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Effect of weed management practices on weed dynamics, nutrient uptake, productivity and profitability of transplanted rice (*Oryza sativa* L.)

Preeti Chaudhary, Vivek, RK Naresh, BP Dhyani and M Sharath Chandra

Abstract
A field experiment was conducted on sandy loam soil at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P. during *kharif*, 2019 in randomised block design with three replications to study the effect of weed management practices on weed dynamics, nutrient uptake, productivity and profitability of transplanted rice. The treatments comprised of ten treatments of weed management i.e Weedy check, weed free, One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT, Penoxsulam (22 g a.i/ha) at 20 DAT, One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT, One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT, One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT, Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT, Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT were used for the experimentation and different observations were recorded during the crop growth period. The results indicated that the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT significantly reduced the weed population and dry weight over weedy check. The highest weed control efficiency, nutrient uptake and grain yield (38.80 q ha^{-1}), were recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT, which established its superiority over rest of the herbicidal treatments. The nitrogen, phosphorus and potassium uptake by rice crop was also highest (77.06, 18.45 and 75.01 kg ha^{-1}), with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT and 42.45 and 22.50 per cent increase in grains and straw yield as compared to weedy check in rice crop. The application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT resulted into higher gross return, net return and B: C ratio. Thus the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT found better for productivity and profitability of rice crop.

Keywords: Weed dynamics, nutrient uptake, productivity, profitability

Introduction
Rice (*Oryza sativa* L.) is a monocot plant belongs to genus *Oryza* under tribe Oryzae in grass family Poaceae and second most important food crops of the world after wheat. It is major staple crop of the world to diet of 2.7 billion people and its contain, 7-8% protein, 3% fat and 3% fiber. Rice occupies a pivotal role in Indian agriculture and it contributes to 15% of annual GDP of agriculture and provides 43% calorie requirement for more than 70% of Indians. Its accounts for about 39.6% of total food grain production and 44.07% of cereal production in the country. About 63 per cent of total rice area is situated in Uttar Pradesh, Bihar, West Bengal, Assam, Orissa and Madhya Pradesh. Demand for rice is going to increase every year and it is estimated that by year 2025 the requirement would be 140 mt (Anonymous, 2015) [1]. Weeds become detrimental to crops by changing the pH of soil, decreasing the nutrient availability, which inturn reduces straw yield by 13-38% and grain yield by 25-47% (Manandhar *et al*., 2007) [2]. In transplanted rice, 45-51% yield reduction caused by weeds (Veeraputhiran and Balasubramanian, 2013) [3]. This is posing a serious problem to even maintain the food grain production and leaving only the option of increasing the productivity of grain crops. Use of herbicides to keep the crop weed free at critical stages of crop weed competition will help in minimizing the cost of weeding as well as managing the weeds below the damaging level. The productivity of transplanted rice to a greater extent depends on adequate and efficient weed management. Transplanted rice faces diverse type of weed flora, consisting of grasses, broad-leaved weeds and sedges. They usually grow faster than rice and absorb available water, nutrient earlier than the rice and suppress rice growth. Effective control of weeds had increased the grain yield by 85.5% (Mukherjee and Singh 2005) [4].

Bispyribac-sodium is a post emergence herbicide, used as broad spectrum weed control of grasses, broad leaves and annual sedges, with excellent control of *Echinochloa* species. Reduction in weed density due to application of bispyribac-sodium at 15 and 25 DAT in transplanted rice were reported by Yadav *et al*. (2009) [5]. Application of either pre or post emergence herbicides were unable to control weeds efficiently, for this reason sequential application of pre and post emergence herbicides to control the weeds in rice is necessary. Herbicides with differential selectivity can be applied sequentially, but it results in enhancing the cost. Therefore, mixing two different herbicides and applying them simultaneously widens the spectrum of weed-control, saves time and application cost.

Keeping all these point in mind a field experiment was conducted with different weed management treatments including application of pre-emergence and post-emergence herbicides as sole and in combination to find out its effect of weed management practices on weed dynamics, nutrient uptake, yield and profitability of transplanted rice.

Materials and Methods

The field experiment was conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during *Kharif* (July –October) season 2019. The experiment was conducted in randomized block design (RBD) with three replications comprising ten weed management treatments. The treatments details, herbicide doses and time of herbicide application was depicted in table 1. The soil of the experimental field was sandy loam in texture, low in organic carbon and available N, medium in available P and K and slightly alkaline in reaction. Rice variety PB- 1509 was transplanted during second fortnight of July, 2019 at 20 cm ×10 cm spacing and harvested in second fortnight of October, 2019. Recommended package and practices were followed for the cultivation of rice except weed management. The herbicides were applied as per treatment details. The required quantity of herbicide were applied with manually operated knapsack sprayer fitted with flat-fan nozzle using a spray volume of 500 litre water/ha. The data collected from the experiment were analyzed statistically by analysis of variance (ANOVA) method for randomized block design (RBD) with weed management treatments as one factor, respectively. The weed dynamics, nutrient uptake, yield and economics data recorded, analysed and tabulated after statistical test.

