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Cultivation method and weed management practices in rice (*Oryza sativa* L.)

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Abstract
Rice is a principal source of food for more than half of the world population. The only way to meet the future food requirements is to increase the productivity per unit area by utilizing improved production technology such as System of Rice Intensification (SRI) and Direct Seeded Rice (DSR). Weed management is the foremost component in rice, 15 to 90% of crop losses in India occurs depending upon the various establishment methods. An experiment was carried out in the agricultural farm, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, West Bengal, under sub-humid, semi arid region of West Bengal during kharif session of 2014 and 2015 for studying the effect of different cultivation method and weed management practices on growth and productivity of rice under lateritic belt of West Bengal. The experiment was laid out in split plot design with three main plot treatment and five sub plot treatments with three replications. Sowing methods used for the experiment were M1: DSR, M2: SRI and M3: Conventional method of rice cultivation and sub plots treatments were application of S1-Azimsulfuron @35 g a.i per ha at 20 DAS/DAT, S2-Bensulfuron Methyle+Pretilachlor@70g +700 g a.i. per ha at 2 DAS/DAT, S3: two hand weeding at 30 DAT & 45 DAT, S4: Cono-weeder at 30 DAT and variety of rice used for transplanting was Naveen. Result revealed that the growth characters and yield attributes of rice in all the growth stages in both the years were recorded highest in SRI method followed by DSR method and conventional method and among the weed control methods the highest values were seen in case of application azimsulfuron @35 g a.i. per ha, followed by bensulfuron methyl + pretilachlor @70g +700 g a.i. per ha and then conoweeder followed by hand weeding. The treatment combination SRI with use of azimsulfuron @35 g a.i. per ha recorded significantly highest values of growth characters and yield attributes in respect with other treatment combination.

Keywords: DSR, SRI, Cono-weeder, azimsulfuron, bensulfuron methyl, pretilachlor

Introduction
Rice is an important source of food for more than half of the world population. About 90 percent of the total rice is grown and consumed in Asia. In most Asian countries rice is grown by manual transplanting of seedlings into puddled soil. However, this operations leads to high losses of water through surface evaporation and percolation. Because of the decreased availability of water or labour and increased production cost, farmers in many Asian countries have been or are shifting from manual transplanting to direct seeded rice system, dry seeded, wet-seeded and water seeded. Tabbal *et al.*, 2002 [24] reported that in recent years, several strategies, *viz*. direct sowing of rice, alternate wetting and drying, etc. have been tried. Beside these methods of rice cultivation System of Rice Intensification (SRI) is reported as a sustainable low-cost alternative to the conventional rice farming. This system ensures high yields with less input, especially with respect to irrigation water and seed. Heavy weed growth is a major problem in SRI mainly because of the wider spacing and lack of flooding in the field. Therefore, SRI warrants repeated weeding either by hand or by machine weeders such as the cono weeder. Latif *et al.* (2005) reported the effectiveness of using herbicides in SRI, which could reduce labour for weeding and thereby minimize economic loss in SRI. In recent years, several strategies, *viz*. direct sowing of rice, alternate wetting and drying, etc. have been tried (Tabbal *et al.*, 2002, Singh *et al*. 2017a; Singh *et al.* 2017b; Singh *et al.* 2017c; Singh *et al.* 2018; Tiwari *et al.* 2018; Tiwari *et al.* 2019a; Tiwari *et al.* 2019b; Kour *et al.* 2019; Singh

et al. 2019) [24, 14, 15, 16, 17, 18, 19, 20, 21]. In India, yearly loss of rice grain production is around 15 million tons due to heavy weed infestation (Singh *et al*., 2018) [17]. Weed management is considered as one of the difficult task in rice due to simultaneous emergence of crops and weed. Weeds not only compete with the crops for space, light, water and nutrients but also hinder its quality. Weeds emerge at the initial crop growth stage are highly competitive than late emerging weeds. Hence the timely weed management is essential for rice cultivation. However, manual weeding is the traditional method with increased wages and labour demand for migration owing to in non-agricultural sectors; it is difficult to find requisite labour at peak periods. Hence, chemical weed management by the combination of pre and post emergence herbicides is highly efficient and cost effective method.

Materials and Method

The experiment was conducted at the agricultural Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal ($23^0$39' N, $87^0$42' E and 58.90 m above mean sea-level) during two consecutive kharif season of 2014 and 2015 to study on cultivation method and weed management practices in rice (*Oryza sativa* L.) The soil of the experimental field was alluvial (Haplaquept), sandy loam in texture, acidic (5.73) with low level of organic carbon (0.46 %) and available nitrogen (137.49 kg N ha^{-1}) but high level of available phosphorus (31.54 kg P ha^{-1}) and medium level of potassium (146.31 kg K ha^{-1}). The experiment was laid out in split plot design. In the main plot treatments the sowing methods were used Direct Seeded Rice (DSR), System of Rice Intensification (SRI), and Conventional method of Rice Cultivation (CRT). In case of sub-plot treatments, weed control measures *viz*.- Azimsulfuron @35g a.i per ha.at 20DAT/DAS, BensulfuronMethyle+Pretilachlor@70g+700g a.i per ha at 2DAT/DAS, Hand weeding at 30 and 45 DAT/DAS, Cono weeder at 30 DAT/DAS. Seed were treated with bavistin@ 2gm kg^{-1} of seed and pre-germinated seeds of the test variety Naveen (125 days duration) were used at a spacing of 20cm X 15 cm with 3 seedlings per hill in case of CRT and in SRI the 14 days old seedling at a spacing of 22.5 cm x 22.5 cm were transplanted in the main field with one seedling transplanted per hill. The fertilizers were applied considering 80:40:40 kg of N: P_2O_5: K_2O ha^{-1} as recommended dose. The sources of fertilizers were urea for N, Single super phosphate (SSP) for P and Muriate of potash (MOP) for K. Half dose of nitrogen and full dose of phosphorus & potassium were applied as basal dose before transplanting. The remaining half of nitrogen was applied as top dressing at 30 days after transplanting and 60 DAT i.e. at active tillering stage and panicle initiation stage. The growth parameters were recorded at different stages of the crop from each plot were randomly selected.

Result and Discussion

The experimental result revealed that the major weed flora associated with the transplanted rice during kharif season in new alluvial zone of West Bengal was mainly comprised of *Echinochloa colona* (30%), *Cyperus difformis* (20%), *Monochoria vaginalis* (30%) and *Ludwigia parviflora* (20%). All the treatments registered significantly lower number of weeds than control plot. The weed dry weight (g m^{-2}) were recorded at 45 DAT and 60 DAT were statistically analyzed after necessary transformation [$\sqrt{(x + 0.5)}$]. The analysis of two years data indicated that among the cultivation method the highest weed dry weight was found in conventional method of rice cultivation (4.08 gm^{-2}at 60 DAT for broad leafed weed in 2014; 3.81 gm^{-2}at 60DAT for grassy weed in 2014 and 2.96 gm^{-2}at 60DAT for sedges in 2015) and lowest result was found in System of Rice Intensification (SRI) (3.35 gm^{-2}at 45 DAT for broad leafed weed; 3.06 gm^{-2}at 45DAT for grassy weed in 2014 and 1.80 gm^{-2}at 45DAT for sedges in 2014) and in weed control method dry weight of broad leaved weeds, grassy weeds and sedges at 45 DAT/DAS and 60 DAT/DAS were highest in the use of mechanical weed control method i.e. use of cono-weeder (3.24 gm^{-2} at 60 DAT for broad leafed weed in 2014; 3.07 gm^{-2}at 60DAT for grassy weed in 2014 and 2.96 gm^{-2}at 60DAT for sedges in 2014) and the lowest data was found in use of herbicide azimsulfuron (2.00 gm^{-2}at 60 DAT for broad leafed weed in 2015; 1.93 gm^{-2}at 45DAT for grassy weed in 2014 and 1.37 gm^{-2}at 45DAT for sedges in 2015) and among the treatment combination with weed control method the highest result recorded at Conventional method with mechanical weeding (cono-weeder at 30 DAT) and the lowest result found in System of Rice Intensificaton with Azimsulfuron @35 g a.i. ha^{-1} (Table-1). All the herbicidal treatment resulted in significant reduction in number of total weed m^{-2} than physical and mechanical weeding method. Among the sowing method in both years the highest result recorded at 45 DAT and 60 DAT on Conventional method of transplanting (5.35m^{-2} at 45 DAT in 2014) and the lowest result on System of Rice Intensification and in the weed management treatment (4.36m^{-2} at 45 DAT in 2015), in both years, the lowest number of total weed m^{-2} was recorded in use of azimsulfuron @35 g a.i ha^{-1} (3.55 m^{-2} at 60 DAT in 2014) and the highest value was recorded at mechanical weeding with cono-weeder at 30DAT [1] (4.40 m^{-2} at 45 DAT in 2014). Saha and Rao 2012 reported that Azimsulfuron is a recently introduced post-emergent sulfonylurea herbicide useful for controlling broad-spectrum of weeds in rice field. Its efficacy against rice weeds has been found excellent. Among the interaction effect of weed management with sowing method the highest value recorded at Conventional method X Mechanical weeding with cono-weeder at 30 DAT and the lowest value observed at M2S1: System of Rice Intensification X Azimsulfuron @35 g a.i ha^{-1} (Table-1).

Table 1: Dry weight (g m^{-2}) and Weed density of Broad Leaved Weeds, Grassy Weeds and Sedges at 45 DAT and 60 DAT of transplanted rice 2014 and 2015.

