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Weed parameters and weed indices as influenced by agronomical practices and weed management in direct-seeded rice

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ABSTRACT

A field experiment was conducted at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, during the kharif seasons of 2024 and 2025. The main motto of research study was to find out the interaction effect of agronomical practices and weed management on the weed parameters and weed indices in direct-seeded rice. The experiment was laid out in a strip plot design with three replications. Four agronomical practices were evaluated in the vertical strips, viz., SSB with glyphosate at 15 DBS (A1), SSB with shallow tillage at 15 DBS (A2), Summer fallow with deep tillage at 80 DBS (A3) and Control (A4). Whereas, five weed management strategies including Weedy check (W1: Control), Weed-free check (W2: 3 HW at 20, 40 and 60 DAS), Pretilachlor 30% + Pyrazosulfuron-ethyl 0.75% WG 15 + 600 g a.i./ha as (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 44 + 22.5 g a.i./ha (PoE) (W3), Pretilachlor 30% + Pyrazosulfuron-ethyl 0.75% WG 15 + 600 g a.i./ha (PE) fb Metsulfuron-methyl 10% + Chlorimuron-ethyl 10% WP 4 g a.i./ha (PoE) (W4) and Pendimethalin 30% EC 1000 g a.i./ha (PE) fb Bispyribac-sodium 10% SC 25 g a.i./ha (PoE) fb one HW at 50 DAS (W5) were evaluated in the horizontal strips. Among the interactions, A1W5 (SSB with glyphosate + Pendimethalin as PE fb Bispyribac-Na as PoE fb one HW) noted significantly minimum total weed density (2.30 weeds/m²) at 60 DAS and it was comparable with A2W5. At harvest, the lower weed dry biomass and maximum weed control efficiency were noted under SSB with glyphosate combined with weed free check (A1W2: 2.74 g/m² and 91.10%) and it was remained comparable with A1W5, A2W2 and A2W5 combinations. In contrast, the A4W1 combination noted the maximum weed density and its dry weight resulted in lowest weed control efficiency. Integration of stale seedbed (glyphosate 1000 g a.i./ha or shallow tillage at 15 DBS) with Pendimethalin 30% EC 1000 g a.i./ha (PE) fb Bispyribac-sodium 10% SC 25 g a.i./ha (PoE) fb one HW at 50 DAS appeared to be a viable strategy for weed control in direct-seeded rice with higher control efficiency.

Keywords: Agronomical practices, Direct seeded rice, Stale seedbed, Weed control efficiency

1. Introduction

Rice (*Oryza sativa* L.) is one of the world's most important staple food crops, sustaining nearly half of the global population, particularly in Asia, where it forms the cornerstone of food and nutritional security and rural livelihoods. In India, rice contributes about 43 per cent of total food grain production and 46 per cent of total cereal production, besides providing employment to millions of people through rice cultivation and rice-based industries. Thus, rice plays a pivotal role in ensuring food security, generating rural employment and contributing significantly to the Indian economy (Deivasigamani, 2016) [1]. Globally, rice is grown on 163 million hectares, producing 769 million tons with an average productivity of 4.71 t/ha. In India, rice is cultivated on 51.27 million hectares, with a production of 150.18 million tons and average productivity of 2.93 t/ha (Anon., 2024) [2]. In Gujarat, rice is cultivated on 0.89 million hectares, producing 2.22 million tons with an average productivity of 2.49 t/ha (Anon., 2025) [3].

Traditionally, rice is cultivated by transplanting seedlings into puddled soil; however, intensive puddling creates a hard pan below the plough layer, reduces soil permeability and results in substantial water losses through evaporation and percolation (Farooq et al., 2011) [4]. Moreover, puddling and transplanting are highly labour- and water-intensive operations. Under these circumstances, direct-seeded rice (DSR) has emerged as a viable alternative to TPR because it eliminates nursery raising and transplanting operations, facilitates earlier crop establishment and timely sowing and reduces labour, water and cultivation costs (Singh et al., 2008; Rahman et al., 2019) [6, 5]. Direct seeding also avoids puddling, transplanting and prolonged maintenance of standing water, thereby improving water-use efficiency (Inagaki et al., 2021) [7].

