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RESEARCH ARTICLE

Effect of herbicides on weed control, yield and profitability of summer greengram under conservation agriculture

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ABSTRACT

Weeds pose a major challenge to the adoption of conservation agriculture (CA), where reduced tillage and crop residues can limit the effectiveness of pre-emergence herbicides, highlighting the need to evaluate herbicides post-emergence application (PoE) option for summer greengram. A two-year field study was undertaken with an objective to assess the effect of eleven weed control treatments on weed density, crop productivity, and profitability of summer greengram under CA. The weed control efficiency declined over time from 30 to 50 days after sowing (DAS) due to weed biomass buildup. Among tested treatments, imazethapyr + imazamox 70 g/ha PoE at 20 DAS caused the best weed suppression, higher (nearly double) greengram seed yield, economic return, and benefit-cost ratio (2.08–2.53), compared to untreated control. The quizalofop was effective against grassy weeds, while higher rates of imazethapyr and sodium- acifluorfen + clodinafop showed limited efficacy. It is concluded that imazethapyr + imazamox at 70 g/ha PoE is the most effective and economical solution to manage weeds in summer greengram under CA.

Keywords: Conservation agriculture, Imazethapyr + imazamox, Post-emergence herbicides, Weed management, Summer greengram

INTRODUCTION

The global population is projected to reach 9.7 billion by 2050, resulting in a 50% increase in food demand compared to 2012 (FAO 2017). The agricultural intensification using high-yielding varieties, irrigation, fertilizers, and agrochemicals remains essential. However, there is a growing shift towards sustainable practices that address environmental concerns, reduce costs, enhance stress resilience, and limit agrochemical use. Ensuring future agricultural sustainability now poses an even greater challenge than increasing productivity. The rice–wheat cropping system (RWCS), spanning ~13.5 million hectares in the Indo-Gangetic Plains, relies heavily on conventional practices that have led to overuse of natural resources and declining soil health (Jat *et al.* 2014; Reddy *et al.* 2025). Repeated tillage depletes soil organic matter and carbon, degrading soil structure and reducing productivity (Kumar *et al.* 2023). These negative impacts highlight the need for sustainable alternatives like conservation agriculture (CA), which focuses on minimal soil disturbance, crop diversification, and residue retention. The CA improves soil physical, chemical, and biological properties, enhancing productivity, profitability, and environmental sustainability (Choudhary *et al.* 2024a, b).

The development of short-duration, photo-insensitive, high-yielding, and disease-resistant greengram varieties has enabled their integration into the RWCS under CA, improving system productivity, profitability, and soil health (Singh *et al.* 2017). However, weed infestation remains a major challenge in CA, often causing greater yield losses than other biotic stresses, with greengram yield reductions reported up to 100% (Choudhary *et al.* 2024b). While various weed management practices such as tillage, competitive cultivars, residue mulching (Choudhary *et al.* 2020), and precise nutrient and water use can help (Parihar *et al.* 2016), CA's reliance on crop residues can delay weed emergence and also complicate late-stage control. Due to rising labour costs and limited availability, non-chemical methods are declining in preference, making herbicides increasingly vital (Rao 2022). Effective, safe herbicide options are essential for weed control, cost reduction, and the broader adoption of CA (Choudhary *et al.* 2012).

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Effective weed management in CA requires the right herbicide applied at the correct time and dose, alongside proper crop practices. Pre-emergence (PE) herbicides often bind to crop residues, reducing their efficacy (Sahu *et al.* 2023). In such cases, post-emergence (PoE) herbicides become crucial, offering a low-cost, broad-spectrum alternative vital for CA adoption. However, systematic studies on PoE herbicides in greengram are limited, hindering its integration into the rice–wheat–greengram system. Research on PoE herbicide efficacy is essential to optimize weed control, boost productivity, and support sustainable adoption of greengram in CA-based systems. Thus, a study was conducted with an objective to identiffy effective post-emergent herbicides to manage weeds, improve crop productivity, and profitability of summer greengram under conservation agriculture.

