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Post-Emergence Chemical Weed Control in Direct Seeded Rice (*Oryza sativa L.)* in New Alluvial Zone of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Direct seeded rice (DSR) seems to be a viable option under erratic rainfall and water scarcity. Despite several advantages of DSR, weeds are the major biological constraint. Afield experiment was conducted at Central Research Farm, Gayeshpur of Bidhan Chandra Krishi Vishwavidyalaya Mohanpur, Nadia, West Bengal during the *kharif* season ((July- November) of 2020 and 2021, comprisingnine weed control methods viz. T_1- Imazethapyr 10% SL @ 1000 ml ha^{-1}at 15 DAS, T_2 - Imazethapyr 10% SL @ 1250 ml ha^{-1}at 15 DAS ,T_3- Imazethapyr 10% SL @ 2000 ml ha^{-1}at 15

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DAS, T_4- Imazethapyr 10% SL @ 750 fb 750 ml ha^{-1}at 15 DAS and 30 DAS, T_5- Imazethapyr 10% SL @ 1000 fb 1000 ml ha^{-1}at 15 DAS and 30 DAS, T_6- Imazethapyr 10% SL @ 1250 fb 1250 ml ha^{-1}at 15 DAS and 30 DAS, and T_7- Imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1}at 15 DAS and 30 DAS, T_8- weed free check (2 times hand weeding at 20 DAS and 40 DAS) and T_9- un-treated control (weedy check) along with 3 replicationslaid out in RBD design in herbicide tolerant rice variety Sava 134 was conducted during two consecutive kharif season of 2020 and 2021 at Central Research Farm, Gayeshpur, B.C.K.V., Nadia under new alluvial zone of West Bengal. The experimental results revealed that maximum grain and straw (4.20 and 4.36 t per ha), as well as net return (Rs. 44546per ha) were recorded in double hand weeding (T_8), which was at par with Imazethapyr treated plots like T_5, T_6 and T_7. Thus the tedious, time-consuming, and costly hand-weeding can be profitably replaced by the application of Imazethapyr 10% SL @ 1000 fb 1000 ml per ha at 15 and 30 DAS. This weed control methodhas satisfactory performance in DSR exhibiting higher weed control efficiency and no phytotoxicity symptoms to the herbicide tolerant rice crop and increased both grain and straw yields vis-à-vis benefit : cost ratio.

Keywords: DSR, herbicide tolerant rice; imazethapyr; weed control efficiency.

1. INTRODUCTION

"Rice is one of the world's most important staple crops and a primary source of food for billions of people around the world" [1]. "India has the largest area and is the second largest producer of rice after China, accounting for approximately 20% of the world's total rice production" [2]. In general, there are three types of rice cultivation viz. transplanted, wet-seeded, and dry-seeded. Among them, transplanted rice is the most popular way to increase yield and income, although it costs around 30% to 40% more to cultivate due to the need to prepare nursery beds and manage seedlings until main field transplanting [3]. An extensive amount of water is used by transplanted rice causes depletion of the groundwater table day by day [4-7]. The sustainability of transplanted rice is severely threatened by a lack of water [8]. "Under this condition, direct seeded rice (DSR) is a viable option to rescue farmers" [9]. DSR requires only 34% of the total labour and can save up to 60% labour requirement, 12–33% water [1], and 29% of the total cost of cultivation compared to transplanted rice cultivation [10]. There are various benefits from direct seeding compared with puddle transplanting, i.e. similar yields, savings inirrigation water, low labor requirement and production costs, and higher income. Despite several advantages of DSR, weeds are the major biological constraint. Due to competition for nutrients, water, light, and space as well as due to their wider adoption and faster development, weeds negatively affect yield, quality, and cost of production [11]. This decreases the potential yield of the crop. On average, this decrease is 15 – 20% but in severe cases it may exceed 50 % in direct seeded rice due to severe weed competition [12] or even complete crop failure [13]. Thus, the success of DSR largely depends on timely and effective weed control methods. Pre and post-emergence herbicides offer selective, timely, effective, and cost-efficient weed control rather than manual weeding. However, it is very difficult to control the complex weed flora observed in DSR without the application of pre and post-emergence herbicides [14]. Though many pre-emergence herbicides are available, the need for post-emergence herbicides is often realized to combat the emerged weeds during later stages of crop growth. Along with pre-emergence herbicides, the application of post-emergence herbicides may be found superior and increase yield [15]. The continuous application of pre and post-emergence herbicides, may cause a phytotoxicity effect, reduce crop yield, environmental damage, and increase the cost of cultivation. In this situation, a new generation herbicide-tolerant rice variety under direct seeded conditions is desirable. Hence, Imazethapyr, a post-emergence herbicide, has been shown to control herbicide tolerant weeds in both imidazolinone-tolerant rice and direct seeded rice [16]. Considering this fact, a field experiment was conducted with different doses of Imazethapyr as post-emergence herbicide in herbicide-tolerant rice varieties under direct seeded conditions.