However, the benefits of DSR are accompanied by a serious weed-management challenge. Unlike transplanted rice, where puddling and standing water suppress several weed species during crop establishment, rice and weeds emerge simultaneously under DSR, resulting in intense crop-weed competition (Raj et al., 2017) [8]. Weed infestation can cause severe yield losses, with losses of 50-60 per cent reported under un

controlled conditions (Subbaiah *et al.*, 2000) [9] and losses as high as 95 per cent reported in India (Naresh *et al.*, 2011) [10]. Therefore, effective and timely weed management is a prerequisite for realizing the productivity and resource-use benefits of direct seeded rice.

The main objective of weed management in direct-seeded rice is to suppress early weed emergence and reduce the weed seed bank while maintaining a competitive environment for rice throughout the critical period of crop-weed competition (Raj *et al.*, 2017) [8]. Agronomical practices such as stale seedbed (SSB) and summer fallow with deep tillage offer considerable potential for proactive weed management by targeting weeds before crop establishment. The SSB technique stimulates weed seed germination before crop sowing, followed by destruction of emerged weed seedlings through shallow tillage or non-selective herbicides, thereby reducing subsequent weed emergence (Sindhu *et al.*, 2011) [11]. Such approaches can reduce the initial weed pressure and dependence on post-emergence weed-control interventions, while providing an environmentally sustainable approach to weed management (Vemulapalli *et al.*, 2016) [12].

Nevertheless, agronomical practices alone may not provide adequate control of the diverse and continuously emerging weed flora in direct-seeded rice. Consequently, herbicides have become an important component of weed management because they provide rapid, economical and effective control of weeds (Bhurer *et al.*, 2013) [13]. Manual and mechanical weed-control methods are often constrained by labour scarcity, unfavourable weather conditions and increasing labour costs, particularly during the critical period of weed competition (Mahajan *et al.*, 2013) [14]. Herbicides are therefore particularly useful for controlling weeds such as *Echinochloa* spp., which may be difficult to distinguish from rice during manual weeding (Ihsan *et al.*, 2014) [15]. However, continuous reliance on herbicides with similar modes of action may result in shifts in weed flora, including shifts from grasses towards sedges and broad-leaved weeds and from annual to perennial species (Rajkhowa *et al.*, 2006) [16]. Furthermore, the complex weed flora of DSR is difficult to manage effectively through a single pre- or post-emergence herbicide application (Mahajan *et al.*, 2013) [14].

The development of low-dose, broad-spectrum herbicides and premix formulations has expanded the available options for managing diverse weed flora. Pre-emergence herbicides provide early suppression of weeds during crop establishment, whereas post-emergence herbicides can control subsequent weed flushes and reduce crop-weed competition (Pusdekar *et al.*, 2020) [17]. Recent advances in broad-spectrum pre- and post-emergence pre-mix herbicides have further provided opportunities to improve weed management while addressing labour and water constraints in DSR (Jehangir *et al.*, 2024) [18]. However, inadequate control, weed escapes and regeneration of certain weed species have been reported despite the use of existing herbicide recommendations. This indicates the need for sequential and integrated approaches involving different weed-management interventions rather than reliance on a single herbicide application (Raj *et al.*, 2013) [19]. Therefore, systematic integration of agronomical practices and herbicide sequences may consequently improve weed-control efficiency, reduce crop-weed competition and enhance the sustainability of direct-seeded rice production. Keeping this in view, the present experiment was carried out with the objective to study the interaction effect of agronomical practices and weed management on the weed parameters and weed indices in direct-seeded rice.

2. Materials and Methods

The present field experiment was conducted during the *kharif* seasons of 2024 and 2025, at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India. The soil of experimental unit was clayey in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potassium with slightly alkaline in reaction with normal electric

