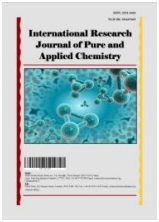

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Effect of Weed Management Practices on Weed Dynamics, Growth, Yield and Yield Attributes of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors Vivek and RKN done conceptualization and designing of the research work. Author PC performed the statistical analysis, managed execution of field experiment and data collection. Authors Vivek, RKN and BPD managed the analysis of data and interpretation. Authors PC and MSC done preparation of manuscript and managed the literature searches. All authors read and approved the final manuscript.

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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* (July –October), 2019 in randomised block design with three replications. The study comprised of ten different statistical treatments for weed management practices in transplanted rice and various 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 plant height, number of tillers (m^{-2}), dry matter accumulation, leaf area index, panicle length, filled grains, unfilled grains, higher protein content, 1000-grain weight and grain yield (38.80 q ha^{-1}), were recorded with the application of

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Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT, which established itssuperiority over rest of the herbicidal treatments. Among weed management treatments, Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) found excellent to control weed population and increase growth parameter, yield attributes and crop productivity.

Keywords:Weed dynamics; growth parameters; yield attributes; grain yield.

1. INTRODUCTION

The 21st century world is facing many challenges, often in an agricultural context. It is still prominent concern for feeding an evergrowing population with safe and healthy food from limited resources. This is urgently needed to management of natural resources such as land, water, nutrients and energy etc. in sustainable manner. 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. Rice (*Oryza sativa* L.) is the most important cereal crop and widely cultivated in the world. Asia is the home of rice as more than two billion people are getting 60-70% of their energy requirement from rice and its derived products[1]. It is major staple crop of the world to diet of 2.7 billion people and it contains 7-8% protein, 3% fat and 3% fibre. In India, rice occupies an area of 43.79 mha with production and productivity of 112.91 MT and 2.58 tonnes ha^{-1}, respectively (Ministry of agriculture Government of India, 2015) [2]. In India weeds were reported to contribute to highest crop yield losses as high as 37 % in kharif season. Monocotyledonous weed density is inversely correlated with crop yield, whereas the correlations between transplanted rice yield and dicotyledonous and sedge weed densities are not significant. Heavy weed infestation is one of the major constraints in transplanted rice causing severe yield losses[3]. Weeds emerge simultaneously with germination rice seedling resulting in severe competition for nutrient, light, and space. Weeds by virtue of their high adaptability and faster growth dominate the crop habitat reduce the yield potential[4]. The degree of rice – weed competition depends on crop factor i.e. cultivar, crop density, crop age, plant spacing etc. Effective weed control in transplanted rice is one of the major limitations hindering its wide spread cultivation. Hand pulling or hand weeding is time consuming, cumbersome and costly alternative. Hence for transplanted rice, the chemical method of weed management is most suited as it takes care of weeds right from beginning of crop growth and is cost effective [5]. Most of the herbicide recommended for rice is generally applied as pre-emergence to take care of weed during initial period. However, to have minimum competition between weeds and rice the weeds need to be kept below threshold level especially during critical weed competition period. 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 and reduction in weed density at 15 and 25 DAT in transplanted rice were reported by Yadav *et al*. (2009) [6].

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 on growth and productivity of transplanted rice in Indo-Gangetic Plain Zones of Western Uttar Pradesh.

2. 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.

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

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. Whenever the treatment differences were found significant (F test), critical differences were worked out at five per cent probability level. Treatment differences that were non-significant were denoted by NS. The weed parameters, growth parameters, yield, yield attributes and protein content of grains data recorded and tabulated after statistical test.

