



Impact of Sequential Application of New Generation Herbicides on Weed Dynamics and Productivity of Redgram [*Cajanus cajan* (L.) Mill sp.]

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ABSTRACT

Background: This study was conducted to access the efficiency of new generation pre and post emergence herbicides and various doses of application on the yield attributes, yield and weed dynamics of redgram. The main aim of this experiment was to find out the suitable new generation herbicide combination to control the weeds

Methods: The experiment was carried out at experimental farm, school of agriculture, Bharath Institute of Higher Education and Research, Tamil Nadu, during *Kharif* season (Jun. to Oct.) of two consecutive years (2022-2023 and 2023-2024). The experiment was conducted in randomized block design comprised of eight treatments with three replications

Result: The experimental result revealed that significantly lowest density of weeds was recorded with Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Ready mix) @ 100 g ha⁻¹ as PoE on 25 DAS (T₇) and it was on par with Oxyfluorfen @ 125 g ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Ready mix) @ 100 g ha⁻¹ as PoE on 25 DAS (T₈). The same treatments resulted in the highest yield characteristics, including the number of pods per plant, seeds per pod, seed weight and grain yield. Effective weed management involves controlling the first wave of weeds with a pre-emergence herbicide, followed by managing later emergences with a post-emergence herbicide application.

Key words: Hand weeding, Imazethapyr+imazomox (Ready mix), New generation herbicides, Oxyfluorfen, Pendimethalin+imazethapyr (Ready mix), Redgram.

INTRODUCTION

Redgram [*Cajanus cajan* (L.) Mill sp.], commonly known as pigeon pea, it is a major pulse crop cultivated across tropical and subtropical regions of the world, contributing significantly to food security, nutritional requirements and soil fertility through biological nitrogen fixation. The total area under redgram cultivation in India is about 4.8 million hectares, with a total production of around 4.3 million tonnes and average productivity of around 900 kg ha⁻¹ (DES, 2024). However, the productivity remains significantly below the potential yield of 2.0-2.5 t ha⁻¹, mainly due to various biotic and abiotic stresses. Among these, weed competition during the early growth stages is a major limiting factor that leads to substantial yield losses, often ranging from 30 to 60 per cent, depending on the intensity and duration of weed interference (Singh *et al.*, 2023). Redgram exhibits slow initial growth during the first 30-45 days after sowing and is commonly infested with a complex weed flora dominated by fast-growing annual grasses, broad-leaved weeds and sedges which emerge simultaneously with the crop and compete aggressively for nutrients, moisture and light. Many of these weeds exhibit rapid early growth, high seed production and prolonged emergence periods, enabling them to outcompete redgram during its slow initial growth stage. The crop has a low leaf area index (LAI) and limited canopy development in its early stages, which results in poor ground coverage. Because of this, weeds germinate and establish more rapidly than the crop,

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competing aggressively for nutrients, moisture and light. This early-stage sluggish growth makes redgram highly susceptible to weed competition, especially during the critical weed-free period of 15-60 days after sowing (Shilurenla *et al.*, 2025)

Using herbicides offers a reliable and cost-effective approach for managing a broad spectrum of weeds. Conventional herbicides, largely limited to single pre-emergence applications, often provide inconsistent control