conductivity. Rice variety GNR-8 (Aarti) was sown with seed rate 60 kg/ha. The seeds were sown manually with row spacing of 30 cm. The experiment was laid out in a Strip Plot Design with three replications, comprising 20 treatment combinations. The experimental treatments consisted of four agronomical practices assigned to the vertical strips, *viz.*, Stale seedbed with glyphosate at 15 DBS (A₁), Stale seedbed with shallow tillage at 15 DBS (A₂), Summer fallow with deep tillage at 80 DBS (A₃) and Control (A₄) as well as five weed management practices assigned to the horizontal strips, *viz.*, Weedy check (W₁: Control), Weed-free check (W₂: 3 HW at 20, 40 and 60 DAS), Pretilachlor 30% + Pyrazosulfuron-ethyl 0.75% WG 15 + 600 g a.i./ha as (PE) *fb* Triafamone 20% + Ethoxysulfuron 10% WG 44 + 22.5 g a.i./ha (PoE) (W₃), Pretilachlor 30% + Pyrazosulfuron-ethyl 0.75% WG 15 + 600 g a.i./ha (PE) *fb* Metsulfuron-methyl 10% + Chlorimuron-ethyl 10% WP 4 g a.i./ha (PoE) (W₄) and Pendimethalin 30% EC 1000 g a.i./ha (PE) *fb* Bispyribac-sodium 10% SC 25 g a.i./ha (PoE) *fb* one HW at 50 DAS (W₅). As per the treatment schedule, stale seedbed (SSB) was prepared by providing pre-sowing irrigation after levelling the plots and allowing them to remain undisturbed for 15 days for weed emergence. The emerged initial flush weeds were subsequently removed by shallow tillage using a spike-tooth harrow in the SSB with shallow tillage treatment, whereas glyphosate was applied at 15 DBS in the SSB with glyphosate treatment. Under summer fallow with deep tillage treatment, the field was deep-ploughed to a depth of 25-30 cm after harvesting the winter crop and left unplanked during summer. The pre-emergence herbicides, *viz.*, pendimethalin and pretilachlor + pyrazosulfuron-ethyl, were applied at 2-3 DAS, while the post-emergence herbicides, *viz.*, bispyribac-sodium at 25 DAS, chlorimuron-ethyl + metsulfuron-methyl and triafamone + ethoxysulfuron at 30 DAS, were applied using a knapsack sprayer fitted with a flat-fan nozzle. Observations on total weed density were recorded at 60 DAS, while weed dry weight was recorded at harvest and subjected to statistical analysis after square-root transformation using the following formula:

$$X = \sqrt{x + 0.5}$$

Where, X = transformed value

x = original value

The weed indices, *viz.*, Weed Control Efficiency (WCE), Treatment Efficiency Index (TEI), Weed Management Index (WMI), Agronomic Management Index (AMI) and Integrated Weed Management Index (IWMI) were calculated using following formulae:

Weed Control Efficiency (WCE) was calculated by using formula proposed by Kondap *et al.* (1985) [20].

$$\text{Weed Control efficiency (\%)} = \frac{DWC - DWT}{DWC} \times 100$$

Where, WCE = Weed control efficiency

DWC = Dry matter accumulation of weeds in weedy check control

Treatment Efficiency Index (TEI) was calculated by using formula proposed by Krishnamurthy *et al.* (1975) [21].

$$TEI = \frac{YT - YC}{YT} \times \frac{WDMC}{WDMT}$$

Where, Y_T = Crop yield from treated plot, Y_C = Crop yield from control plot

WDMC = Weed dry matter in control, WDMT = Weed dry matter in treatment

Weed Management Index (WMI) was calculated by using formula proposed by Sarma (2016) [22].

$$WMI = \frac{\text{Percent crop yield over control}}{\text{Percent control of weeds}}$$

Agronomic management index (AMI) was calculated by using formula proposed by Sarma (2016) [22].

$$AMI = \frac{\text{Percent crop yield over control} - \text{Percent control of weeds}}{\text{Percent control of weeds}}$$

Integrated Weed Management Index (IWMI) was calculated by using formula proposed by Sarma (2016) [22].

$$IWMI = \frac{WMI + AMI}{2}$$

Where, WMI = Weed management index

AMI = Agronomic management index

3. Results and Discussion

3.1 Total weed density (No./m²)

The mean values pertaining to total weed density at 60 DAS in response to agronomical practices and weed management and its interaction during pooled analysis was significantly influenced and are presented in the Table.1.

Agronomical practices

Among the tested practices, SSB with Glyphosate (A₁) noted significantly the lower total weed density (5.25 weeds/m²) at 60 DAS, but it was par with SSB with shallow tillage (A₂). The reduction in weed density under stale seedbed treatments was attributed to the stimulation and subsequent destruction of early-emerging weeds before crop establishment. This depleted the readily germinable weed seed bank and reduced subsequent weed emergence. Similar reductions in weed density under stale seedbed practices were reported by Hazarika *et al.* (2025) [23], Sinchana *et al.* (2022) [24] and Saikia *et al.* (2013) [25].