2. MATERIALS AND METHODS

The field experiment was conducted at Central Research Farm, Gayeshpur of Bidhan Chandra Krishi Vishwavidyalaya Mohanpur, Nadia, West Bengal during the *kharif* season ((July-November)of 2020 and 2021. The experiment site was geographically situated with an average altitude of 15m above the mean sea level (MSL), and had fairly leveled medium-upland topography with good drainage facility under sub-humid tropical climate. The experiment was done with the hybrid rice variety Sava 134 (developed by Savanah), which is a non-aromatic, early maturity, herbicide resistance, lodging, and disease resistance with super fine long slender grains were directly sown on 28th July , 2020 and 2021 in the field using a seed rate of 30 kg ha^{-1} and at 20 cm row to rowand 15 cm plant to plant spacing with plot size of 5 m × 5 m, laid out in randomized block design (RBD) with three replications and nine treatments viz. T_1- Imazethapyr 10% SL @ 1000 ml ha^{-1} at 15 DAS, T_2 -Imazethapyr 10% SL @ 1250 ml ha^{-1} at 15 DAS ,T_3 - Imazethapyr 10% SL @ 2000 ml ha^{-1} at 15 DAS, T_4- Imazethapyr 10% SL @ 750 fb 750 ml ha^{-1} at 15 DAS and 30 DAS, T_5- Imazethapyr 10% SL @ 1000 fb 1000 ml ha^{-1} at 15 DAS and 30 DAS, T_6- Imazethapyr 10% SL @ 1250 fb 1250 ml ha^{-1} at 15 DAS and 30 DAS, and T_7- Imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} at 15 DAS and 30 DAS, T_8- weed free check (2 times hand weeding at 20 DAS and 40 DAS) and T_9- un-treated control (weedy check). In this experiment, the recommended dose of fertilizers was 60 kg N, 30 Kg P_2O_5 and 30 kg K_2O ha^{-1} applied through Urea, DAP and Muriate of Potash (MOP) respectively. Entire dose nitrogenous fertilizer was applied in 3 splits viz. ½ N as basal, ¼ N at 30 DAS and rest ¼ N at 60 DAS and full doses of P_2O_5 and K_2O were applied as basal and there should be sufficient moisture in the soil during fertilizer application.

For counting the observed weed population per sq. m. in each plot, a quadrate of size 1m x 1m was thrown randomly at three places in each plot and the mean value of counted weed population was taken and converted in to one sq. m. weeds belongs to three categories into grasses, sedges and broad leaved weeds obtained in population at 15, 30, 45 and 60 DAA and expressed as number m^{-2}. The mean data were subjected to square root transformation $\sqrt{x}$ + 0.5 to normalize their distribution. After counting the weed population, the weeds inside each quadrate were uprooted, cleaned and separated species-wise. The amount of the herbicides was calculated as per treatments based on the gross plot area and applied as a solution in water at the rate of 375 lit ha^{-1} fitted with a flat fan nozzle. Early post-emergence herbicides were applied at 15 DAS and late post-emergence herbicides were applied at 30 DAS in the presence of sufficient soil moisture and two hand weeding was done at 20 and 40 DAS for hand-weeded plots. A surfactant sticker (Main spread) was added with herbicide @ 1.5 ml l^{-1} of water. For dry matter, samples were sun dried for 24 hours and then oven dried at 70^{o} C until constant dry weight was obtained. The crop was harvested on 13rd November, 2020 and 2021 when 80 % cent of seeds became matured. Grains and straw were properly sun dried and cleaned. Grain and straw yields per plot were recorded and converted into tones per hector on the basis of 10 % moisture level for better storage.