2.1 Data Recorded on Weed Parameter, Yield, Yield Attributes and Protein Content in Grains

1. **Weed population per meter square:** Weed population was counted from an area enclosed in a quadrant of 0.40 cm2 from each plot and then converted into per meter square. The original data was transformed by taking square root of the original value of each treatment.
2. **Number of panicles per meter:** The total number of panicles per meter were counted at the time of harvesting from the net plot area.
3. **Panicle length (cm):** Five panicles randomly selected from the tagged plants were harvested separately. The lengths of panicles were measured in cm from the neck node to its tip and finally the average length of panicle was worked out.
4. **Number of filled and unfilled grains per panicles:** Ten panicles were selected randomly from each plot and number of filled and unfilled grains per ten panicles was counted and average number of grains per panicles was worked out.
5. **1000-grain Weight (g):** To avoid biasness, handful seeds were taken from each net plot and thousand seeds were counted randomly and weighed. The average of three sub samples from each plot was taken to compute the final 1000-grain weight.
6. **Grain yield (q ha^{-1}):** Grain yield was determined from the net plot area and was weighed in kg and converted into q ha^{-1}. Grains were harvested, dried and weighed, and grain weight was taken at 14 % moisture content.
7. **Biological yield (q ha^{-1}):** The crop in each net plot will be harvested bundled, labelled and dried in the field for 4-5 days. Bundles will be weighed just before threshing to record biological yield (Grain yield q ha^{-1} + straw yield q ha^{-1}) per plot and expressed in q ha^{-1}.
8. **Harvest index (%):** The recovery of seed in total biological yield was considered as harvest index which was calculated with the help of following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield (q ha}^{-1})}{\text{Biological Yield (q ha}^{-1})} \text{ x } 100$$

9. **Protein content in grains:** Protein content in grains of rice at maturity was worked out by multiplying the nitrogen percentage of grains with 5.75 (AOAC, 1990) [7].

Table1. 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

3. RESULTS

3.1 Effect on Weed Parameters

3.1.1 Density of *Echinochloacrusgalli* (m^{-2})

Density of *Echinochloacrusgalli* was affected significantly by various treatments involving weed management practices (Table 2). Among weed control treatments, significantly highest density of *Echinochloacrusgalli* 6.83, 6.74 & 6.10 m^{-2} at 30, 60, and 90 DAT respectively was found in weedy check (T_1). However, the lowest weed density (2.19 m^{-2}) at 30 DAT found in 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) 2.43 m^{-2}. Among herbicide lowest weed density at 60 & 90 DAT 2.61 & 2.66 m^{-2} recorded in 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) 2.85 & 2.98 m^{-2}.

3.1.2 Density of *Echinochloacolona* (m^{-2})

Density of *Echinochloacolona* was affected significantly by various treatments involving weed management practices (Table 3). Among weed control treatments significantly highest density of *Echinochloacolona* 6.57, 6.35 & 5.78 m^{-2} at 30, 60, 90 DAT, respectively was found in weedy check (T_1). However, the lowest weed density (2.15 m^{-2}) at 30 DAT found in 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) 2.68 m^{-2}. Among herbicide lowest weed density at 60 & 90 DAT 2.88 & 2.58 m^{-2} recorded in 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) 3.11 & 2.82 m^{-2}.

3.1.3 Density of *Commelinabenghalensis* (m^{-2})

Density of *Commelinabenghalensis* was affected significantly by various treatments involving weed management practices (Table 4). Among weed control treatments, significantly highest density of *Commelinabenghalensis* 4.95, 5.31 & 5.16 m^{-2} at 30, 60, 90 DAT, respectively was found in weedy check (T_1). However, the lowest weed density (2.11 m^{-2})at 30DAT found in 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) 2.27 m^{-2}. Among herbicide lowest weed density at 60 & 90 DAT 2.27 & 2.06 m^{-2} recorded in 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) 2.32 & 2.23 m^{-2}.

Table 2. Effect of weed management practices on density of *Echinochloacrusgalli* (m^{-2}) at different stages

Treatments		Density of *Echinochloacrusgalli* (m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	6.83 (45.6)	6.74 (44.4)	6.10 (36.2)
T_2	Weed free	1.18 (0.4)	1.22 (0.5)	1.18 (0.4)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	3.65 (12.2)	4.27 (17.2)	3.77 (13.2)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	3.90 (14.2)	4.50 (19.2)	4.27 (17.2)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.88 (7.3)	3.74 (13.2)	3.49 (11.2)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	3.16 (9.0)	3.77 (14.2)	3.77 (13.2)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	3.38 (10.4)	4.14 (16.1)	3.76 (13.2)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	2.19 (3.8)	2.61 (5.8)	2.66 (6.1)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	2.43 (4.9)	2.85 (7.1)	2.98 (7.9)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.83 (7.0)	3.27 (9.7)	3.03 (8.2)
	C.D.(P=0.05)	0.36	0.40	0.38