Weed management

The total weed density was significantly influenced by different weed management at 60 DAS. Significantly the lowest total weed density (3.02 weeds/m²) was noted under W₅ (Pendimethalin as PE *fb* Bispyribac-Na as PoE *fb* one HW) and was followed by W₂ (3 HW at 20, 40 and 60 DAS), W₃ (Pretilachlor + Pyrazosulfuron-ethyl as PE *fb* Triafamone + Ethoxysulfuron as PoE) and W₄ (Pretilachlor + Pyrazosulfuron as PE *fb* Metsulfuron + Chlorimuron as PoE). The superior performance of sequential herbicide treatments was attributed to their complementary action in controlling successive weed flushes throughout the crop growth period. Pendimethalin suppressed early-emerging weeds, whereas Bispyribac-Na and hand weeding controlled subsequent and escaped weeds, ensuring sustained weed suppression. Similar effectiveness of sequential herbicide application, particularly Pendimethalin *fb* Bispyribac-Na with hand weeding, was

reported by Sar *et al.* (2024) [26], Baghel *et al.* (2018) [27], Tej *et al.* (2017) [28] and Kumari *et al.* (2016) [29].

Interaction

The interaction between agronomical practices and weed management on total weed density was significant and are depicted in the Table.2. Among the combinations, at 60 DAS, A₁W₅ (SSB with glyphosate + Pendimethalin as PE *fb* Bispyribac-Na as PoE *fb* one HW) noted significantly the minimum total weed density (2.30 weeds/m²) and it was comparable with A₂W₅. The lower weed density under integrated treatments was attributed to the combined effect of stale seedbed-induced depletion of the initial weed flush and sequential herbicide action against subsequent weed cohorts. In A₁W₅, Pendimethalin *fb* Bispyribac-Na with supplementary hand weeding provided sustained suppression by controlling early- and late-emerging and escaped weeds through complementary actions. Similar superiority of integrated stale seedbed and sequential herbicide-based approaches in reducing successive weed flushes has been reported by Yonas *et al.* (2023) [30], Das *et al.* (2025) [31] and Barik *et al.* (2025) [32]. Conversely, the maximum total weed density was noted in A₄W₁ (control + weedy check) with value of 14.64 weeds/m² at 60 DAS.

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed ($\sqrt{X + 0.5}$) value density at 60 DAS and weed dry weight at harvest in DSR (pooled over 2 year)

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed ($\sqrt{X + 0.5}$) value

3.2 Total weed dry weight (kg/ha)

The data regarding to the total weed dry weight was significantly influenced by agronomical practices, weed management and their interaction at harvest during pooled analysis are represented in the Table.1.

Table 1. Total weed density at 60 DAS and total weed dry weight at harvest as influenced

Treatment	Dose (g a.i./ha)	Total weed density at 60 DAS (No./m ²)	Total weed dry weight at harvest (kg/ha)
Agronomical Practices (A)			
A ₁ : SSB with glyphosate	1000	5.25 (37.84)	17.70 (344.88)
A ₂ : SSB with Shallow tillage	—	5.44 (39.80)	18.72 (391.75)
A ₃ : Summer fallow with deep tillage	—	6.52 (56.47)	21.84 (532.13)
A ₄ : Control	—	7.12 (64.97)	24.87 (705.35)
SEm±		0.09	0.34
C. D. (P = 0.05)		0.30	1.07
C. V (a) %		8.89	9.11
Weed Management (W)			
W ₁ : Weedy check (Control)	—	13.00 (170.50)	33.69 (1160.82)
W ₂ : Weedy free check (3 HW at 20, 40 and 60 DAS)	—	3.72 (13.84)	13.98 (199.78)
W ₃ : Pretilachlor + Pyrazosulfuron (PE) <i>fb</i> Triafamone + Ethoxysulfuron (PoE)	15 + 600, 44 + 22.5	5.17 (26.92)	20.45 (430.78)
W ₄ : Pretilachlor + Pyrazosulfuron (PE) <i>fb</i> Metsulfuron + Chlorimuron (30 DAS)	15 + 600, 4	5.48 (28.42)	21.20 (462.48)
W ₅ : Pendimethalin (PE) <i>fb</i> Bispyribac-sodium (PoE) <i>fb</i> 1 HW at 50 DAS	1000, 25	3.02 (9.17)	14.60 (213.76)
SEm±		0.10	0.32
C. D. (P = 0.05)		0.31	0.95
C. V (b) %		8.39	7.49
Interactions			
(A×W)		S	S
Others (A×Y, W×Y, A×W×Y)		NS	NS