Weed data were subjected to square root transformation (√x + 0.5) to improve the homogeneity of variance. Treatment means were separated using the critical difference (CD) at 5% level of significance (*P* = .05). Data for each character were statistically analyzed by Gomez and Gomez [17], and the benefit-cost ratio of each weed control treatment was worked out accordingly.

Weed control efficiency (WCE) and weed control index (WCI) were calculated as per Mani et al. [18] and Das [19] using the following formulae

$$WCE (\%) = [(WDC - WDT) \div WDC] \times 100$$
$$WCI (\%) = [(WDMC - WDMT) \div WDMC] \times 100$$

Where, WDT and WDC, weed density (no. m^{-2}) in treated and unweeded control plot respectively; WDMT and WDMC, weed dry weight (g m^{-2}) in treated and unweeded control plot respectively.

3. RESULTS AND DISCUSSION

3.1 Predominant Weed Flora

“The predominant weed flora of different categories i.e. narrow-leaf weeds (grass), sedge weeds, and broadleaf weeds were observed and identified. Narrow-leaf weeds like *Echinochloa sp., Digitaria sanguinalis, Eleusine indica, Echinichloa crusgalli, Cynodon dactylon,* sedges like *Cyperus rotundus, Cyperus irria* and broad-leaf weeds like *Eclipta alba, Alternanthera philoxeroides, Sphenoclcea zeylenica, Commelina benghalensis, Phyllanthus niruri, Ageratum conyzoides, Alternanthera philoxeroides* were predominant weed flora in the rice field” Velasquez et al., [20]. Both the weed density and dry weight of weeds were significantly reduced in different treatment plots as compared to untreated control (Weedy check). Imazethapyr 10% SL fb imazethapyr

10% SL @ 2000 fb 2000 ml per ha recorded minimum grassy weed density (1.33at 45 DAS and 1.56 at 60 DAS), sedge weed density (1.92 at 45DAS and 2.27 at 60 DAS) as well as broad leaf weed density (1.03 at 45 DAS and 1.20 at 60 DAS) followed by T_6 (Table 1). Although the herbicide dose in imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml per ha is much more higher but there is no negative effect on plant because of herbicide tolerance. This treatment effectively controls different weed species at critical growth stages of rice which reduces the competition for nutrient, light and space. This results in less density of weeds and good growth of rice crop which is similar to Masson et al., [21] and Steele et al., [22] Similarly maximum weed control efficiency (92.58% and 91.99% at 45 DAS and 60 DAS respectively) and maximum weed control index (92.93% and 92.01% at 45 DAS and 60 DAS) was observed under in imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml per ha. Minimum weed control efficiency of sedge by 92.97% and 91.83% (Fig. 2) and dry matter by 92.69% and 91.83% (WCI) at 45 DAS and 60 DAS respectively (Fig. 5) and same observation also found in grassy and broad leaf weed which is at par with hand weeding twice at 20 and 40 DAS and caused maximum reduction in weed growth during both the years. These findings are in conformity with the findings of Webster [23]. Application of imazethapyr 10% SL fb imazethapyr 10% SL @ 1250 fb 1250 ml ha^{-1} ranked second by reducing the grassy weed density and maximum weed control efficiency 92.29% and 91.37% at 45 DAS 60 DAS (Fig. 1), minimum sedge weed density and weed control efficiency by 92.11%at 45 DAS and 91.48%at 60 DAS (Fig. 2) and same result also observed in grassy weeds , sedge and broad leaf weeds that at par with imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} which issimilar to Pellerin et al. [24] ; Narwal et al. [25]; Dubey et al. [26].

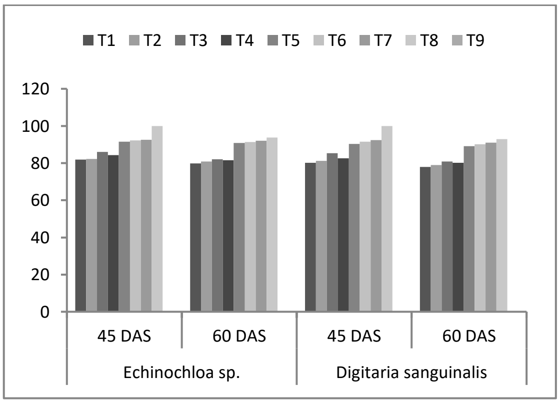

Fig. 1. weed control efficiency of grassy weeds (%)

