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Nutrient use efficiency, nutrient uptake and yield of direct seed rice influenced by integrated weed management practice in the sub-montane zone of Maharastra

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Abstract
The capacity of crop to absorb and use nutrients for maximum yields is demonstrated by their nutrient usage efficiency (NUE). Thus, the three main mechanisms that plants use to absorb, assimilate, and utilize nutrients are included in the NUE idea. Many parameters, including agro-climate, soil conditions, parental rock type, crop factors, crop variety, fertilizers, particle size, soil salinity, acidity, organic matter, humus and water content, pH, aeration, temperature, root surface area, microbial presence, rhizoflora, etc., affect how well plants utilize nutrients. The highest grain and straw yields were recorded by WFC (59.17 q ha^{-1} and 88.17 q ha^{-1} respectively) and the lowest by UWC (15.84 q ha^{-1} and 30.07 q ha^{-1} respectively). The integration of different weed management treatments significantly enhanced the yield attributes. The treatment 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 grain yield (55.24 q ha^{-1}), straw yield (85.04 q ha^{-1}) and biological yield (140.28 q ha^{-1}). The nutrient uptake by the crop was significantly higher in all the integrated weed management treatments than the UWC. The season-long weed-free situation in WFC was attributed to the highest nutrient uptake by crop (151.51, 63.31 and 138.90 kg ha^{-1} N, P and K respectively), it was on par with pretilachlor 30.7% EC @ 0.450 130 kg a. i. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 25 DAS *fb* hand weeding at 40 DAS (T_8; 140.52, 59.56 and 129.79 kg ha^{-1} N, P and K respectively).

Keywords: Nutrient uptake, yield, seed rice, integrated weed

Introduction
Rice (*Oryza sativa* L.) is the world's most important crop, and it is also 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. India is the 2nd largest producer of rice in the world next to China, where it is grown round the year in one or the other parts of the country, in diverse ecologies spread over 45 million hectares, with a production of 128 million tonnes and a productivity of 2.7 tonnes per hectare (Anonymous, 2021a) [2]. West Bengal is the largest rice producing state in India, followed by Uttar Pradesh. In West Bengal, rice is grown in an area of 5.58 million hectares with the production of 16.65 million tonnes and a productivity of 2.98 tonnes per hectare, whereas in Punjab, productivity of rice is 4.36 tonnes per hectare with a production of 12.18 million tonnes from an area of 2.79 million hectares (Anonymous, 2021b) [2]. In Maharashtra, rice is grown over an area of 15.61 lakh hectares with an annual rice production of about 32.91 lakh tonnes with an average productivity of 2.1 tonnes per hectare (Anonymous, 2022b) [4]. In sub-montane zone of Maharashtra, particularly in Kolhapur district, rice cultivated in an area of 1.14 lakh hectares with an annual rice production of 3.96 lakh tonnes and productivity of 3.48 tonnes per hectare (Anonymous, 2020) [1].
Transplanting is the major method of rice cultivation in India. However, transplanting is becoming increasingly difficult due to shortage and high cost of labour, scarcity of water, and reduced profit.

Thus, direct seeding is gaining popularity among farmers of India as in other Asian countries. Several studies revealed that, in comparison to puddled transplanted rice, direct seeded rice system can reduce overall labour requirements by 11-66% (Kumar *et al.*, 2009) [15] and irrigation water needs by 35-57% (Jat *et al.*, 2009) [12]. 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.

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. Awan *et al.* (2016) [5] suggest that it is better to avoid herbicide application when the soil is too wet, and irrigation should be put off for at least a week after using an herbicide. As per previous studies, oxyfluorfen, pretilachlor, bispyribac-sodium, and metsulfuron-ethyl + chlorimuron-ethyl have hardly shown prominent phytotoxic symptoms in rice for a long time. 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) [8]. In the long run, an integrated weed management system has the potential to minimise herbicide use (Swanton and Weise, 1991) [24] and result in sustainable weed control in DSR.