Original values in parenthesis. Values are square root √(X+1.0)

Table 3. Effect of weed management practices on density of *Echinochloacolona* (m^{-2}) at different stages

Treatments		Density of *Echinochloacolona* (m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	6.57 (42.2)	6.35 (39.3)	5.78 (32.4)
T_2	Weed free	1.26 (0.6)	1.34 (0.8)	1.30 (0.7)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	3.48 (11.1)	4.15 (16.2)	3.90 (14.2)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	3.59 (11.9)	4.38 (18.2)	4.15 (16.2)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.98 (7.9)	3.66 (12.4)	3.56 (11.7)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	3.05 (8.3)	4.00 (15.0)	3.56 (11.9)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	3.11 (8.7)	3.90 (14.2)	3.77 (13.2)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	2.15 (3.6)	2.88 (7.3)	2.58 (5.7)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	2.68 (6.2)	3.11 (8.7)	2.82 (7.0)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.90 (7.4)	3.49 (11.2)	2.98 (7.9)
	C.D.(P=0.05)	0.35	0.40	0.37

Original values in parenthesis. Values are square root √(X+1.0)

Table 4. Effect of weed management practices on density of *Commelinabenghalensis*(m^{-2}) at different stages

Treatments		Density of *Commelinabenghalensis*(m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	4.95 (23.5)	5.31 (27.2)	5.16 (25.6)
T_2	Weed free	1.22 (0.5)	1.30 (0.7)	1.26 (0.6)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	2.86 (7.2)	3.03 (8.2)	2.77 (6.7)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	3.20 (9.2)	3.12 (8.7)	3.01 (8.1)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.64 (6.0)	2.68 (6.2)	2.50 (5.3)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	2.34 (4.5)	2.86 (7.2)	2.63 (6.0)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	2.44 (5.0)	2.92 (7.5)	2.67 (6.2)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	2.11 (3.5)	2.27 (4.2)	2.06 (3.3)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	2.27 (4.2)	2.32 (4.4)	2.23 (4.0)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.48 (5.2)	2.53 (5.4)	2.42 (4.9)
	C.D.(P=0.05)	0.29	0.30	0.28

Original values in parenthesis. Values are square root √(X+1.0)

3.1.4 Density of *Caesuliaaxillaris* (m^{-2})

Density of *Caesuliaaxillaris* was affected significantly by various treatments involving weed management practices (Table 5). Among weed control treatments significantly highest density of *Caesuliaaxillaris* 4.78, 5.28 & 5.02 m^{-2} at 30, 60, 90 DAT, respectively was found in weedy check (T_1). However, the lowest weed density (2.12 m^{-2}) at 30 DAT found in 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) 2.32 m^{-2}. Among herbicide lowest weed density at 60 & 90 DAT 2.04 & 1.96 m^{-2} recorded in 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) 2.25 & 2.21 m^{-2}.

3.2 Effect on Crop Growth

Plant height, number of tillers and dry matter accumulation tended to increase with advancement in crop age, irrespective of the weed management practices (Table 6 and Fig. 1). At harvest stage, significantly highest plant height, no of tillers and dry matter accumulation 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) and 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. Lowest plant height, number of tillers and dry matter accumulation was recorded under weedy check plot (T_1) at 90 DAT and harvest.

3.3 Effect on Yield Attributes and Yield

3.3.1 Yield attributes

The highest panicle length, filled grain, unfilled grain and test weight of grain was found in weed free (T_2) treatment (Table 7 and Fig. 2). Among the herbicides the highest panicle length, filled grain, unfilled grain and test weight of grain 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) and were significantly higher than the rest of the treatments. The lowest panicle length, filled grain, unfilled grain and test weight of grain was found in weedy check (T_1).

3.3.2 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 8 and Fig. 3). 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 with 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}. Moreover, 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).