(continued on next page)

Treatment	Dose (g a.i./ha)	Total weed density at 60 DAS (No./m ²)	Total weed dry weight at harvest (kg/ha)
C.V (c) %		6.84	8.12

Agronomical practices

It was clear from the Table.1, SSB with Glyphosate (A_1) recorded significantly the lowest total weed dry weight (17.70 kg/ha) and remained statistically at par with SSB with shallow tillage. Maximum weed dry weight was noted in Control (W_1 : 33.69 kg/ha). The lower weed biomass under stale seedbeds was attributed to the destruction of the initial weed flush before crop establishment, thereby reducing subsequent weed emergence and biomass accumulation. Both glyphosate and shallow tillage effectively suppressed emerged weeds, resulting in lower weed dry matter throughout the crop growth period. Similar reductions in weed biomass under stale seedbed practices have been reported by Patil *et al.* (2017) [33], Chandrakar *et al.* (2015) [34], Sinchana *et al.* (2022) [24] and Ravikiran *et al.* (2019) [35].

Weed management

At harvest, W_2 (3 HW at 20, 40 and 60 DAS) noted significantly the minimum total weed dry weight (13.98 kg/ha), being at par with W_5 . The treatments W_3 and W_4 showed intermediate performance, whereas the maximum weed dry weight was noted under weedy check (W_1 : 33.69 kg/ha). The lower weed biomass under sequential herbicide treatments was attributed to sustained suppression of successive weed flushes, thereby restricting weed establishment and biomass accumulation throughout the crop growth period. Pendimethalin *fb* Bispyribac-Na with supplementary HW further enhanced control by suppressing early- and late-emerging weeds, including herbicide escapes. Similar reductions in weed dry biomass with sequential Pendimethalin *fb* Bispyribac-Na, particularly when integrated with HW, were reported by Karki *et al.* (2022) [36], Pooja *et al.* (2021) [37] and Rana *et al.* (2016) [38].

Interaction

Agronomical practices and weed management interaction on total weed dry biomass was significant at harvest during the pooled analysis (Table-2). At harvest, the lowest weed dry biomass was noted un-

der SSB with glyphosate combined with weed free check (A_1W_2 : 2.74 g/m²), which remained statistically comparable with other effective combinations involving SSB with glyphosate or shallow tillage integrated with weed free check and Pendimethalin *fb* Bispyribac-sodium with one HW (A_1W_5 , A_2W_2 and A_2W_5), where these treatment combinations maintained lower weed dry biomass, whereas control with weedy check (A_4W_1) recorded the maximum weed dry biomass (40.96 kg/ha) due to unrestricted weed growth throughout the crop season. As depicted in Fig. 1, A_1W_2 recorded the maximum reduction (70.1%) followed by A_2W_2 (69.3%), A_1W_5 (67.0%) and A_2W_5 (65.1%) as compared with the control + weedy check (A_4W_1). The lower weed biomass under integrated treatments was attributed to depletion of the initial weed flush through stale seedbed preparation, followed by effective suppression of successive weed cohorts through sequential herbicide application and hand weeding. The combination of Pendimethalin as PE *fb* Bispyribac-Na as PoE with one hand weeding provided season-long weed suppression and achieved weed biomass comparable to the weed-free treatment. Similar effectiveness of integrating stale seedbed with sequential herbicide application in achieving weed control comparable to intensive hand weeding was reported by Das *et al.* (2025) [31] and Barik *et al.* (2025) [32].

3.3 Weed control efficiency (%)

The data presented in the Fig. 2 revealed that weed control efficiency (WCE) was markedly influenced by agronomical practices and weed management treatments in mean values of two years.

Agronomical practices

At harvest, SSB with glyphosate (A_1) exhibited the highest WCE (51.10%), followed by SSB with shallow tillage (A_2 : 44.46%), while summer fallow with deep tillage (A_3) recorded comparatively lower WCE (24.56%). The control treatment (A_4) served as the untreated reference and therefore no WCE value was assigned. Thus, the effectiveness of agronomical practices in improving weed control efficiency followed the order $A_1 > A_2 > A_3 > A_4$.