$$\text{Amount of herbicide (kg/ha)} = \frac{\text{Rate of application (kg a. i/ha)}}{\text{Active ingredient content in herbicide formulation}} \times 100$$

Table 1: Treatments and their details

Treatments		Dose (g.a.i. ha^{-1})	Time of application (DAT)
T_1	Weedy check	-	
T_2	Weed free	-	
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	25	15+40
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	22	20
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	22	15+30
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	22	20+35
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	22	25+40
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	750+22	3+20
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	750+22	3+25
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	750+22	3+30

DAT : Days after transplanting

Results

Effect on weed parameters

Total weed density (m^{-2})

Density of total weeds was affected significantly by various treatments involving weed management practices (Table 2 and Fig. 1). Among weed control treatments, significantly highest total weed density at 30, 60 and 90 DAT (16.7, 17.4 and 16.2 m^{-2}, respectively) was found under weedy check (T_1) treatment. However, the herbicides lower density of total weeds 5.8 m^{-2} found at 30 DAT with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 6.3 m^{-2}. At 60 and 90 DAT significantly lower weed density 6.4 and 6.0 m^{-2} observed with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was found at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 7.5 & 6.8 m^{-2} respectively.

Table 2: Effect of weed management practices on total weeds density (m^{-2}) in rice at different stages

Treatments		Total weed density (m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	16.7 (277.7)	17.4 (301.7)	16.2 (261.4)
T_2	Weed free	2.19 (3.8)	2.46 (5.1)	2.36 (4.6)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	8.8 (77.1)	9.9 (96.3)	9.2 (83.4)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	9.5 (89.0)	10.3 (105.7)	9.8 (94.5)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	7.3 (52.0)	8.5 (71.8)	8.0 (63.3)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	7.5 (56.0)	9.3 (84.9)	8.7 (74.6)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	7.9 (60.9)	9.5 (89.5)	8.9 (78.1)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	5.8 (32.9)	6.4 (40.0)	6.0 (35.1)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	6.3 (39.1)	7.5 (55.4)	6.8 (45.5)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	7.4 (53.1)	7.8 (60.2)	7.2 (50.5)
	SEm+	0.30	0.33	0.31
	C.D.(P=0.05)	0.88	0.96	0.90

