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Effect of integrated weed management practices on the growth and yield of direct-seeded rice in the sub-montane zone of Maharashtra

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Abstract
Heavy weed infestation is the major problem faced by the farmers in direct seeded rice, which in severe cases results in full crop loss and diminishes the economic return. It is reported that the critical period of weed competition in DSR continues to be up to 41 days after sowing (DAS). In the long run, an integrated weed management system has the potential to minimise herbicide use and result in sustainable weed control in DSR. Keeping the above facts in view, an experiment entitled "Integrated weed management in direct-seeded rice in the sub-montane zone of Maharashtra" in *Kharif* season of 2021 was carried out at the Agronomy farm, survey number 359, RCSM College of Agriculture, Kolhapur (Maharashtra). The experiment was conducted in a randomized block design (RBD) with twelve treatments replicated three times. All the integrated weed management treatments resulted in a significant reduction in weed intensity and dry matter accumulation with higher weed control efficiency and other weed indices as compared to unwedded check (UWC). Among the integrated weed management treatments, pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T_8) recorded the highest plant height (87.23 cm), number of functional leaves $plant^{-1}$ (28.38), leaf area $plant^{-1}$ (15.60 dm^2), number of tillers m^{-2} (366.67) and dry matter accumulation (1626.87 g m^{-2}) at harvest as compared to the other treatments. It also recorded the highest values for all the yield attributing characters and yield, *viz*., number of panicles m^{-2} (274.33), panicle length (23.63 cm), weight of panicle (3.62 g), number of grains $panicle^{-1}$ (113.33), test weight (19.80 g), grain yield (55.24 q ha^{-1}), straw yield (85.04 q per ha) and biological yield (140.28 q ha^{-1}) and found to be the best integrated weed management practice.

Keywords: Weed free crop (WFC), Unweeded check (UWC)

Introduction
Rice (*Oryza sativa* L.) is the world's most important crop, grown widely over 161 million hectares in more than 100 countries, and is a principal source of food for more than half of the world's population. It is a nutritionally indispensable food crop which provides 35–80% of total calories to the Asian population (Rahman and Masood, 2012) and is a good source of important vitamins and minerals, including phosphorus, magnesium, selenium, Vitamin B and folic acid. Globally, rice production is about 756.74 million tonnes with a productivity of 4.6 tonnes per ha (Anonymous, 2022) [2] and is one of the four crops that account for about half of global primary crop production. Around 90% of the global rice production is being grown and consumed in Asia (Chauhan *et al.*, 2012) [3], which produces around 670 million tonnes of rice. Traditionally, rice was established by transplanting of 3–6-week-old seedlings after puddling, which involves compacting the soil to lessen water seepage. Repeated puddling adversely affects soil physical properties by breaking soil aggregates and capillary pores, forming hardpans at shallow depths and reducing permeability in sub-surface layers. Transplanted puddled rice (TPR) has several other constrains that make it unaffordable for many farmers, especially small and marginal farmers in Southeast Asia, which include a huge water demand (1000-2000 mm) for puddling and maintaining continuous flooding, a huge energy requirement ranging between 5630-8448 MJ per ha and almost 15-20% higher labour inputs than direct-seeded rice (DSR), (Shekhawat *et al.*, 2020) [18].