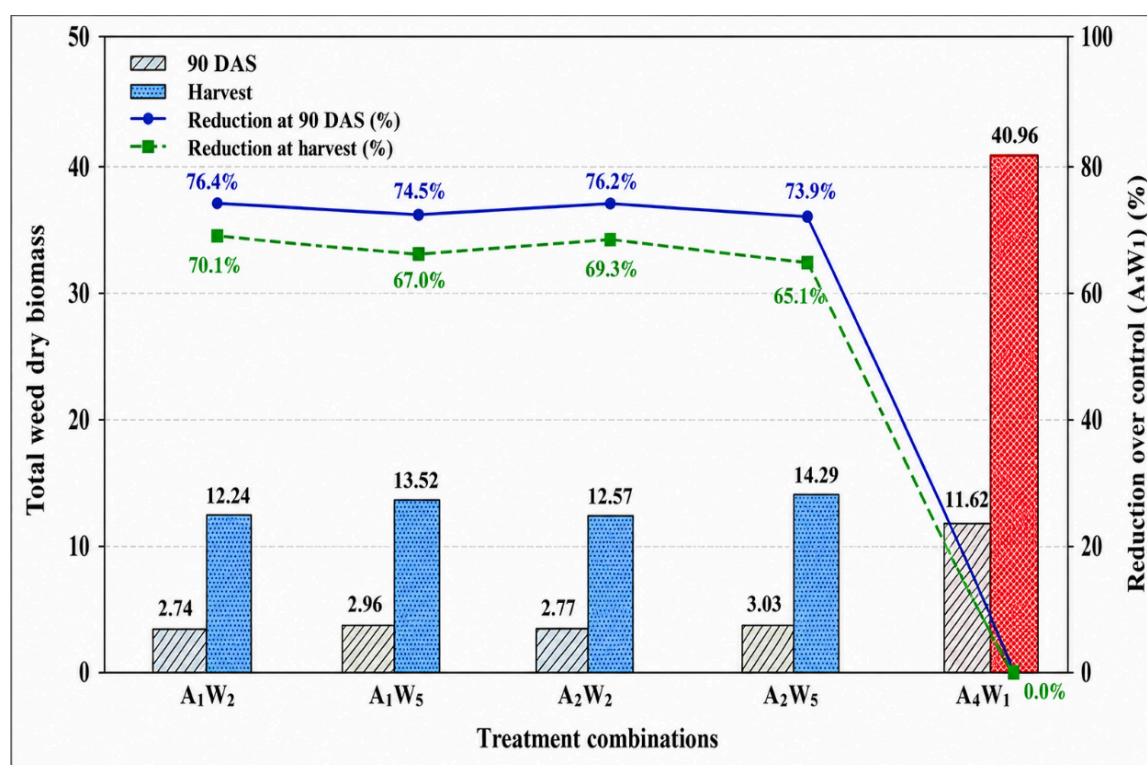


Figure 1. Per cent reduction in total weed dry biomass under superior interactions over control + weedy check in DSR (pooled over 2 year)

Weed management

The highest WCE was observed with weed free check (W_2) attaining 82.79 per cent at harvest. The performance of W_2 was closely approached by Pendimethalin *fb* Bispyribac-Na *fb* one HW (W_5) that attained 81.59 per cent weed control efficiency. Thus, the effectiveness of agronomical practices in improving weed control efficiency followed the order $W_2 > W_5 > W_3 > W_4 > W_1$.

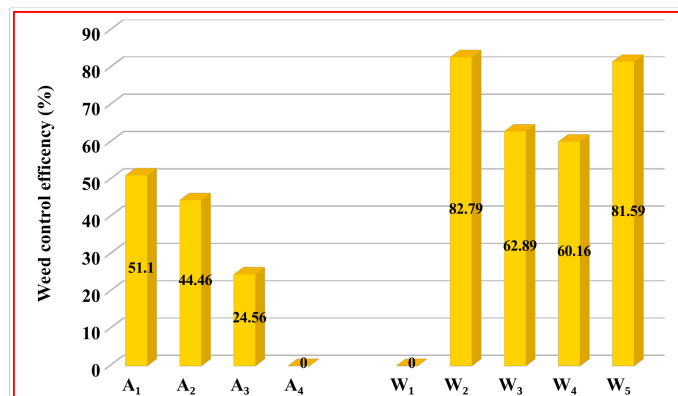


Figure 2. Weed control efficiency as influenced by agronomical and weed management practices in DSR (mean of two years)