MATERIALS AND METHODS

A field experiment was conducted during the summers of 2017 and 2018 on deep black vertisol at ICAR - Directorate of Weed Research, Jabalpur, India (23°132 N, 79°592 E; 388 m AMSL), within a long-term CA block established in 2012. The site has a subtropical climate with 1386 mm average annual rainfall, 80% of which occurs from June to September. Temperatures range from 4–7°C in January to 42–45°C in May. The soil had medium organic carbon content (0.54%), neutral pH (7.20), low $KMnO_4$ oxidizable nitrogen (245 kg/ha), medium 0.5N $NaHCO_3$-extractable phosphorus (16.9 kg/ha), and high 1N NH_4OAc-exchangeable potassium (350 g/ha), with a clay loam texture in the top 0–20 cm. A randomized complete block design (RCBD) with three replications was used. Wheat residues (~4 t/ha) were retained after its harvest, and glyphosate (1.0 kg/ha) was applied to control existing weeds. Greengram variety ‘Samrat’ was drilled two days later into the untilled soil, followed by sprinkler irrigation. The experiment layout was marked 16 days after sowing. Eleven treatments were tested including: post-emergence application (PoE) of imazethapyr 80 g/ha and 100 g/ha; quizalofop 60 g/ha and 75 g/ha, imazethapyr + imazamox 56 g/ha and 70 g/ha, sodium-acifluorfen + clodinafop at 196 g/ha and 245 g/ha, oxyfluorfen 150 g/ha; hand weeding at 25 days after sowing (DAS) and weedy check. Herbicides were applied at 20 DAS using a solar-powered knapsack sprayer (375 L/ha at 350 kPa). Gross plot size was 5 × 5 m (net plot size of 3.8 × 4.2 m) with 1.0 m spacing between plots. Greengram seeds (25 kg/ha), treated with carbendazim (3 g/kg), were sown at 30 × 10 cm spacing and 5 cm depth using a zero-till seed-cum-ferti drill (Happy Seeder), with a basal dose of 20:60 kg/ha N and P_2O_5 using di-ammonium phosphate.

At flowering, leaf area index (LAI) and plant biomass were recorded. Leaf area of five plants per plot was measured using a LI-3100 meter, and LAI was calculated. Plants were then oven-dried at 65 ± 2°C to a constant weight to determine biomass and extrapolated to m² based on plant density. Weed counts were taken at 30 and 50 DAS using two 0.5 × 0.5 m quadrats per plot. Weeds were classified as grasses, broad-leaved weeds (BLWs), and sedges. Above-ground weed parts were collected, cleaned, and oven-dried at 65 ± 2°C for 72 h to estimate weed biomass. The weed control efficiency was calculated from weed biomass. The Shapiro–Wilk test indicated that the data deviated from normality; therefore, a square root transformation ($\sqrt{x+0.5}$) was performed to achieve normalization. Phyto-toxicity was visually rated 1 to 9 days after herbicide application (DAHA) on a 0–10 phyto-toxicity rating scale, where 0 indicates no injury and 10 indicates complete destruction of the plant.

At physiological maturity, greengram was manually harvested. Yield attributes were recorded from five plants at five locations per plot and averaged. Seeds and haulm from the net plot were threshed separately to determine yield, with seed moisture adjusted to 11%. The cost of cultivation included expenses for seeds, zero-till sowing, fertilizers, irrigation, agrochemicals (including weed control), harvesting, and threshing. Gross returns were based on market prices, and the benefit-cost ratio (B: C) was calculated as gross returns divided by total cost. Treatment effects were analyzed using ANOVA in SAS 9.3 under the general linear model (GLM) for RCBD. Mean differences were tested using LSD at a 5% significance level (p/ =/ 0.05). As year effects were significant, results were presented separately for each year.

RESULTS AND DISCUSSION

The study area comprised the major grassy weeds jungle rice [*Echinochloa colona* (L.) Link], bermuda grass [*Cynodon dactylon* L.], viper grass [*Dinebra retroflexa* (Vahl) Panz.], hairy crabgrass [*Digitaria sanguinalis* (L.) Scop.] and yellow watercrown grass [*Paspalidium flavidum* (Retz.) A. Camus]. The major BLWs were false daisy [*Eclipta alba* (L.) Hassk.], gooseberry [*Physalis minima* L.], benghal dayflower [*Commelina benghalensis* (L.)], sessile joyweed [*Alternanthera sessilis* (L.) R. Br. Ex

DC], giant pigweed [*Trianthema portulacastrum* (L.)], green amaranth [*Amaranthus viridis* (L.)], Asiatic dayflower [*Commelina communis* (L.)] and bur clover [*Medicago polymorpha* (L.)]. purple nutsedge [*Cyperus rotundus* (L.)] was the only sedge species identified in the study area.

