishment (Piggin *et al.,* 2002). There are some limiting factors associated with DSR that impair yields including crop-weed competition. Compared to transplanted rice, the yield losses in DSR is greater due to absence of flooding water at the early stage of the crop to suppress weed growth (Singh *et al.,* 2007). Aerobic rice is the most promising one in terms of water saving (Anwar *et al.*, 2010). In precise, aerobic rice system refers to growing direct seeded rice on non-puddled aerobic soil without standing water (Bouman 2003) and rice is managed intensively as an upland crop like wheat or maize. Aerobic rice is either rainfed or irrigated and soil water is maintained around field capacity in the root zone. This system eliminates surface runoff percolation and evaporation losses (Singh and Chinnusamy 2006) resulting in twice the water productivity of flood irrigated rice (Bouman *et al.,* 2002). Industrialization also threatens rice production due to migration of rural labour to cities in search of job, which causes shortage of manual labour during the peak period of rice cultivation. This, results in late transplanting, less acreage under rice, low yield and delay in planting of the next crop. Therefore the objective of this study was to evaluate the best method of rice establishment and weed control method in DSR.

Materials and Methods

Adaptive research trail were conducted for two years in 2014 and 2015 in *kharif* season at Kumar (Sikandara) village of Jamui district (Bihar) under Cereal System Initiative for South Asia (CSISA) project. The research site soil was sandy loam having 50% sand, 30% silt and 14.4% clay. The soil contained 0.66% organic carbon, 182.5 kg ha^{-1} of available nitrogen, 29 kg ha^{-1} of available Phosphorus and 160 kg ha^{-1} of available Potassium with pH 7.2 in the year of experiment. The experiment was laid out in RBD (Factorial) with treatment comprising four sowing methods *viz*. T_1 - Stale bed direct seeded rice (STDSR), T_2- Zero tillage direct seeded rice (ZTDSR), T_3 Mechanical transplanted Rice (MTPR) and T_4 conventional tillage (CT) and six different weed control methods *viz.* W_1 - Weedy check (control), W_2 -Weed free, W_3 - Pyrazosulfuron at 20 g ha^{-1} as pre emergence, W_4 - Oxadarzil at 18 g ai ha^{-1} as pre emergence, W_5 - Pyrazosulfuron at 20 g ha^{-1} as pre emergence followed by bispyribac sodium at 25 g ai ha^{-1} at 22 DAS, W_6 - Oxadarzil at 18 g ai ha^{-1} as pre emergence followed by bispyribac sodium at 25 g ai ha^{-1} at 22 DAS. Rice variety MTU 7029 were sown under STDSR and ZTDSR on 20th June 2014 and 22th June 2015 respectively, where as in MTPR and CT nursery was done on same day. 18 days old seedling was transplanted under MTPR in unpuddled condition whereas in CT method 25 days old seedling was manually transplanted in puddle condition. In SDSR pre – plant herbicide glyphosate at 1.00 kg ai ha^{-1} was sprayed two times Ist at one month before and second time seven days before of sowing in proper moisture and rice was sown through zero tillage machine keeping rows 20 cm. apart without any tillage operations. Pre – plant herbicide glyphosate at 1.00 kg ai ha^{-1} was sprayed one week before sowing in ZTDSR at proper moisture in the soil and seed was sown through zero tillage keeping rows 20 cm. apart without any tillage practices. In MTPR rice nursery prepared on mat and 18 days old nursery was transplanted through rice transplanter. Whereas, in conventional tillage field was ploughed through mould board plough followed by cultivator and planking was done after each ploughing and puddling was done in standing water. Seed rate 30 kg ha^{-1} was used in all treatments except conventional tillage. Whereas, in conventional tillage 50 kg ha^{-1} seed rate was used. In weed management treatments Pre-emergence herbicide pendamethalin at 1.5 kg, Pyrazosulfuron at 20 g and Oxadarzil at 18 g ai ha^{-1} were applied as pre emergence within 48 hours of sowing. Whereas, Post – emergence herbicide bispyribac sodium at 25 g ai ha^{-1} as tank mixture was sprayed at 22 days after sowing in rice as per treatment required. Under weed free treatment four weeding was done at different intervals of crop. The crop was fertilized with recommended 110 kg N + 50 kg P_2O_5 + 50 kg K_2O was applied in the form of urea, DAP and MOP respectively.