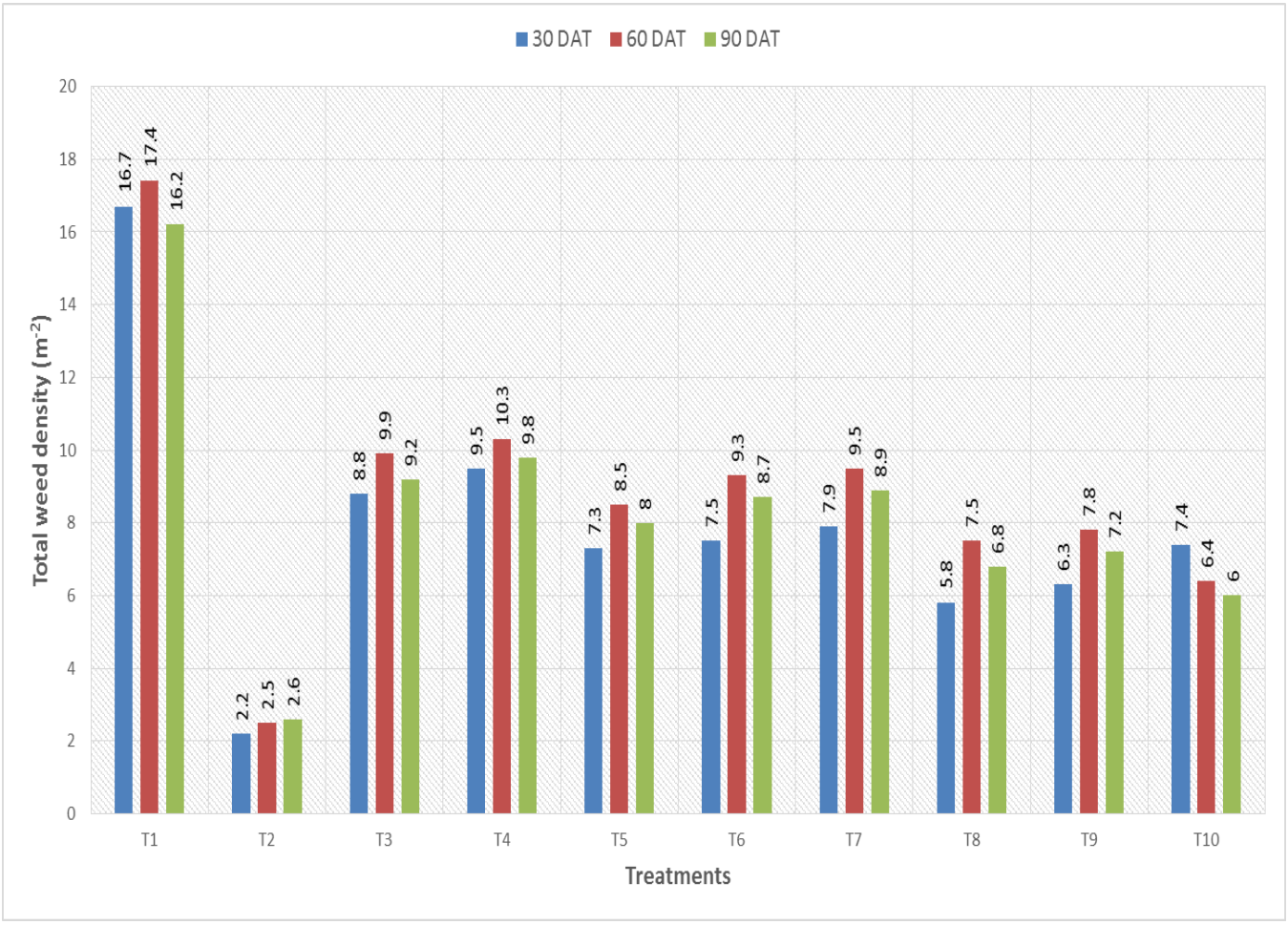

Fig 1: Effect of weed management practices on total weeds density (m^{-2}) in rice at different stages

Total weed dry weight (g m^{-2})

Total weed dry weight was affected significantly by various treatments involving weed management practices (Table 3 and Fig. 2). Among weed control treatments, significantly highest total weed dry weight 7.6, 11.6, & 13.0 g m^{-2} at 30, 60 and 90 DAT respectably was found in weedy check (T_1). However, the herbicides lower total weed dry weight 3.6 g m^{-2} found at 30 DAT with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) (3.8 g m^{-2}) and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) (4.1 g m^{-2}). Significantly lower total dry weight at 60 and 90 DAT respectively 5.7 and 6.6 g m^{-2} observed with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was found at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) (6.3 & 7.2 g m^{-2}) and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) (7.2 & 7.4 g m^{-2}) and significantly lower than the remaining treatments.

Table 3: Effect of weed management practices on total weed dry weight (g m^{-2}) in rice at different stages

Treatments		Total weed dry weight (g m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	7.6 (56.4)	11.6 (134.1)	13.0 (168.7)
T_2	Weed free	1.84 (2.4)	2.1 (3.4)	2.2 (3.8)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	5.5 (29.9)	8.2 (66.9)	9.0 (79.2)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	5.6 (29.9)	8.1 (65.3)	8.8 (76.2)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	4.2 (16.6)	6.7 (43.7)	7.5 (55.8)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	5.2 (26.3)	8.0 (62.5)	8.8 (76.6)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	5.4 (28.5)	8.0 (62.9)	8.7 (74.4)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	3.6 (12.2)	5.7 (31.3)	6.6 (42.0)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	3.8 (13.3)	6.3 (38.4)	7.2 (50.6)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	4.1 (15.5)	6.5 (40.9)	7.4 (53.2)
	SEm+	0.17	0.27	0.30
	C.D.(P=0.05)	0.51	0.77	0.86

