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Weed management indices as affected by carfentrazone-ethyl in direct seeded rice cultivation

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Abstract
A field experiment was conducted to study the bio-efficacy of carfentrazone ethyl for managing weeds in direct-seeded rice (*Oryza sativa* L) through different weed management indices during *kharif* 2022 at the Experimental Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P). The study assessed various doses of carfentrazone-ethyl (16, 25, 31.25, 34, and 50 g/ha) along with a market sample, pyrithiobac sodium 625 ml/ha (standard check), hand weeding (twice), and an untreated control. Results revealed that all weed control treatments significantly improved weed control efficiency (WCI), herbicide efficiency index (HEI), weed management index (WMI), and plant height compared to the weedy check. Carfentrazone-ethyl at 25 g/ha and 34 g/ha recorded higher WCI (73.98% and 71.23%, respectively) and HEI, resulting in better crop growth and yield attributes. The earliest attainment of 50% heading and physiological maturity was also observed under carfentrazone-ethyl 25 g/ha. Maximum grain yield (3.85 t/ha) was achieved in hand weeding, followed closely by carfentrazone-ethyl 25 g/ha (3.81 t/ha). The study concludes that carfentrazone-ethyl 25 g/ha is an effective and economical option for weed management in DSR systems.

Keywords: Direct seeded rice, carfentrazone-ethyl, weed control efficiency, herbicide efficiency index, weed management index, yield

Introduction
Direct seeded rice (DSR) has emerged as a viable alternative to the detrimental technique of puddling and nursery transplanting. Higher water productivity, lower labor and energy inputs, lower methane emissions and early crop maturity are some of the linked benefits. Despite its many advantages, direct-seeded rice production has been limited by number of factors, the most significant of which is the severity of weeds infestation (Chauhan, 2012) [1]. Gaire *et al*., (2013) [4] reported that the primary problem is the severe infestation of weeds in direct-seeded rice which resulted in yield losses up to 90%. Weeds are one of the most critical biological constraints in DSR, significantly reducing yield potential by competing with the crop for nutrients, light, water, and space. Unlike transplanted rice, DSR lacks a stagnant water layer during early growth stages, which normally suppresses weed emergence, thereby making it more susceptible to severe weed infestations (Nagar *et al*., 2025) [8]. Effective and timely weed control is therefore crucial for realizing the yield potential of DSR. Low plant population due to a lack of irrigation water and inadequate weed control, particularly in direct-sown rice, are two of the most important constraints contributing to low productivity of rice in Himachal Pradesh (Choudhary *et al*., 2024) [3].
Herbicide usage has gained popularity for efficient weed management in direct-seeded upland rice as an alternative to mechanical and manual weed control measures. In the recent past, a number of pre- and post-emergence herbicides have been recommended for controlling weeds in direct-seeded rice, the most common of which are butachlor as a pre-emergence herbicide and bispyribac sodium as a post-emergence herbicide (Rana *et al*., 2025) [10]. However, repeated use of the same herbicide over time can lead to the development of herbicide resistance in weeds. Carfentrazone-ethyl, a protoporphyrinogen oxidase (PPO) inhibitor, is a post-emergence herbicide with broad-spectrum activity, particularly effective against broadleaf weeds and sedges. The 40% DF (dry flowable) formulation of carfentrazone-ethyl ensures better dispersion and adherence on foliage, which

enhances its weed control efficiency under field conditions. To evaluate the efficacy of herbicides beyond simple weed control, integrated weed management strategies often incorporate weed management indices (WMIs) such as weed control efficiency (WCE), weed index (WI), and herbicide efficiency index (HEI) (Kumar *et al*., 2022) [6]. These indices serve as useful tools for assessing the biological effectiveness, economic viability, and crop-weed competition outcomes of various weed management practices.

Despite the known efficacy of carfentrazone-ethyl, limited research is available on its performance in terms of weed management indices in DSR ecosystems. Therefore, the present investigation was undertaken to evaluate the impact of carfentrazone-ethyl 40% DF on weed flora, rice growth, yield, and associated weed management indices in direct seeded rice. The findings aim to provide insights into the herbicide's potential role in sustainable and economically viable weed management strategies for DSR cultivation systems.

Materials and Methods

A field experiment was conducted at the Research Farm of Department of Agronomy CSKHPKV Palampur. The experimental site is situated at 32°6´ N latitude, 76°3´ E longitude and at an altitude of 1290.8 metres above mean sea level in the North-West Himalayan region during *kharif* 2022. All the post-emergence herbicides were applied by knapsack sprayer fitted with flat fan nozzle using spray volume of 750 liters. Five plants were randomly selected in the plot and were tagged. The height of these plants was recorded at monthly intervals. The height of the plant was recorded from ground level to the tip of the top of the youngest leaf/top most spikelets. The average was worked out to get the mean plant height.

