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M Revathi
Research Scholar, Agricultural College and Research Institute, Zazhavachanur, Hiruvannamalai, Tamil Nadu, India

K Annadurai
Proffessor (Agronomy), Agricultural College and Research Institute, Zazhavachanur, Hiruvannamalai, Tamil Nadu, India

C Chinnusamy
Professor, Department of Agronomy, TNAU, Coimbatore, Tamil Nadu, India

Correspondence
M Revathi
Research Scholar, Agricultural College and Research Institute, Zazhavachanur, Hiruvannamalai, Tamil Nadu, India

Effect of various pre and post emergence herbicides on crop yield and weed dynamics under different rice establishment methods in Sodic soil environment

M Revathi, K Annadurai and C Chinnusamy

Abstract
Field experiments were conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli during *rabi* 2011-12 and 2012-13. Four crop establishment techniques *viz*., Manual line transplanting, Mechanical line transplanting, Direct Planting System (DPS) and Drum seeded rice and six weed management practices *viz*., PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} + POE Almix (pre-mix formulation of metsulfuron methyl 10% + chlorimuron ethyl 10% WP) 4 g a.i. ha^{-1}, PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} + POE Bispyribac Sodium 20 g a.i. ha^{-1}, PE Londax power (pre-mix formulation of bensulfuron methyl 0.6% + pretilachlor 6% GR) 10.0 Kg ha^{-1} + POE Almix (pre-mix formulation of metsulfuron methyl 10% + chlorimuron ethyl 10% WP) 4 g a.i. ha^{-1}, PE Londax power (pre-mix formulation of bensulfuron methyl 0.6% + pretilachlor 6% GR) 10.0 Kg ha^{-1} + POE Bispyribac sodium 20 g a.i. ha^{-1}, two hand weeding and un-weeded control were allotted to main and sub plots, respectively. The experiments were laid out in a strip plot design with three replications. Direct planting system (DPS) reduced weed density and dry weight, and it was followed by mechanical line transplanting at all the stages during both the years. Regarding weed management practices, significantly lower weed density and dry weight and higher weed control efficiency were observed in two hand weeding at 20 and 40 DAT/S and it was comparable with PE pyrazosulfuron ethyl 30 g a.i. ha^{-1} + POE bispyribac sodium 20 g a.i. ha^{-1} during both the years of study. Among crop establishment techniques, direct planting system (DPS) recorded higher yield of 5048 & 4639 kg ha^{-1} during *rabi* 2011-12 & 2012-13 and among weed management practices, hand weeding twice gave better yield of 5335 & 5062 kg ha^{-1} during *rabi* 2011-12 & 2012-13, respectively.

Keywords: crop establishment techniques, rice, weed control efficiency, weed density, weed management practices, yield

Introduction
Rice is one of the most important food grains produced and consumed more than half of the world's population which influences the livelihoods and economics of several billion. It is most important crop in India which plays a critical role in food security. India has to produce 135-145 million tonnes of rice by 2020 to feed the additional 350 million people (Prakash *et al.,* 2008) [6]. Rice crop suffers from various biotic and abiotic production stresses. Severe competition from weeds is one of the important factors deterring productivity and sustainability. The average loss in grain yield due to weed threat is reported to be 32.0 per cent (Singh *et al*., 2007) [9]. There are many weed control methods are practiced for better control of weeds in rice crop. The final choice of any weed control method depends to a greater extent on the cost of the herbicides and their relative efficiency. In the present study, research work was carried out to study the effect of different rice establishment methods and weed management practices on weed dynamics, weed control efficiency and yield of rice under sodic soil environment.

Materials and Methods
Field experiments were conducted during *rabi* 2011-12 and 2012-13 at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli. The soil was sandy clay loam with pH of 8.82 and 8.96 during *rabi* 2011-12 and 2012-13, respectively. Medium duration rice cultivar TRY 1 was used during both the years. The field experiments were laid out in strip plot design with three replications. Four crop establishment methods *viz*., manual line