due to a narrow weed spectrum, poor persistence and dependence on soil moisture. Repeated reliance on these herbicides has further resulted in weed escapes and reduced control efficiency, necessitating evaluation of alternative and sequential herbicide strategies for effective weed management in redgram. The use of new generation herbicides with improved selectivity and residual activity ensures season long weed suppression with minimal crop injury. Moreover, the sequential application of herbicides, involving a pre-emergence herbicide followed by a post-emergence application, has been reported to provide effective and sustained weed control throughout the critical crop weed competition period, resulting in enhanced growth and yield of redgram (Korav, 2024). Pendimethalin inhibits cell division (mitosis) by interfering with microtubule formation in the root and shoot meristem of germinating weed seeds, mainly its control annual grasses (*Echinochloa colona*, *Panicum spp.*, *Dactyloctenium aegyptium*) and some small-seeded broad-leaved weeds (*Amaranthus viridis*, *Trianthema portulacastrum*). Imazethapyr inhibit the acetolactate synthase (ALS) enzyme, which is essential for the synthesis of branched-chain amino acids and control Broad-leaved weeds (*Acalypha indica*, *Digera arvensis*, *Euphorbia geniculata*) and some sedges (*Cyperus rotundus*, *Cyperus iria*). Pre-emergence herbicides effectively control weeds during the initial crop growth stage, thereby reducing early competition. However, to manage weeds that germinate later in the season, the use of post-emergence herbicides is essential for extended and effective weed control throughout the crop growth period. Imazethapyr 35% + Imazomox 35% WG is act as a post-emergence herbicide belongs to the imidazolinone group and functions as an acetolactate synthase (ALS) inhibitor also known as Acetohydroxyacid synthase (AHAS) enzyme, which is essential for the biosynthesis of the branched-chain amino acids valine, leucine and isoleucine. Inhibition of this pathway disrupts protein synthesis and cell division, ultimately halting meristematic growth in susceptible weeds (Perumal *et al.*, 2025a and Perumal *et al.*, 2025b). The herbicide is absorbed through both foliage and roots and translocated to actively growing tissues, resulting in gradual growth cessation followed by chlorosis and necrosis of meristematic regions. The formulation provides effective post-emergence control of a broad spectrum of broad-leaved weeds, sedges and some grasses in legumes (Kartik *et al.*, 2021 and Girish *et al.*, 2025). The selected herbicides were chosen based on their contrasting modes of action and effectiveness against major weed flora in redgram. Keeping this in view, the present investigation was carried out to identify the most effective combination of sequential herbicide applications for achieving season-long weed control in redgram, with the aim of reducing weed population and enhancing crop productivity.

MATERIALS AND METHODS

The experiment was conducted at school of Agriculture Experimental farm, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, during the *Kharif*

season (Jun. to Oct.) of two consecutive years (2022-2023 and 2023-2024). The experimental farm is geographically situated at 13.0°N latitude and 79.8°E longitude, with an elevation of about 274 m above mean sea level. The soil at the experimental site was classified as clay loam in texture, containing low organic carbon (0.69%) and medium levels of available nitrogen (330 kg ha⁻¹), phosphorus (15.82 kg ha⁻¹) and potassium (176 kg ha⁻¹). The experiment comprised eight different herbicidal combination treatments *viz.*, Control (T₁), Weed free check (T₂), Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha⁻¹ as PE on 3 DAS (T₃), Oxyfluorfen @125 g ha⁻¹ as PE on 3 DAS (T₄), Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha⁻¹ as PE on 3 DAS *fb* Hand weeding on 30 DAS (T₅), Oxyfluorfen @125 g ha⁻¹ as PE on 3 DAS *fb* Hand weeding on 30 DAS (T₆), Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Ready-mix) @ 100 g ha⁻¹ as PoE on 25 DAS (T₇) and Oxyfluorfen @ 125 g ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Ready-mix) @ 100 g ha⁻¹ as PoE on 25 DAS (T₈).

The experiment was arranged in a randomized block design with three replications. The redgram variety CO (Rg) 7 was sown using a seed rate of 15 kg ha⁻¹. Recommended dose of N, P₂O₅ and K₂O were applied at 25, 50 and 25 kg ha⁻¹ respectively. Entire doses of N, P and K applied as basal dose before sowing and incorporated well into the soil. The redgram was sown on 15th July 2023 and 25th August of 2024 with 90 cm row to row and 30 cm plant to plant spacing were adopted. Herbicides were applied using a knapsack sprayer fitted with a flat-fan nozzle, operated at a pressure of 2.0 kg cm⁻². A spray volume of 500 L ha⁻¹ was used to ensure uniform coverage. The pre-emergence herbicide was applied immediately after sowing, while the post-emergence herbicide was sprayed at 25 days after sowing (DAS) according to the prescribed treatments. Control plots continued to be overrun by the native weed population until harvest time. Information regarding weed density was gathered from a randomly chosen 0.5 m² area at two distinct locations within each plot. Weeds collected from the two 0.5 m² areas were initially sun-dried for 2 to 3 days and subsequently dried in an oven at 65°C until a constant weight was achieved. The dry weight of weeds collected at 60 DAS was recorded in grams per square meter (g m⁻²). The recorded data on weed density and dry weight were then subjected to square root transformation ($\sqrt{x+0.5}$) due to the significant variations observed among the treatments prior to statistical analysis. This research evaluated the efficiency of weed control and the weed index were assessed to determine the effectiveness of different new generation herbicidal treatments. Data on various parameters such as weed count, weed density, yield attributes and grain yield were recorded, tabulated and statistically analysed using analysis of variance (ANOVA) techniques as described by Gomez and Gomez (1984).