The experimental field was visited on alternate days as the emergence of the first panicle/flower was observed and when 50 per cent of the shoot in all the two observational units produced a panicle/flower, the date was taken as the flowering stage. The number of days from sowing to this date was counted and then recorded.The crop was considered physiologically mature when 75 per cent of grains from randomly selected panicles in the net plot were found hardened. The date was noted and number of days taken for physiological maturity was calculated from the date of sowing.

Two observational units of one-meter row length each were selected randomly in each net plot and demarcated. Total number of tillers from observed observational units were counted at 30 days' intervals. The mean from these two observational units was taken as the number of tillers per metre row length and was multiplied by 5 to get the number of tillers per square metre. Different weed management indices were calculated to advocate the results as per following formulas:

1. WCI: WCI was worked out taking into consideration the reduction in weed population in treated plot over weed population in unweeded check. It is expressed in %.

$$WCI = \frac{WPC - WPT}{WPC} \times 100$$

Where, WPC = Weed population in control (unweeded) plot
WPT= Weed population in treated plot

2. WPI: This index indicates the resistance in weeds against the tested treatments and confirms the effectiveness of the selected herbicides.

$$WPI = \frac{DWT}{DWC} \times \frac{WPC}{WPT}$$

Where, DWC= Weed dry weight in control (unweeded) plot
DWT= Weed dry weight in treated plot
WPC = Weed population in control (unweeded) plot
WPT= Weed dry weight in treated plot

3. HEI: This index indicates the weed killing potential of a herbicide treatment and its phytotoxicity on the crop.

$$HEI = \frac{Y_T - Y_C}{Y_C} \Big/ \frac{DWT}{DWC}$$

Where, Y_T = Yield of treated plot
Y_C= Yield of control (unweeded) plot
DWC = Weed dry weight in control (unweeded) plot
DWT= Weed dry weight in treated plot

4. WMI: This index is the ratio of yield increase over the control because of weed management and per cent control of weeds by the respective treatment.

$$WMI = \frac{Y_T - Y_C}{Y_C} \Big/ \frac{DWC - DWT}{DWC}$$

Where, Y_T = Yield of treated plot
Y_C= Yield of control (unweeded) plot
DWC = Weed dry weight in control (unweeded) plot
DWT= Weed dry weight in treated plot

Results and Discussion

The value of weed indices like WCI, WPI, HEI and WMI were inferior in plot receiving no weed control throughout the growing season i.e., weedy check plot (Table 1). Carfentrazone ethyl 25 g/ha and 34 g/ha recorded superior values of WCI, WPI, HEI and WMI followed by pyrithiobac sodium 625 ml/ha and market sample of carfentrazone ethyl 25 g/ha indicating effective control of weeds with these chemicals. Better control of weeds under these treatments could be assigned the reason for superior weed indices.

Table 1: Effect of weed control treatments on different weed management indices in rice at 60 days after spray. (DAS)

Treatment	Dose (g/ha)	WCI	WPI	HEI	WMI
Carfentrazone-ethyl 40% DF	16 g	47.94	1.05	0.65	0.79
Carfentrazone-ethyl 40% DF	25 g	73.98	1.22	2.07	0.97
Carfentrazone-ethyl 40% DF	34 g	71.23	1.55	1.33	1.08
Carfentrazone-ethyl 40% DF	25 g	61.65	0.95	1.60	0.91
Pyrithiobac sodium 10% SC Standard check	625 ml	63.01	1.17	1.36	1.03
Hand weeding	-	98.97	9.32	7.04	0.75
Control (Weedy check)	-	0.00	1.00	0.00	0.00
Carfentrazone-ethyl 40% DF	31.25 g	73.98	1.28	1.79	0.89
Carfentrazone-ethyl 40% DF	50 g	68.49	1.19	1.61	0.97

Plant height (cm)

The perusal of the data pertaining to effect of weed control treatments on plant height have been presented in Table 2. A cursory glance of the data revealed that all the weed control treatments significantly influenced the plant height and were superior to untreated check at all the stages of observation. Application of carfentrazone-ethyl 25g/ha behaving statistically alike with 34g/ha, market sample of 25g/ha and pyrithiobac sodium 625 ml/ha resulted in significantly taller plants as compared to other weed control treatments at all the stages of observation. These findings are in close conformity with the findings of Kumar *et al*. (2013) [5].

Table 2: Effect of different treatments of plant height (cm) on rice at different stages of observation.