Materials and Methods

The experiment was laid out using 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. The soil of the experimental plot was medium black clay (vertisol) with 90 cm depth, low in available N (208.64 kg ha^{-1}), medium in available P_2O_5 (34.05 kg ha^{-1}) and high in available K_2O (398.50 kg ha^{-1}). The status of organic carbon content (0.58%) was medium. The available N, P_2O_5, K_2O, and organic carbon content were classified based on a three-tier system, and the results were interpreted accordingly. The electrical conductivity and pH values were 0.43 dSm^{-1} (normal-low saline) and 7.75 (neutral), respectively.

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

Plant analysis: The samples collected from different plant parts of the observational plants were used to estimate the total nitrogen, phosphorus, and potassium content of the straw and grains. The percent total content of nitrogen (N) in plants and grain was estimated using Micro Kjeldhal method. Total Phosphorus (P) content in the plant & grain was determined through the calorimetric method given by Jackson (1973) [11], and potassium (K) was determined by the flame photometer method.

Nitrogen (N): The powdered 0.5 g plant sample was digested by continuously applying concentrated sulphuric acid (H_2SO_4) till it become colorless and a digestion mixture ($CuSO_4$ + K_2SO_4 + selenium powder). The digest later transferred to the micro Kjeldhal distillation flask and the ammonia liberated was distilled in the presence of alkali collected in 2 percent boric acid and the distillate was titrated against standard acid (Jackson, 1973) [11].

Phosphorus (P): The phosphorus in the plant sample was determined by the Vanado-molybdo-phosphoric yellow colour method (Jackson, 1973) [11] using Lab India UV/VIS model 3000.

Potassium (K): The potassium content in the digested samples was determined by a flame photometer after making an appropriate dilution (Jackson, 1973) [11].

Uptake studies: The uptake of N, P and K (kg ha^{-1}) by plant was worked out by multiplying the percentage of these nutrients present in grain, straw with the dry matter obtained per hectare at maturity and dividing it by 100.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient conc. (\%) x grain yield (kg ha}^{-1})}{100}$$

Results and Discussion

Effect on Yield of Rice

Grain Yield: The data in Table 1 and Figure 1 shows that 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 (T_8; 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 (T_3; 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. It was 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) (T_{10}; 52.30 q ha^{-1}), 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) (T_5; 51.88 q ha^{-1}), pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron- methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_9; 48.31 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_4; 47.06 q ha^{-1}) in that order. The results are in line Mandal *et al.* (2011) [17], Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [7], Surin *et al.* (2019) [23], Hemalatha *et al*. (2020) [10] and Soujanya *et al*. (2020) [22].

Straw Yield: The 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 (T_8; 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 (T_3; 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. 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) (T_{10}; 78.31 q ha^{-1}), 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) (T_5; 77.77 q ha^{-1}) and pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_9; 75.43 q ha^{-1}). Similar findings were also reported by Mandal *et al.* (2011) [17], Kaur and Singh (2015) [13], Dhanapal *et al.* (2018) [7], Surin *et al.* (2019) [23], Hemalatha *et al.* (2020) [10] and Soujanya *et al.* (2020) [22].

Biological Yield: The total dry matter produced by a crop, including grain yield and straw yield, is referred to as biological yield. The data presented in Table 1 clearly shows that biological yield followed more or less the same trend as in grain yield and straw yield. 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 (T_8; 140.28 q ha^{-1}) and oxyfluorfen 23.

Table 1: 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 (%)
T_1	37.94	59.67	97.28	38.85
T_2	39.17	63.48	102.66	38.24
T_3	53.40	83.39	136.80	39.01
T_4	47.06	73.42	120.48	39.02
T_5	51.88	77.77	128.98	39.67
T_6	38.32	60.65	98.97	38.68
T_7	40.74	66.42	107.16	37.98
T_8	55.24	85.04	140.28	39.32
T_9	48.31	75.43	123.74	39.00
T_{10}	52.30	78.31	130.61	40.00
T_{11}	59.17	88.17	147.33	40.09
T_{12}	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