transplanting, mechanical line transplanting, direct planting system (DPS) and drum seeded rice and six weed management practices *viz*., pre-emergence pyrazosulfuron ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + post-emergence almix (pre-mix formulation of metsulfuron methyl 10% + chlorimuron ethyl 10% WP) 4 g a.i. ha^{-1} at 21-25 DAT / 20 DAS, pre-emergence pyrazosulfuron ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + post-emergence bispyribac sodium 20 g a.i. ha^{-1} at 15- 20 DAT / 20 DAS, pre-emergence londax power (pre-mix formulation of bensulfuron methyl 0.6% + pretilachlor 6% GR) 10.0 kg ha^{-1} at 0-3 DAT / 10-15 DAS + post-emergence almix (pre-mix formulation of metsulfuron methyl 10% + chlorimuron ethyl 10% WP) 4 g a.i. ha^{-1} at 21-25 DAT / 20 DAS, pre-emergence londax power (pre-mix formulation of bensulfuron methyl 0.6% + pretilachlor 6% GR) 10.0 kg ha^{-1} at 0-3 DAT / 10-15 DAS + post-emergence bispyribac sodium 20 g a.i. ha^{-1} at 15-20 DAT / 20 DAS, two hand weeding at 20 and 40 DAT/S and un-weeded control were taken for the experiments.

Fertilizers were applied at the rate of 150: 50: 50 kg of N, P_2O_5 and K_2O ha^{-1}, respectively. For sodic soil environment, 25 per cent extra nitrogen was recommended and applied. Full dose of phosphorus and fifty per cent of potassium were applied basally before sowing / transplanting. The balance fifty per cent of potassium was top dressed at 35th day after transplanting of rice crop. The nitrogen fertilizer was applied in three equal splits *viz*; 20th and 35th day after transplanting, and at 7th and 55th day after transplanting where one splits applied in equal quantity. For direct wet seeded lowland rice, the recommendation was same that of transplanted rice. Entire phosphorous as basal applied at the time of ploughing. Nitrogen and potassium were applied 25 % each at 21 DAS, at active tillering, panicle initiation and heading stages.

Calculated quantity of herbicides for *rabi*, 2011-12 and 2012-13 was mixed with water at the rate of 600 liters ha^{-1} and sprayed with knapsack sprayer fitted with deflector nozzle and granular herbicide was applied with dry sand at 150 kg ha^{-1}. A thin film of water was maintained at the time of both liquid and granular herbicide application.

Weed species present in the experimental plot were identified at flowering stage of crop from un-weeded control plot and grouped as grasses, sedges and broad leaved weeds (BLW). Weeds were sampled in each plot at 15, 30, 45 and 60 DAT/S of crop from an area of 0.5 m^2, counted and dried to constant weight at 80° C in hot air oven. Species wise density and group wise dry weight of weeds were expressed as number m^{-2} and g m^{-2}, respectively. Weed control efficiency was worked out from weed dry weight during both the years. Grain and straw were separated from net plot area, sun dried, weighed and expressed in kg ha^{-1}.

Results and Discussion

Major weeds found in experimental rice fields were *Echinochloa colonum* (L.), *Echinochloa crus-galli* (L.) among grasses, *Cyperus rotundus*, *Cyperus difformis* among sedges and *Ammannia baccifera, Eclipta alba, Marsilea quadrifoliata, Bergia capensis* among broad leaved weeds.

Among various rice establishments, significantly lower density of grass weed was recorded in direct planting system (DPS). This might be due to incorporation of weeds at the time of rotary thinning during early stage of crop and at later stages; weed management practices also reduced the density of grasses in DPS. Regarding weed management practices, in early stages, application of PE pyrazosulfuron ethyl at 30 g a.i. ha^{-1} at 3 DAT/8 DAS + POE metsulfuron methyl 10% + chlorimuron ethyl 10% WP (pre-mix formulation) at 4 g a.i. ha^{-1} at 21-25 DAT/20 DAS treatment recorded lower density of grasses during both the years and it was comparable with PE pyrazosulfuron ethyl at 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + POE bispyribac sodium at 20 g a.i. ha^{-1} at 15- 20 DAT / 20 DAS and also PE bensulfuron methyl 0.6% + pretilachlor 6% GR (pre-mix formulation) at 660 g a.i. ha^{-1} at 10.0 kg ha^{-1} at 0-3 DAT/10-15 DAS + POE metsulfuron methyl 10% + chlorimuron ethyl 10% WP (pre-mix formulation) at 4 g a.i. ha^{-1} at 21-25 DAT/20 DAS. This was mainly because of pre emergence herbicides applied in these treatments where new herbicides under sulfonylurea group such as pyrazosulfuron-ethyl, bensulfuron methyl which reduced the density of complex weed flora at early stages of crop. Mode of action of pretilachlor is by inhibition of cell division and protein synthesis. Sangeetha *et al*. (2009) [8] also concluded that pre-emergence application of pretilachlor through starch formulation at 5 kg ha^{-1} was found to be effective in controlling weeds and thereby increasing the growth and yield of rice. Sunil *et al*. (2010) [11] also reported that pre-emergence application of bensulfuron methyl + pretilachlor (6.6 GR) @ 0.06 + 0.60 kg ha^{-1}, respectively + one inter-cultivation at 40 days after sowing recorded significantly lower weed population and its dry weight.