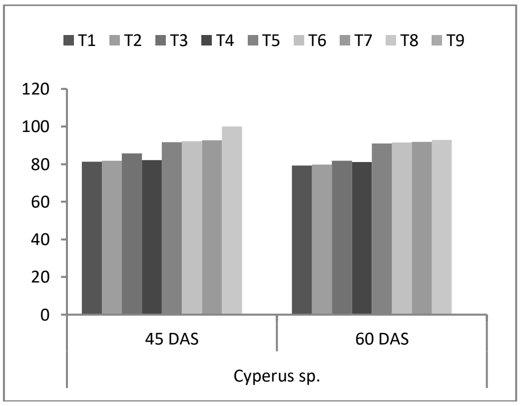

Fig. 2. weed control efficiency of sedges (%)

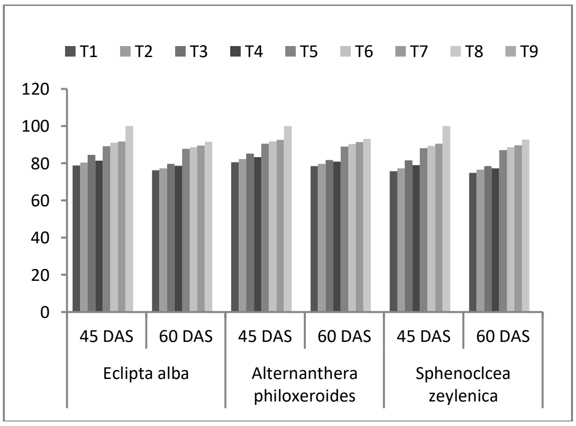

Fig. 3. weed control efficiency of broad leaf weeds (%)

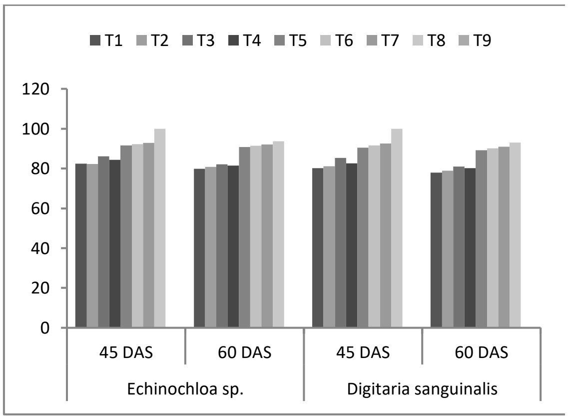

Fig. 4. weed index of grassy weeds (%)

Table 1. Effect of weed control treatments on weed density at 45 and 60 DAS (pooled over 2 years)