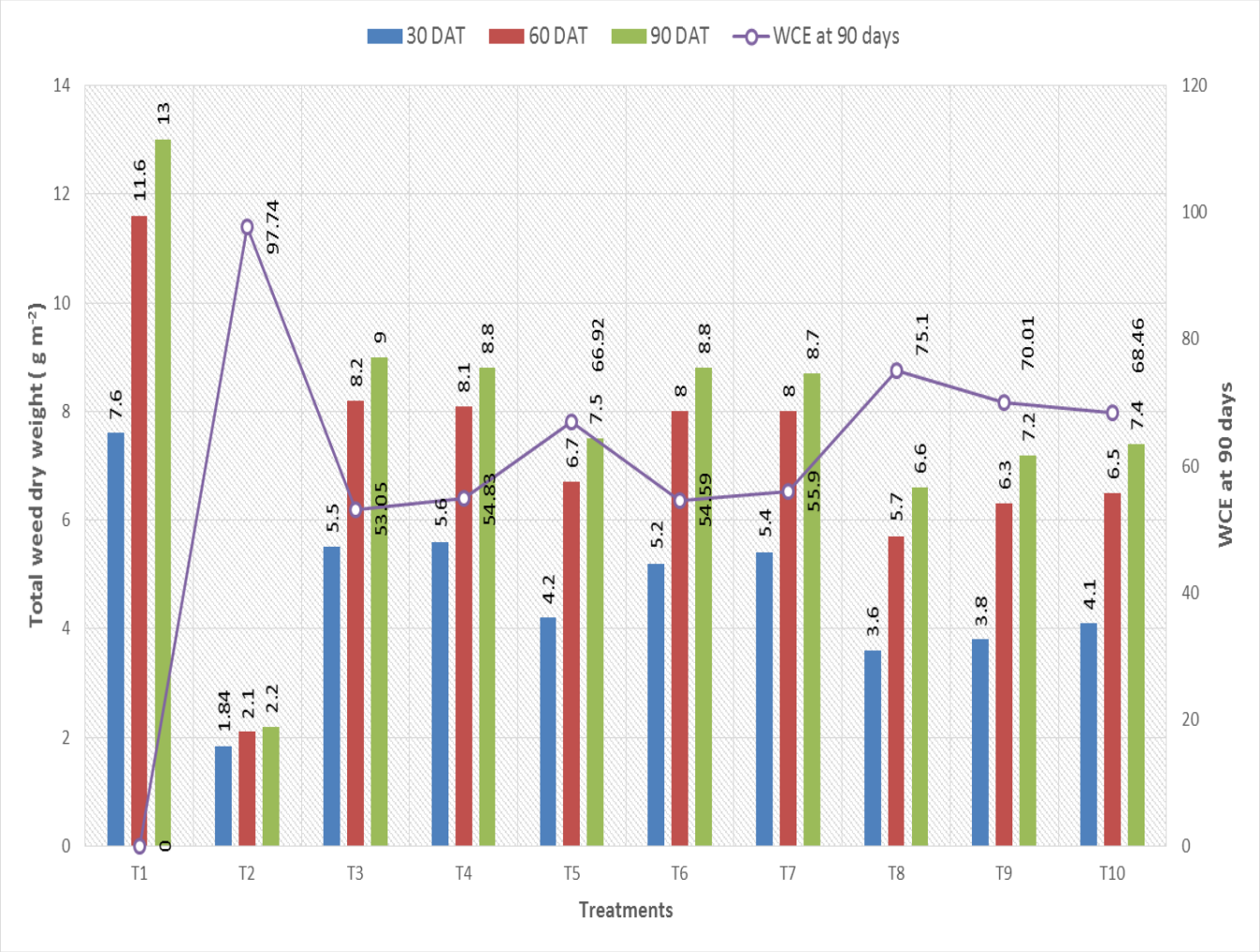

Fig 2: Effect of weed management practices on total weed dry weight (g m^{-2}) in rice at different stages & WCE at 90 Days

Nutrient uptake (kg ha^{-1})

Nutrient uptake (kg ha^{-1}) by weeds at 90 DAT

The highest Nitrogen uptake by weeds 20.24 kg ha^{-1} was found under weedy check while lowest 3.37 kg ha^{-1} in weed free (T_2) treatment (Table 4 and Fig.3). Significantly highest phosphorus and potassium uptake 5.40 and 21.76 kg ha^{-1} respectively found in weedy check (T_1), while the lowest phosphorus and potassium uptake 0.64 & 3.76 kg ha^{-1} respectively was found in weed free (T_2) treatment. Among the herbicides, lowest nitrogen, phosphorus and potassium uptake at harvest stage was found with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9).

Table 4: Effect of weed management practices on nutrient uptake (kg ha^{-1}) by weeds at 90 Days

Treatments		Nutrient uptake (kg ha^{-1})		
		Nitrogen	Phosphorus	Potassium
T_1	Weedy check	20.24	5.40	21.76
T_2	Weed free	3.37	0.64	3.76
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	8.71	2.30	9.90
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	8.69	2.29	9.68
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	5.64	1.34	6.53
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	8.12	1.99	9.35
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	8.04	2.01	9.15
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	4.03	0.84	4.62
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	4.96	1.06	5.62
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	5.27	1.22	6.06
	SEm+	0.30	0.08	0.33
	C.D.(P=0.05)	0.86	0.22	0.95