In later stage of critical crop weed competition in rice, hand weeding twice at 20 and 40 DAT/S recorded lower density of grass during both the years which might be due to the reason that in manual weeding, manual labourers possess greater knowledge to identify and remove all types of weeds especially grassy weeds which had grown along with rice seedlings in same hill with close resemblance of rice. Bhanu Rekha *et al*. (2002) [1] reported that hand weeding twice at 20 and 40 DAT resulted in significantly lower weed density and dry weight as compared to herbicide treatment and un-weeded check. Application of PE pyrazosulfuron ethyl at 30 g a.i. ha^{-1} at 3 DAT/8 DAS + POE bispyribac sodium at 20 g a.i. ha^{-1} at 15- 20 DAT/20 DAS was comparable with hand weeding due to the reason that post emergence herbicide of bispyribac sodium effectively controlled grassy weeds in rice crop. Yadav *et al*. (2009) reported that bispyribac sodium applied at 15 or 25 DAT was found equally effective against grassy weeds, but control of broad leaved weeds and sedges was comparatively more when applied at 15 DAT. Yadav *et al*. (2010) [13] also concluded that bispyribac sodium at 25 g ha^{-1} applied at 15 to 20 DAT could be a suitable herbicide for controlling complex weed flora in transplanted rice.

Regarding sedges, Cyperus rotundus was the only sedge weed which was observed in both the years of experimental field. This might be due to the presence of perennial nature which sustained to follow up rice crop. The other species *viz.*, Cyperus difformis, Fimristylis miliacea are annual sedges which were destroyed and decomposed along with incorporation of green manure crop daincha at 50 per cent flowering.

In different rice establishment methods, direct planting system recorded significantly lower density of Cyperus rotundus at all the stages in both the years which might have destroyed the weeds due to incorporation of weeds at the time of rotary thinning during early stage of crop. Mechanical and manual line transplanting methods were comparable with DPS with respect to reduced density of Cyperus rotundus. This is in conformity with the findings of Revathi (2009) [7]. Distinctly higher Cyperus rotundus density was observed in drum seeded rice at all the stages during both the years. This was mainly because of establishment of weed and rice plant

simultaneously and sedge weeds produced rhizomes and spread rapidly. Chauhan and Johnson (2009) [2] stated that weeds were a greater problem in direct seeded rice than that in transplanted rice because of the absence of the crop seedling size advantage and standing water at the time of crop emergence.

As far as weed management practices are concerned, the trend was similar as that of weed density of grasses as discussed above. Several authors reported that pre emergence application of pyrazosulfuron ethyl have ability to control sedge and broad leaved weed density effectively. Deepthi Kiran and Subramanyam (2010) [4] concluded that pyrazosulfuron-ethyl at 35 g ha^{-1} was very effective in reducing the density and dry weight of sedges than other pre-emergence herbicides. In the later stages, manual weeding also removed sedge weeds effectively. Un-weeded control recorded higher density of Cyperus rotundus at all the stages during both the years and this is because of the continuous growth of weeds throughout the cropping period which increased the density of all the types of weeds.

In the first year of study, broad leaved weed density was very low which means the relative density of broad leaved weeds was below 12.04 and 9.64 per cent at 30 and 60 DAT/S, respectively. Broad leaved weed species such as Ammania baccifera, Eclipta alba, Marselia quadrifoliata, Bergia capensis and Monochoria vaginalis were present under sodic soils around the experimental field. Whereas, in the experimental field, only Ammania baccifera, Eclipta alba and Bergia capensis were observed during *rabi* 2011-12. This might be due to the reason that the most of the broad leaved weeds were completely destroyed during incorporation and decomposition of pre sown rice crop daincha. Applied pre and post emergence herbicides also reduced the density of broad leaved weeds. In the second year of study, there complete absence of broad leaved weeds in the experimental field. This might be due to the reason that majority of the applied herbicides were belong to sulfonylurea group such as pyrazosulfuron ethyl, bensulfuron methyl, chlorimuron ethyl, metsulfuron methyl. It has eminent activity against a broad spectrum of annual and perennial rice weeds, especially broad leaved weeds and sedges, with pre-emergence and early post-emergence application and at extremely low use rates. The same trend was observed in total weed density during both the year of study (Table 1a, 1b and 2a, 2b).