Sowing method	Dry weight (g m^{-2})												Weed density			
	45 DAT					60DAT							45DAT		60DAT	
	Broad Leaved Weed		Grassy weed		Sedge	Broad Leaved Weed		Grassy weed		Sedge						
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
M1:Direct Seeded Rice	3.66	3.63	3.41	3.57	2.11	2.10	3.66	3.31	3.43	3.41	2.65	2.64	4.96	4.91	4.94	5.05
M2:System of Rice Intensification (SRI)	3.35	3.41	3.06	3.26	1.80	1.82	4.35	4.39	4.38	4.18	3.54	3.33	4.47	4.36	4.44	4.37
M3:Conventional method of Rice Cultivation (CRT)	3.84	3.95	3.57	3.76	2.52	2.27	4.08	3.84	3.81	3.61	2.95	2.96	5.35	5.27	5.12	5.29
SE(m)±	0.22	0.20	0.19	0.22	0.10	0.07	0.24	0.27	0.16	0.14	0.12	0.13	0.26	0.23	0.25	0.21

CD(P=0.05)	0.62	0.56	0.54	0.62	0.29	0.21	0.68	0.75	0.44	0.39	0.33	0.35	0.72	0.65	0.71	0.57
Weed control method																
S1: Azimsulfuron @35 g a.i. per ha.	2.20	2.25	1.93	2.12	1.42	1.37	2.21	2.00	2.32	2.04	2.27	2.26	3.71	3.64	3.55	3.60
S2:Bensulfuron Methayle+Pretilachlor @70g +700 g a.i. per ha	2.50	2.55	2.23	2.41	1.72	1.66	2.41	2.32	2.66	2.60	2.56	2.56	4.01	3.94	3.84	4.00
S3: Two hand weeding at 30 DAT & 45 DAT	2.56	2.61	2.29	2.48	1.78	1.73	2.47	2.46	2.75	2.69	2.63	2.62	4.07	4.00	3.91	4.05
S4: Mechanical weeding with cono-weeder at 30 DAT	2.89	2.94	2.62	2.81	2.11	2.06	3.24	2.98	3.07	3.02	2.96	2.95	4.40	4.33	4.24	4.36
S5: Control Plot	7.93	7.98	7.67	7.85	3.67	3.51	9.82	9.47	8.55	8.31	4.82	4.49	8.44	8.31	8.63	8.51
SE(m)±	0.26	0.26	0.26	0.26	0.09	0.07	0.23	0.32	0.17	0.15	0.24	0.12	0.21	0.24	0.41	0.38
CD(P=0.05)	0.54	0.54	0.54	0.54	0.19	0.15	0.47	0.67	0.34	0.31	0.50	0.26	0.44	0.49	0.84	0.78
Treatment combination with weed control method																
M1S1	2.20	2.18	1.95	2.12	1.33	1.37	2.12	1.91	2.33	2.08	2.27	2.27	3.77	3.67	3.55	3.57
M1S2	2.57	2.55	2.32	2.49	1.70	1.74	2.49	2.35	2.71	2.46	2.64	2.64	4.14	4.04	3.92	4.16
M1S3	2.64	2.61	2.39	2.55	1.76	1.80	2.56	2.41	2.79	2.54	2.70	2.70	4.20	4.10	3.98	4.23
M1S4	2.92	2.89	2.67	2.84	2.04	2.09	3.47	3.32	3.08	2.90	2.99	2.98	4.49	4.39	4.27	4.51
M1S5	7.96	7.93	7.71	7.87	3.71	3.51	9.75	9.22	8.13	8.08	4.16	4.22	8.21	8.35	8.96	8.78
M2S1	1.79	1.85	1.50	1.70	0.91	0.95	1.96	1.56	1.80	1.74	1.85	1.85	3.17	3.10	3.13	3.10
M2S2	2.24	2.31	1.95	2.16	1.36	1.41	2.13	2.00	2.35	2.32	2.31	2.30	3.62	3.55	3.59	3.63
M2S3	2.29	2.35	2.00	2.20	1.41	1.45	2.18	2.04	2.47	2.43	2.35	2.36	3.67	3.60	3.63	3.63
M2S4	2.70	2.76	2.41	2.61	1.82	1.86	2.92	2.40	2.79	2.75	2.76	2.79	4.08	4.01	4.04	3.99
M2S5	7.73	7.79	7.44	7.64	3.49	3.41	9.11	8.54	7.75	7.83	3.96	3.94	7.82	7.55	7.81	7.49
M3S1	2.61	2.71	2.34	2.52	2.03	1.77	2.54	2.54	2.84	2.31	2.67	2.67	4.20	4.16	3.95	4.14
M3S2	2.68	2.79	2.41	2.60	2.10	1.85	2.61	2.61	2.92	3.03	2.75	2.74	4.27	4.24	4.03	4.21
M3S3	2.75	2.86	2.48	2.67	2.18	1.92	2.69	2.94	3.00	3.11	2.82	2.82	4.34	4.31	4.10	4.29
M3S4	3.05	3.16	2.78	2.97	2.47	2.22	3.32	3.23	3.34	3.42	3.12	3.11	4.64	4.61	4.40	4.58
M3S5	8.12	8.23	7.85	8.04	3.82	3.61	10.62	10.64	9.78	9.04	6.33	5.31	9.30	9.03	9.13	9.25
SE(m)±	0.45	0.45	0.43	0.45	0.16	0.13	0.39	0.56	0.29	0.26	0.42	0.21	0.37	0.41	0.70	0.62
CD(P=0.05)	0.93	0.93	0.90	0.93	0.33	0.28	0.81	1.16	0.59	0.53	0.86	0.44	0.77	0.85	1.45	1.35

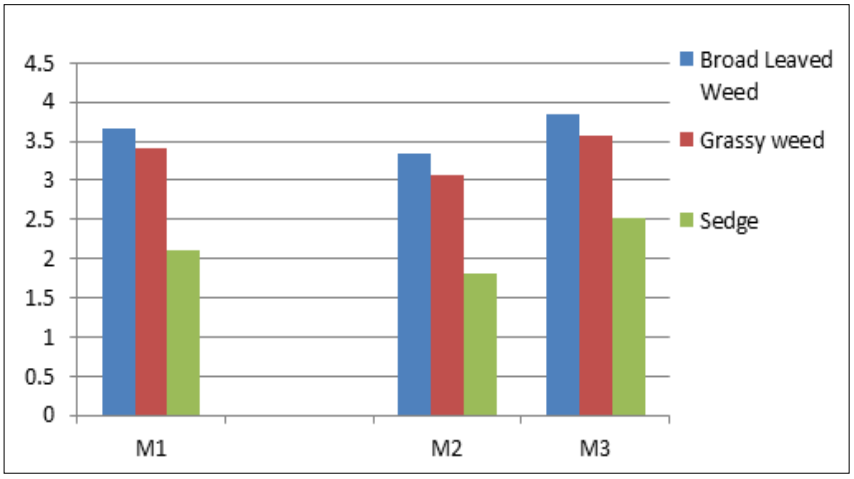

Fig 1: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 45 DAT in sowing method of transplanted rice 2014

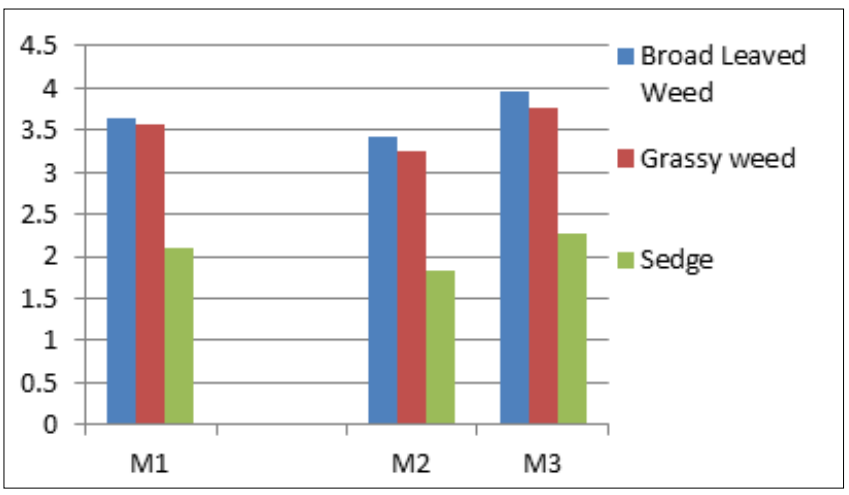

Fig 2: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 45 DAT in sowing method of transplanted rice 2015

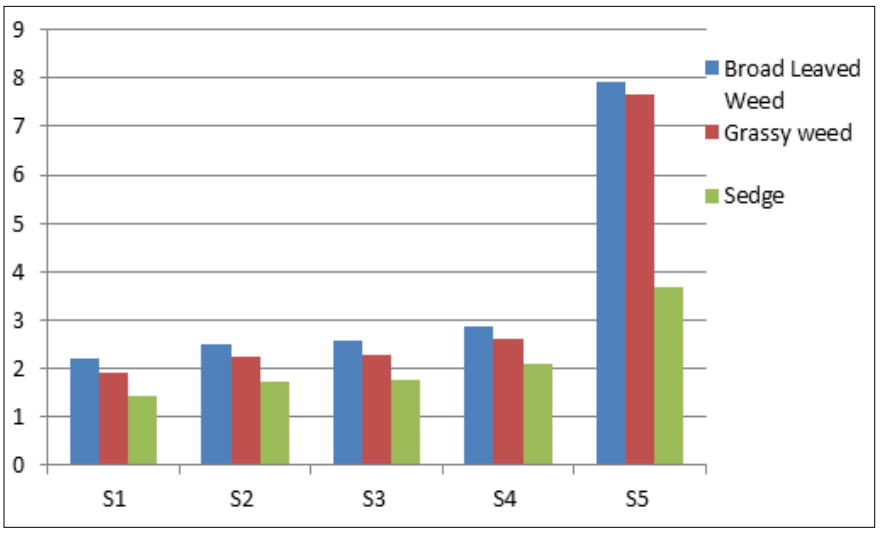

Fig 3: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 45 DAT in Weed control method of transplanted rice 2014

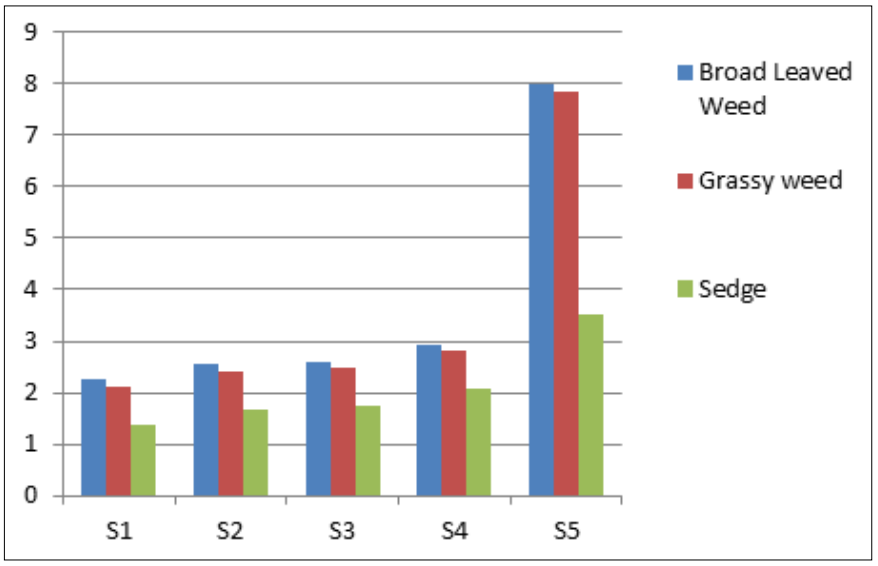

Fig 4: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 45 DAT in weed control method of transplanted rice 2015.