The IRRI recorded a rice productivity of 7 tonnes per ha under Dry-DSR with good agronomic management in the Philippines in the early 1970's (Datta *et al.*, 1972) [5]. Despite these recompenses, heavy weed infestation is the major problem faced by the farmers in DSR, which in severe cases results in full crop loss and diminishes the economic return. Chauhan and Johnson (2011) [4] reported that the critical period of weed competition in DSR continues to be up to 41 days after sowing (DAS). Weeds are the major biotic constraint which acts as a shelter for crop pests and competes with agricultural crops for space, light, nutrients, soil moisture, etc., thereby reducing the yield, quality, and economic return. There are 18 genera and 50 weed species from 22 distinct families that were observed under DSR (Kaur and Singh, 2017) [12]. There are many weed management options which help in maintaining its population below the threshold level, viz., physical or mechanical, cultural or ecological, biological and chemical methods of weed management. Adequate knowledge of the correct rate, time, and method of herbicide application and irrigation scheduling after herbicide application is needed to minimise damage to the crop. The continuous adoption of a single weed control approach or a single herbicide as a weed management strategy is not able to keep weeds below the threshold level leading to several economic and environmental hazards. It results in a shift in weed flora and the development of herbicide resistance in weeds. To achieve effective and sustainable weed control in DSR, various components should be integrated in a logical sequence. Pre-emergence herbicide application followed by hand weeding resulted in greater weed control efficiency and yield than mechanical weed control alone. Combined use of two or more herbicides having different modes of action for weed control is effective against the development of herbicide resistance in weeds (Diggle *et al.*, 2003) [7].

Materials and Methods

The Kolhapur comes under the Sub-montane Zone of Maharashtra and is situated at an elevation of 548 m above the mean sea level on 16°42'548" North latitude and 74°14'329" east longitudinal. The experiment was laid out in a randomized block design with twelve treatments replicated thrice with treatments viz, T_1: Pre emergence application of Oxyfluorfen 23.5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS *fb* Hoeing at 30 DAS, T_2: Pre emergence application of *Oxyfluorfen* 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS *fb* Hand weeding at 30 DAS, T_3: Pre emergence application of Oxyfluorfen 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS *fb* Hoeing at 25 DAS *fb* Hand weeding at 40 DAS, T_4: Pre emergence application of Oxyfluorfen 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS *fb* Post emergence application of Metsulfuron-methyl + Chlorimuron-ethyl @ 0.004 kg A.I. ha^{-1} at 25 DAS, T_5: Pre emergence application of Oxyfluorfen 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS *fb* Post emergence application of Bispyribac sodium 10% @ 0.02 kg A.I. ha^{-1} at 25 DAS, T_6: Pre emergence application of Pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS *fb* Hoeing at 30 DAS, T_7: Pre emergence application of Pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS *fb* Hand weeding at 30 DAS, T_8: Pre emergence application of Pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS *fb* Hoeing at 25 DAS *fb* Hand weeding at 40 DAS, T_9: Pre emergence application of Pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS fb Post emergence application of Metsulfuron-methyl + Chlorimuron-ethyl @ 0.004 kg A.I. ha^{-1} at 25 DAS T_{10}: Pre emergence application of Pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS *fb* Post emergence application of Bispyribac sodium 10% @ 0.02 kg A.I. ha^{-1} at 25 DAS, T_{11}: Weed free crop, T_{12}: Unweeded check.

Plant growth studies: For studying the effects of various treatments on the plant characters, biometric observations, viz. plant height, number of functional leaves, leaf area, and dry matter of the plant, were recorded at a regular interval of fourteen days throughout the life period of the rice crop. Five plants were selected randomly from each net plot by using random numbers. The selected plants were marked by fixing pegs and labelled it. All the observations were recorded on five selected plants.

Yield determination: Yield and yield attributing characters was determined using standard procedures. Finally, yield was expressed as q ha^{-1}.

Results and Discussion

Growth parameters

Plant height (cm): The data presented in Table No. 01 revealed that taller plants were shown by WFC and shorter plants in UWC at all the growth stages. At harvest, taller plants were shown by weed free crop (WFC), however it was on par with pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T_8). This could be because the weeds were suppressed using an integrated approach of pre- and post- emergence herbicide application along with hand weeding and hoeing, which increased plant height, thereby significantly affecting the other growth attributes over the UWC.

Number of tillers m^{-2}: At harvest, the number of tillers per square meter was decreased than the earlier growth observations. However, the trend of the treatments for the number of tillers per square meter remained similar with the earlier observational periods. The higher number of tillers per square meter in pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3) might be due the more availability of nutrients, water, light and space to rice crop as a result of effective weed control achieved by hand weeding at 40 DAS and the growth attributing characters. These results were in conformity with Kaur and Singh (2015) [13], Jadhav *et al.* (2016) [10], and Rathika and Ramesh (2019) [16].