Effect on weeds at 30 and 50 DAS

Weed density and biomass in greengram under CA were significantly affected (p=0.05) by weed management treatments (**Tables 1-4**). Grassy weeds such as *E. colona, C. dactylon,* and *D. retroflexa* were more prevalent in 2018 than in 2017, whereas *P. flavidum* density remained relatively stable. The highest densities of grassy weeds were observed in un-weeded control plots, while the lowest were recorded with hand weeding at 25 DAS followed by quizalofop 60 and 75 g/ha. In contrast, imazethapyr 80 and 100 g/ha and sodium-acifluorfen + clodinafop 196 g/ha were less effective, particularly at later crop stages. *D. sanguinalis* and *C. dactylon* densities tended to be higher under lower herbicide doses. *Paspalidium flavidum* was significantly suppressed in all treated plots. *Dinebra retroflexa* and *C. rotundus* were poorly controlled by lower herbicide rates, with the latter appearing prominently in 2018 but absent in hand-weeded plots in 2017.

Un-weeded control plots exhibited the highest density of BLWs across both years and sampling times, with overall weed densities generally higher in 2018, except for *E. alba*. *M. polymorpha* was absent in 2017 (**Table 1**). *Physalis minima* density peaked at 30 DAS in plots treated with sodium-acifluorfen + clodinafop 196 g/ha and 245 g/ha and low-dose imazethapyr 80 g/ha, and remained high at 50 DAS under imazethapyr 80 g/ha and 100 g/ha and oxyfluorfen 150 g/ha. The lowest BLW densities were observed in hand-weeded plots and those treated with the higher dose of imazethapyr + imazamox 70 g/ha.

Eclipta alba density was not influenced by year but was higher at 30 DAS under imazethapyr + imazamox, both doses of sodium-acifluorfen + clodinafop, and the lower dose of imazethapyr. By 50 DAS, the highest density was recorded with oxyfluorfen 150 g/ha, followed by the lower dose of sodium-acifluorfen + clodinafop and imazethapyr + imazamox. *Amaranthus viridis* was effectively suppressed by all treatments except quizalofop and was eventually controlled by crop competition. *Commelina communis* was poorly managed under low-dose sodium acifluorfen + clodinafop and imazethapyr + imazamox. *Medicago polymorpha* density increased in plots treated with these

Table 1. Density and biomass of grassy weeds at 30 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture (2017 and 2018)