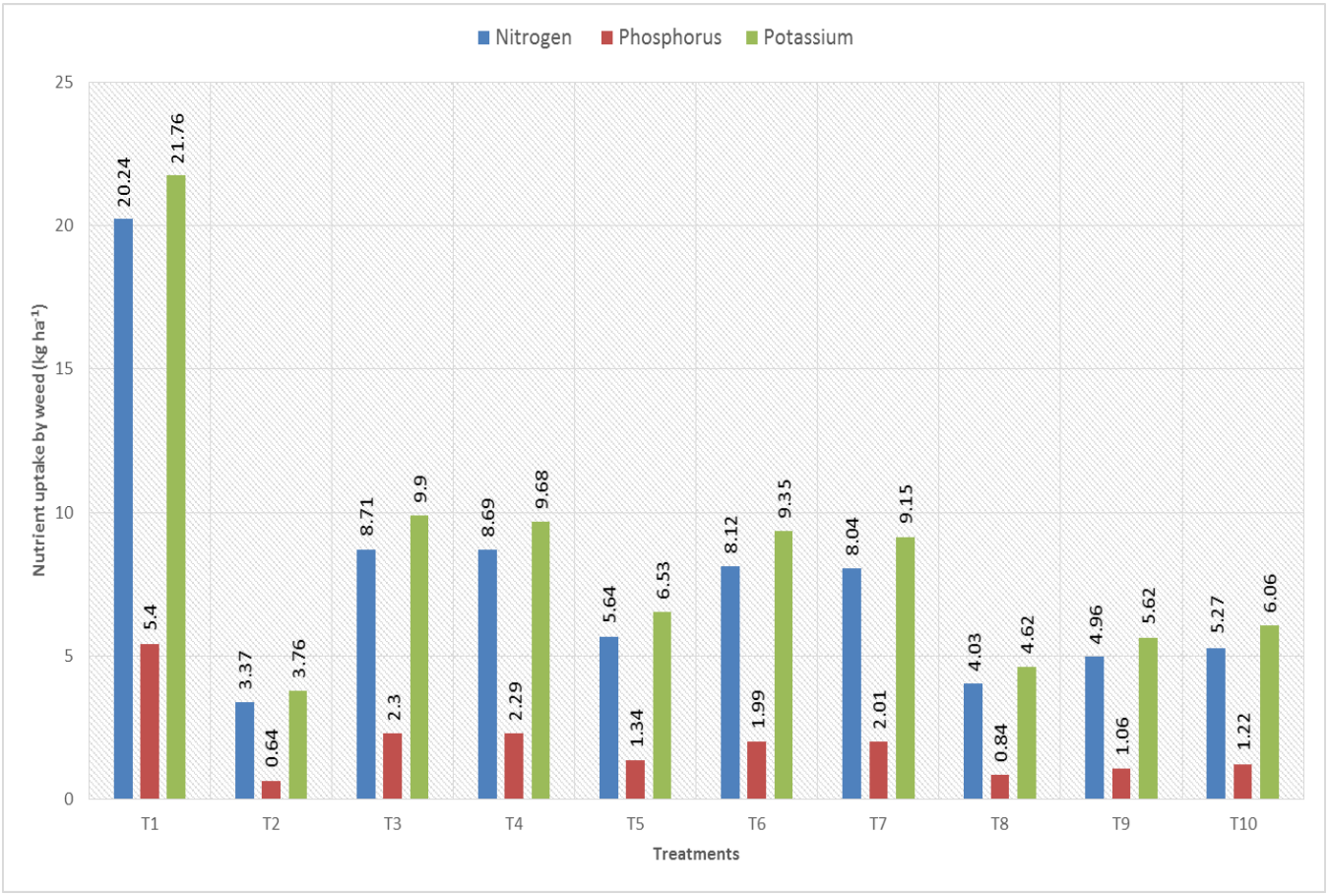

Fig 3: Effect of weed management practices on nutrient uptake (kg ha^{-1}) of weeds at 90 Days

Nutrient uptake (kg ha^{-1}) by crop

The highest nitrogen 61.73 kg ha^{-1}, phosphorus 15.66 kg ha^{-1} and potassium 16.10 kg ha^{-1} uptake in grain was observed in weed free (T_2) treatment (Table 5 and Fig.4). Among the herbicides, highest nitrogen, phosphorus and potassium uptake in grain with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) and significantly higher than the remaining herbicides treatments.

The highest nitrogen, phosphorus and potassium uptake in straw 27.77, 7.48 & 68.89 kg ha^{-1} respectively was found in weed free (T_2) treatment. Among the herbicides, highest nitrogen uptake found with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) and significantly higher than the remaining treatments. The highest phosphorus found with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}). The highest potassium uptake found with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}), significantly higher than the remaining treatments.

Table 5: Effect of weed management practices on N, P & K uptake (kg ha^{-1}) in rice grain & straw at harvest

Treatments		Nutrient uptake (kg ha^{-1})					
		Nitrogen		Phosphorus		Potassium	
		Grains	Straw	Grains	Straw	Grains	Straw
T_1	Weedy check	28.14	16.26	5.81	4.28	6.48	19.22
T_2	Weed free	61.73	27.77	15.66	7.48	16.10	68.89
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	44.63	21.13	9.54	5.16	10.22	56.35
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	43.85	19.70	9.44	4.69	10.12	54.87
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	46.46	22.16	10.56	5.30	10.91	59.73
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	47.09	22.10	10.54	5.28	10.54	58.16
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	46.16	21.58	10.14	5.27	10.49	57.55
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	52.38	24.68	12.03	6.42	12.80	62.21
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	51.93	24.62	11.93	6.40	12.70	62.06
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	50.49	22.63	11.59	5.90	11.97	61.50
	SEm+	1.70	0.79	0.38	0.20	0.40	2.04
	C.D.(P=0.05)	4.91	2.28	1.11	0.58	1.17	5.91