Table 1: Efficiency of new generation herbicides on total weed density of sedges, grasses and broad leave weeds (BLW) (m^{-2}) (Pooled data of two years).

Treatments	Density of sedges (m^{-2})						Density of grasses (m^{-2})						Density of BLW (m^{-2})					
	30		60		90		30		60		90		30		60		90	
	DAS	At	DAS	At	DAS	At	DAS	At	DAS	At	DAS	At	DAS	At	DAS	At	DAS	At
Control (T_1)	3.76 (10.66)	6.19 (32.48)	5.90 (29.18)	6.57 (36.87)	3.79 (10.85)	5.11 (21.33)	5.63 (26.37)	5.84 (28.55)	3.20 (7.32)	4.47 (15.77)	4.79 (18.48)	5.61 (26.17)	3.20 (7.32)	4.47 (15.77)	4.79 (18.48)	5.61 (26.17)	3.20 (7.32)	4.47 (15.77)
Weed free check (T_2)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha^{-1} as PE on 3 DAS (T_3)	2.02 (2.33)	5.40 (24.08)	4.61 (16.92)	5.92 (29.44)	2.23 (3.01)	4.52 (16.20)	5.09 (21.09)	5.31 (23.19)	2.22 (2.99)	3.56 (9.37)	4.22 (13.84)	4.36 (14.93)	2.22 (2.99)	3.56 (9.37)	4.22 (13.84)	4.36 (14.93)	2.22 (2.99)	3.56 (9.37)
Oxyfluorfen @ 125 g ha^{-1} as PE on 3 DAS (T_4)	2.07 (4.88)	5.90 (29.33)	5.14 (21.55)	6.12 (31.62)	2.84 (5.49)	4.79 (18.48)	5.35 (23.59)	5.47 (24.75)	2.71 (4.92)	3.93 (11.81)	4.47 (15.77)	5.12 (21.40)	2.71 (4.92)	3.93 (11.81)	4.47 (15.77)	5.12 (21.40)	2.71 (4.92)	3.93 (11.81)
Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha^{-1} as PE on 3 DAS fb hand weeding on 30 DAS (T_5)	2.07 (2.49)	5.01 (20.43)	3.76 (10.67)	5.51 (25.12)	2.30 (3.25)	4.20 (13.74)	4.64 (17.19)	4.93 (19.67)	2.12 (2.63)	2.99 (6.23)	3.51 (9.12)	3.84 (11.20)	2.12 (2.63)	2.99 (6.23)	3.51 (9.12)	3.84 (11.20)	2.12 (2.63)	2.99 (6.23)
Oxyfluorfen @125 g ha^{-1} as PE on 3 DAS fb hand weeding on 30 DAS (T_6)	2.88 (5.71)	5.29 (22.97)	4.27 (14.23)	5.77 (27.81)	2.86 (5.61)	4.46 (15.74)	4.88 (19.27)	5.15 (21.69)	2.70 (4.88)	3.48 (8.89)	3.91 (11.64)	4.17 (13.51)	2.70 (4.88)	3.48 (8.89)	3.91 (11.64)	4.17 (13.51)	2.70 (4.88)	3.48 (8.89)
Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha^{-1} as PE on 3 DAS fb Imazethapyr 35% + Imazomox 35% WG	1.98 (2.21)	4.47 (18.03)	3.55 (9.33)	5.25 (22.64)	2.24 (3.06)	3.72 (10.37)	4.41 (15.33)	4.64 (17.22)	2.19 (2.87)	2.59 (4.39)	3.24 (7.56)	3.59 (9.59)	2.19 (2.87)	2.59 (4.39)	3.24 (7.56)	3.59 (9.59)	2.19 (2.87)	2.59 (4.39)
(Ready mix) @ 100 g ha^{-1} as PoE on 25 DAS (T_7)																		
Oxyfluorfen @ 125 g ha^{-1} as PE on 3 DAS fb	2.82 (5.40)	4.77 (18.29)	3.53 (9.22)	5.27 (22.84)	2.80 (5.33)	3.68 (10.12)	4.42 (15.40)	17.67 (17.47)	2.74 (5.03)	2.61 (4.46)	3.25 (7.61)	3.6 (9.61)	2.74 (5.03)	2.61 (4.46)	3.25 (7.61)	3.6 (9.61)	2.74 (5.03)	2.61 (4.46)
Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha^{-1} as PoE on 25 DAS (T_8)																		
CD (5%)	NS	0.24	0.29	0.33	NS	0.33	0.21	0.31	NS	0.33	0.36	0.26	NS	0.33	0.36	0.26	NS	0.33