Full dose of the phosphorus and potash and half nitrogen were applied at the time of seeding. Remaining nitrogen was applied in two equal splits at mid tillering and panicle initiation stage. Data were recorded from an area enclosed in quadrate of 0.25 m^2 randomly selected at three places in each plot. Herbicidal spray was done with knapsack sprayer fitted with flat fan nozzle using 500 litres of water ha^{-1}. Other packages of practices rather than treatments were followed as per recommendation for rice crop.

Results and Discussion

A perusal of the pool data (Table 1) clearly shows that there was significant difference among different tillage practices on weed density and weed dry weight at 30 and 60 DAS. Minimu weed density at 30 and 60 DAS was recorded in treatment T_3 (Mechanical transplanted Rice) as 90.60 g and 6.02 g followed by treatment T_2 (ZTDSR).

Similarly weed dry weight also recorded minimum pooled values as 2.24 g and 6.04 g at 30 and 60 DAS in treatment T_3 which was closely followed by treatment T_2 and were far superior to treatment T_4 (CT) which recorded weed density (259.57 and 117.20) and weed dry weight (46.36 g and 107.13 g) at 30 and 60 DAS respectively. This may be due to non-disturbance of soil in mechanical transplanting which did not allowed the weed seeds to come at the surface an emerge.

Herbicide treatment also showed significant variation with respect to weed density and weed dry weight at 30 and 60 DAS. Minimum weed density (9.34 and 3.04) was recorded in treatment W_5 (pyrazosulfuron at 20 g ha^{-1} as pre – emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS) at 30 and 60 DAS respectively followed by treatment W_6 (Oxadarzil at 18 g ai ha^{-1} as pre emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS). The pooled data also revolved that at 60 DAS weed density recorded under treatment W_6 (3.04 g) was found to be at par to that recorded under treatment W_5 (3.38 g). Similarly pooled values on weeds dry weight at 30 and 60 DAS also showed significant variation.

Minimum weed dry weight (0.88 g and 2.63 g) was recorded in treatment W_5 at 30 and 60 DAS respectively and was closely followed by treatment W_6 which recorded weed dry weight (1.05 g and 2.82 g) at 30 and 60 DAS and was found to be at par to treatment W_5 this may be due to these herbicides belong to sulfonyl urease group which do not allow or rather kill the emerging weeds and the weed which escape from pyrazosulfuron are killed by bispyribac sodium which is applied 22 DAS. The other reason may be due to the fact that these herbicides are protein inhibitors thus not allowing the weed plants to synthesis protein and hence are killed.

The pooled data of table 2 revealed that tillage practices had significant effect on growth parameters of rice at panicle initiation stage. Maximum values of growth attributes viz. plant height (94.20 cm), no. of effective tillers (250.64 m^{-2}), dry matter (1396.70 g m^{-2}), length of panicle (24.12 cm), weight of panicle (2.72 g), no. of grains $panicle^{-1}$ (115.47) and test weight (25.62 g) was recorded in treatment T_3 (MTPR) followed by treatment T_2 (ZTDSR) which was found to be at par to treatment T_3 (Gangwar *et al.*, 2005). This may be due to the fact that in MTPR only 16 days old seedlings are transplanted with soil attached to their roots which escapes transplanting shock as CT method rice.

Table.1 Impact of different tillage practices with weed management on weed density and Weed dry weight in rice crop (pooled data of 2 years)