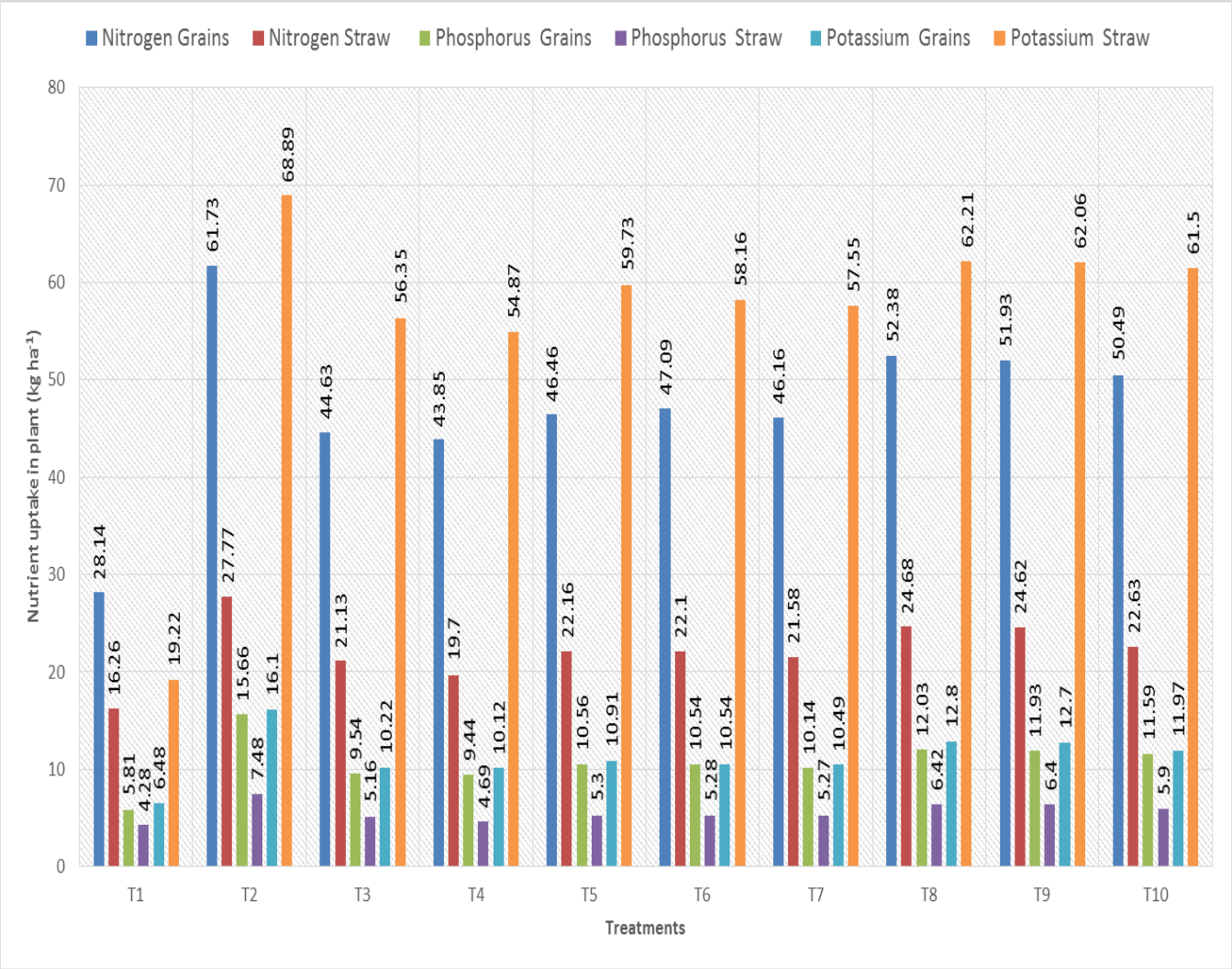

Fig 4: Effect of weed management practices on N, P & K uptake (kg ha^{-1}) in rice grain & straw at harvest

Effect on Crop yield

Grain yield

The highest grain yield 44.73 q ha^{-1} was found in weed free (T_2) and significantly higher to other treatments (Table 6 and Fig. 5). Among the herbicides, the highest grain yield 38.80 q ha^{-1} recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 38.47 q ha^{-1} and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) 37.40 q ha^{-1}. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 73.75% higher grain yield over weedy check (T_1).

Straw yield

The highest straw yield 53.40 q ha^{-1} was found in weed free (T_2) and significantly higher to other treatments (Table 6). Among the herbicides, the highest straw yield 49.37 q ha^{-1} recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 49.25 q ha^{-1} and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) 49.20 q ha^{-1}. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 22.50% higher grain yield over weedy check (T_1).

Biological yield

Among the herbicides, the highest biological yield 88.17 q ha^{-1} recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 87.72 q ha^{-1}, Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) 86.60 q ha^{-1} and significantly higher than the rest treatments. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 40.77% higher biological yield over weedy check (T_1).

Harvest index

Weed control treatments the lowest harvest index 35.65% was found in weedy check (T_1) while the highest harvest index 45.58% in weed free (T_2) treatment (Table 6 and Fig.5). Among the herbicides, the highest harvest index 44.01% recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) and Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}). Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 23.45% higher harvest index over weedy check (T_1).

Table 6: Effect of weed management practices on grains, straw, biological yield (q ha^{-1}) and harvest index (%) of rice

Treatments		Yield (q ha^{-1})			Harvest index (%)
		Grains	Straw	Biological	
T_1	Weedy check	22.33	40.30	62.63	35.65
T_2	Weed free	44.73	53.40	98.13	45.58
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	34.07	46.96	81.03	42.05
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	33.73	46.90	80.63	41.83
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	35.20	48.17	83.37	42.22
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	35.14	48.04	83.18	42.25
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	34.97	47.96	82.93	42.17
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	38.80	49.37	88.17	44.01
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	38.47	49.25	87.72	43.86
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	37.40	49.20	86.60	43.19
	SEm+	1.27	1.70	2.97	1.51
	C.D.(P=0.05)	3.68	4.93	8.60	4.36