Data were subjected to $\sqrt{x+0.5}$. Figures in parenthesis are original value.

RESULTS AND DISCUSSION

Major weed flora in experimental field

The experimental field was heavily infested with a diverse weed flora throughout both years of study. The predominant grasses observed were *Echinochloa colona*, *Dactyloctenium aegyptium* and *Cynodon dactylon*; the major sedges included *Cyperus rotundus* and *Cyperus iria*; while the dominant broad-leaved weeds (BLW) comprised *Amaranthus viridis*, *Trianthema portulacastrum*, *Phyllanthus niruri*, *Digera arvensis* and *Parthenium hysterophorus*. These weed species collectively contributed to intense competition with the redgram crop during both the cropping seasons. The most dominant weed flora was *Digera arvensis*, *Trianthema portulacastrum* and *Cynodon dactylon* during both years.

Weed infestation, weed biomass and weed indices

The use of herbicides greatly influenced the population of sedges, grasses and broad-leaved weeds, overall density and weed dry weight in comparison to the weedy control at various stages of crop growth. The outcomes are presented in Table 1. The minimum density of sedges, grasses and BLW were Pendimethalin 30% EC + Imazethapyr 2% EC (Ready mix) @ 1 kg ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Readymix) @ 100 g ha⁻¹ as PoE on 25 DAS and it was on par with Oxyfluorfen @ 125 g ha⁻¹ as PE on 3 DAS *fb* Imazethapyr 35% + Imazomox 35% WG (Readymix) @ 100 g ha⁻¹ as PoE on 25 DAS considerably less effective compared to the other treatments at 60, 90 and at harvest. The superior weed suppression can be attributed to the complementary mode of action and extended soil residual activity of the herbicide used. Pendimethalin, a dinitroaniline herbicide, inhibit cell division in germinating weeds seeds and early flushes of grasses and small seeded BLW weeds, thereby ensuring a weed free environment during the critical early crop growth phase. The presence of imazethapyr in the tank mix further enhances pre-emergence control through inhibition of acetolactate synthase (ALS), which restricts amino acid synthesis and arrests weed growth. The subsequent post-emergence application of imazethapyr + imazomox at 25 DAS provided broad spectrum and systemic control of later emerging weed cohorts. The pooled data on weed biomass over two years demonstrated significant differences among the herbicide treatments, attributable to the varied herbicidal combinations used. The treatment-wise results are presented in Table 2. At 30 DAS, the lowest weed biomass was observed with the application of pendimethalin 30% EC + imazethapyr 2% EC (ready mix) @ 1 kg ha⁻¹ as pre-emergence on 3 DAS. At 60 DAS and at harvest, the sequential application of pendimethalin 30% EC + imazethapyr 2% EC @ 1 kg ha⁻¹ as PE on 3 DAS followed by imazethapyr 35% + imazomox 35% WG @ 100 g ha⁻¹ as PoE on 25 DAS recorded the minimum weed biomass and this treatment was statistically comparable with oxyfluorfen @ 125 g ha⁻¹ as PE on 3 DAS followed by imazethapyr 35% + imazomox 35% WG @ 100 g ha⁻¹ as PoE on 25 DAS.