Interaction

The interaction between agronomical practices and weed management exerted a marked influence on weed control efficiency (Fig. 3). Among all the treatment combinations, SSB with glyphosate + weed free check (A_1W_2) recorded the highest WCE (91.10%), closely followed by SSB with shallow tillage + weed-free check (A_2W_2) (90.57%). Among the herbicide-based treatments, SSB with glyphosate + Pendimethalin *fb* Bispyribac-Na *fb* one HW at 50 DAS (A_1W_5) registered 89.17% WCE, followed by SSB with shallow

tillage + the same herbicide sequence (A_2W_5) (87.89%). In contrast, the weedy check under summer fallow with deep tillage (A_3W_1) recorded the lowest weed control efficiency (27.88%).

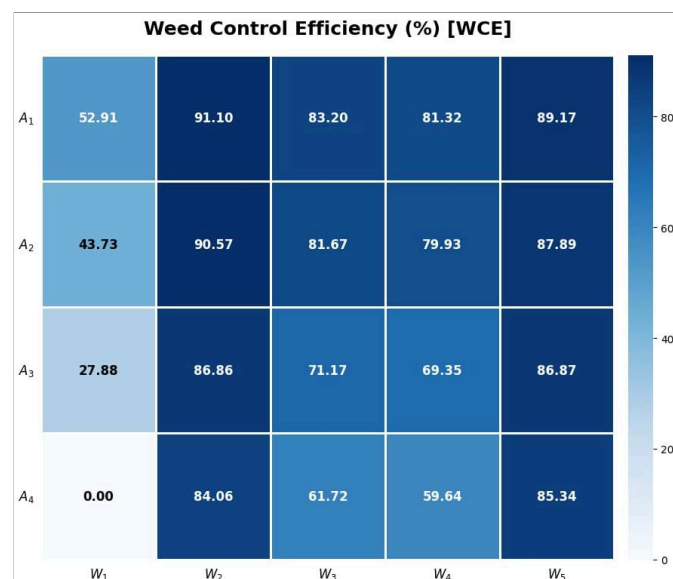


Figure 3. Weed control efficiency as influenced by interaction of agronomical practices and weed management in DSR (mean of two years)

3.4 Weed management efficiency indices

The treatment efficiency index (TEI), weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IMI) displayed in the Table-3 showed variation in mean values of two years, indicating the relative effectiveness of treatments in weed suppression and crop performance.

Table 2. Interaction of agronomical practices and weed management on total weed

Weed Management (W)	Total weed density at 60 DAS (No./m ²)				Total weed dry weight at harvest (kg/ha)			
	Agronomical Practices (A)							
	A ₁	A ₂	A ₃	A ₄	A ₁	A ₂	A ₃	A ₄
W ₁	11.61	11.81	13.95	14.64	28.17	30.78	34.83	40.96
	(134.33)	(139.33)	(194.50)	(213.83)	(793.76)	(948.50)	(1215.54)	(1685.50)
W ₂	3.02	3.23	4.02	4.62	12.24	12.57	14.87	16.23
	(8.67)	(10.00)	(15.67)	(21.00)	(149.99)	(158.98)	(221.44)	(268.68)
W ₃	4.46	4.66	5.52	6.05	16.82	17.58	22.00	25.39
	(19.83)	(21.33)	(30.17)	(36.33)	(283.21)	(308.89)	(485.85)	(645.17)
W ₄	4.82	4.99	5.74	6.35	17.75	18.39	22.61	26.03
	(22.83)	(24.50)	(32.50)	(40.00)	(314.93)	(338.25)	(516.550)	(680.21)
W ₅	2.30	2.52	3.33	3.93	(13.52)	(14.29)	(14.88)	(15.72)
	(4.83)	(6.00)	(10.67)	(15.17)	(182.48)	(204.11)	(221.27)	(247.17)
SEm±			0.17				0.69	
C. D. (<i>P</i> = 0.05)			0.48				2.08	
C.V (%)			6.84				8.12	

Agronomical practices

The data presented in Table.3 indicated that SSB with glyphosate (A_1) exhibited superior TEI with a mean value of 0.49, followed by SSB with shallow tillage (A_2 : 0.42), while summer fallow with deep tillage (A_3) recorded the lowest TEI (0.14). However, the weed management index (WMI) and integrated weed management index (IWMI) showed a different response pattern, with A_2 recording the highest values (WMI: 0.52 and IMI: -0.24), followed by A_1 (WMI: 0.47 and IWMI: -0.26) and A_3 (WMI: 0.43 and IWMI: -0.28). The higher efficiency indices under stale seedbed practices indicated their better con-

tribution towards reducing weed interference and improving overall crop performance. Whereas, Agronomic Management Index (AMI) remained almost identical among all the agronomical practices.