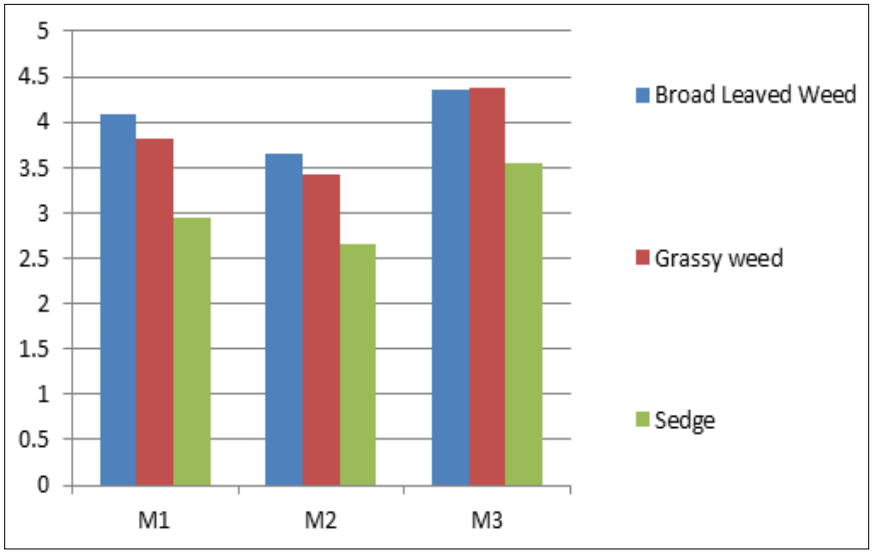

Fig 5: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 60 DAT in Sowing method of transplanted rice 2014.

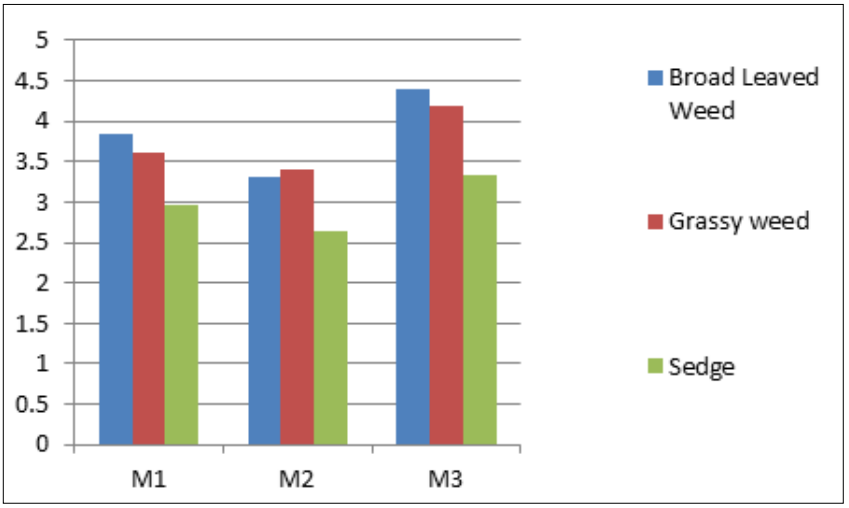

Fig 6: Effect of weed control measure on dry weight (g m^{-2}) of Broad Leaved Weeds, Grassy Weeds and Sedges at 60 DAT in Sowing method of transplanted rice 2015.

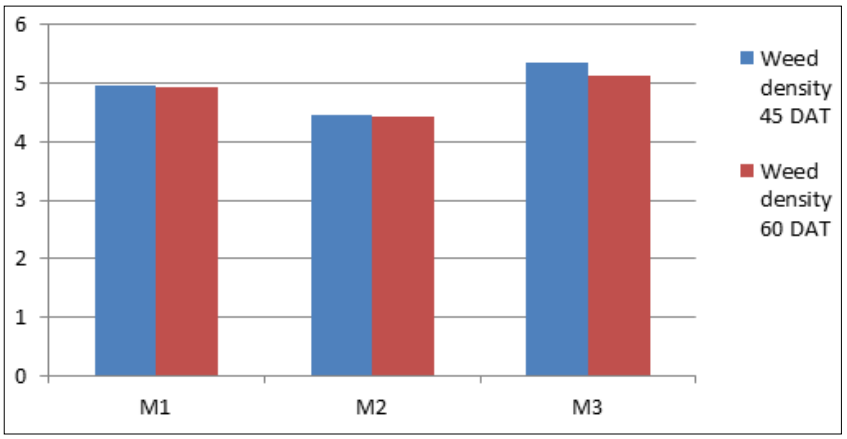

Fig 7: Effect of weed control measure on number of total weeds m^{-2} of different sowing method at 45 DAT and 60 DAT in transplanted rice at 2014

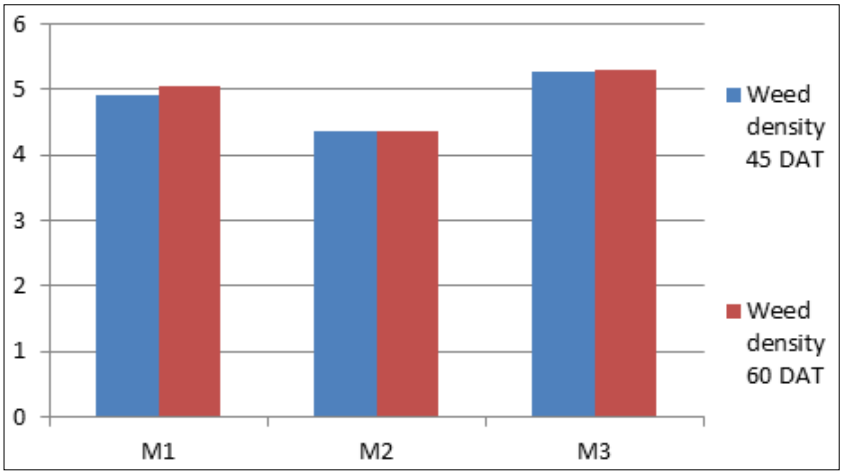

Fig 8: Effect of weed control measure on number of total weeds m^{-2} of different sowing method at 45 DAT and 60 DAT in transplanted rice at 2015.

Effect of weed control measure on different growth attributes of transplanted rice in 2014 and 2015: Data recorded at different growth stages (20DAT, 40DAT, 60DAT, 80 DAT and at harvest stage) in both years (2014 &2015) for plant height were statistically analyzed. The result of the experiment indicated that plant height of rice at different growth stages were significantly influenced by the weed management practices and methods of cultivation. The increasing trend in plant height was noticed with the advancement of the crop growth up to harvest. The result revealed that in cultivation method the highest value observed in System of Rice Intensification (113.17cm at harvesting stage in 2015) followed by Direct Seeded Rice (106.07 cm at harvesting stage in 2015) and lowest value observed in Conventional method of application (101.86 cm at harvesting stage in 2015). Sharma and Masand (2008) [9] to compare the performance of SRI *vis-a-vis* conventional transplanting revealed that SRI produced taller plants than conventionally transplanted rice. highest value of plant height was recorded and on the other hand the highest value recorded in the weed

control method observed on use of Azimsulfuron@35g a.i./ha (116.26 cm at harvesting stage in 2014) followed by use of bensulfuron methyl + pretilachlor @70g +700 g a.i. per ha. (110.58 cm at harvesting stage in 2014) and the lowest plant height was observed in the hand weeding (104.59 DAT in 2015) immediately followed by cono weeder. The treatment combination of System of Rice Intensification (SRI) with use of weedicide azimsulfuron registered significantly highest values of plant height (125.91 cm at harvesting stage in 2015) which is comparable with others treatment combination among the two years at the different growth stages (Table-2).

Table 2: Effect of weed control measure on Plant Height (cm) transplanted rice in 2014, 2015.

Sowing method	20DAT		40DAT		60 DAT		80DAT		AT Harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
M1:Direct Seeded Rice	20.29	20.14	52.53	52.30	71.85	71.96	102.33	102.62	105.66	106.07
M2:System of Rice Intensification (SRI)	22.04	22.31	57.21	56.98	77.11	77.22	108.10	108.53	112.18	113.17
M3:Conventional method of Rice Cultivation (CRT)	19.31	19.26	47.61	47.38	68.66	68.77	98.97	99.58	102.73	101.86
SE(m)±	0.63	0.54	1.66	1.66	1.88	1.87	2.68	2.69	2.73	3.18
CD(P=0.05)	1.75	1.51	4.61	4.61	5.21	5.20	7.43	7.49	7.58	8.83
Weed control method										
S1:Azimsulfuron @35 g a.i. per ha.	23.57	23.34	60.71	60.48	80.74	80.85	112.03	112.91	116.26	117.46
S2:Bensulfuron Methayle+Pretilachlor@70g +700 g a.i. per ha	22.15	22.31	56.39	56.16	75.55	75.66	106.30	107.76	110.58	111.46
S3: Two hand weeding at 30 DAT & 45 DAT	19.07	19.14	51.61	51.39	72.30	72.42	102.18	102.30	105.40	104.59
S4: Mechanical weeding with cono-weeder at 30 DAT	19.09	19.31	51.87	51.65	72.42	72.53	102.81	103.44	106.03	106.29
S5: Control Plot	18.85	18.77	41.65	41.43	61.70	61.81	92.37	91.49	9.02	95.37
SE(m)±	0.69	0.69	1.74	1.74	2.40	2.40	3.40	3.42	3.67	3.54
CD(P=0.05)	1.42	1.43	3.58	3.58	4.95	4.95	7.02	7.06	7.57	7.31
Treatment combination with weed control method										
M1S1	23.00	22.04	61.43	61.21	79.65	79.76	111.54	111.89	115.26	116.17
M1S2	22.90	22.62	56.28	56.05	76.21	76.32	106.42	106.76	109.64	109.99
M1S3	18.29	18.65	51.76	51.53	70.71	70.84	100.93	101.28	104.16	104.52
M1S4	18.77	19.13	52.31	52.09	71.57	71.68	101.77	102.12	105.00	105.36
M1S5	18.50	18.26	40.85	40.63	61.11	61.22	91.00	91.06	94.22	94.30
M2S1	25.94	26.36	67.79	67.56	85.77	85.89	115.98	118.96	121.22	125.91
M2S2	23.11	23.65	62.33	62.11	79.54	79.65	111.36	111.95	116.85	116.73
M2S3	20.80	21.37	58.43	58.21	78.39	78.50	107.57	105.61	110.74	108.85
M2S4	20.65	20.50	55.04	54.81	78.01	78.12	108.21	112.10	111.44	115.34
M2S5	19.70	19.68	42.44	42.22	63.87	63.98	97.39	94.00	100.62	99.02
M3S1	21.78	21.61	52.90	52.68	76.79	76.90	108.56	107.87	112.29	110.31
M3S2	20.43	20.64	50.56	50.33	70.90	71.01	101.11	104.57	105.29	107.65
M3S3	18.13	17.40	44.65	44.42	67.82	67.93	98.03	100.00	101.25	100.40
M3S4	17.86	18.30	48.27	48.05	67.69	67.80	98.43	96.08	101.65	98.18
M3S5	18.34	18.36	41.67	41.49	60.11	60.00	88.73	89.40	93.22	92.79
SE(m)±	1.19	1.20	3.09	3.01	4.16	4.12	5.89	5.92	6.36	6.13
CD(P=0.05)	2.46	2.48	6.21	6.21	8.58	8.45	12.16	12.23	13.12	12.66