Treatment	Dose (g/ha)	*E. colona*		*C. dactylon*		*P. flavidum*		*D. retroflexa*	
		2017	2018	2017	2018	2017	2018	2017	2018
Weed density (no./m^2)									
Imazethapyr	80	1.2(1.0)*	2.2(4.3)	0.9(0.3)	1.5(1.7)	1.1(0.7)	1.2(1.0)	1.1(0.7)	1.2(1.0)
Imazethapyr	100	0.9(0.3)	1.7(2.3)	0.7(0.0)	1.2(1.0)	1.1(0.7)	0.9(0.3)	1.1(0.7)	1.1(0.7)
Quizalofop	60	0.7(0.0)	1.1(0.7)	0.9(0.3)	1.2(1.0)	0.9(0.3)	0.9(0.3)	0.9(0.3)	0.9(0.3)
Quizalofop	75	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.9(0.3)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)
Imazethapyr + imazamox	56	1.3(1.3)	1.5(1.7)	1.2(1.0)	1.3(1.3)	1.2(0.7)	1.2(1.0)	1.2(1.0)	1.4(1.7)
Imazethapyr + imazamox	70	1.2(1.0)	1.3(1.3)	0.9(0.3)	0.9(0.3)	1.1(0.3)	0.9(0.3)	1.1(0.7)	1.2(1.0)
Sodium-acifluorfen + clodinafop	196	1.5(1.7)	1.7(2.3)	1.2(1.0)	1.4(1.7)	0.9(0.7)	1.2(1.0)	0.9(0.3)	1.1(0.7)
Sodium-acifluorfen + clodinafop	245	1.1(0.7)	1.3(1.3)	1.1(0.7)	1.1(0.7)	1.1(0.7)	1.1(0.7)	1.1(0.7)	1.1(0.7)
Oxyfluorfen	150	0.9(0.3)	1.1(0.7)	1.1(0.7)	1.2(1.0)	1.1(0.0)	0.7(0.0)	1.1(0.7)	1.1(0.7)
Hand weeding at 25 DAS	-	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.9(0.3)	0.7(0.0)	0.7(0.0)	0.7(0.0)	1.2(1.0)
Control	-	2.0(3.3)	2.7(6.7)	1.5(1.7)	1.9(3.0)	1.7(3.0)	1.9(3.0)	1.7(2.3)	1.9(3.0)
LSD (p=0.05)		0.39	0.47	0.39	0.46	0.42	0.51	0.43	0.64
Weed biomass (g/m^2)									
Imazethapyr	80	1.2(1.2)	1.7(2.5)	0.8(0.1)	1.0(0.5)	0.8(0.2)	0.8(0.2)	0.9(0.4)	0.8(0.1)
Imazethapyr	100	0.9(0.5)	1.4(1.5)	0.7(0.0)	0.9(0.2)	0.8(0.2)	0.8(0.2)	0.9(0.3)	0.8(0.1)
Quizalofop	60	0.7(0.0)	1.0(0.5)	0.7(0.0)	0.9(0.3)	0.7(0.0)	0.8(0.1)	0.7(0.0)	0.7(0.0)
Quizalofop	75	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.8(0.1)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)
Imazethapyr + imazamox	56	1.4(1.5)	1.3(1.3)	0.9(0.3)	1.0(0.4)	0.8(0.2)	0.8(0.2)	1.0(0.5)	0.9(0.3)
Imazethapyr + imazamox	70	1.1(0.7)	1.2(0.9)	0.8(0.2)	0.8(0.1)	0.8(0.1)	0.8(0.1)	1.0(0.5)	0.8(0.1)
Sodium-acifluorfen + clodinafop	196	1.5(1.7)	1.4(1.6)	1.3(1.2)	1.0(0.6)	1.1(0.7)	0.9(0.2)	0.8(0.2)	0.8(0.1)
Sodium-acifluorfen + clodinafop	245	1.1(0.7)	1.2(0.7)	0.9(0.3)	0.9(0.2)	0.8(0.2)	0.8(0.1)	0.9(0.4)	0.8(0.1)
Oxyfluorfen	150	0.9(0.4)	0.9(0.3)	0.9(0.3)	0.9(0.2)	0.7(0.0)	0.7(0.0)	0.9(0.3)	0.8(0.1)
Hand weeding at 25 DAS	-	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.8(0.2)
Control	-	1.7(2.5)	2.0(3.5)	1.5(1.8)	1.1(0.8)	1.7(2.3)	1.2(0.8)	1.6(2.2)	1.0(0.5)
LSD (p=0.05)		0.41	0.30	0.16	0.18	0.20	0.15	0.25	0.14

*Figures in parentheses are original value

herbicides, particularly at lower application rates (**Table 2**).

At 50 DAS, *E. geniculata* density was highest under oxyfluorfen 150 g/ha, followed by imazethapyr + imazamox 56 g/ha, while other herbicides provided only moderate control compared to hand weeding (**Table 3**). *Alternanthera sessilis* was more prevalent under imazethapyr 80 g/ha and 100 g/ha and at low doses of sodium-acifluorfen + clodinafop. *Trianthema portulacastrum* density increased under both doses of sodium-acifluorfen + clodinafop, imazethapyr + imazamox, and oxyfluorfen. *Commelina communis* showed higher density with low doses of sodium acifluorfen + clodinafop, imazethapyr, and imazethapyr + imazamox, but was better suppressed at higher doses. *Medicago polymorpha* density was elevated under sodium acifluorfen + clodinafop and imazethapyr + imazamox, particularly at lower rates. No sedges were observed at 30 DAS. Weed biomass patterns closely reflected density trends across both sampling times and years (**Table 4**).

Table 2. Density and biomass of broad-leaved weeds at 30 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture (2017 and 2018)