Weed management

The efficiency indices exhibited marked variation among the weed management treatments. Among the treatments, Pendimethalin *fb* Bispyribac-Na *fb* HW (W_5 : 4.97) recorded the highest treatment efficiency index (TEI), followed by Pretilachlor + Pyrazosulfuron *fb* Triafamone + Ethoxysulfuron (W_3 : 2.34) or Metsulfuron + Chlorimuron (W_4 : 2.13). The higher TEI under W_5 indicated greater

efficiency in converting weed management benefits into improved crop performance. The weed management index (WMI) was highest under Pretilachlor + Pyrazosulfuron *fb* Metsulfuron + Chlorimuron (W_4 : 1.41), followed by Pretilachlor + Pyrazosulfuron *fb* Triafamone + Ethoxysulfuron (W_3 : 1.38) and Pendimethalin *fb* Bispyribac-Na and one HW (W_5 : 1.12). The integrated weed management index (IWMI) was comparatively higher under Pretilachlor + Pyrazosulfuron *fb* Metsulfuron + Chlorimuron (W_4 : 0.21) and Pretilachlor + Pyrazosulfuron *fb* Triafamone + Ethoxysulfuron (W_3 : 0.20) than Pendimethalin *fb* Bispyribac-Na *fb* HW (W_5 : 0.07) indicating better

integration of weed management practices for effective weed suppression and improved rice productivity. However, the Agronomic Management Index (AMI) exhibited negligible variation among the weed management practices.

Overall, the higher TEI under W_5 indicated greater treatment efficiency associated with effective weed suppression and improved crop performance, whereas higher WMI and IWMI values under W_4 and W_3 reflected better weed management efficiency and integration of sequential herbicide-based weed management strategies. and weed management in DSR

Table 3. TEI, WMI, AMI and IMI at harvest as influenced by agronomical practices

Treatment	Dose (g a.i./ha)	TEI	WMI	AMI	IWMI
Agronomical Practices (A)					
A ₁ : SSB with glyphosate	1000	0.49	0.47	-1.00	-0.26
A ₂ : SSB with Shallow tillage	—	0.42	0.52	-0.99	-0.24
A ₃ : Summer fallow with deep tillage	—	0.14	0.43	-1.00	-0.28
A ₄ : Control	—	—	—	—	—
Weed Management (W)					
W ₁ : Weedy check (Control)	—	—	—	—	—
W ₂ : Weedy free check (3 HW at 20, 40 and 60 DAS)	—	—	—	—	—
W ₃ : Pretilachlor + Pyrazosulfuron (PE) <i>fb</i> Triafamone + Ethoxysulfuron (PoE)	15 + 600, 44 + 22.5	2.34	1.38	-0.99	0.20
W ₄ : Pretilachlor + Pyrazosulfuron (PE) <i>fb</i> Metsulfuron + Chlorimuron (30 DAS)	15 + 600, 4	2.13	1.41	-0.99	0.21
W ₅ : Pendimethalin (PE) <i>fb</i> Bispyribac-sodium (PoE) <i>fb</i> 1 HW at 50 DAS	1000, 25	4.97	1.12	-0.99	0.07

TEI: Treatment efficiency index, **WMI:** Weed management index, **AMI:** Agronomic management index

IWMI: Integrated weed management index

4. Conclusion

From above results and discussion, it could be concluded that, integration of stale seedbed (remove one flush of weeds through glyphosate 1000 g a.i./ha or shallow tillage at 15 DBS) with Pendimethalin 30% EC 1000 g a.i./ha (PE) *fb* Bispyribac-sodium 10% SC 25 g a.i./ha (PoE) *fb* one hand weeding at 50 DAS effectively managed weeds for achieving higher weed control efficiency in direct-seeded rice.

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