Treatment	Dose (g/ha)	Stage of observation			
		30 DAS	60 DAS	90 DAS*	At harvest
Carfentrazone-ethyl 40% DF	16 g	34.53	58.53	81.53	101.53
Carfentrazone-ethyl 40% DF	25 g	36.41	60.41	83.41	103.41
Carfentrazone-ethyl 40% DF	34 g	35.97	59.97	82.97	102.97
Carfentrazone-ethyl 40% DF	25 g	36.22	60.22	83.22	103.22
Pyrithiobac sodium 10% SC Standard check	625 ml	35.77	59.77	82.80	102.80
Hand weeding	-	36.87	60.87	83.87	103.87
Control (Weedy check)	-	30.18	54.08	76.75	96.41
Carfentrazone-ethyl 40% DF	31.25 g	36.38	60.38	83.38	103.38
Carfentrazone-ethyl 40% DF	50 g	36.52	60.52	83.52	103.52
SEm ±		0.39	0.39	0.42	0.41
LSD (0.05)		1.16	1.17	1.26	1.23

*DAS: Days after spray

Development Studies

The data on the effect of weed control treatments on number of days taken for different phenophases *viz*. days to taken 50% heading and day to taken physiological maturity have been presented in Table 3. A perusal of data revealed that crop reached maturity between 75 to 73 days where application of carfentrazone 25g/ha reached early maturity which was followed by 34g/ha, market sample of carfentrazone 25g/ha but weedy check plots shown delay maturity. Similarly, physiological maturity was observed at 123 days in carfentrazone 25g/ha plot which was significantly earlier than the weedy check. The results corroborated with the findings of Chauhan *et al* (2022) [2].

Table 3: Effect of treatments on number of days taken to different phenosphases of rice

Treatment	Dose (g/ha)	Days taken to 50% heading	Days taken to physiological maturity
Carfentrazone-ethyl 40% DF	16 g	75.3	125.9
Carfentrazone-ethyl 40% DF	25 g	73.1	123.2
Carfentrazone-ethyl 40% DF	34 g	73.3	123.6
Carfentrazone-ethyl 40% DF	25 g	74.2	124.1
Pyrithiobac sodium 10% SC Standard check	625 ml	74.8	124.3
Hand weeding	-	73.6	123.3
Control (Weedy check)	-	76.8	126.4
Carfentrazone-ethyl 40% DF	31.25 g	75.5	125.2
Carfentrazone-ethyl 40% DF	50 g	75.9	125.7
SEm ±	--	0.64	0.42
LSD (0.05)	--	1.91	1.28

Yield attribute and yield

Tillers with filled panicles are known as effective tillers and significantly contribution in grain yield these were varied significant in different herbicide treatments. Highest number of effective tillers was recorded under the hand weeded plot where completion was very less compared to the weedy check (table 4). Therefore, yield parameters such as number of effective tillers, test weight as well as grain yield was observed highest in hand weeding twice while among herbicide treatments highest value of these parameters was record under carfentrazone 25g/ha, followed by 34g/ha.

Table 4: Effect of treatments on yield parameters and yield of rice

Treatment	Effective tillers m^{-2}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Carfentrazone-ethyl	260.50	3.12	4.38
Carfentrazone-ethyl	280.50	3.81	5.33
Carfentrazone-ethyl	283.00	3.67	5.13
Carfentrazone-ethyl	278.00	3.63	5.11
Pyrithiobac sodium (Standard check)	290.50	3.65	5.11
Hand weeding (weed free)	293.00	3.85	5.37
Untreated check	223.00	2.30	3.45
Carfentrazone-ethyl	290.50	3.67	5.11
Carfentrazone-ethyl	288.00	3.69	5.13
SEm ±	9.17	1.17	1.74
LSD (0.05)	27.48	3.50	5.20

Conclusion

The present study concluded that effective weed control through herbicidal treatments significantly enhanced weed management indices and crop performance in direct seeded rice. The untreated weedy check plots recorded the lowest values for WCI, HEI, WMI, and plant growth parameters, indicating severe competition from weeds. Among the herbicide treatments, carfentrazone-ethyl 40% DF at 25 g/ha and 34 g/ha performed consistently well, showing superior weed control and higher values of WCI, HEI, and WMI. These treatments also led to taller plants, more effective tillers, and improved grain yield compared to the untreated check. Early attainment of phenophases such as 50% heading and physiological maturity further confirmed the reduced stress on the crop. Although hand weeding produced the highest yield, carfentrazone-ethyl at 25 g/ha proved to be the most effective herbicidal treatment, offering a viable and efficient alternative to manual weeding in DSR cultivation.

Conflict of Interest: The authors have no conflict of interest.

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