Table 2: Efficiency of new generation herbicides on total weed density (m⁻²) and total dry matter of weed (g m⁻²) (Pooled data of two years).

Treatments	Total weed density (m ⁻²)			Weed dry matter production (g m ⁻²)				
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Control (T ₁)	5.04 (20.64)	(26.97)	5.73 (27.38)	5.78 (27.95)	4.53 (6.31)	4.04 (12.55)	4.23 (13.92)	4.26 (14.20)
Weed free check (T ₂)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)	0.5 (0.00)
Pendimethalin 30% EC + imazethapyr 2% EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS (T ₃)	3.52 (9.14)	4.51 (16.19)	4.38 (15.11)	4.76 (18.22)	2.15 (2.75)	3.22 (7.43)	3.64 (9.92)	3.65 (9.96)
Oxyfluorfen @ 125 g ha ⁻¹ as PE on 3 DAS (T ₄)	3.90 (11.61)	4.80(18.53)	5.00(20.30)	5.22(22.31)	2.35(3.44)	3.55(9.33)	3.76(10.63)	3.87(11.41)
Pendimethalin 30 % EC + imazethapyr 2% EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS <i>fb</i> hand weeding on 30 DAS (T ₅)	3.79 (10.86)	4.13 (13.22)	4.11 (13.05)	4.43 (15.46)	2.06 (2.47)	2.98 (6.16)	7.78 (7.76)	3.31 (7.92)
Oxyfluorfen @ 125 g ha ⁻¹ as PE on 3 DAS <i>fb</i> Imazethapyr 2% EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS <i>fb</i> Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T ₆)	3.85 (11.28)	4.46 (15.71)	4.35 (14.85)	4.64 (17.20)	2.32 (3.32)	3.14 (6.99)	3.60 (9.66)	3.74 (10.54)
Oxyfluorfen @ 125 g ha ⁻¹ as PE on 3 DAS <i>fb</i> Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T ₇)	3.53 (9.23)	3.81 (11.02)	3.9 (11.56)	4.19 (13.67)	2.01 (2.31)	2.48 (3.96)	2.87 (5.63)	2.86 (5.59)
Oxyfluorfen @ 125 g ha ⁻¹ as PE on 3 DAS <i>fb</i> Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T ₈)	3.89 (11.54)	3.86 (11.29)	3.95 (11.93)	4.20 (13.75)	2.41 (3.65)	2.52 (4.12)	2.90 (5.78)	2.93 (5.91)
CD (5%)	NS	0.33	0.29	0.41	NS	0.43	0.31	0.36

Data were subjected to $\chi^2+0.5$. Figures in parenthesis are original value.

Table 3: Efficiency of new generation herbicides on weed control efficiency % (WCI) and weed index % (WI) (Pooled data of two years).

Treatments	WCE %				WI%
	30 DAS	60 DAS	90 DAS	At harvest	
Control (T_1)	-	-	-	-	56.68
Weed free check (T_2)	100	100	100	100	0.00
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS (T_3)	56.42	40.80	28.74	29.86	32.96
Oxyfluorfen @125 g ha ⁻¹ as PE on 3 DAS (T_4)	45.48	25.66	23.64	19.65	41.55
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS fb Hand weeding on 30 DAS (T_5)	60.86	50.92	44.25	44.23	18.75
Oxyfluorfen @125 g ha ⁻¹ as PE on 3 DAS fb hand weeding on 30 DAS (T_6)	47.39	44.30	30.60	25.77	24.67
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS fb imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T_7)	63.39	68.45	59.67	60.33	6.82
Oxyfluorfen @ 125 g ha ⁻¹ as PE on 3 DAS fb Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T_8)	42.16	67.17	58.42	58.31	12.26

Table 4: Efficiency of new generation herbicides on yield and yield attributing characters (Pooled data of two years).