Treatments	Grassy weed density(no.m^{-2})				Sedge weed density(no.m^{-2})		Broad leaf weed density (no.m^{-2})					
	Echinochloa sp.		*Digitariasanguinalis*		*Cyperus sp.*		*Eclipta alba*		*Alternantheraphiloxeroides*		*Sphenoclceazeylenica*	
	45DAS	***60DAS***	***45DAS***	***60DAS***	***45DAS***	***60DAS***	***45DAS***	***60DAS***	***45DAS***	***60DAS***	***45DAS***	***60DAS***
T_1	2.03	2.22	1.75	1.93	2.45	2.69	1.81	1.95	1.69	1.85	1.70	1.84
	(3.63)	(4.43)	(2.56)	(3.22)	(5.51)	(6.74)	(2.79)	(3.32)	(2.35)	(2.95)	(2.40)	(2.89)
T2	1.98	2.18	1.71	1.85	2.41	2.66	1.75	1.92	1.64	1.81	1.63	1.80
	(3.43)	(4.25)	(2.41)	(2.91)	(5.33)	(6.58)	(2.56)	(3.18)	(2.21)	(2.79)	(2.17)	(2.76)
T3	1.79	3.88	1.53	1.75	2.11	5.83	1.58	1.81	1.47	1.71	1.46	1.69
	(2.70)	(2.09)	(1.84)	(2.58)	(3.94)	(2.51)	(2.00)	(2.79)	(1.68)	(2.43)	(1.64)	(2.38)
T_4	1.90	4.02	1.66	1.79	2.40	2.55	1.70	1.85	1.60	1.73	1.59	1.73
	(3.12)	(2.12)	(2.24)	(2.70)	(5.26)	(6.01)	(2.41)	(2.94)	(2.06)	(2.51)	(2.05)	(2.49)
T_5	1.46	1.82	1.28	1.34	1.64	1.74	1.34	1.39	1.22	1.30	1.21	1.28
	(1.63)	(1.52)	(1.15)	(1.31)	(2.18)	(2.52)	(1.30)	(1.43)	(0.99)	(1.20)	(0.98)	(1.16)
T_6	1.41	1.68	1.22	1.30	1.59	1.70	1.28	1.34	1.16	1.24	1.16	1.24
	(1.48)	(1.48)	(1.00)	(1.20)	(2.05)	(2.40)	(1.14)	(1.32)	(0.86)	(1.03)	(0.86)	(1.03)
T_7	1.35	1.43	1.18	1.25	1.55	1.66	1.24	1.30	1.12	1.18	1.12	1.10
	(1.33)	(1.56)	(0.90)	(1.08)	(1.92)	(2.27)	(1.03)	(1.20)	(0.75)	(0.91)	(0.75)	(0.91)
T_8	0.71	1.34	0.71	1.18	0.71	1.58	0.71	1.20	0.71	1.11	0.71	1.08
	(0.00)	(1.30)	(0.00)	(0.89)	(0.00)	(1.99)	(0.00)	(0.96)	(0.00)	(0.73)	(0.00)	(0.66)
T_9	4.87	5.17	3.80	3.94	5.55	5.93	3.93	4.12	3.74	3.95	3.33	3.56
	(23.29)	(26.30)	(13.98)	(15.02)	(30.20)	(34.69)	(15.01)	(16.48)	(13.54)	(14.12)	(10.62)	(12.19)
S.Em (±)	**0.07**	**0.09**	**0.06**	**0.07**	**0.09**	**0.11**	**0.07**	**0.08**	**0.06**	**0.07**	**0.06**	**0.06**
C.D. (.05)	**0.23**	**0.27**	**0.20**	**0.23**	**0.30**	**0.33**	**0.23**	**0.25**	**0.20**	**0.23**	**0.18**	**0.20**

T_1-Imazethapyr 10% SL @ 1000 ml ha^{-1} at 15 DAS, T_2 -Imazethapyr 10% SL @ 1250 ml ha^{-1} at 15 DAS ,T_3 - Imazethapyr 10% SL @ 2000 ml ha^{-1} at 15 DAS, T_4- Imazethapyr 10% SL @ 750 fb 750 ml ha^{-1} at 15 DAS and 30 DAS, T_5- Imazethapyr 10% SL @ 1000 fb 1000 ml ha^{-1} at 15 DAS and 30 DAS, T_6- Imazethapyr 10% SL @ 1250 fb 1250 ml ha^{-1} at 15 DAS and 30 DAS, and T_7- Imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} at 15 DAS and 30 DAS, T_8- weed free check (2 times hand weeding at 20 DAS and 40 DAS) and T_9- un-treated control (weedy check)

Table 2. Effect of weed control treatments on Dry matter (g m^{-2}) of weed flora at 45 DAS and 60 DAS (pooled over 2 years):