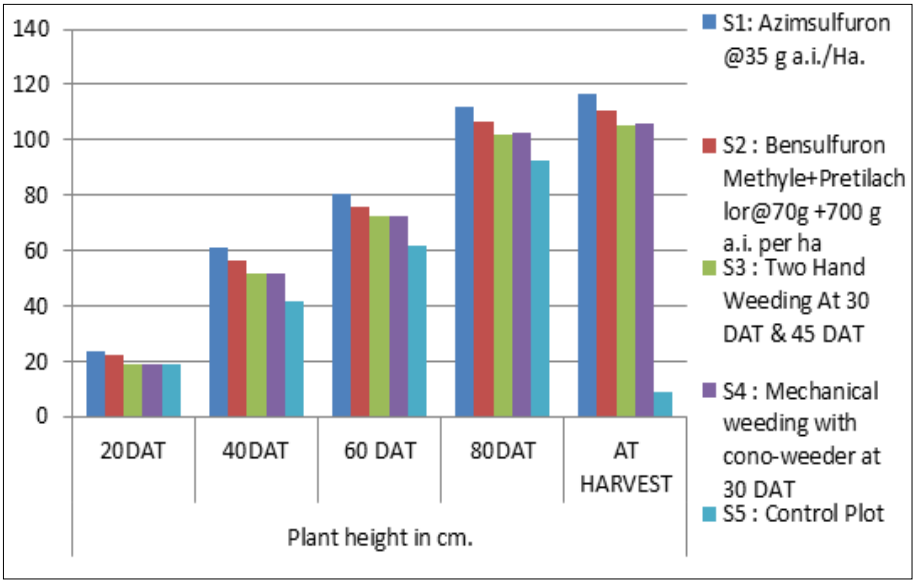

Fig 9: Effect of weed control measure on plant height (cm) in use of weed control method, 2014

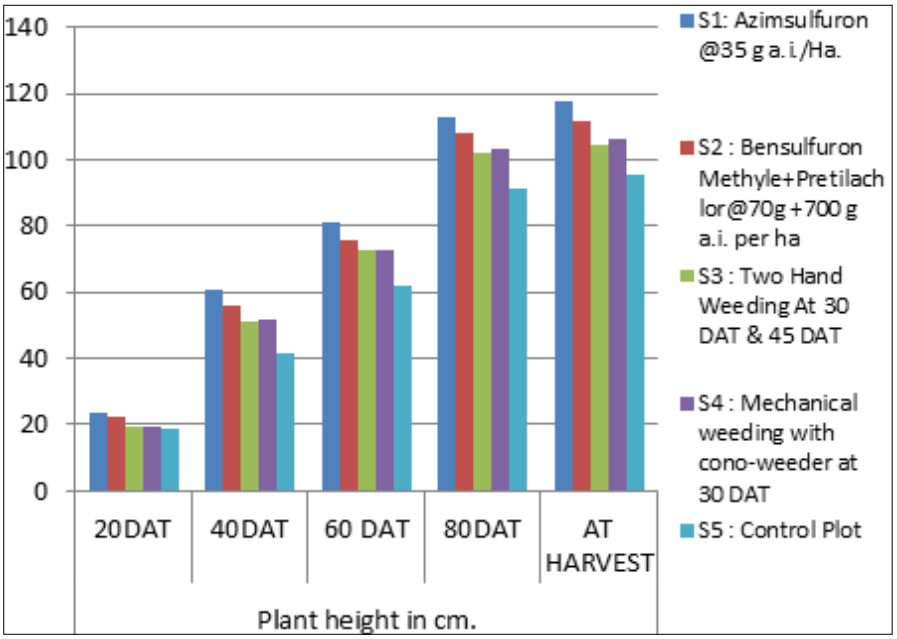

Fig 10: Effect of weed control measure on plant height (cm) in use of weed control method, 2015

In the other hand total dry matter production (gm^{-2}), leaf area index and crop growth rate (g $m^{-2}day^{-1}$) was progressively increased from 40 DAT to 80 DAT in all level of treatment. The Total dry matter production, leaf area index and crop growth rate (g $m^{-2}day^{-1}$) also varied significantly among the sowing method when observation was recorded among the two experimental years. The highest values registered in System of Rice Intensification (800.70 gm^{-1} at 80 DAT in 2014 for total dry matter production, 4.49 at 60DAT in 2015 for leaf area index and 10.63 at 60-80 DAT in 2015 for crop growth rate) followed by Direct Seeded Rice (M1). The lowest value was registered in Conventional method of Rice Cultivation. Same report observed that Singh *et al*. (2008) [17] In case of weed management treatments, there was significant difference among the treatment in both the years. At all the growth stages, the highest total dry matter production, leaf area index and crop growth rate (g $m^{-2}day^{-1}$) at 40-60 DAT and 60 to 80 DAT was observed in use of Azimsulfuron @35 g a.i./ha. (). followed by Bensulfuron Methyle+ Pretilachlor@70g +700 g a.i. per ha and the lowest value among the weed management treatment in both the years was observed in use of mechanical weeding with cono-weeder at 30 DAT (in total dry matter production 860.98 gm^{-1} in 2014 at 80 DAT and 859.78 gm^{-1} in 2014 at 80 DAT, in leaf area index 3.95 at 80DAT and 3.87 AT 80 DAT in 2015 and in Crop growth rate 9.66 at 60-80 DAT in 2014 and 9.77 at 60-80 DAT in 2015). All the weed management treatments were significantly superior than control plot. This is in accordance with the findings of Singh *et al*. (2013) [13]. All the herbicidal weed management treatment was significantly superior than hand weeding and mechanical weeding. This result is in agreement with the results obtained by Nayak *et al*. (2014). Considering the both year, the highest value was recorded in the treatment combination of System of Rice Intensification X Azimsulfuron @35 g a.i./Ha.(M2S1) followed by Direct Seeded Rice X Azimsulfuron @35 g a.i./Ha (M1S1) and the lowest value observed in the treatment combination of Conventional method X Control (M3S5) (Table-3).

Table 3: Effect of weed control measure on total dry matter (TDM) production (gm^{-2}), leaf area index, crop growth rate (g $m^{-2}day^{-1}$) transplanted rice in 2014, 2015.

Sowing method	Total dry matter (TDM) production (gm^{-2})						Leaf area index						Crop Growth Rate (g $m^{-2}day^{-1}$)			
	40DAT		60 DAT		80DAT		40DAT		60 DAT		80DAT		(40 – 60) DAT		(60– 80) DAT	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
M1:Direct Seeded Rice	440.27	439.79	619.08	631.28	790.39	790.38	3.18	3.19	4.37	4.37	3.95	3.90	8.13	8.09	10.01	9.76
M2:System of Rice Intensification (SRI)	443.17	441.48	622.44	636.66	800.70	798.94	3.27	3.28	4.50	4.49	4.11	4.14	8.51	8.49	10.55	10.63
M3:Conventional method of Rice Cultivation (CRT)	435.52	434.56	606.52	616.01	783.49	782.59	3.13	3.14	4.26	4.27	3.90	3.76	7.36	7.22	8.64	8.82
SE(m)±	22.67	22.94	26.12	19.08	26.64	26.93	0.08	0.09	0.13	0.12	0.12	0.12	0.61	0.57	0.76	1.94
CD(P=0.05)	62.95	63.69	72.51	52.99	73.97	74.76	0.24	0.24	0.36	0.32	0.34	0.34	7.57	7.09	7.71	19.67
Weed control method																
S1:Azimsulfuron @35 g a.i. per ha.	485.58	485.90	684.04	683.29	880.14	878.97	3.51	3.54	4.92	4.93	4.54	4.32	9.49	9.43	11.24	11.41
S2:Bensulfuron Methayle+Pretilachlor @70g +700 g a.i. per ha	482.21	480.58	680.67	677.97	870.29	869.09	3.26	3.27	4.68	4.68	3.97	4.00	8.94	8.86	10.67	10.61
S3: Two hand weeding at 30 DAT & 45 DAT	471.19	469.92	669.65	667.31	861.17	859.97	3.20	3.21	4.23	4.26	3.96	3.96	8.66	8.51	10.30	10.01
S4: Mechanical weeding with cono-weeder at 30 DAT	471.56	471.14	662.77	664.47	860.98	859.78	3.12	3.10	4.24	4.23	3.95	3.87	7.90	7.85	9.66	9.77
S5: Control Plot	287.74	285.52	382.95	446.88	485.03	485.37	2.88	2.88	3.82	3.79	3.52	3.50	5.03	5.00	6.81	6.87
SE(m)±	19.46	19.61	20.43	21.94	24.30	24.13	0.22	0.24	0.28	0.28	0.19	0.18	0.27	0.27	0.33	0.36
CD(P=0.05)	40.17	40.46	42.17	45.28	50.15	49.80	0.46	0.49	0.57	0.58	0.39	0.38	0.55	0.56	0.68	0.74

Treatment combination with weed control method																
M1S1	485.97	486.03	684.43	684.91	881.27	881.10	3.50	3.55	4.94	4.91	4.55	4.16	9.61	9.57	11.50	11.49
M1S2	482.55	482.00	681.00	680.87	869.89	869.28	3.24	3.25	4.67	4.68	3.83	3.98	9.08	9.01	10.93	10.86
M1S3	471.10	469.91	669.55	668.79	858.44	857.83	3.18	3.18	4.22	4.27	3.82	3.92	8.67	8.65	10.57	10.17
M1S4	471.98	472.68	670.43	671.55	859.32	858.71	3.11	3.07	4.22	4.26	3.93	3.83	8.11	8.09	10.01	9.61
M1S5	289.77	288.33	390.00	450.28	483.00	485.00	2.88	2.90	3.80	3.73	3.64	3.60	5.19	5.14	7.06	6.66
M2S1	487.77	488.33	686.23	690.26	890.69	888.63	3.59	3.60	5.07	5.03	4.73	4.77	9.88	9.90	11.98	12.12
M2S2	484.44	482.41	682.89	684.00	875.87	874.17	3.34	3.35	4.77	4.80	4.05	4.07	9.55	9.51	11.59	11.39
M2S3	474.33	473.00	672.79	674.60	871.46	869.77	3.29	3.30	4.34	4.36	4.11	4.13	9.32	9.24	11.25	11.00
M2S4	474.67	473.00	673.12	674.60	870.13	868.44	3.20	3.22	4.35	4.31	4.12	4.12	8.51	8.46	10.54	10.88
M2S5	294.67	290.33	397.19	459.82	495.33	493.67	2.90	2.92	3.98	3.92	3.56	3.60	5.31	5.32	7.40	7.77
M3S1	483.00	483.00	681.46	674.70	868.46	867.17	3.45	3.48	4.76	4.84	4.33	4.03	8.98	8.81	10.23	10.62
M3S2	479.65	477.34	678.10	669.04	865.11	863.81	3.19	3.21	4.59	4.56	4.04	3.94	8.17	8.08	9.50	9.59
M3S3	468.15	466.84	666.61	658.54	853.61	852.32	3.13	3.15	4.12	4.14	3.94	3.84	8.00	7.65	9.07	8.86
M3S4	468.04	467.74	644.76	647.25	853.50	852.20	3.05	3.02	4.14	4.11	3.81	3.67	7.08	7.00	8.42	8.83
M3S5	410.00	277.88	361.67	430.52	476.77	477.44	2.86	2.83	3.69	3.73	3.36	3.29	4.58	4.54	5.96	6.19
SE(m)±	33.71	33.96	35.39	38.00	42.09	41.79	0.38	0.41	0.48	0.49	0.32	0.32	0.46	0.47	0.57	0.62
CD(P=0.05)	69.58	70.08	73.04	78.42	86.86	86.26	0.79	0.85	0.99	1.00	0.67	0.65	0.95	0.97	1.17	1.28