3.3.3 Biological yield

The highest biological yield 98.13 q ha^{-1} found in weed free (T_2) treatment (Table 8 and Fig. 3). 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 87.72 q ha^{-1} (T_9), 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).

3.3.4 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 8 and Fig. 3). 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).

3.3.5 Protein content in grain

The highest protein content 7.82% found in weed free (T_2) treatment (Table 8 and Fig. 3). Among the herbicides, the highest protein content 7.76% 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 of the treatments. Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) recorded 12.0% increase protein content over weedy check (T_1).

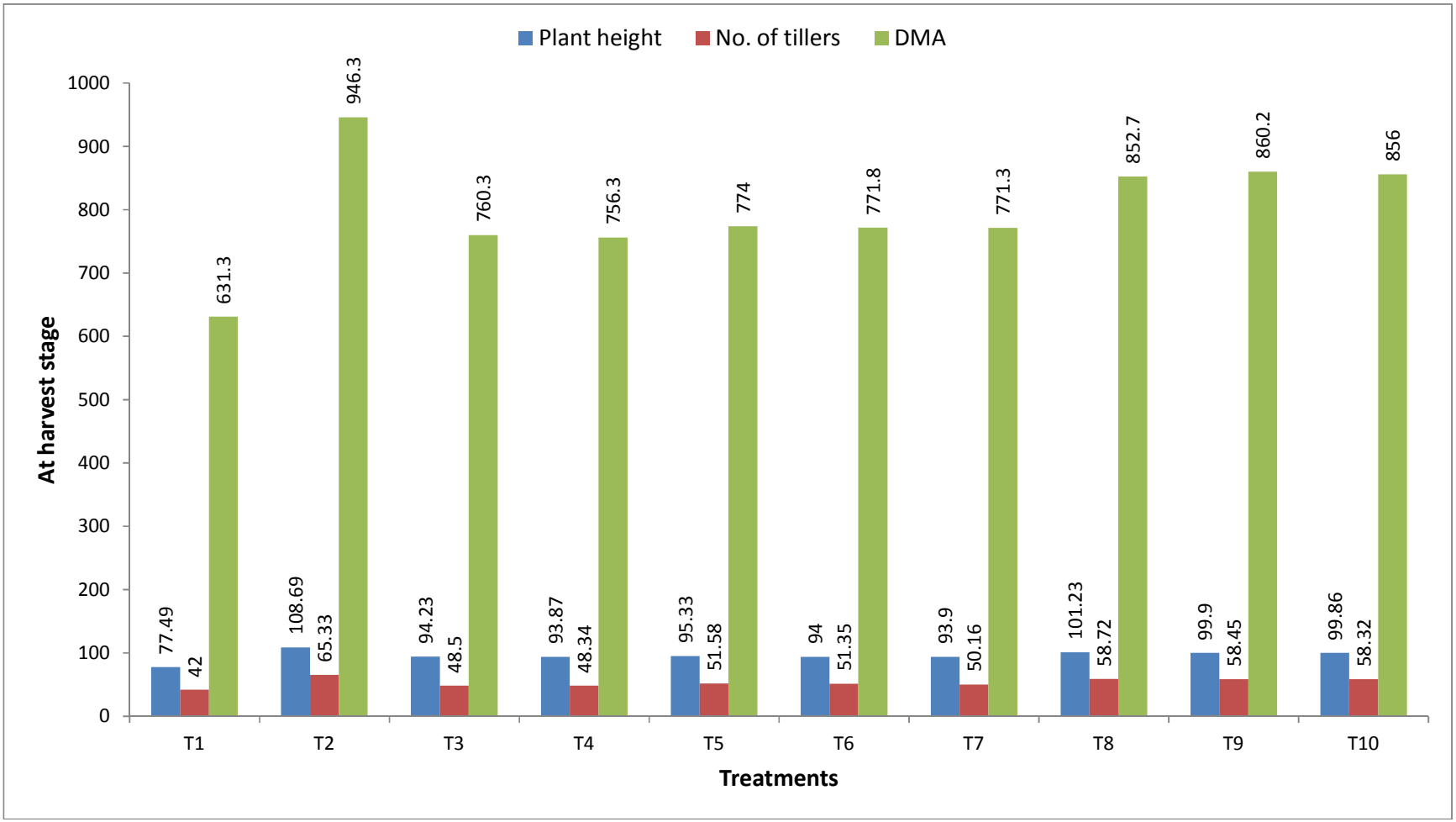

Fig. 1. Effect of weed management treatment on plant height (cm), number of tillers (m^{-2}), dry matter accumulation (DMA) at harvest stage