No. of functional leaves plant^{-1}: The leaves are the basic unit to harness the sunlight and produce the food for the plant through photosynthesis i.e., it acts as the source in the sink relationships. Number of functional leaves per plant progressively increases as crop stages up to 56 DAS, thereafter its increment was in a slow pace and it is reduced at harvest due to senescence. The maximum number of leaves per plant recorded by WFC and minimum by UWC at all the growth stages.

Leaf area plant^{-1} (dm^2): During all these growth observation period, WFC shown the highest leaf area per plant which was on par with pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3). This might be due to the effective weed control provided a better environment for the full development of the canopy by the hand weeding operation done at 40 DAS and the growth attributing

characters were also equally responsible. At harvest, the leaf area per plant was decreased due to the senescence and attaining the physiological maturity.

Table 1: Effect of integrated weed management treatments on growth parameter of direct seeded rice at harvest

Treatments	Plant Height (cm)	No of tillers m^{-2}	No. of functional leaves $plant^{-1}$	Leaf area per plant (dm^2)	Dry matter accumulation (g/m^2)
T1	72.78	304.33	22.33	10.38	1049.03
T2	74.82	318.00	22.98	11.17	1190.93
T3	85.01	360.33	26.78	15.15	1517.87
T4	77.83	332.00	24.31	12.35	1297.80
T5	79.96	339.00	24.99	13.85	1419.33
T6	73.34	316.00	22.52	10.62	1084.30
T7	75.67	330.00	23.70	11.57	1228.73
T8	87.23	366.67	28.38	15.60	1626.87
T9	78.05	334.33	23.96	12.89	1340.60
T10	80.00	341.67	25.59	14.23	1466.60
T11	92.93	402.67	30.46	17.48	1732.83
T12	61.09	204.33	16.24	7.69	417.30
S.Em±	4.24	20.44	1.50	0.82	90.47
CD (P=0.05)	12.43	59.97	4.41	2.40	265.33
General mean	78.23	329.11	24.35	12.75	1281.00

Dry matter accumulation (g m^{-2}): At harvest, the treatments WFC, pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3) recorded the highest dry matter accumulation over the other treatments. It was closely followed by pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* bispyribac sodium 10% @ 0.02 kg A.I.ha^{-1} at 25 DAS (POE) (T10) and oxyfluorfen 23. 5% EC@ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* bispyribac sodium 10% @ 0.02 kg A.I.ha^{-1} at 25 DAS (POE) (T5). This might be due to comparatively weed- free environment created by the integrated application of pre-and post-emergence herbicides or application of pre-emergence herbicide followed by hoeing and hand weeding improved the water and nutrient uptake by crop led to better crop growth parameters like plant height, number of functional leaves per plant, leaf area per plant, number of tillers per square meter and thereby improved the yield attributes. The similar results were reported by Kaur and Singh (2015) [13], Jadhav *et al*. (2016) [10], Sreelakshmi *et al*. (2016) and Rathika and Ramesh (2019) [16].

Table 2: Yield attributing characters as influenced by integrated weed management treatments in direct-seeded rice

	No of panicles per m^2	Panicle length (cm)	Weight of panicle (g)	No of grains per panicle	Test weight (g)
T1	191.67	20.77	1.47	89.33	18.42
T2	204.00	21.10	1.83	92.33	18.49
T3	268.00	23.27	3.50	110.00	19.60
T4	213.67	21.73	2.52	95.67	19.10
T5	247.67	22.13	2.91	101.00	19.44
T6	194.67	20.07	1.77	90.00	18.44
T7	201.33	20.43	2.22	93.33	18.50
T8	274.33	23.63	3.62	113.33	19.80
T9	219.67	21.97	2.73	96.33	19.35
T10	250.00	22.50	3.03	108.33	19.47
T11	281.67	24.42	3.83	118.00	20.12
T12	103.33	16.80	0.92	72.00	17.45
S.Em±	10.57	1.01	0.18	5.72	0.54
CD (P=0.05)	30.99	2.95	0.52	16.79	NS
General mean	220.83	21.57	2.53	98.31	19.01

Yield parameters

Number of panicles m^{-2}: The highest number was obtained in the WFC (281.67) and it was on par with pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8 ; 274.33) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 268.00). Early application of herbicide and inter-culturing (hoeing and hand weeding) were found to be beneficial also crop-weed competition was minimum and all the growth attributing characters noted higher values which may have resulted in increasing the number of panicles in unit area over the other treatments.