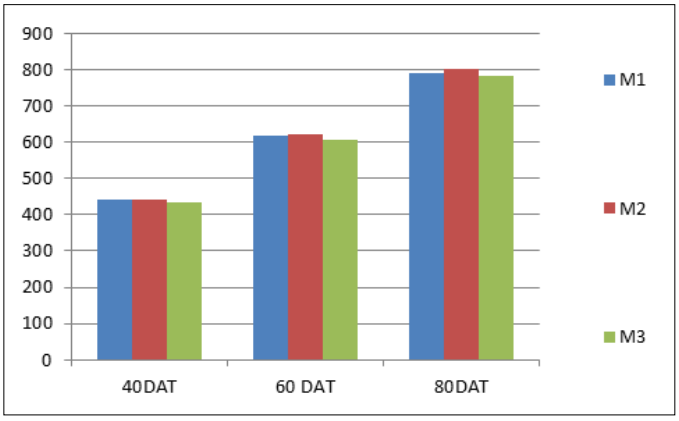

Fig 11: Effect of weed control measure on total dry matter (TDM) production (gm^{-2}) on sowing method of transplanted rice in 2014

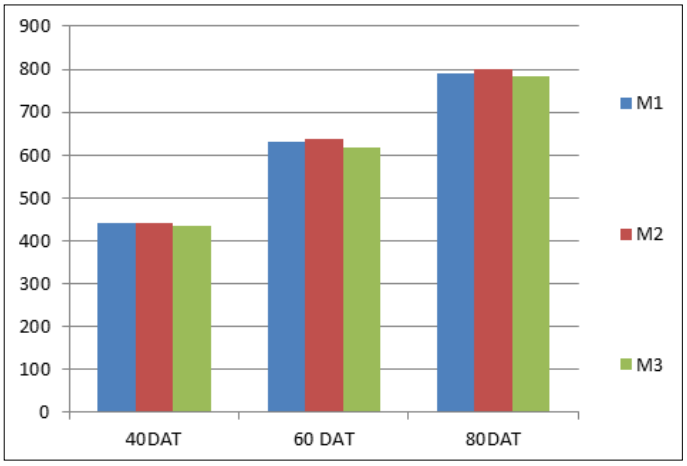

Fig 12: Effect of weed control measure on total dry matter (TDM) production (gm^{-2}) on sowing method of transplanted rice in 2015

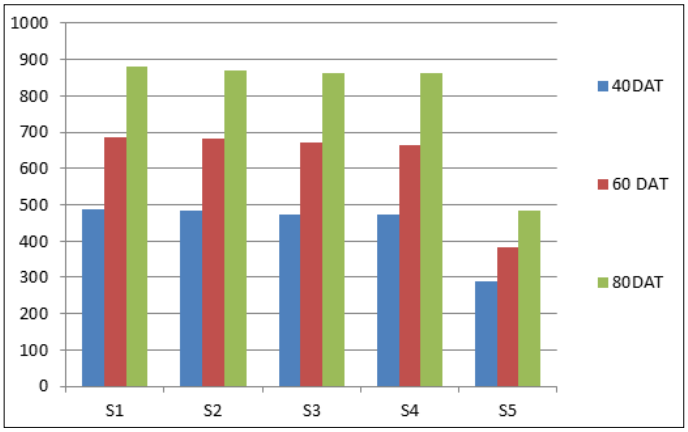

Fig 13: Effect of weed control measure on total dry matter (TDM) production (gm^{-2}) on weed control method of transplanted rice in 2014

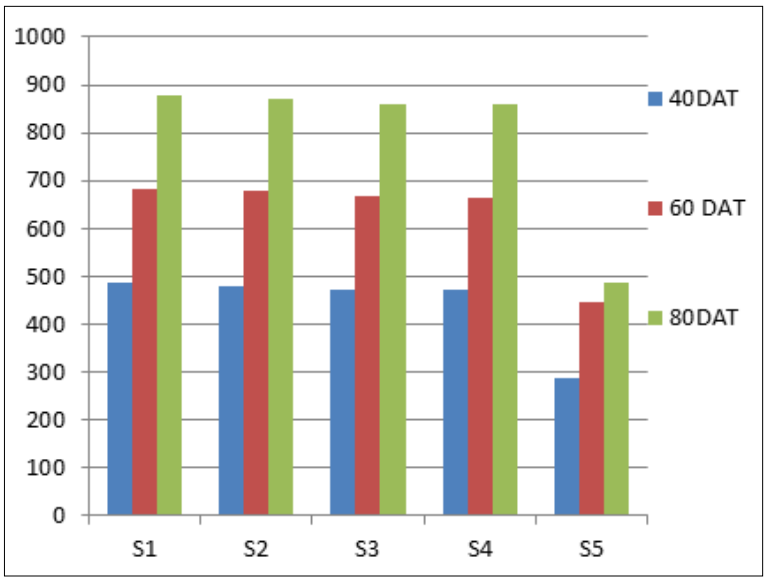

Fig 14: Effect of weed control measure on total dry matter (TDM) production (gm^{-2}) on weed control method of transplanted rice in 2015

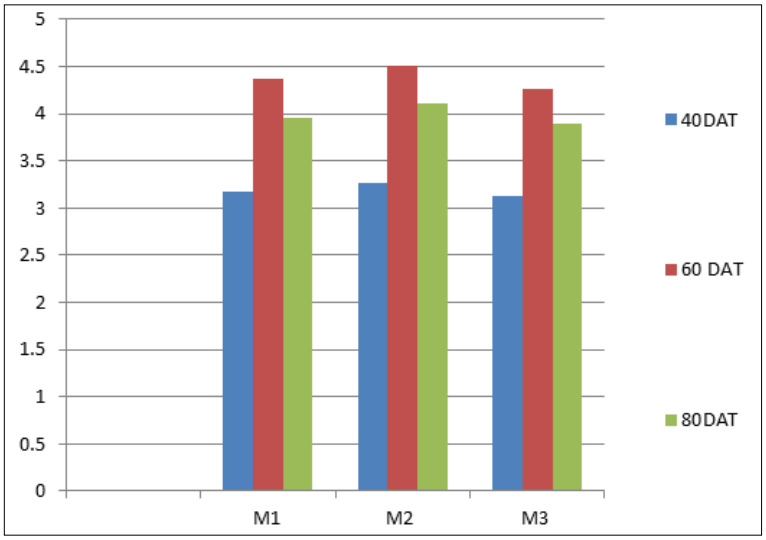

Fig 15: Effect of weed control measure on Leaf area index (LAI) among sowing method of transplanted rice for the year of 2014

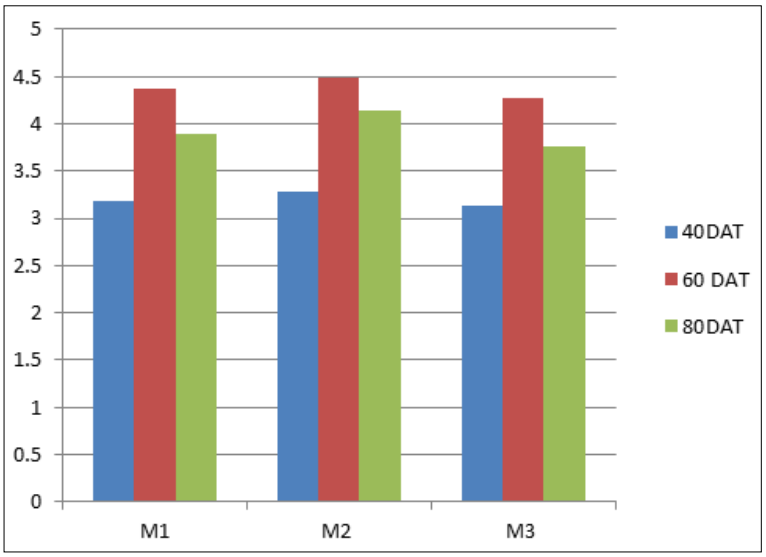

Fig 16: Effect of weed control measure on Leaf area index (LAI) among sowing method of transplanted rice for the year of 2015

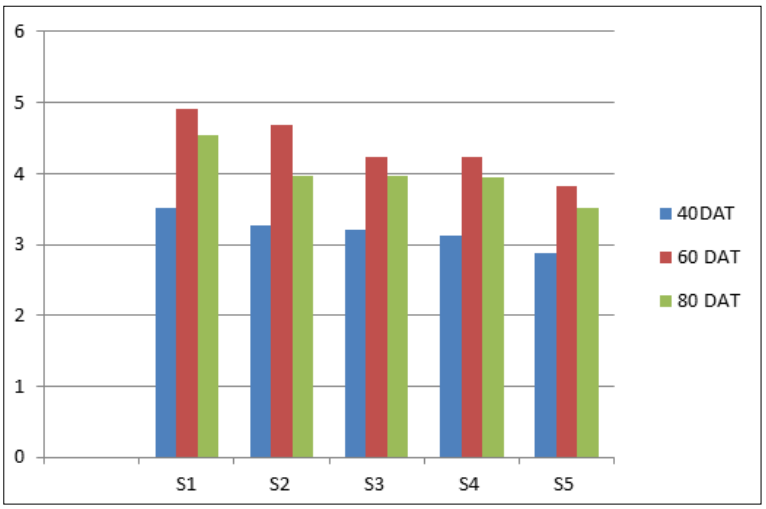

Fig 17: Effect of weed control measure on Leaf area index (LAI) among weed control method of transplanted rice for the year of 2014

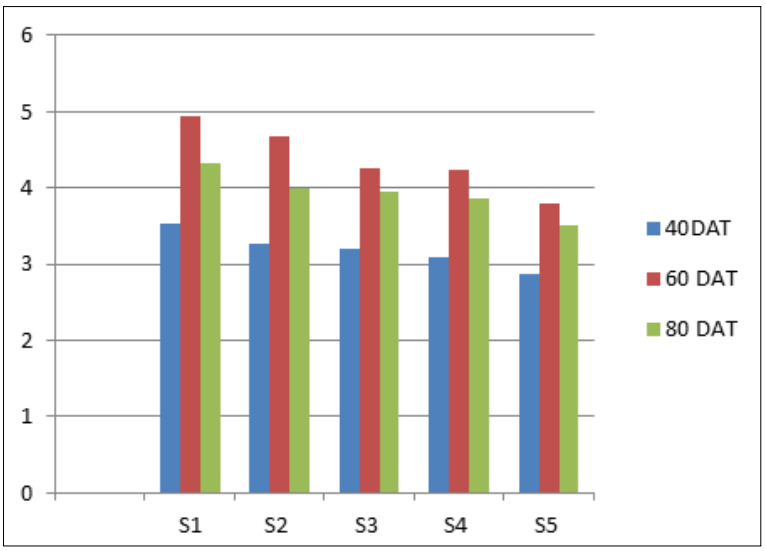

Fig 18: Effect of weed control measure on Leaf area index (LAI) among weed control method of transplanted rice for the year of 2015