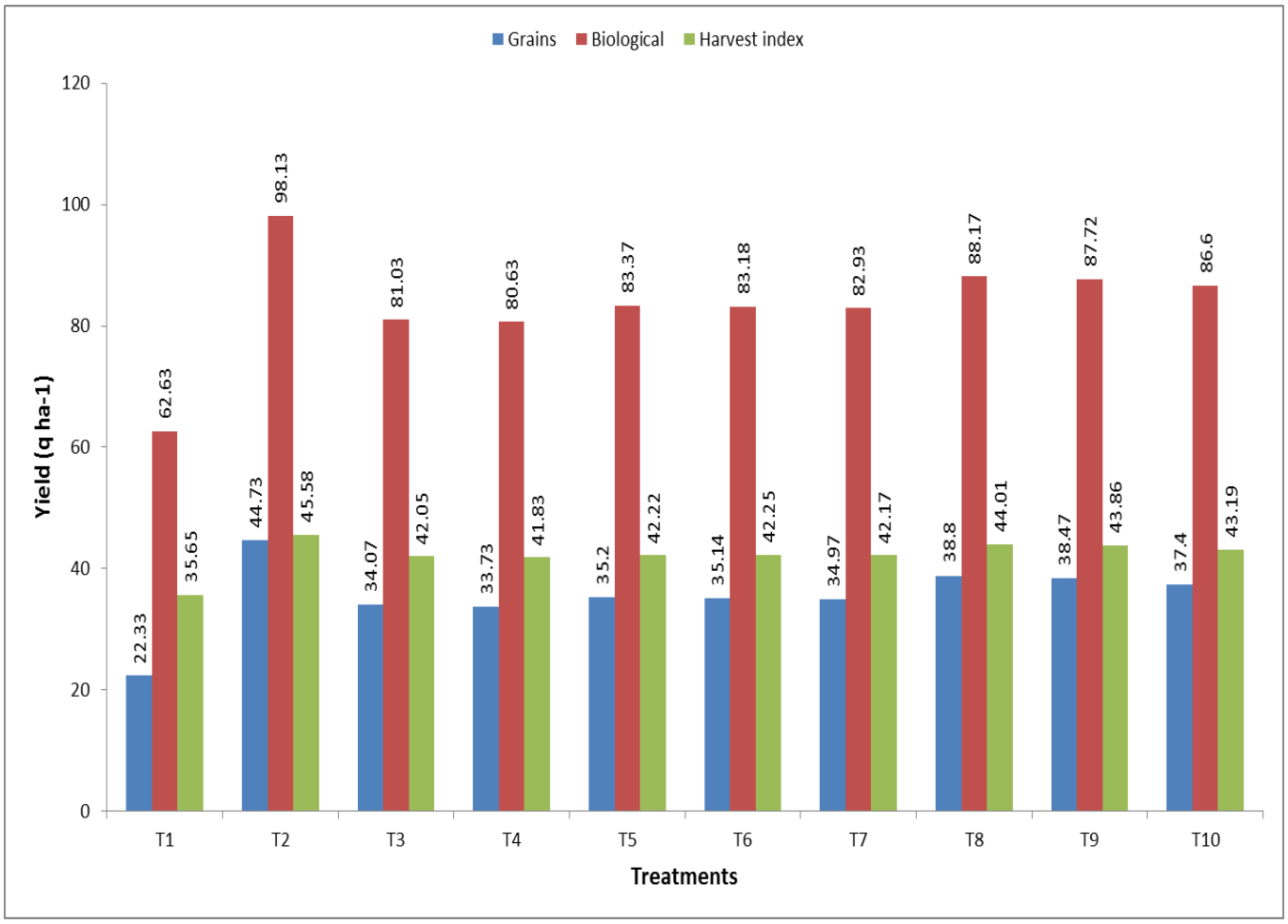

Fig 5: Effect of weed management practices on grains, biological yield (q ha^{-1}) and harvest index (%) of rice

Economics

The highest cost of cultivation 44814 Rs ha^{-1} found in weed free (T_2) treatment was significantly higher to other treatments (Table 7). Among the herbicides, the highest cost of cultivation 39564 Rs ha^{-1} recorded with the application of One hand weeding at 40 DAT+ Bispyribac-Na (EPoE) at 15 DAT (T_3). The highest gross return 86009 Rs ha^{-1} recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) followed by Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) and significantly higher than the rest treatments. The highest net return 48157 Rs ha^{-1} recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was stitistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 47495 Rs ha^{-1}, Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) 45497 Rs ha^{-1} and significantly higher than the rest treatments. The highest B: C ratio recorded with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) 2.27, which was statistically at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) 2.25, Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) 2.20 and significantly higher than the rest of the treatments. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 56.55% higher net return B: C ratio over weedy check (T_1).