Among crop establishment methods, direct planting system recorded laudably higher weed control efficiency of 76.67 and 78.23 per cent at 45 DAT/S during *rabi* 2011-12 and 2012-13, respectively. This was mainly because of the reason that in DPS, besides weeding treatment, rotary weeder was used to thin the plant stand twice at early stages of crop growth which was greatly reduced the weed density as well as weed dry weight.

With regard to weed management practices, higher weed control efficiency was recorded (81.40 and 80.91 per cent at 45 DAT/S during *rabi* 2011-12 and 2012-13, respectively) in two hand weeding at 20 and 40 DAT/S (Table 3). Because of the reason that manual weeding was more efficient to identify and destroy all group of weed at later stages of crop and it was followed by PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + POE Bispyribac Sodium 20 g a.i. ha^{-1} at 15-20 DAT / 20 DAS recorded higher weed control efficiency due to the reason that this herbicided combination effectively contolled weeds at early and later stages of crop accordingly it was recorded reduced weed dry weight when compared to other treatments during both the years of study. Bhanu Rekha *et al.* (2002) [1] reported that hand weeding twice at 20 and 40 DAT resulted in significantly lower weed density and dry weight as compared to herbicide treatment and un-weeded check.

Among crop establishment methods, direct planting system recorded significantly higher grain yield of 5048 and 4639 kg ha^{-1} during *rabi* 2011-12 and 2012-13, respectively (Table 4). This might be due to the reason that which possessed single seedling maintained like system of rice intensification due to rotary thinning at early stages, wider spacing (25×25 cm) better soil aeration due to rotary thinning and incorporation of weeds as well as extra seedling in to soil serves additional nutrient to crop. Grain yield is the product of number of filled grains per unit area. Similar findings were recorded by Kalaiyarasi *et al.* (2012) [5]. Distinctly lower grain yield was obtained with drum seeded rice (3756 and 3466 kg ha^{-1} during *rabi* 2011-12 and 2012-13, respectively) was mainly because of the reason that higher weed infestation leads to severe crop weed competition at early stages of crop which resulted in reduced yield.

Among weed management practices, hand weeding twice at 20 and 40 DAT/S recorded significantly higher grain yield (Table 4) and yield components like productive tillers m^{-2}, number of filled grains $panicle^{-1}$, and 1000 grain weight which might be due to the reason that manual weeding gave better weed controlled environment which provides higher rice yield. Subha Lakshmi and Venkata Ramana (2008) [10] indicated that hand weeding at 20 and 40 DAT recorded highest plant height, dry matter production, tillers m^{-2}, nutrient uptake by crop and lowest nutrient uptake by weeds throughout the crop growth period and registered higher grain and straw yield. Followed by PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + POE Bispyribac Sodium 20 g a.i. ha^{-1} at 15- 20 DAT / 20 DAS registered higher grain yield during both the years and this was mainly because of better weed control due to pre and post emergence application of herbicides which decreases the crop weed competition and increases the crop yield. Cherati *et al.* (2011) [3] concluded that chemical treatments were the best treatments because in all sampling stages, the least dry weight of weed produced and it has an important effect on yield while the most yield rate belonged to this treatment.

Table 1 a): Effect of crop establishment methods and weed management practices on total weeds density ($No.m^{-2}$) in rice during *rabi* 2011-12