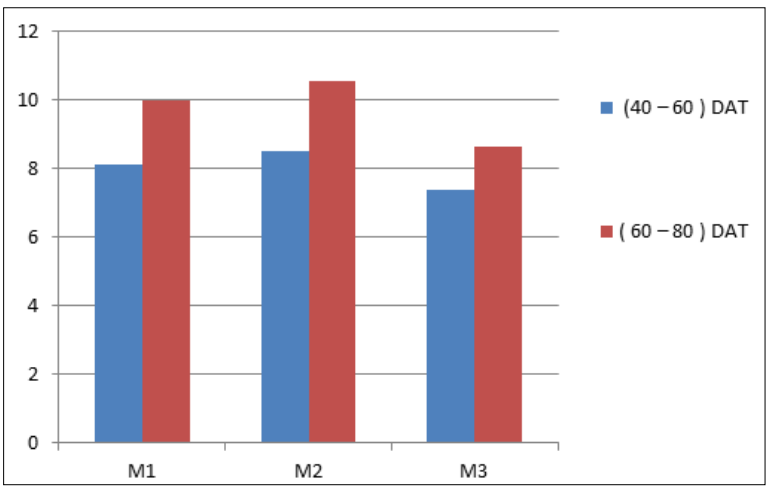

Fig 19: Effect of weed control measure on Crop Growth Rate (g $m^{-2}day^{-1}$) in different sowing method of transplanted rice for the year of 2014

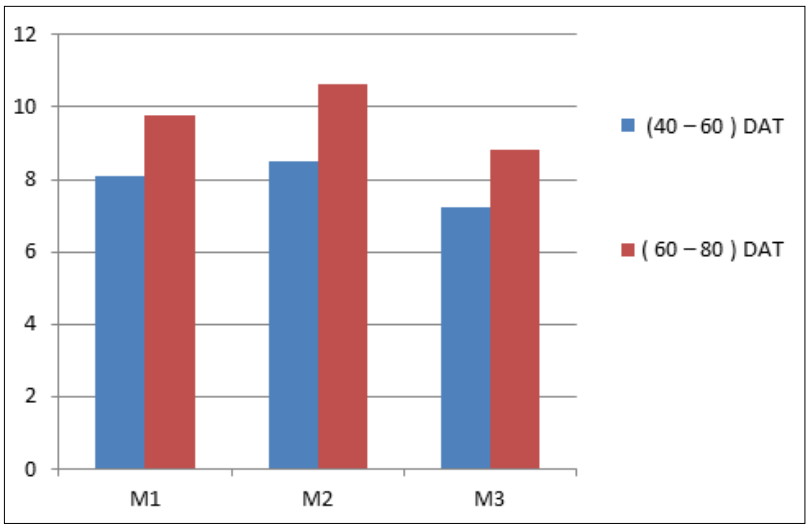

Fig 20: Effect of weed control measure on Crop Growth Rate (g $m^{-72}day^{-1}$) in different sowing method of transplanted rice for the year of 2015

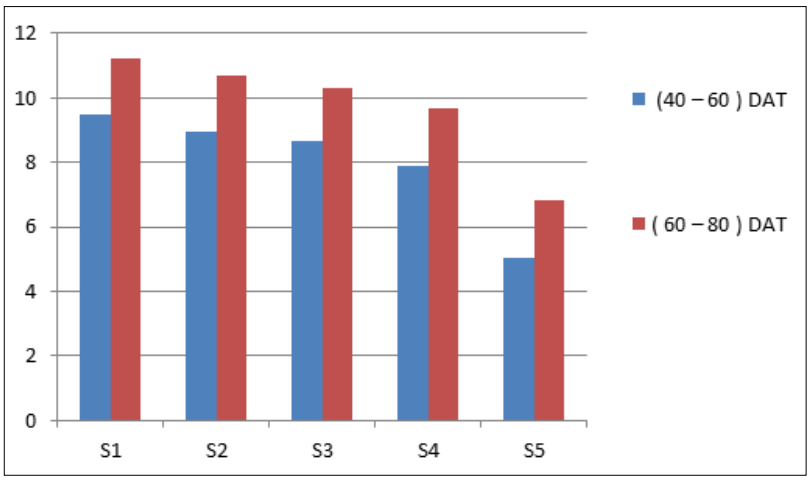

Fig 21: Effect of weed control measure on Crop Growth Rate (g $m^{-2}day^{-1}$) in different weed control method of transplanted rice for the year of 2014

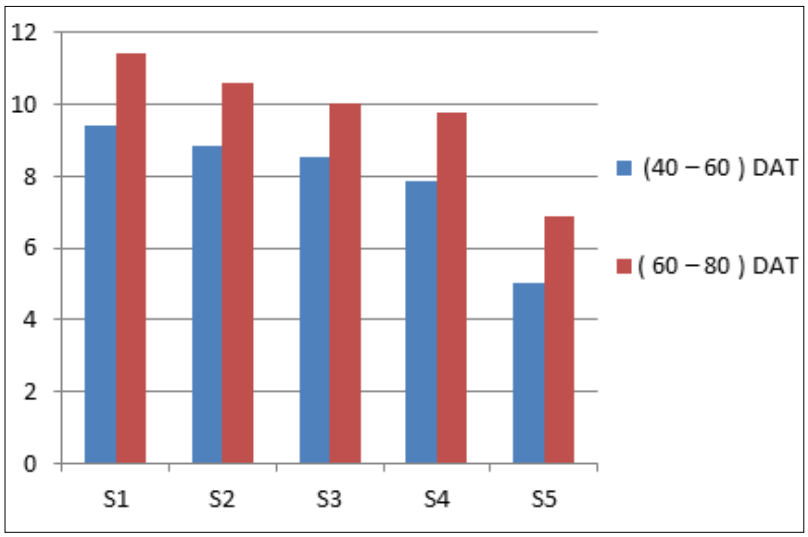

Fig 22: Effect of weed control measure on Crop Growth Rate (g $m^{-2}day^{-1}$) in different weed control method of transplanted rice for the year of 2015

Effect of weed control measure on different yield attributes of transplanted rice in 2014 and 2015

The data presented in the following table expressed that there was significant differences among the treatments regarding number of tillers m^{-2}, panicle length in cm, numbers of filled grain, test weight among the two experimental year of transplanted rice. Considering the both year, the highest value were registered in System of Rice Intensification [numbers of tillers per m^2 352.50 (pooled), panicle length 22.05 cm (pooled), number of filled grain 120.16 (pooled), test weight 21.08 (pooled), fertility ratio 0.94 (pooled)] followed by Direct Seeded Rice. The lowest value was registered in Conventional method of Rice Cultivation [numbers of tillers per m^2 317.38 (pooled), panicle length 20.12 cm (pooled),

number of filled grain 112.89 (pooled), test weight 20.15 (pooled), fertility ratio 0.89 (pooled)] (Table-4) and in case of sterility % the highest vales recorded at conventional method of rice cultivation [9.11 pooled)] and the lowest value was recorded in system of rice cultivation [8.07 (pooled)]. Uphoff 2002 reported that SRI have claimed substantial increases in rice yields, sometimes as high as 3-4 times, with the consequent increase in the productivity of land, labour, water and capital. Roul *et al.* (2008) observed significantly higher number of ear bearing tillers, length of panicle and grain yield in SRI rice when than conventional transplanting. Mankotia *et al*. (2009) [5] also revealed the number of panicles m-2 were higher in case of drum seeded rice as compared to conventional tillage. The highest number of different yield attributes were observed in the use of Azimsulfuron @35 g a.i./ha [numbers of tillers per m^2 378.60 (pooled), panicle length 23.87 cm (pooled), number of filled grain 124.63 (pooled), test weight 22.85 (pooled), fertility ratio 5.55 (pooled)] and Bensulfuron Methyle+Pretilachlor@70g +700 g a.i. per ha (S2) followed by two hand weeding at 30 DAT and 45 DAT (S3) and mechanical weeding with Cono weeder at 30 DAT and the lowest value were recorded in control plot (S5). In case of sterility % the highest value observed in weed control method was mechanical weeding with cono weeder at 30 DAT (9.15%) and lowest value observed in use of azimsulfuron @35 g a.i.per ha (5.55%). Similar observation was also recorded by Singh *et al*. (2007). It was also seen that the number of tillers m^{-2}, panicle length in cm, numbers of filled grain, test weight among the two experimental years were registered statistically at par with the use of two hand weeding at 30 DAT and 45 DAT and mechanical weeding with cono weeder at 30 DAT. In case of weed control method the highest pooled data were recorded in the treatment combination of System of Rice Intensification X Azimsulfuron @35 g a.i./Ha.(M2S1) followed by Direct Seeded Rice X Azimsulfuron @35 g a.i./Ha (M1S1) and the lowest numbers of tillers observed in the treatment combination of Conventional method X Control (M3S5).

Table 4: Effect of weed control measure on numbers of tillers per m² (Pooled data), Panicle length in cm.(Pooled data), Numbers of filled grain, Test weight, fertility ratio, sterility% of transplanted rice in 2014, 2015(Pooled data

Sowing method	Numbers of tillers per m² (Pooled data)	Panicle length in cm.(Pooled data)	Numbers of filled grain(Pooled data)	Test weight(Pooled data)	fertility ratio(Pooled data)	sterility% (Pooled data)
M1:Direct Seeded Rice	343.93	21.53	116.27	20.50	0.91	8.41
M2:System of Rice Intensification (SRI)	352.50	22.05	120.16	21.08	0.94	8.07
M3:Conventional method of Rice Cultivation (CRT)	317.38	20.12	112.89	20.15	0.89	9.11
SE(m)±	8.87	0.55	3.09	0.68	0.03	0.34
CD(P=0.05)	24.63	1.52	8.59	1.88	0.08	0.93
Weed control method						
S1:Azimsulfuron @35 g a.i. per ha.	378.60	23.87	124.63	22.85	5.55	5.55
S2:Bensulfuron Methayle+Pretilachlor@70g +700 g a.i. per ha	366.34	22.35	122.48	21.37	5.57	5.57
S3: Two hand weeding at 30 DAT & 45 DAT	357.63	21.72	120.51	20.35	9.14	9.14
S4: Mechanical weeding with cono-weeder at 30 DAT	357.19	21.33	120.67	20.22	9.15	9.15
S5: Control Plot	229.90	16.90	93.89	18.10	13.25	13.25
SE(m)±	11.14	0.70	4.31	0.74	0.04	0.42
CD(P=0.05)	23.00	1.45	8.89	1.53	0.08	0.87
Treatment combination with weed control method						
M1S1	383.69	24.03	123.56	22.97	0.96	5.40
M1S2	369.00	22.49	120.74	21.52	0.94	5.43
M1S3	363.86	21.90	120.13	20.05	0.91	9.00
M1S4	366.90	21.90	120.14	20.25	0.90	9.1
M1S5	236.18	17.35	96.76	17.72	0.88	13.21
M2S1	393.27	24.53	128.96	23.09	0.96	5.28
M2S2	378.36	23.72	126.63	21.65	0.95	5.28
M2S3	366.84	22.89	122.56	20.96	0.94	8.38
M2S4	367.20	21.92	122.72	20.69	0.93	8.38
M2S5	256.81	17.19	99.91	19.01	0.93	13.03
M3S1	358.83	23.04	121.36	22.49	0.92	5.97
M3S2	351.67	20.82	120.07	20.94	0.90	5.99
M3S3	342.20	20.38	118.85	20.04	0.89	10.04
M3S4	337.46	20.18	119.16	19.73	0.89	10.05
M3S5	196.72	16.16	85.00	17.56	0.86	13.50
SE(m)±	19.30	1.22	7.46	1.28	0.07	0.73
CD(P=0.05)	39.84	2.51	15.39	2.65	0.14	1.51