Treatments	Grassy weed population(no.m^{-2})				Sedge weed population(no.m^{-2})		Broad leaf weed population (no.m^{-2})					
	Echinochloa sp.		***Digitariasanguinalis***		***Cyperus sp***		***Eclipta alba***		***Alternanthera philoxeroides***		***Sphenoclceazeylenica***	
	45 DAS	**60 DAS**	**45 DAS**	**60 DAS**	**45 DAS**	**60 DAS**	**45 DAS**	**60 DAS**	**45 DAS**	**60 DAS**	**45 DAS**	**60 DAS**
T_1	2.11 (3.84)	2.30 (4.80)	1.78 (2.67)	1.91 (3.18)	2.39 (5.20)	2.70 (6.83)	1.84 (2.88)	2.01 (3.55)	1.65 (2.27)	1.81 (2.81)	1.66 (2.27)	1.85 (2.91)
T_2	2.09 (3.86)	2.25 (4.58)	1.74 (2.53)	1.88 (3.04)	2.35 (5.03)	2.67 (6.67)	1.78 (2.68)	1.97 (3.39)	1.60 (2.08)	1.77 (2.66)	1.61 (2.11)	1.79 (2.71)
T_3	1.88 (3.02)	2.18 (4.29)	1.57 (1.97)	1.80 (2.76)	2.11 (3.94)	2.54 (5.97)	1.62 (2.11)	1.88 (3.03)	1.49 (1.73)	1.70 (2.38)	1.48 (1.71)	1.73 (2.50)
T_4	1.97 (3.41)	2.22 (4.42)	1.68 (2.34)	1.83 (2.87)	2.34 (4.96)	2.58 (6.20)	1.74 (2.54)	1.92 (3.17)	1.56 (1.94)	1.73 (2.51)	1.56 (1.95)	1.77 (2.64)
T_5	1.53 (1.83)	1.64 (2.20)	1.34 (1.29)	1.43 (1.57)	1.68 (2.32)	1.86 (2.97)	1.40 (1.48)	1.52 (1.83)	1.26 (1.10)	1.39 (1.44)	1.26 (1.11)	1.41 (1.49)
T_6	1.47 (1.68)	1.60 (2.06)	1.28 (1.14)	1.39 (1.43)	1.64 (2.19)	1.81 (2.80)	1.35 (1.34)	1.47 (1.68)	1.20 (0.95)	1.32 (1.26)	1.22 (0.99)	1.35 (1.32)
T_7	1.43 (1.54)	1.55 (1.91)	1.23 (1.01)	1.34 (1.30)	1.59 (2.03)	1.78 (2.69)	1.31 (1.21)	1.43 (1.56)	1.16 (0.85)	1.27 (1.12)	1.17 (0.88)	1.30 (1.20)
T_8	0.71 (0.00)	1.42 (1.50)	0.71 (0.00)	1.23 (1.01)	0.71 (0.00)	1.67 (2.32)	0.71 (0.00)	1.32 (1.25)	0.71 (0.00)	1.18 (0.89)	0.71 (0.00)	1.16 (0.84)
T_9	4.72 (21.79)	4.93 (23.90)	3.73 (13.46)	3.86 (14.45)	5.32 (27.76)	5.78 (32.96)	3.76 (13.66)	3.92 (14.92)	3.49 (11.70)	3.68 (13.10)	3.14 (9.35)	3.48 (11.62)
S.Em (±)	**0.07**	**0.09**	**0.06**	**0.08**	**0.09**	**0.11**	**0.07**	**0.08**	**0.05**	**0.07**	**0.05**	**0.06**
C.D. (.05)	**0.22**	**0.29**	**0.20**	**0.24**	**0.29**	**0.33**	**0.22**	**0.26**	**0.17**	**0.22**	**0.16**	**0.20**

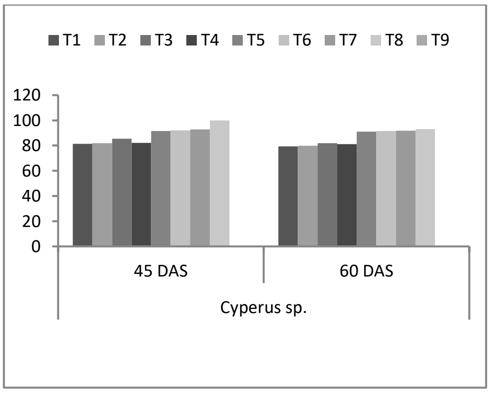

Fig. 5. weed index of sedge (%)

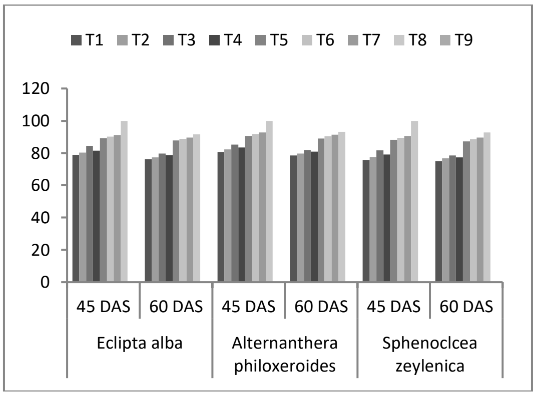

Fig. 6. weed index of broad leaf weeds (%)