Treatments	15 DAT/S					30 DAT/S				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	2.48(4.13)	1.91(1.67)	1.53(0.33)	2.71(5.33)	2.16(2.87)	2.85(6.17)	2.30 (3.33)	2.41(3.83)	3.53(10.50)	2.78(5.96)
S_2	2.35(3.54)	2.35(3.53)	1.83(1.33)	2.71(5.33)	2.31(3.44)	2.49(4.23)	1.71(0.93)	1.83(1.33)	2.40(3.77)	2.11(2.57)
S_3	2.71(5.33)	2.64(5.00)	1.73(1.00)	3.05(7.33)	2.53(4.67)	2.83(6.00)	2.64(5.00)	2.38(3.67)	3.91(13.33)	2.94(7.00)
S_4	2.70(5.33)	2.58(4.67)	2.10(2.43)	2.89(6.33)	2.57(4.69)	2.16(2.67)	1.91(1.67)	2.04(2.17)	3.00(7.00)	2.28(3.38)
S_5	3.38(9.43)	3.16(8.00)	2.47(4.10)	4.16(15.33)	3.29(9.22)	3.28(8.77)	2.69(5.27)	2.27(3.20)	3.62(11.10)	2.97(7.08)
S_6	3.72(11.90)	3.59(10.87)	2.77(5.67)	4.76(20.67)	3.71(12.28)	5.42(27.33)	4.97(22.67)	3.73(11.97)	7.23(50.33)	5.34(28.08)
Mean	2.89(6.61)	2.71(5.62)	2.07(2.48)	3.38(10.06)		3.17(9.19)	2.70(6.48)	2.44(4.36)	3.95(16.01)	

	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.05	0.08	0.18	0.19		0.07	0.11	0.21	0.22	
C.D.(P=0.05)	0.12	0.18	0.42	0.41		0.17	0.25	0.47	0.48	

(Figures in parenthesis are original values)

M1 – Manual line transplanting S1 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M2 – Mechanical line transplanting S2 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15- 20 DAT / 20 DAS

M3 – Direct planting system (DPS) S3 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M4 – Drum seeded rice (Sprouted seeds) S4 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15-20 DAT / 20 DAS

S5 – Two hand weeding at 20 and 40 DAT/S

S6 – Un-weeded control

Table 1 b): Effect of crop establishment methods and weed management practices on total weeds density (No.m^{-2}) in rice during *rabi* 2011-12

Treatments	45 DAT/S					60 DAT/S				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	2.72(5.40)	2.35(3.53)	2.52(4.37)	3.03(7.17)	2.65(5.12)	2.87(6.33)	2.77(5.67)	2.58(4.67)	3.39(9.50)	2.90(6.54)
S_2	2.49(4.24)	1.88(1.53)	1.88(1.55)	2.48(4.17)	2.18(2.87)	2.29(3.23)	2.38(3.67)	2.25(3.07)	3.00(7.00)	2.48(4.24)
S_3	2.94(6.67)	2.64(5.00)	2.52(4.33)	3.56(10.67)	2.91(6.67)	3.36(9.33)	2.94(6.67)	2.61(4.83)	3.78(12.33)	3.17(8.29)
S_4	2.24(3.03)	2.23(3.00)	2.26(3.10)	2.91(6.50)	2.41(3.91)	2.61(4.83)	2.64(5.00)	2.37(3.67)	3.08(7.50)	2.68(5.25)
S_5	2.16(2.67)	1.91(1.67)	1.73(1.00)	2.71(5.33)	2.13(2.67)	2.64(5.00)	2.38(3.67)	2.08(2.33)	3.10(7.60)	2.55(4.65)
S_6	6.71(43.00)	5.86(32.33)	4.69(20.00)	8.59(71.80)	6.46(41.78)	7.55(55.00)	7.14(49.00)	6.12(35.57)	9.25(83.63)	7.52(55.80)
Mean	3.21(10.83)	2.81(7.84)	2.60(5.73)	3.88(17.61)		3.55(13.96)	3.38(12.28)	3.00(9.02)	4.27(21.26)	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.08	0.12	0.20	0.21		0.10	0.14	0.25	0.25	
C.D.(P=0.05)	0.19	0.26	0.45	0.46		0.25	0.30	0.57	0.57	

(Figures in parenthesis are original values)

M1 – Manual line transplanting S1 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M2 – Mechanical line transplanting S2 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15- 20 DAT / 20 DAS

M3 – Direct planting system (DPS) S3 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M4 – Drum seeded rice (Sprouted seeds) S4 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15-20 DAT / 20 DAS

S5 – Two hand weeding at 20 and 40 DAT/S

S6 – Un-weeded control

Table 2 a): Effect of crop establishment methods and weed management practices on total weeds density (No.m^{-2}) in rice during *rabi* 2012-13