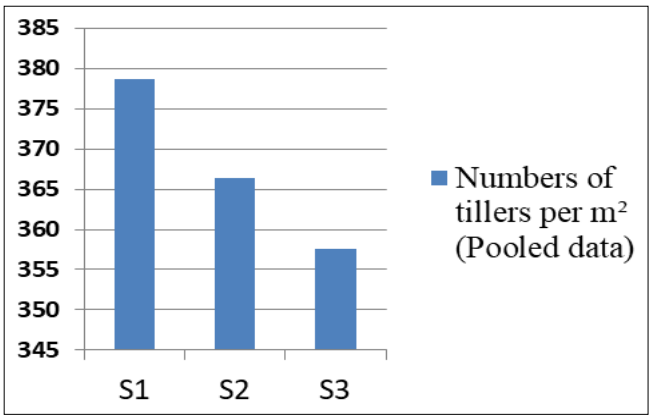

Fig 23: Numbers of tillers per m² (Pooled data)

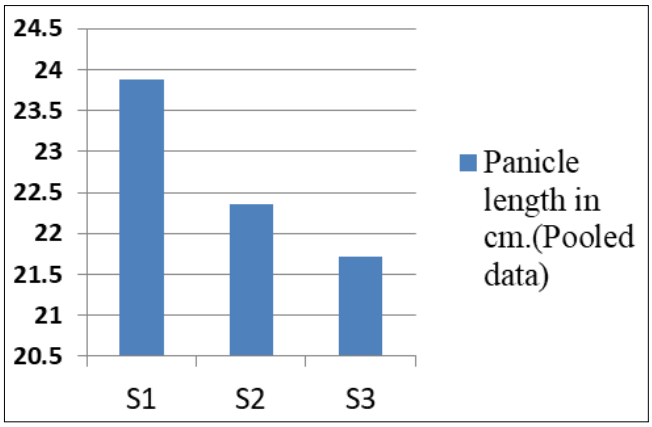

Fig 24: Panicle length in cm. (Pooled data)

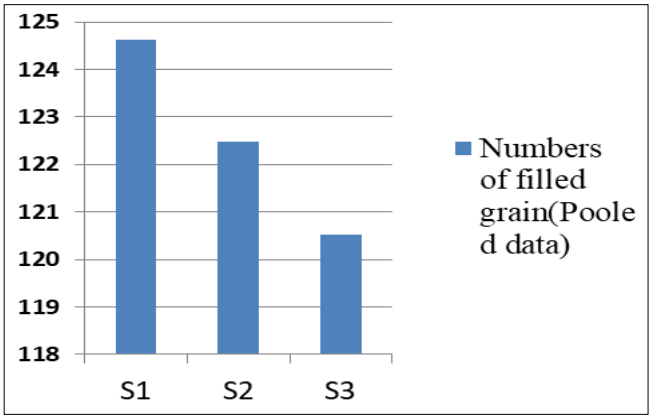

Fig 25: Numbers of filled grain (Pooled data)

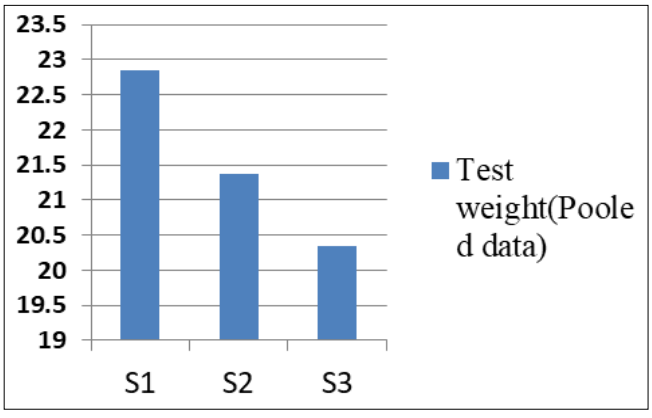

Fig 26: Test weight (Pooled data)

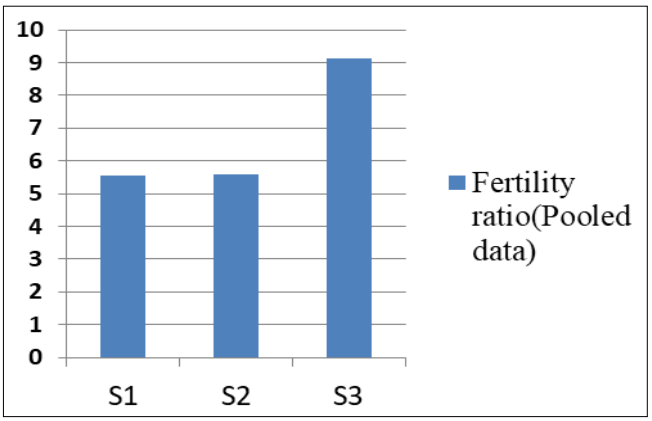

Fig 27: Fertility ratio (Pooled data)

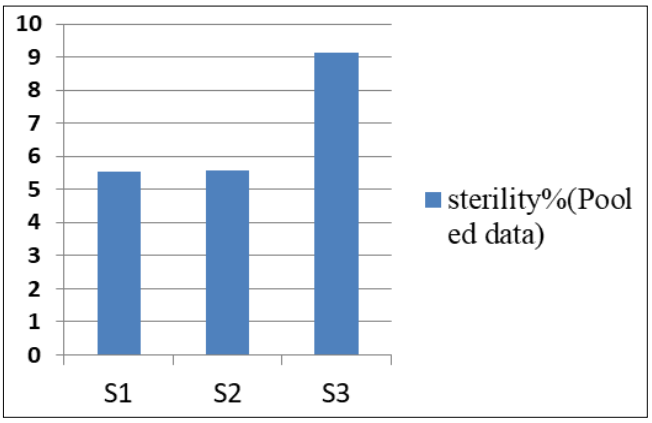

Fig 28: Sterility% (Pooled data)

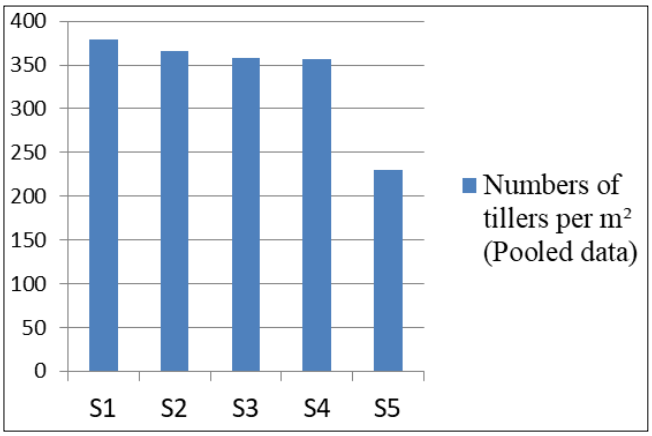

Fig 29: Numbers of tillers per m² (Pooled data)

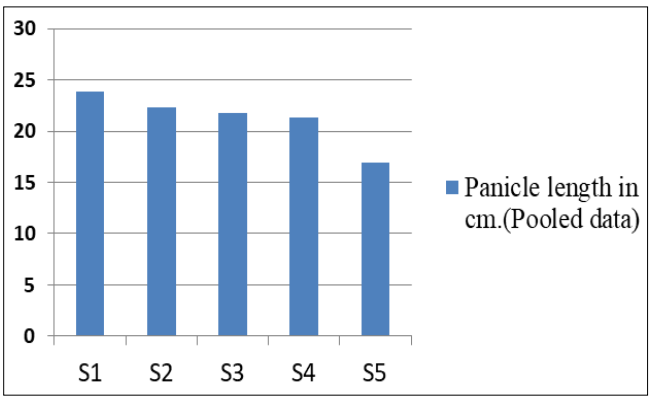

Fig 30: Panicle length in cm. (Pooled data)

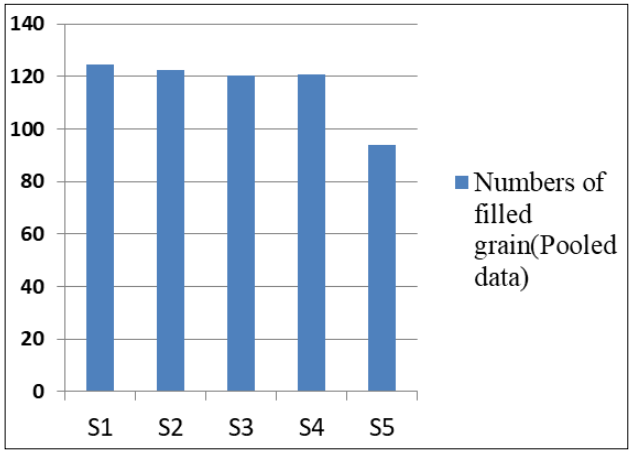

Fig 31: Numbers of filled grain (Pooled data)

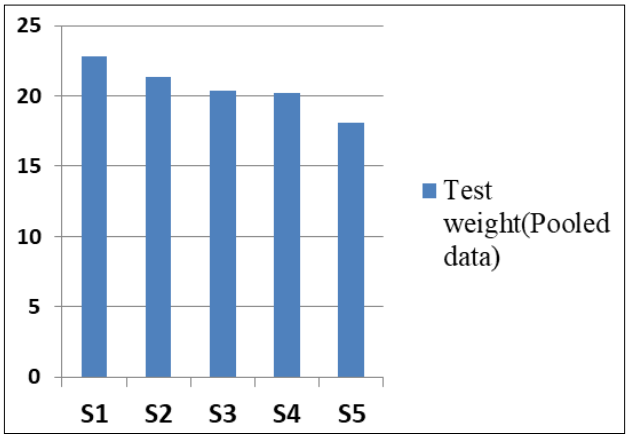

Fig 32: Test weight (Pooled data)