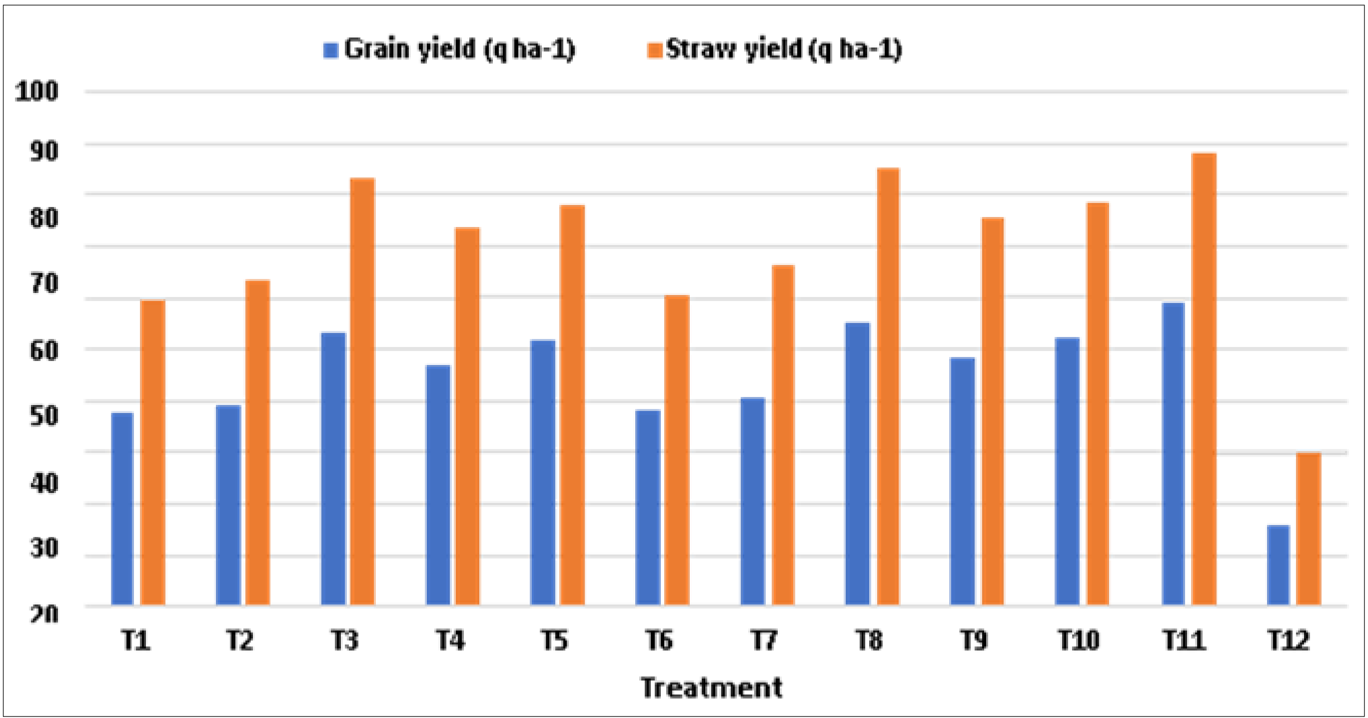

Fig 1: Grain yield (q ha^{-1}) and straw yield (q ha^{-1}) as influenced by integrated weed management practices in direct-seeded rice

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 (T_3; 136.80 q ha^{-1}). 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) (T_{10}; 130.61 q ha^{-1}) 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) (T_5; 128.98 q ha^{-1}). These treatments were on par with pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_9; 123.74 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_4; 120.48 q ha^{-1}). The treatments pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_7; 107.16 q ha^{-1}), oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_2; 102.66 q ha^{-1}), pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_6; 98.97 q ha^{-1}) and oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1; 97.28 q ha^{-1}) noted significantly higher values of biological yield than the UWC (45.90 q ha^{-1}). Results are also supported by Mandal *et al.* (2011) [17], Kaur and Singh (2015) [13], Dhanapal *et al*. (2018) [7], Surin *et al.* (2019) [23], Hemalatha *et al*. (2020) [10] and Soujanya *et al*. (2020) [22].