Panicle length (cm): WFC was showing the longer panicle length (24.42 cm), and it was on par with the integrated weed management treatments such as T8 (23.63 cm) and T3 (23.27 cm), T10 (22.50 cm), T5 (22.13 cm), T9 (21.97 cm) and T4 (21.73 cm). This might be due to the higher growth attributes in these treatments over the UWC. Sunil *et al.* (2010) [21], Mandal *et al.* (2011) [14], Rawat *et al.* (2012) [17], Ganie *et al*. (2014) [8] have noted the same.

Weight of panicle (g): The higher weight of panicle was noted in the WFC (3.83 g), and it was on par with pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 3.62 g) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 3.50 g). All the Integrated weed

management treatments noted higher values for yield attributing characters over the UWC. Results were in line with those reported by Sunil *et al.* (2010) [21], Mandal *et al.* (2011) [14], Rawat *et al.* (2012) [17], Ganie *et al.* (2014) [8] and Soujanya *et al.* (2020) [19].

Number of grains panicle^{-1}: Higher number of grains per panicle was observed in the WFC (118), and it was on par with integrated weed management treatments including pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 113.33), oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 110.00) and pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* bispyribac sodium 10% @ 0.02 kg A.I. ha^{-1} at 25 DAS (POE) (T10; 108.33). The lowest number of grains per panicle was observed with the UWC (72.00). Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [6], Surin *et al.* (2019), Hemalatha *et al.* (2020) [9] and Soujanya *et al.* (2020) [19] have also worked on the similar lines and reported the same.

Test weight (g): Among the different treatments, the WFC (20.12 g) noted higher value followed by pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 19.80 g), oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 19.60 g) and pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* bispyribac sodium 10% @ 0.02 kg A.I.ha^{-1} at 25 DAS (POE) (T10;19.47 g).

Grain yield (q ha^{-1}): Table no. 03 shows that the higher grain yield was observed in the WFC (59.17 q ha^{-1}), pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 55.24 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 53.40 q ha^{-1}) and those were on par with each other. This may be due to the lowest values of weed intensity and weed dry matter, higher WCE and lower WI, also the plant growth characters and yield attributes were higher in these treatments. The results are in line Sunil *et al.* (2010) [21], Mandal *et al.* (2011) [14], Rawat *et al.* (2012) [17], Ganie *et al.* (2014) [8], Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [6], Surin *et al.* (2019), Hemalatha *et al.* (2020) [9] and Soujanya *et al.* (2020) [19].

Straw yield (q ha^{-1}): The data in Table 3 showed that higher values of straw yield was observed in the WFC (88.17 q ha^{-1}), and it was on par with treatments having integrated weed management treatments such as pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 85.04 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 83.39 q ha^{-1}). This might have resulted because of the better plant growth characters and yield attributes achieved by the reduced crop-weed competition in these treatments. Similar findings were also reported by Sunil *et al.* (2010) [21], Mandal *et al.* (2011) [14], Rawat *et al.* (2012) [17], Ganie *et al.* (2014) [8], Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [6], Surin *et al.* (2019), Hemalatha *et al.* (2020) [9] and Soujanya *et al.* (2020) [19].

Biological yield (q ha^{-1}): The highest biological yield of 147.33 q ha^{-1} was observed in WFC, and it was on par with integrated weed management treatments including pretilachlor 30.7% EC @ 0.450 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T8; 140.28 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg A.I.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T3; 136.80 q ha^{-1}). Results are also supported by Sunil *et al.* (2010) [21], Mandal *et al.* (2011) [14], Rawat *et al.* (2012) [17], Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [6], Surin *et al.* (2019), Hemalatha *et al.* (2020) [9] and Soujanya *et al.* (2020) [19].