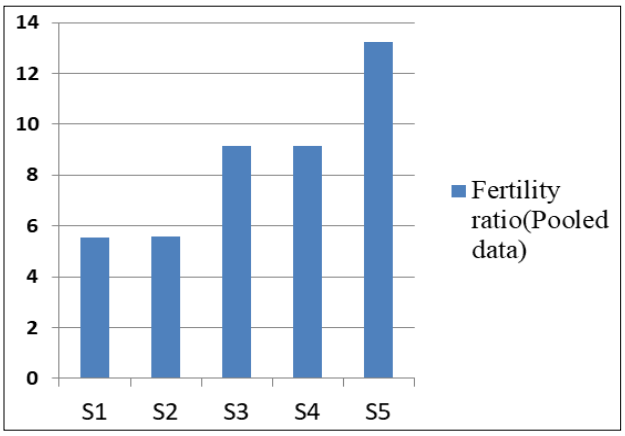

Fig 33: Fertility ratio (Pooled data)

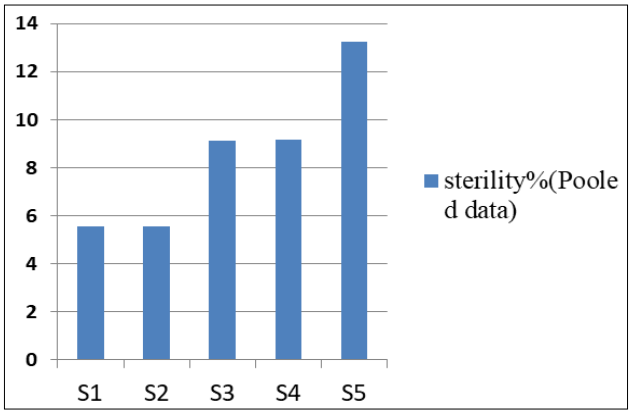

Fig 34: Sterility % (Pooled data)

Yield and harvest index

All the weed control treatments significantly outnumbered and out-weighed the control plot in respect to grain yield and straw yield of rice. In sowing method treatment, grain yield and straw yield was significantly affected. System of Rice Intensification applied plot were significantly superior [grain yield 4.88 ton/ha (pooled) and straw yield 5.17 ton/ha (pooled)] than Direct Seeded Method applied plot and Conventional Method of Rice Transplanting applied plot. Nissanka and Bandara (2004) [7] reported 9 and 12% more grain yield in SRI compared to conventional transplanting and direct sowing methods. Subbulakshmi *et al.* (2008) [23] recorded significantly higher filled grains panicle-1 (92.2), grain yield (5496 kg ha-1) and straw yield (6388 kg ha-1) under line transplanting than drum seeding which produced 90.7 numbers of filled grains panicle-1, 4574 and 5447 kg ha-1 grain and straw yield, respectively. The increase in yield is due to several factors such as release of growth promoting substances, control of plant pathogens, and proliferation of beneficial organisms in the rhizosphere. These findings were in accordance with Tein *et al.* (1979) and Kundu and Gaur (1984) [3]. The highest grain yield and straw yield recorded among the weed control method was use of Azimsulfuron @35 g a.i./ha. [grain yield 5.78 ton/ha(pooled) and straw yield 5.78 ton/ha (pooled)]followed by Bensulfuron Methyle+Pretilachlor@70g +700 g a.i. per ha among the two experimental year and Pooled. Among the hand weeding method and mechanical control method the highest grain yield was recorded in two hand weeding At 30 DAT & 45 DAT than mechanical weeding with cono-weeder at 30 DAT. The result showed that the grain yield production and straw yield production by herbicidal weed control method was higher than the use of physical and mechanical weed control method. It eliminates competition due to weeds. Timely and effective control of weeds with integrated use of herbicides resulted in increased yield components, which ultimately reflected on grain yield and straw yield. The similar results was reported by Walia *et al.* (2011) [27]. This was confirmed by highly significant and negative correlation between weed dry weight with number of panicles/m2 and grains per panicle thus indicated the negative effects of weed growth on development of yield components in rice plants as emphasized in the past by various authors (Zhang 1996) [30]. The table also showed that there was significant variation was observed among the treatment combination with weed control method which revealed that the use of weed control method in different sowing method was showed impact on the performance of grain yield production and straw yield production. The highest pooled grain yield and straw yield was recorded in the combination of System of Rice Intensification X Azimsulfuron @35 g a.i./Ha.(M2S1) followed by: Direct Seeded Rice X Azimsulfuron @35 g a.i./Ha (M1S1)and the lowest result recorded in System of Rice Intensification X Control (M3S5) (Table-5).

Table 5: Effect of weed control measure on Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), Harvest Index % of transplanted rice in 2014, 2015 and Pooled

Sowing method	Grain yield(t ha^{-1})			Straw yield(t ha^{-1})			Harvest Index %		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
M1:Direct Seeded Rice	4.39	4.33	4.36	4.88	4.88	4.88	46.22	45.88	46.05
M2:System of Rice Intensification (SRI)	4.92	4.85	4.88	5.16	5.18	5.17	48.00	47.61	47.81
M3:Conventional method of Rice Cultivation (CRT)	4.00	3.86	3.93	4.29	4.25	4.27	46.90	46.44	46.67
CD(P=0.05)	0.71	0.56	0.62	0.54	0.67	0.61	4.51	3.62	3.94
CV %	15.82	12.80	13.90	11.24	13.86	12.50	9.46	7.66	8.31
Weed control method									
S1: Azimsulfuron @35 g a.i. per ha.	5.73	5.83	5.78	5.79	5.78	5.78	49.75	50.29	50.02
S2: Bensulfuron Methayle+Pretilachlor@70g +700 g a.i. per ha	5.09	5.06	5.08	5.23	5.34	5.29	49.05	48.63	48.84
S3: Two hand weeding at 30 DAT & 45 DAT	4.97	4.70	4.84	5.08	5.02	5.05	49.56	48.01	48.79
S4: Mechanical weeding with cono-weeder at 30 DAT	4.65	4.38	4.52	4.75	4.71	4.73	49.34	48.11	48.72
S5: Control Plot	1.73	1.78	1.76	3.03	3.02	3.02	37.51	38.19	37.85
SE(m)±	0.18	0.18	0.13	0.25	0.25	0.25	2.14	2.37	2.14
CD(P=0.05)	0.37	0.38	0.26	0.53	0.51	0.51	4.42	4.89	4.42
Treatment combination with weed control method									
M1S1	6.03	5.98	6.01	6.00	6.02	6.01	50.11	50.29	49.97
M1S2	5.06	5.11	5.09	5.46	5.63	5.55	48.14	48.63	47.85
M1S3	4.82	4.71	4.77	5.24	5.19	5.22	47.94	48.01	47.59
M1S4	4.44	4.21	4.32	4.69	4.63	4.66	48.65	48.11	48.15
M1S5	1.62	1.65	1.64	3.03	2.94	2.98	36.27	38.19	36.71
M2S1	6.15	6.10	6.12	6.20	6.18	6.19	49.79	49.66	49.73
M2S2	5.66	5.78	5.72	5.41	5.62	5.52	51.14	50.77	50.95
M2S3	5.46	5.37	5.42	5.55	5.51	5.53	49.56	49.37	49.47
M2S4	5.24	4.91	5.08	5.47	5.44	5.45	48.98	49.83	48.23
M2S5	2.07	2.10	2.08	3.16	3.17	3.17	40.55	47.56	40.67
M3S1	5.02	5.41	5.21	5.15	5.12	5.14	49.35	51.36	50.36
M3S2	4.55	4.30	4.43	4.83	4.77	4.80	47.8	47.55	47.71
M3S3	4.64	4.01	4.33	4.44	4.37	4.41	51.18	47.43	49.30
M3S4	4.28	4.01	4.15	4.11	4.06	4.08	50.38	49.20	49.79
M3S5	1.50	1.60	1.55	2.90	2.95	2.93	35.71	36.64	36.17
SE(m)±	0.31	0.32	0.22	0.44	0.42	0.43	3.71	4.10	3.71
CD(P=0.05)	0.63	0.85	0.46	0.91	0.88	2.93	7.66	8.47	7.65

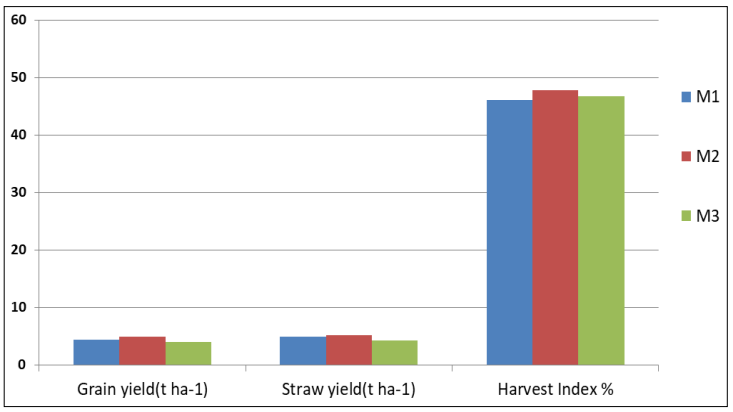

Fig 35: Effect of weed control measure on Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), Harvest Index % in sowing method of transplanted rice

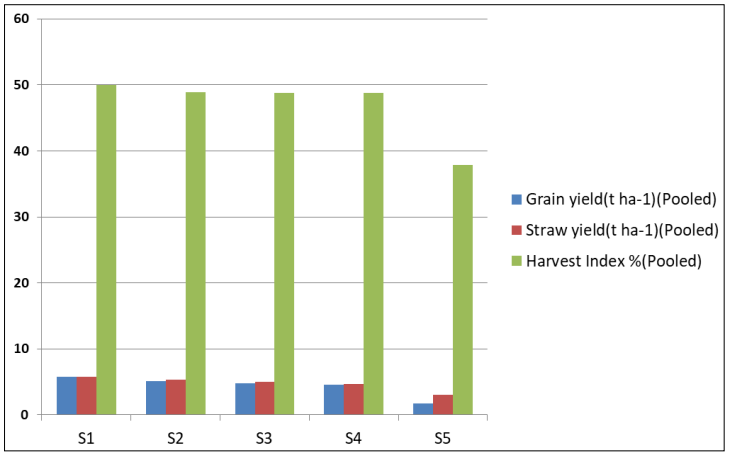

Fig 36: Effect of weed control measure on Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), Harvest Index % in different weed control method of transplanted rice

Conclusion

For efficient weed management and performance of better in terms of growth attributes, yield attributes and productivity in rice and net income; application of Azimsulfuron @35 g a.i. per ha at 20 DAT followed by Bensulfuron Methayle+Pretilachlor@70g +700 g a.i. per ha at 2 DAT was found better result which was followed by application of two hand weeding at 30 DAT & 45 DAT and Mechanical weeding with cono-weeder at 30 DAT. On the other hand System of Rice Intensification (SRI) followed by Direct Seeded Rice showed better result than Conventional Method of Rice transplanting.

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