Harvest index: is the proportion of economic yield or grain yield to the biological yield which is expressed in percent or as a ratio (Donald, 1962). The data related to harvest index presented in Table 1 indicated that there was no significant effect of integrated weed management treatments on 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 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) (T_{10}; 40.09%), oxyfluorfen 23. 5% EC @ 0.150 kg aha^{-1} at 2-3 DAS (PE) *fb* bispyribac sodium 10% @ 0.02 kg a. i.ha^{-1} at 25 DAS (POE) (T_5: 39.67%), 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; 39.32%), oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_4; 39.02%), 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 (T_3: 39.01%), pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_9: 39.0%), oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1;38.85%), pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_6; 38.68%) and oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_2; 38.24%) and pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_7; 37.98%) in that descending order.

Plant analysis

N, P, and K content in grain and straw (%): The data pertaining to the N, P, and K content of grain & straw presented in Table 2 indicated that the nitrogen content in the grain and straw varied from 1.15% to 1.41% &.66 to 0.77% respectively. The maximum nitrogen content was recorded by WFC (Grain: 1.41%, Straw: 0.79%), which was on par with all other treatments except oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1; Grain:1.29%, Straw: 0.70%) and UWC (Grain:1.15%, Straw: 0.41%). The phosphorus content and potassium content also varied significantly among the different integrated weed management treatments. It ranged from 0.46% to 0.57% and 0.26% to 0.38%, respectively, for P and K in grain. While in straw, it had a range of 0.26 to 0.34% and 1.05 to 1.32%, respectively, for P and K. In the case of phosphorus content for both gain and straw, the maximum value was shown by WFC, which was on par with all other treatments except oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1) and UWC. For potassium content, the maximum was shown by WFC, which was on par with all the other treatments except pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_6), oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1) and UWC.

Table 2: Nutrient content in grain and straw (%) as influenced by integrated weed management treatments in direct-seeded rice

	Nutrient content in grain (%)			Nutrient content in straw (%)		
	N	P	K	N	P	K
T_1	1.29	0.50	0.33	0.70	0.30	1.20
T_2	1.31	0.53	0.34	0.72	0.31	1.23
T_3	1.36	0.56	0.37	0.76	0.33	1.28
T_4	1.30	0.53	0.35	0.73	0.31	1.25
T_5	1.32	0.54	0.36	0.74	0.32	1.26
T_6	1.30	0.53	0.35	0.72	0.31	1.24
T_7	1.30	0.53	0.35	0.73	0.31	1.24
T_8	1.37	0.56	0.37	0.76	0.33	1.28
T_9	1.31	0.54	0.36	0.74	0.32	1.26
T_{10}	1.34	0.55	0.36	0.75	0.33	1.27
T_{11}	1.41	0.57	0.38	0.77	0.34	1.32
T_{12}	1.15	0.46	0.26	0.66	0.26	1.05
S.Em±	0.041	0.016	0.011	0.019	0.009	0.032
CD (P=0.05)	0.119	0.048	0.033	0.056	0.027	0.093
General mean	1.314	0.534	0.348	0.729	0.313	1.240

Nutrient uptake by crop (kg ha^{-1}): The total nutrient uptake by the crop was significantly influenced by different integrated weed management treatments. The data presented in the Table 3 and Figure 2 revealed that, more or less similar trend was observed for total N and P uptake by the crop among the different integrated weed management treatments, The maximum total N and P uptake by crop was observed by WFC (151.51 and 63.31 kg ha^{-1} N and P respectively), 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 (T_8; 140.52 and 59.56 kg ha^{-1} N and P respectively). It was followed by 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 (T_3; 135.65 and 57.19 kg ha^{-1} N and P respectively), 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) (T_{10}; 128.79 and 54.27 kg ha^{-1} N and P respectively), 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) (T_5; 125.88 and 53.12 kg ha^{-1} N and P respectively), pretilachlor 30.7% EC @ 0.450 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i.ha^{-1} at 25 DAS (POE) (T_9; 118.98 and 49.86 kg ha^{-1} N and P respectively), oxyfluorfen 23. 5% EC @ 0.150 kg a. i.ha^{-1} at 2-3 DAS (PE) *fb* metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg a. i. ha^{-1} at 25.