Treatments	15 DAT/S					30 DAT/S				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	2.38(3.67)	2.16(2.67)	1.82(1.33)	2.88(6.33)	2.31(3.50)	3.41(9.67)	3.16(8.00)	2.31(3.34)	3.87(13.00)	3.19(8.50)
S_2	2.45(3.99)	2.45(4.00)	1.82(1.33)	2.88(6.33)	2.40(3.91)	3.00(6.99)	2.31(3.33)	1.82(1.33)	2.94(6.67)	2.52(4.58)
S_3	3.21(8.34)	3.00(7.01)	2.31(3.34)	3.36(9.34)	2.97(7.01)	3.51(10.33)	3.41(9.67)	2.64(5.00)	4.28(16.33)	3.46(10.33)
S_4	2.88(6.33)	2.83(6.00)	2.08(2.33)	3.16(7.99)	2.74(5.66)	2.94(6.67)	2.58(4.66)	2.24(3.00)	3.41(9.67)	2.79(6.00)
S_5	3.56(10.67)	3.41(9.66)	2.38(3.67)	4.58(19.00)	3.48(10.75)	3.60(11.00)	3.16(8.01)	2.64(5.00)	4.08(14.66)	3.37(9.67)
S_6	4.16(15.34)	3.91(13.33)	2.94(6.66)	4.97(22.67)	3.99(14.50)	5.97(33.66)	5.4(27.34)	4.47(18.00)	7.02(47.34)	5.72(31.59)
Mean	3.11(8.06)	2.96(7.11)	2.23(3.11)	3.64(11.94)		3.74(13.05)	3.34(10.17)	2.69(5.95)	4.27(17.95)	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.05	0.09	0.19	0.19		0.04	0.07	0.08	0.10	
C.D.(P=0.05)	0.12	0.20	0.42	0.43		0.10	0.16	0.18	0.21	

(Figures in parenthesis are original values)

M1 – Manual line transplanting S1 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M2 – Mechanical line transplanting S2 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15- 20 DAT / 20 DAS

M3 – Direct planting system (DPS) S3 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS

M4 – Drum seeded rice (Sprouted seeds) S4 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE bispyribac sodium 20 g a.i. ha-1 at 15-20 DAT / 20 DAS

S5 – Two hand weeding at 20 and 40 DAT/S

S6 – Un-weeded control

Table 2 b): Effect of crop establishment methods and weed management practices on total weeds density (No.m^{-2}) in rice during *rabi* 2012-13

Treatments	45 DAT/S					60 DAT/S				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	3.46 (9.99)	3.16 (8.00)	2.51 (4.33)	3.78 (12.34)	3.23 (8.67)	3.77 (12.33)	3.51 (10.33)	2.95 (6.67)	4.20 (15.67)	3.60 (11.25)
S_2	3.00(7.00)	2.52(4.34)	1.82(1.33)	2.94(6.67)	2.57(4.84)	3.31(9.00)	3.05(7.32)	2.38(3.66)	3.69(11.67)	3.11(7.91)
S_3	4.00(14.00)	3.36(9.33)	2.94(6.67)	4.12(15.00)	3.61(11.25)	4.28(16.33)	4.00(14.00)	3.36(9.33)	4.93(22.33)	4.14(15.50)
S_4	3.11(7.66)	2.64(5.00)	2.16(2.66)	3.26(8.67)	2.79(6.00)	3.51(10.34)	3.16(8.00)	2.70(5.34)	3.78(12.34)	3.29(9.00)
S_5	2.44(4.00)	2.16(2.66)	1.53(0.33)	2.88(6.33)	2.25(3.33)	3.05(7.33)	2.58(4.67)	2.24(3.00)	3.41(9.67)	2.82(6.17)
S_6	6.78(44.00)	6.16(36.00)	5.38(27.00)	7.95(61.34)	6.57(42.09)	8.00(62.00)	7.32(51.67)	6.50(40.33)	8.9(77.33)	7.68(57.83)
Mean	3.80(14.44)	3.33(10.89)	2.73(7.05)	4.16(18.39)		4.32(19.56)	3.94(16.00)	3.35(11.39)	4.82(24.84)	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.10	0.14	0.20	0.21		0.08	0.13	0.18	0.20	
C.D.(P=0.05)	0.25	0.30	0.46	0.48		0.21	0.30	0.41	0.45	

(Figures in parenthesis are original values)