Treatments	No. of pods plant ⁻¹	Seed pod ⁻¹	Seed yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)	BCR
Control (T_1)	34.03	1.33	10.25	13.10	1.06
Weed free check (T_2)	51.26	1.86	24.92	29.01	2.14
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS (T_3)	42.30	1.48	16.11	20.04	1.53
Oxyfluorfen @125 g ha ⁻¹ as PE on 3 DAS (T_4)	39.23	1.15	13.10	18.41	1.20
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE on 3 DAS fb hand weeding on 30 DAS (T_5)	47.88	1.63	19.27	24.55	1.80
Oxyfluorfen @125 g ha ⁻¹ as PE on 3 DAS fb hand weeding on 30 DAS (T_6)	44.54	1.29	18.36	22.26	1.65
Pendimethalin 30 % EC + imazethapyr 2 % EC (Ready mix) @ 1 kg ha ⁻¹ as PE o 3 DAS fb Imazethapyr 35% + imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T_7)	50.36	1.68	22.61	27.64	2.09
Oxyfluorfen @125 g ha ⁻¹ as PE on 3 DAS fb Imazethapyr 35% + Imazomox 35% WG (Ready mix) @ 100 g ha ⁻¹ as PoE on 25 DAS (T_8)	49.88	1.55	21.15	26.17	1.98
CD (5%)	2.92	NS	2.02	2.15	NS

A reduction in weed biomass correspondingly enhanced weed control efficiency and the associated results are presented in Table 3. The highest weed control efficiency was achieved with the sequential application of pendimethalin + imazethapyr followed by imazethapyr + imazamox, whereas the untreated control recorded the lowest efficiency due to the substantially higher weed biomass under this treatment. Pendimethalin + Imazethapyr acts as a dual-action pre-emergence herbicide, where Pendimethalin inhibits weed seed germination by inhibiting cell division and elongation. Imazethapyr controls the growth of broad-leaved weeds and sedges by blocking the plastid enzyme acetolactate synthase (ALS) in plants, which is responsible for the initial step in synthesising crucial branched-chain amino acids. As a result, ALS inhibitors halt cell division and decrease carbohydrate movement within susceptible plants. This leads to a reduction in both the number and dry weight of these plants, effectively ensuring thorough weed management. These outcomes align with the conclusions drawn by Nepali *et al.* (2022) and Kumar *et al.* (2024).

Yield and yield attributes

Various combinations of pre- and post-emergence herbicidal weed management strategies showed an impact on the yield of the redgram crop. The outcomes are presented in Table 4. The highest yield-related factors were recorded with the application of pendimethalin 30% EC + imazethapyr 2% EC at a rate of 1 kg ha⁻¹ applied as a pre-emergence treatment on 3 days after sowing, followed by imazethapyr 35% + imazamox 35% WG at 100 g ha⁻¹ as a post-emergence on 25 days after sowing, demonstrating significantly better results than the other treatments throughout the study. A sequential application of herbicides can be attributed to their complementary weed control spectrum and sustained suppression of early and late emerging weeds. Moreover, minimizes weed competition throughout the crop growth period, leading to improved nutrient and moisture availability, better canopy development and ultimately higher yield parameters. Thus, the combination proved more efficient and consistent in suppressing weed flora compared to other treatments, resulting in a significant enhancement in redgram productivity. Nimbargi *et al.* (2021) also reported the highest growth and yield attributing parameters of redgram with the sequential application of herbicides.

CONCLUSION

Based on the pooled results over two years, it is evident that effective weed management significantly reduced weed infestation and improved the yield of redgram. The study demonstrated that the sequential application of the new-generation herbicide pendimethalin 30% EC + imazethapyr 2% EC (ready-mix) at 1 kg ha⁻¹ as a pre-emergence treatment on 3 DAS, followed by imazethapyr 35% + imazamox 35% WG (ready-mix) at 100 g ha⁻¹ as a post-emergence application at 25 DAS, proved highly effective for weed suppression and achieving superior seed yield in redgram.

Conflict of interest

All authors declared that there is no conflict of interest.

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