Table 3: Nutrient uptake by grain and straw (kg ha^{-1}) as influenced by integrated weed management treatments in direct-seeded rice

	Nutrient uptake in grain (kg ha^{-1})			Nutrient uptake in straw (kg ha^{-1})		
	N	P	K	N	P	K
T_1	48.93	18.80	12.63	41.96	17.92	71.74
T_2	51.42	20.57	13.37	45.33	19.53	77.94
T_3	72.53	30.06	19.91	63.12	27.13	106.94
T_4	61.32	24.97	16.68	53.50	22.92	91.58
T_5	68.50	28.01	18.49	57.38	25.12	97.75
T_6	49.75	19.98	13.25	43.37	18.68	74.94
T_7	53.55	21.61	14.12	48.40	20.64	82.78
T_8	76.01	31.20	20.61	64.51	28.36	109.18
T_9	63.31	25.92	17.19	55.67	23.93	94.67
T_{10}	70.29	28.72	19.02	58.51	25.56	99.33
T_{11}	83.48	33.77	22.29	68.02	29.53	116.61
T_{12}	18.16	7.21	4.04	19.87	7.74	31.84
S.Em±	4.05	1.52	0.80	3.07	1.16	4.48
CD (P=0.05)	11.87	4.45	2.36	8.99	3.42	13.15
General mean	59.77	24.26	15.97	51.64	21.26	87.94