Treatments	Weed Density at 30 DAS No.	Weed Dry wt. at 30 DAS (g)	Weed Density at 60 DAS No.	Weed Dry wt. at 60 DAS (g)
Tillage (T)				
T_1-Stale bed direct seeded rice	23.64	3.03	6.02	6.04
T_2-ZT direct seeded rice	19.60	2,24	9.38	9.86
T_3-Mechanical transplanted rice	38.91	6.01	19.38	15.74
T_4-Conventional puddle transplanted rice	259.57	46.36	117.20	107.13
F-test	S	S	S	S
S.Ed. (±)	0.34	0.13	0.16	0.21
CD (P=0.05)	1.46	0.59	0.70	0.91
Herbicide (W)				
Treatments	Weed Density at 30 DAS No.	Weed Dry wt. at 30 DAS (g)	Weed Density at 60 DAS No.	Weed Dry wt. at 60 DAS (g)
W_1 -Weedy check (control)	262.40	46.65	118.10	107.00
W_2 -Weed free	0	0	0	0
W_3 -Pyrazosulfuron at 20 g ha^{-1} as pre- emergence	23.75	3.10	3.98	4.31
W_4 –Oxadarzil at 18 g ai ha^{-1} as pre- emergence	29.75	4,14	5.20	5.52
W_5 - Pyrazosulfuron at 20 g ha^{-1} as pre emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS	9.34	0.88	3.04	2.63
W_6 - Oxadarzil at 18 g ai ha^{-1} as pre emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS	11.64	1.05	3.38	2.82
F-test	S	S	S	S
S.Ed. (±)	0.32	0.13	0.08	0.19
CD (P=0.05)	1.24	0.52	0.35	0.74

Table.2 Impact of different tillage practices with weed management on Growth attributes of rice (pooled data of 2 years)

Treatments	Plant height (cm)	No. of effective tillers m^{-2}	Dry matter m^{-2}	Length of Panicle (cm)	Weight of panicle (g)	No. of grains $panicle^{-1}$	Test weight (g)
Tillage practices (T)							
T_1 –Stale bed Direct Seeded Rice	92.30	241.00	1344.5	22.00	2.48	108.38	25.60
T_2 –Zero Tillage Direct Seeded Rice	92.0	233.50	1302.7	21.20	2.39	111.11	24.46
T_3 –Mechanical Transplanted Rice	94.20	250.64	1396.7	24.12	2.72	115.47	25.62
T_4 –Conventional Rice	73.40	182.65	1110.3	19.60	1.89	99.14	22.00
F-test	S	S	S	S	S	S	S
S.Ed. (±)	0.79	0.63	18.25	0.07	0.07	1.02	1.38
C.D. at 5%	3.36	2.70	77.29	0.28	0.30	4.35	0.31
Herbicides (W)							
W_1 -Weedy check (control)	72.85	180.85	1108.4	19.45	1.82	69.64	22.20
W_2 -Weed free	99.80	265.4	1480.5	25.78	2.85	125.53	25.70
W_3 -Pyrazosulfuron at 20 g ha^{-1} as pre- emergence	88.52	230.5	1265.4	21.70	2.30	123.34	24.00
W_4 –Oxadarzil at 18 g ha^{-1} as pre- emergence	80.5	218.7	1205.6	21.00	2.17	105.65	23.85
W_5 - Pyrazosulfuron 20 g ha^{-1} as pre- emergence fb bispyribac sodium at 25 g ha^{-1} at 22 DAS	93.5	244.65	1370.0	24.85	2.68	115.34	25.68
W_6 - Oxadarzil at 18 g ha^{-1} as pre emergence fb bispyribac sodium 25 g ha^{-1} at 22 DAS	91.0	238.4	1303.2	22.50	2.50	113.21	25.60
F-test	S	S	S	**S**	S	S	S
S.Ed. (±)	0.68	0.70	0.60	0.25	0.04	0.49	0.28
C.D. at 5%	2.65	2.73	2.35	0.96	0.18	1.90	1.08

Table.3 Impact of different tillage practices with weed management on Yield attributes and economics of rice (pooled data of 2 years)

Treatments	Grain yield ($Kgha^{-1}$)	Straw yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return Rs. ha^{-1}	B: C ratio
Tillage practices (T)						
T_1 –Stale bed Direct Seeded Rice	3503	6004	27,517	50,793	23,276	1.84
T_2 –Zero Tillage Direct Seeded Rice	3457	5813	26,500	50,126	23,626	1.89
T_3 –Mechanical Transplanted Rice	3778	6105	27,500	53,331	25,831	1.93
T_4 –Conventional Rice	3114	5367	32,425	45,153	12,728	1.39
F-test	S	S				
S.Ed. (±)	1.04	0.87				
C.D. at 5%	4.43	3.71				
Herbicides (W)						
W_1 -Weedy check (control);	2451	4453	30,225	35,539	5,314	1.17
W_2 -Weed free	3910	6243	39,400	56,695	16,755	1.43
W_3 -Pyrazosulfuron at 20 g ha^{-1} as pre emergence	3559	6032	26,000	51,605	25,605	1.94
W_4 –Oxadarzil at 18 g ai ha^{-1} as pre emergence	3380	5832	26,350	49,010	22,660	1.85
W_5 - Pyrazosulfuron at 20 g ha^{-1} as pre-emergence fb bispyribac sodium at 20 g ai ha^{-1} at 22 DAS	3847	6184	27,150	55,781.5	28,631	2.05
W_6 - Oxadarzil at 18 g ai ha^{-1} as pre-emergence fb bispyribac sodium at 25 g ai ha^{-1} at 22 DAS	3694	6048	27,350	53,563	24563	1.96
F-test	S	S				
S.Ed. (±)	7.74	4.42				
C.D. at 5%	29.51	1.63				