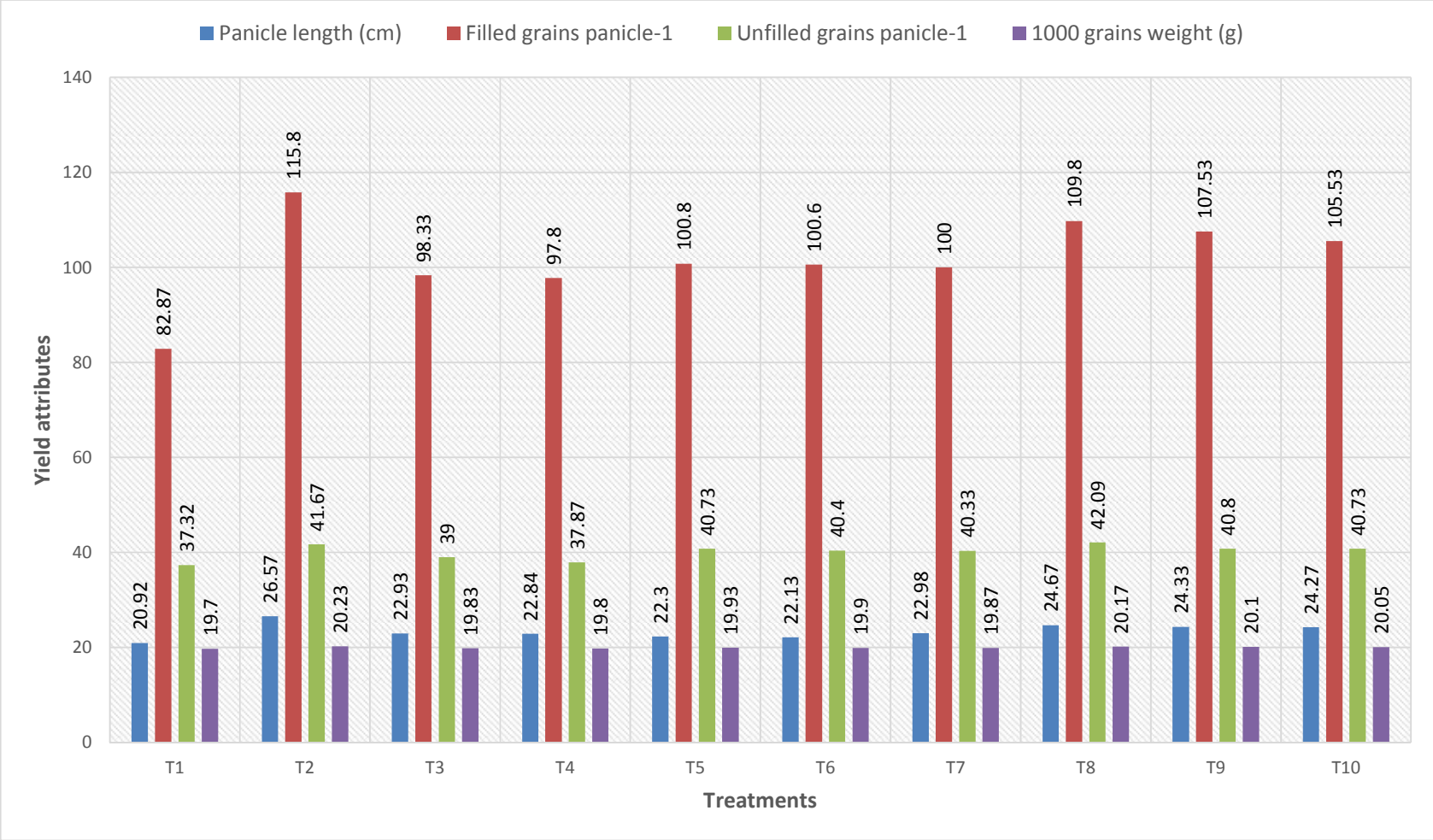

Fig. 2. Effect of weed management practices on yield attributes of rice

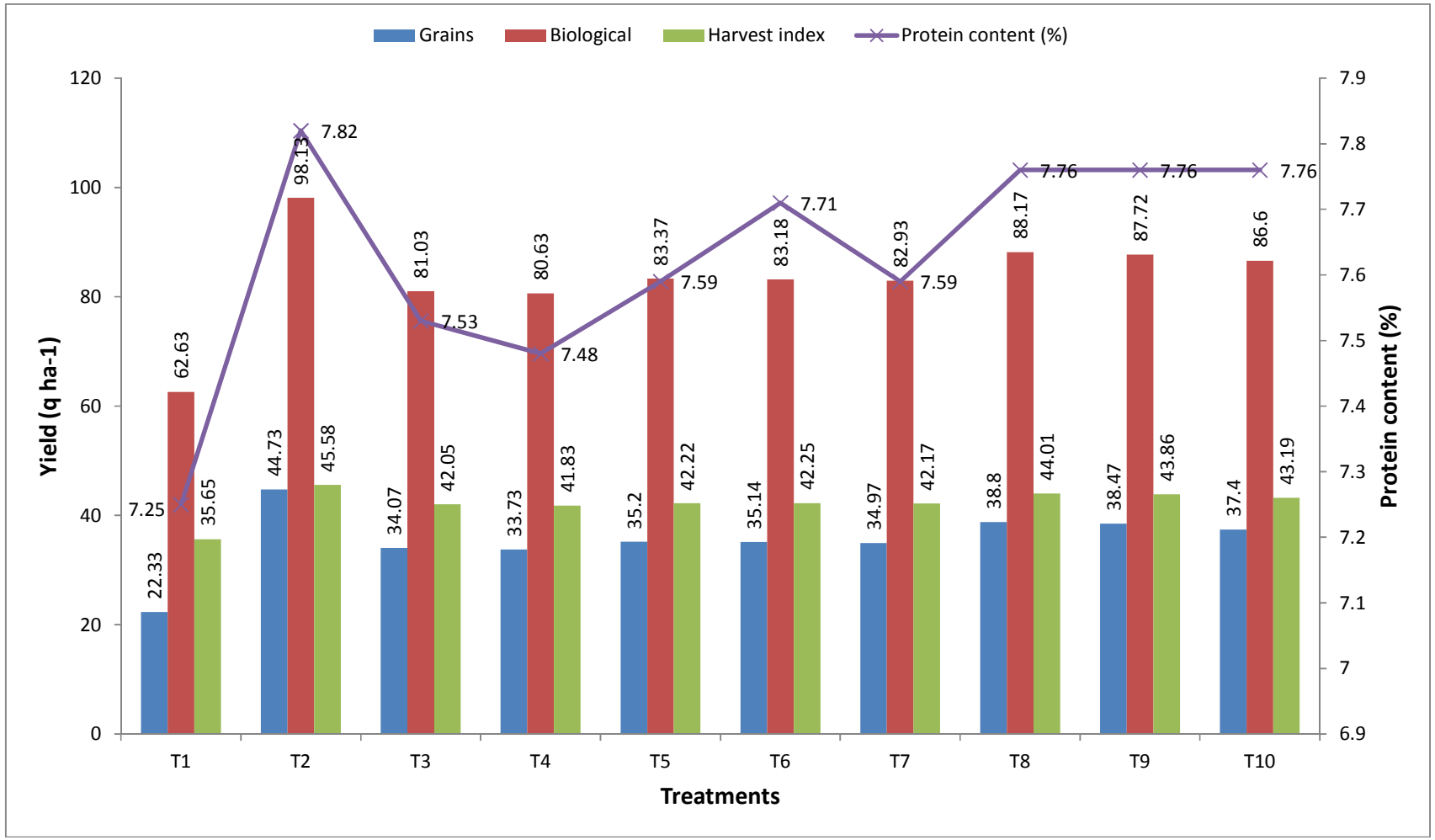

Fig. 3. Effect of weed management practices on grains, biological yield (q ha^{-1}), harvest index (%) and protein content (%) of rice