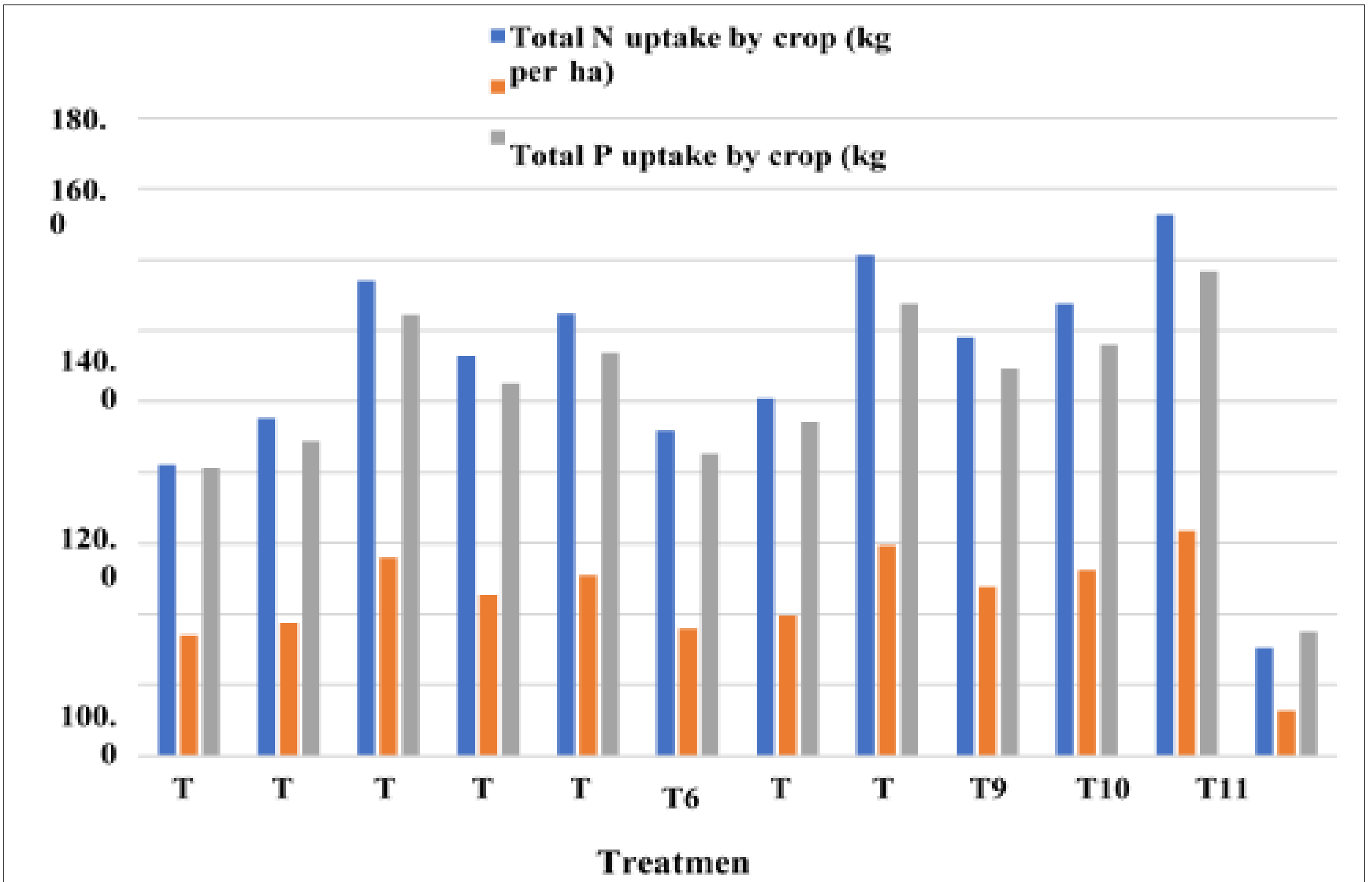

Fig 2: Total nutrient uptake by crop (kg ha^{-1}) as influenced by integrated weed management treatments in direct-seeded rice

DAS (POE) (T_4; 114.82 and 47.89 kg ha^{-1} N and P respectively), pretilachlor 30.7% EC @ 0.450 kg a. i. ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_7; 101.95 and 42.24 kg ha^{-1} N and P respectively), oxyfluorfen 23. 5% EC @ 0.150 kg a. i. ha^{-1} at 2-3 DAS (PE) *fb* hand weeding at 30 DAS (T_2; 96.76 and 40.09 kg ha^{-1} N and P respectively), pretilachlor 30.7% EC @ 0.450 kg a.

i.ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_6; 93.13 and 38.66 kg ha^{-1} N and P respectively) and oxyfluorfen 23. 5% EC @ 0.150 kg a. i. ha^{-1} at 2-3 DAS (PE) *fb* hoeing at 30 DAS (T_1; 90.89 and 36.72 kg ha^{-1} N and P respectively) in their descending order, which showed significantly higher total N and P uptake by the crop than the UWC (38.03 and 15.27 kg ha^{-1} N and P respectively).

The maximum potassium uptake by the crop was observed by WFC (138.90 kg ha^{-1}), 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; 129.79 kg 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 (T_3; 126.84 kg ha^{-1}). These results were in conformity with Singh *et el*. (2013) [21], Parameswari and Srinivas (2014) [19], Kundu *et al.* (2020) [16], Naz *et al.* (2020) [18], and Dhaliwal *et al*. (2021) [6].

Summary and Conclusion

The highest grain and straw yields were recorded by WFC (59.17 q ha^{-1} and 88.17 q ha-1 respectively) and the lowest by UWC (15.84 q ha-1 and 30.07 q ha-1 respectively). The integration of different weed management treatments significantly enhanced the yield attributes. The treatment 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 number of panicles per square meter (274.33), panicle length (23.63 cm), weight of panicle (3.62 g), number of grains per panicle (113.33), test weight (19.80 g), grain yield (55.24 q per ha), straw yield (85.04 q per ha) and biological yield (140.28 q per ha). Numerically highest harvest index was recorded by WFC (40.09%).

The N, P and K content in grain varied from 1.15 to 1.41%, 0.46 to 0.57% and 0.26 to 0.38%, respectively, whereas in straw, it varied from 0.66 to 0.77%, 0.26 to 0.34% and 1.05 to 1.32%, respectively. The nutrient uptake by the crop was significantly higher in all the integrated weed management treatments than the UWC. The season-long weed-free situation in WFC was attributed to the highest nutrient uptake by crop (151.51, 63.31 and 138.90 kg ha-1 N, P and K respectively), 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; 140.52, 59.56 and 129.79 kg ha-1 N, P and K respectively).

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