Harvest index (%):- The highest harvest index was observed in WFC (40.09%) and the lowest was in UWC (34.68%). Among the integrated weed management treatments T10 (40.09%), T5 (39.67%), T8 (39.32%), T4 (39.02%), T3 (39.01%), T9 (39.0%), T_1 (38.85%), T_2 (38.24%) and T7 (37.98%) in that descending order.

Table 3: Grain yield, straw yield, biological yield, harvest index as influenced by integrated weed management treatments in direct-seeded rice

	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T1	37.94	59.67	97.28	38.85
T2	39.17	63.48	102.66	38.24
T3	53.40	83.39	136.80	39.01
T4	47.06	73.42	120.48	39.02
T5	51.88	77.77	128.98	39.67
T6	38.32	60.65	98.97	38.68
T7	40.74	66.42	107.16	37.98
T8	55.24	85.04	140.28	39.32
T9	48.31	75.43	123.74	39.00
T10	52.30	78.31	130.61	40.00
T11	59.17	88.17	147.33	40.09
T12	15.84	30.07	45.90	34.68
S.Em±	2.34	3.32	5.53	1.83
CD (P=0.05)	6.86	9.73	16.21	NS
General mean	44.95	70.15	115.02	38.71

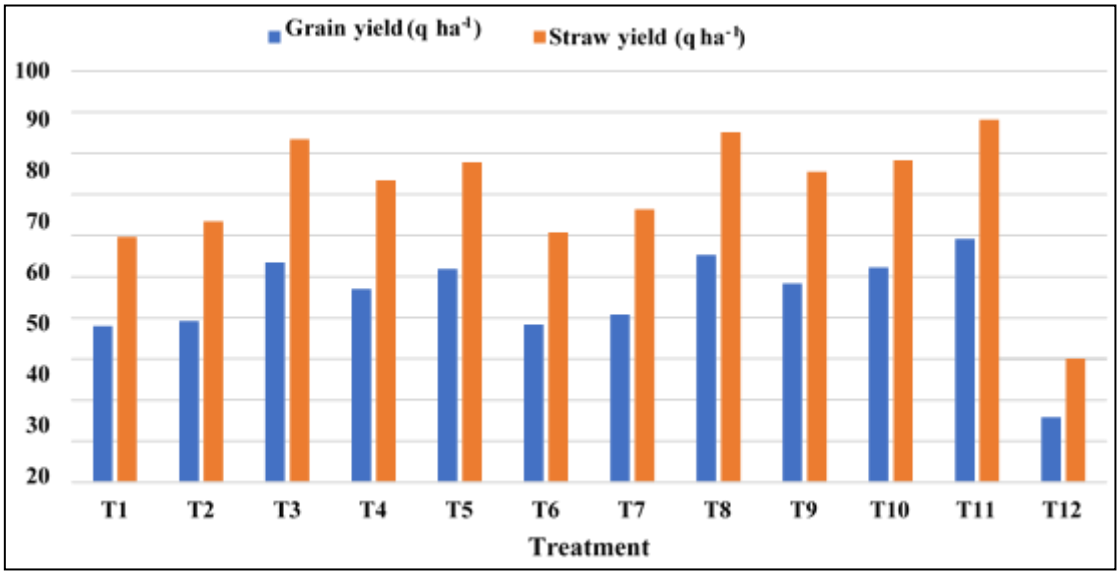

Fig 1: Grain yield, straw yield, biological yield, harvest index as influenced by integrated weed management treatments in direct-seeded rice

Summary and Conclusion

Based on the current field experiment results, it can be concluded that the integrated weed management treatment, pre-emergence application of pretilachlor 30.7% EC @ 0.450 kg A.I. ha^{-1} at 2-3 DAS fb hoeing at 25 DAS fb hand weeding at 40 DAS (T_8) recorded the higher growth parameters and yield attributing characters in direct- seeded rice in the sub-montane zone of Maharashtra.

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