Table 3. Effect of weed control treatments on yield and yield attributes (pooled over 2 years)

Treatment	No. of effective tillers m^{-2}	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)	Cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1	184	21.86	3.41	3.96	46.16	32794/-	34873/-	1.06
T_2	195	22.07	3.73	4.07	47.73	32879/-	40898/-	1.24
T_3	191	22.26	3.90	4.18	48.31	33134/-	44125/-	1.33
T_4	196	22.16	3.61	4.02	47.28	33292/-	38171/-	1.14
T_5	203	23.29	4.13	4.27	48.05	33790/-	43120/-	1.27
T_6	210	23.39	4.15	4.30	48.04	33960/-	47938/-	1.41
T_7	215	23.46	4.17	4.33	48.99	34470/-	47838/-	1.38
T_8	232	23.55	4.20	4.36	49.09	38358/-	44546/-	1.16
T_9	170	20.79	2.30	3.09	42.58	31798/-	14297/-	0.44
S.Em (±)	**2.19**	**1.17**	**0.68**	**0.41**	-	-	-	-
C.D. (.05)	**6.36**	**NS**	**2.05**	**1.25**	-	-	-	-

3.2 Phytotoxicity

Phytotoxicity was assessed in the treatments of imazethapyr 10% SL fb imazethapyr 10% SL at 1000 fb 1000 and 2000 fb 2000 ml ha^{-1} in direct seeded rice plants. The observations on yellowing, chlorosis, wilting, vein clearing, leaf tip injury, hyponasty and epinasty of direct seeded rice (DSR) plants were recorded at 0, 1, 3, 5, 7 and at 10 days after application (DAS) and result indicates that, there was no phyto-toxicity symptom observed at any of the dose of imazethapyr 10% SL at 1000 fb 1000 and 2000 fb 2000 ml per ha at all the observation days in the both years. This finding similar to Mahajan et al., 2021 [27].

3.3 Yield Attributes and Yield

There was significant increase in total numbers of effective tillers m^{-2} with the imposition of weed control treatments over unweeded check in both the years of the experiment. The difference in effective tillers was probably due to varying degree of crop-weed competition under different treatments. Total yield could be considered to be the mirror of all the growth features. The highest grain and straw yields (4.20 t ha^{-1} and 4.36 t ha^{-1} respectively) were recorded under hand weeding twice at 20 DAS and 40 DAS.This finding is similar to Dubey et al. [26]. Among herbicide treatments imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} applied at 15 DAS and 30 DAS recorded maximum test weight (23.46 g), grain yield (4.17 t ha^{-1}) and straw yield (4.33 t ha^{-1}) which is at par with imazethapyr 10% SL fbImazethapyr 10% SL @ 1250 fb 1250 ml ha^{-1} comparable to two hand weeding (Table 3). These results corroborate the findings of Masson et al. [21]; Gairola et al., [28].

Maximum values of benefit: cost ratio (BCR) 1.41 in both years of the experiment respectively was achieved with the use of imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} applied at 15 DAS and 30 DAS (Table 3). Hand weeding though formed well but it involved higher cost of cultivation resulting in much lower benefit to the farmers compared to the chemical weed control measures. Evidently, post-emergence application of imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} applied at 15 DAS and 30 DAS may be a cost-effective and alternative to conventional hand weeding practice of weed management in direct seeded rice. On other hand, imazethapyr 10% SL fb imazethapyr 10% SL 1250 fb 1250 ml ha^{-1} and imazethapyr 10% SL fb imazethapyr 10% SL 1000 fb 1000 ml ha^{-1} may also be used wherever it becomes possible and available, especially under the situations of labour scarcity or rising labour wages.

4. CONCLUSION

From the experiment it is clear that post-emergence application of imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} applied at 15 DAS and 30 in direct seeded rice is the best amongst the herbicidal treatments used in the field to control all kinds of weeds. This herbicide recorded the maximum economical benefit. Though the highest economical was recorded with hand weeding twice but it depicted low economic benefit due high labour requirement. So this post-emergence application of imazethapyr 10% SL fb imazethapyr 10% SL @ 2000 fb 2000 ml ha^{-1} provides us with a great opportunity to overcome uneconomic hand weeding. This finding is similar to Masilamany et al.[29]; Scarabel et al. [30].

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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