Table 5. Effect of weed management practices on density of *Caesuliaaxillaris*(m^{-2}) at different stages

Treatments		Density of *Caesuliaaxillaris*(m^{-2})		
		30 DAT	60 DAT	90 DAT
T_1	Weedy check	4.78 (21.8)	5.28 (26.8)	5.02 (24.2)
T_2	Weed free	1.14 (0.3)	1.22 (0.5)	1.18 (0.4)
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	2.38 (4.7)	2.86 (7.2)	2.68 (6.2)
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	2.98 (7.9)	2.98 (7.9)	2.77 (6.7)
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.27 (4.2)	2.52 (5.4)	2.48 (5.3)
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	2.36 (4.6)	2.66 (6.1)	2.47 (5.2)
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	2.21 (3.9)	2.70 (6.3)	2.72 (6.4)
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	2.12 (3.5)	2.04 (3.2)	1.96 (2.9)
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	2.32 (4.4)	2.25 (4.1)	2.21 (3.9)
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	2.38 (4.7)	2.32 (4.4)	2.34 (4.0)
	C.D.(P=0.05)	0.27	0.30	0.29

Original values in parenthesis. Values are square root √(X+1.0)

4. DISCUSSION

The different chemical treatments effectively controlled the weeds, as noticed on the weedy check. Significantly the lowest total weed population under two hand weeding treatment because two hand weeding treatment has been 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.

The plant height, number of tillers m^{-2} and dry matter accumulation were recorded maximum under two hand weeding treatment at different growth stage during experimentation. Among herbicides, treatment Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was recorded the maximum plant height. This may be due to lower dry weight of weed in Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) applied plots followed Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 25 DAT (T_9), which resulted in less crop-weed competition. Furthermore, increased infestation of weeds showed negative influence on the crop growth as reflected in terms of lower initial plant height and plant biomass due to poor resource utilization (like nutrients uptake) at the critical period of crop-weed competition period i.e. 15-60 DAT. The possible reason of the maximum plant height in these treatments might be due to congenial and longer weed free environment during crop growth period provided better opportunity for overall growth and development of rice plants lead to maximum plant height. Sharma *et al*. (2003) [8] noted that application of ethoxysulfuron was as effective as weed free treatment, hand weeding to produce maximum plant height. This is in accordance with finding of Narwal *et al*. (2002) [9]; Mukherjee *et al*. (2008) [10]in transplanted rice. However, in general, all the plots where herbicides, cultural and mechanical (alone or with herbicide) method applied to control weeds accumulated the higher dry matter of rice than un-weeded control. The possible reason of higher accumulation of dry matter of rice was the effect of herbicides on weeds so rice plant received more space, moisture, light and nutrient for their proper growth and this favored the higher dry matter accumulation of rice per unit area. The higher dry matter accumulation also associated with the higher height and number of tillers. The increasing foliage might have enhanced the photosynthesis due to which plant dry matter accumulation was higher under these treatments. This is in accordance with the findings of Khaliq (2013) [11]in direct seeded rice.

Panicle length, filled grains, unfilled grains and test weight, were significantly influenced due to

various weed management practices. Treatment Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) was found superior as compared to all other weed management plots except Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 25 DAT (T_9). Due to reduced crop-weed competition and better sink capacity performed more panicle length, filled grains, unfilled grains and test weight. The yield attributes are decided by genetic makeup of the crop and variety, but the agronomic manipulation also affects them to a great extent. The reproductive growth depends on vegetative growth of plant. More vegetative growth increases the photosynthetic area and supply of photosynthetic toward sink which decided the yield attributes and ultimately the yield. The higher values of yield attributes were due to increased synthesis and translocation of metabolites for the panicle development and grain formation. Besides, thousand grain weights were also maintained because of high mobilization of photo-synthesis from source to sink. However, this is quite possible because these combinations of herbicides might have been very effective to reduce the mixed weeds density and their growth resulting better and congenial environment favoured the rice plant to utilize nutrients, light, space luxuriantly and grew well to produce more number of fertile tillers. Rest of the treatments of weed management also proved to be significantly effective in producing higher number of effective tillers as compared to un-weeded control under which the minimum tiller m^{-2} was recorded. Similar results were noted by Ghosh and Bhowmick (2006) [12] and Sharma *et al*. (2003) [8] also confirmed the same.