M1 – Manual line transplanting ha-1 at 21-25 DAT / 20 DAS
M2 – Mechanical line transplanting sodium 20 g a.i. ha-1 at 15- 20 DAT / 20 DAS
M3 – Direct planting system (DPS) a.i. ha-1 at 21-25 DAT / 20 DAS
M4 – Drum seeded rice (Sprouted seeds) sodium 20 g a.i. ha-1 at 15-20 DAT / 20 DAS

S1 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE AlmixTM 4 g a.i.
S2 – PE pyrazosulfuron ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE bispyribac
S3 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE AlmixTM 4 g
S4 – PE Londax PowerTM 10.0 kg ha-1 at 0-3 DAT / 10-15 DAS + POE bispyribac
S5 – Two hand weeding at 20 and 40 DAT/S
S6 – Un-weeded control

Table 3: Effect of crop establishment methods and weed management practices on weed control efficiency (per cent) in rice at 45 DAT/S during *rabi* 2011-12 and 2012-13

Treatments	***Rabi* 2011-12**	***Rabi* 2012-13**
Establishment methods		
M_1 - Manual line transplanting	73.81	74.36
M_2 - Mechanical line transplanting	76.03	74.68
M_3 - Direct Planting System (DPS)	76.67	78.23
M_4 - Drum seeded rice (Sprouted seeds)	72.32	74.38
Weed management practices		
S_1 - PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + POE Almix^{TM} 4 g a.i. ha^{-1} at 21-25 DAT / 20 DAS	72.62	73.52
S_2 - PE Pyrazosulfuron Ethyl 30 g a.i. ha^{-1} at 3 DAT / 8 DAS + POE Bispyribac Sodium 20 g a.i. ha^{-1} at 15- 20 DAT / 20 DAS	75.51	78.48
S_3 - PE Londax power^{TM} 10.0 Kg ha^{-1} at 0-3 DAT / 10-15 DAS + POE Almix^{TM} 4 g a.i. ha^{-1} at 21-25 DAT / 20 DAS	70.83	68.52
S_4 - PE Londax power^{TM} 10.0 Kg ha^{-1} at 0-3 DAT / 10-15 DAS + POE Bispyribac sodium 20 g a.i. ha^{-1} at 15-20 DAT / 20 DAS	73.17	75.64
S_5 - Two hand weeding at 20 and 40 DAT/S	81.40	80.91
S_6 - Un-Weeded control	-	-

(Data statistically not analysed)

Table 4: Effect of crop establishment techniques and weed management practices on grain yield (kg ha^{-1}) of rice during *rabi* 2011-12 and 2012-13

Treatments	***Rabi* 2011-12**					***Rabi* 2012-13**				
	M1	**M2**	**M3**	**M4**	**Mean**	**M1**	**M2**	**M3**	**M4**	**Mean**
S1	4157	4479	4926	3765	4332	4084	4240	4471	3398	4048
S2	4935	5061	5424	4295	4929	4634	4705	5107	4101	4637
S3	4078	4393	4715	3334	4130	3906	3987	4300	3167	3840
S4	4728	4776	5284	3817	4651	4350	4550	4786	3579	4316
S5	5268	5471	5759	4843	5335	5060	5194	5486	4508	5062
S6	3345	3986	4179	2480	3497	3018	3230	3685	2040	2993
Mean	4418	4694	5048	3756		4176	4318	4639	3466	
	M	S	M at S	S at M		M	S	M at S	S at M	
S.Ed.	101	176	176	223		85	162	132	188	
C.D.(P=0.05)	246	392	399	497		207	360	300	420	

M1 – Manual line transplanting
M2 – Mechanical line transplanting
M3 – Direct Planting System (DPS)
M4 – Drum seeded rice (Sprouted seeds)
S1 – PE Pyrazosulfuron Ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS
S2 – PE Pyrazosulfuron Ethyl 30 g a.i. ha-1 at 3 DAT / 8 DAS + POE Bispyribac Sodium 20 g a.i. ha-1 at 15- 20 DAT / 20 DAS
S3 – PE Londax powerTM 10.0 Kg ha-1 at 0-3 DAT / 10-15 DAS + POE AlmixTM 4 g a.i. ha-1 at 21-25 DAT / 20 DAS
S4 – PE Londax power TM10.0 Kg ha-1 at 0-3 DAT / 10-15 DAS + POE Bispyribac sodium 20 g a.i. ha-1 at 15-20 DAT / 20 DAS
S5 – Two hand weeding at 20 and 40 DAT/S
S6 – Un-Weeded control

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