Mechanically transplanted rice results in early maturity and short the crop duration that transplanted rice (Gill 2008). The other reason for higher growth parameter in MTPR is that the seedlings are transplanted in un puddle condition with proper spacing and depth and there is less competition among plants for sun light, nutrients and moisture (Singh and Singh 1993, Gill *et al.*, 2006).

In direct seeded rice there is saving of water, input, energy and time due un puddle condition, less manual labour required and use of machines (Zero tillage and Rice transplanter). Chauhan and Opena (2012) reported that puddling in transplanted rice system consumes up to 30% of the total rice water required. Similar result was also reported by Sharma *et al.*, (2002) and Singh *et al.*, (2002) that input water saving of 35-57% have been reported for dry direct seeded rice sown in to non-puddled soil compared with conventional method. The third reason may be due to less weed density in MTPR. Similarly herbicide treatments also showed significant variation with respect to growth components. Maximum pooled values as plant height (93.5 cm), no. of effective tillers (244.65), dry matter (1370 g m^{-2}), panicle length (24.85 cm), weight of panicle (2.68 g), no. of grains per panicle (115.34) and test weight (25.68 g) was recorded in treatment W_5 followed by treatment W_6 which was found to be at par to treatment W_5 in all growth parameters except dry matter accumulation m^{-2} this may be due to these herbicides belong to sulfonyl urease group which do not allow or rather kill the emerging weeds and the weed which escape from pyrazosulfuron are killed by bispyribac sodium which is applied 22 DAS. The other reason may be due to the fact that these herbicides are protein inhibitors thus not allowing the weed plants to synthesis protein and hence are killed. Irrigation water application was higher in transplanted rice than DSR. Direct seeded rice gave more water productivity than transplanted rice. Due to cracking in puddle transplanted rice irrigation water was required more and continuously.

An appraisal of table 3 shows significant variation with respect to tillage practice on grain and straw yield maximum pooled values of grain yield (3778 kg ha^{-1}) and straw yield (6105 kg ha^{-1}) was recorded in treatment T_3 (MTPR) followed by treatment T_2 (ZTDSR) this may be due to higher and maximum yield attributes recorded under treatment T_3. Similarly herbicide treatments also showed significant variation with respect to grain and straw yield. Maximum pooled values of grain and straw yield were recorded as 3847 kg ha^{-1} and 3694 kg ha^{-1} respectively in treatment W_5 followed by treatment W_6. Further the table also revolved that among tillage practices maximum net return (Rs. 25831) and B: C ratio (1.93) was recorded in treatment T_3 followed by treatment T_2 which recorded net return and B: C ratio as (Rs. 23626 ha-1) and 1.89) respectively. Among herbicidal treatment maximum net return and B: C ratio as (Rs 28631 and 2.05) was recorded in treatment W_5 followed by treatment W_6 (KP Bhurer *et al.*, 2013). This may be due to higher yield attributes resulting in higher grain and straw yield and lower cost of cultivation in treatment T_3 and followed by treatment T_2 than in conventional tillage T_4 (Gill *et al.*, 2014). The labour cost in conventional tillage was much higher and tillage practices CT also recorded maximum time there by resulting in higher cost on labour wages and fuel use for ploughing, puddling and irrigation, while less number of labours and minimum time of work by them led to low cost of cultivation in treatment T_3 and treatment T_2. Similarly weeding by manual labour in conventional tillage resulted in more cost of cultivation than herbicidal treatments.

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