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 due to better vegetative growth and more dry matter accumulation. This wasmight be due to the higher crop growth of rice in terms offoliage, 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 in transplanted rice (Ghosh and Bhowmick (2006) [12]. 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) [9]in transplanted rice.

Table 6.Effect of weed management treatment on plant height (cm), number of tillers (m^{-2}), Dry matter accumulation (DMA) (g m^{-2}) at harvest stage

Treatments		Plant height (cm)	No. of tillers (m^{-2})	DMA (g m^{-2})
T_1	Weedy check	77.49	42.00	631.30
T_2	Weed free	108.69	65.33	946.30
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	94.23	48.50	760.30
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	93.87	48.34	756.30
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	95.33	51.58	774.00
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	94.00	51.35	771.80
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	93.90	50.16	771.30
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	101.23	58.72	852.70
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	99.90	58.45	860.20
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	99.86	58.32	856.00
	C.D.(P=0.05)	10.31	5.52	82.68

Table 7. Effect of weed management practices on yield attributes of rice

Treatments		Yield attributes			
		Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grains weight (g)
T_1	Weedy check	20.92	82.87	34.10	19.70
T_2	Weed free	26.57	115.80	17.24	20.23
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	22.93	98.33	26.62	19.83
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	22.84	97.80	27.71	19.80
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	22.30	100.80	23.16	19.93
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	22.13	100.60	24.39	19.90
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	22.98	100.00	25.46	19.87
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	24.67	109.80	20.29	20.17
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	24.33	107.53	21.67	20.10
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	24.27	105.53	22.73	20.05
	C.D.(P=0.05)	2.42	10.51	4.10	NS

Table 8. Effect of weed management practices on grains, biological yield (q ha^{-1}), harvest index (%) and protein content (%) of rice

Treatments		Yield (q ha^{-1})			Protein content (%)
		Grains	Biological	Harvest index (%)	
T_1	Weedy check	22.33	62.63	35.65	7.25
T_2	Weed free	44.73	98.13	45.58	7.82
T_3	One hand weeding at 40 DAT+ Bispyribac-Na (25 g a.i/ha) at 15 DAT	34.07	81.03	42.05	7.53
T_4	Penoxsulam (22 g a.i/ha) at 20 DAT	33.73	80.63	41.83	7.48
T_5	One hand weeding at 15 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	35.20	83.37	42.22	7.59
T_6	One hand weeding at 20 DAT+ Penoxsulam (22 g a.i/ha) at 35 DAT	35.14	83.18	42.25	7.71
T_7	One hand weeding at 25 DAT+ Penoxsulam (22 g a.i/ha) at 40 DAT	34.97	82.93	42.17	7.59
T_8	Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT	38.80	88.17	44.01	7.76
T_9	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 25 DAT	38.47	87.72	43.86	7.76
T_{10}	Pretilachlor (750 g a.i/ha) at 3 DAT+ Penoxsulam (22 g a.i/ha) at 30 DAT	37.40	86.60	43.19	7.76
	C.D.(P=0.05)	3.68	8.60	4.36	NS

5. CONCLUSION

Our results show that all of the tested weed control procedures proved effective to treat transplanted rice. Moreover, they lead to significantly higher grain yields over weedy check. The application Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT (T_8) most effective control different weeds species very effectively resulted into higher value of weed control efficiency. Highest growth parameters, yield attributes and 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. Among weed management treatments, Pretilachlor (750 g a.i/ha) at 3 DAT + Penoxsulam (22 g a.i/ha) at 20 DAT found excellent to control weed population and

increase growth parameter, yield attributes and yield. 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 higher productivity and profitability of rice crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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