Table 7: Effect of various treatments on economic analysis of rice cultivation

Treatment	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit: cost ratio
Weedy check	36624	53066	16442	1.45
Weed free	44814	98100	53286	2.19
One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	39564	76606	37042	1.94
Penoxsulam (22 g a.i/ha) at 20 DAT	37108	75965	38857	2.05
One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	39494	79043	39549	2.00
One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	39514	78894	39380	2.00
One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	39534	78558	39024	1.99
Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	37852	86009	48157	2.27
Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	37872	85367	47495	2.25
Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	37892	83389	45497	2.20
SEm+	-	2842.60	1496.54	0.07
C.D.(P=0.05)	-	8221.91	4328.58	0.21

Discussion

The different chemical controls the weeds effectively as compared to weedy check. Significantly the lowest total weed population under two hand weeding treatment because two hand weeding treatment was kept of weeds free by hand weeding. Among the herbicides, Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) found the best to control the weed population was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) to control weeds.

A cursory glance at the data reveals that the higher available nitrogen (212.10 kg ha$^{-1)}$ in soil was recorded in weed free (T_2) treatment. Among the herbicides, Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), showed higher available nitrogen (209.50 kg ha^{-1}) as compared to other herbicidal treatments. The lowest nitrogen (203.20 kg ha^{-1}) by crop was recorded in weedy check (T_1). Highest available phosphorus (17.60 kg ha^{-1}) observed in weed free (T_2) treatment. Among the herbicidal treatments, the highest available phosphorus (16.50 kg ha^{-1}) was observed in Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8), which was significant higher over the weed free (T_2). The lowest available phosphorus (14.80 kg ha^{-1}) was observed in weedy check (T_1). The available potassium varied significantly under different weed management practices. The highest available potassium (214.70 kg ha^{-1}) was recorded in weed free (T_2). Among the herbicides, the highest available potassium (213.80 kg ha^{-1}) was recorded in Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8). This might be due to less crop-weed competition in these plots. The results are in conformity with the findings of Singh *et al.* (2015) [6], Duary *et al.* (2015) [7] and Sangeeta *et al.* (2015) [8].

The uptake of nitrogen, phosphorus and potassium in grain and straw in a product of their nitrogen, phosphorus and potassium contents with respective dry matter yield. Significantly highest content and uptake of nitrogen, phosphorus and potassium were recorded with the weed free (T_2) treatment. Among the application of herbicides, highest content and uptake of nitrogen, phosphorus and potassium with the application of Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9). This was perhaps due to more dry matter production by crop and less nutrient (N, P and K) depletion by weeds and subsequently more availability of these nutrients to crop. The minimum uptake and content of these nutrients was observed in weedy check, simply because of low shoot dry matter production and low availability of these nutrients as major amount of nutrient were depleted by weeds. Almost similar results were obtained by Kiran *et al.* (2010) [9]; Sreelakshmi *et al.* (2016) [10].

Higher grain and biological yield was due to more accumulation of dry matter in the plant along with highest plant height, and number of tillers plant^{-1}. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 73.75, 22.50 and 40.77% higher grain and biological yield over weedy check (T_1) due to better vegetative growth and more dry matter accumulation. This was might be due to the higher crop growth of rice in terms of foliage, large amount of photosynthesis, which act as source and helped in developing yield attributes due to low crop weed competition and finally the higher grain yield Application of post emergence herbicide resulted in the highest grain yield (Ghosh and Bhowmick (2005)) [11]. The minimum grain yield was obtained from un-weeded control due to no control measure was adopted in this plot. Finding of present investigation are in agreement with finding of Narwal *et al.* (2002) [12].

In weed management practices the highest cost of cultivation (44814 Rs ha^{-1}) was recorded under weed free plot (T_2) due to higher labor charge and lowest cost of cultivation (36624 Rs ha^{-1}) was observed in weedy check (T_1) treatment. Hossain (2015) also reported similar results. The highest gross return (98100 Rs ha^{-1}) was recorded in weed free (T_2) treatment followed by Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) 86009 Rs ha^{-1}. The lowest gross return observed in weedy check (T_1), Singh et al. (2015) also reported similar results. The highest net return (53286 Rs ha^{-1}) was obtained under the treatment weed free (T_2). Among the herbicides, highest value of net return was obtained with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) (48157 Rs ha^{-1}) and lower net return (16442 Rs ha^{-1}) observed in weedy check (T_1). The highest value of B: C Ratio (2.19) was recorded with Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was at par with Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT (T_9) (2.25), Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT (T_{10}) (2.20). The lowest B: C ratio observed in weedy check (T_1) (1.45). Kabdal *et al.* (2014) [13] also reported similar results.

Conclusion

Based on the results of experimentation, it can be concluded that all weed control practices proved effective in controlling the weeds in transplanted rice and gave significantly higher grain yield over weedy check. The application Pretilachlor

(750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT most effective control different weeds species very effectively resulted into higher value of weed control efficiency. Highest nutrient uptake and grain yield of rice was noticed with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT. The nitrogen, phosphorus and potassium uptake by rice crop was also highest (77.06, 18.45 and 75.01 kg ha^{-1}), with the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT and 42.45 and 22.50 per cent increase in grains and straw yield as compared to weedy check in rice crop. The application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT resulted in to higher gross return, net return and B: C ratio. Thus the application of Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) found better for higher productivity and profitability of rice crop.

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