Treatment	Dose (g/ha)	*P. minima*		*E. alba*		*A. sessilis*		*A. viridis*		*C. communis*		*M. polymorpha*	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Weed density (no./m²)													
Imazethapyr	80	1.1 (0.7)*	1.2 (1.0)	0.7 (0.0)	0.9 (0.3)	1.3 (1.3)	1.7 (2.3)	0.7 (0.0)	0.9 (0.3)	1.2 (1.0)	1.7 (2.3)	1.2 (1.0)	1.2 (1.0)
Imazethapyr	100	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)	1.1 (0.7)	1.2 (1.0)	0.7 (0.0)	0.9 (0.3)	1.1 (0.7)	1.3 (1.3)	1.1 (0.7)	1.1 (0.7)
Quizalofop	60	2.1 (4.0)	2.1 (4.0)	2.1 (4.0)	1.8 (2.7)	2.4 (5.3)	2.4 (5.3)	1.9 (3.3)	1.8 (2.7)	2.1 (4.0)	2.2 (4.3)	2.0 (3.3)	3.4 (11.0)
Quizalofop	75	1.9 (3.0)	1.9 (3.0)	2.1 (4.0)	1.7 (2.3)	2.4 (5.3)	2.4 (5.3)	1.7 (2.3)	1.7 (2.3)	2.0 (3.7)	2.0 (3.7)	1.9 (3.0)	3.3 (10.3)
Imazethapyr + imazamox	56	0.7 (0.0)	1.0 (0.7)	1.3 (1.3)	1.3 (1.3)	1.3 (1.3)	1.7 (2.3)	1.1 (0.7)	1.1 (0.7)	1.2 (1.0)	1.3 (1.3)	1.3 (1.3)	2.0 (3.3)
Imazethapyr + imazamox	70	0.7 (0.0)	0.9 (0.3)	1.1 (0.7)	1.1 (0.7)	1.1 (0.7)	1.3 (1.3)	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)	1.1 (0.7)	1.1 (0.7)	1.5 (1.7)
Sodium-acifluorfen + clodinafop	196	1.2 (1.0)	1.3 (1.3)	0.9 (0.3)	0.9 (0.3)	1.5 (1.7)	1.8 (2.7)	1.1 (0.7)	1.1 (0.7)	1.1 (0.7)	1.7 (2.3)	1.3 (1.3)	2.3 (4.7)
Sodium-acifluorfen + clodinafop	245	0.9 (0.3)	1.2 (1.0)	0.9 (0.3)	0.9 (0.3)	1.3 (1.3)	1.6 (2.0)	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)	1.2 (1.0)	1.1 (0.7)	1.8 (2.7)
Oxyfluorfen	150	0.9 (0.3)	0.9 (0.3)	0.7 (0.0)	0.7 (0.0)	1.3 (1.3)	1.3 (1.3)	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)	1.1 (0.7)	1.1 (0.7)	1.1 (0.7)
Hand weeding at 25 DAS	-	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	1.0 (0.7)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	1.2 (1.0)
Control	-	2.3 (4.7)	2.5 (5.7)	1.9 (3.0)	1.7 (2.3)	2.6 (6.3)	2.5 (6.0)	1.0 (3.0)	1.9 (3.0)	2.1 (4.0)	2.4 (5.3)	2.0 (3.3)	3.9 (15.0)
LSD (p=0.05)		0.50	0.64	0.40	0.03	0.30	0.50	0.39	0.42	0.53	0.48	0.45	0.50
Weed biomass (g/m²)													
Imazethapyr	80	0.9 (0.4)	0.9 (0.3)	0.7 (0.0)	0.8 (0.1)	1.0 (0.6)	1.1 (0.7)	0.7 (0.0)	0.8 (0.1)	0.9 (0.3)	0.9 (0.3)	0.8 (0.2)	0.9 (0.2)
Imazethapyr	100	0.8 (0.2)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.2)	0.9 (0.3)	0.7 (0.0)	0.8 (0.1)	0.8 (0.2)	0.8 (0.2)	0.8 (0.1)	0.8 (0.1)
Quizalofop	60	1.4 (1.4)	1.1 (0.8)	1.2 (1.0)	1.1 (0.6)	1.2 (1.0)	1.3 (1.1)	0.9 (0.3)	1.1 (0.6)	1.2 (0.9)	1.0 (0.5)	1.0 (0.5)	1.4 (1.4)
Quizalofop	75	1.3 (1.2)	1.1 (0.8)	1.2 (0.8)	0.9 (0.4)	1.2 (0.9)	1.2 (1.0)	0.8 (0.1)	1.0 (0.5)	1.1 (0.8)	1.0 (0.4)	0.9 (0.3)	1.3 (1.3)
Imazethapyr + imazamox	56	0.7 (0.0)	0.8 (0.2)	0.9 (0.3)	0.9 (0.3)	0.9 (0.4)	1.0 (0.6)	0.8 (0.1)	0.8 (0.2)	0.9 (0.3)	0.8 (0.2)	0.8 (0.1)	1.1 (0.7)
Imazethapyr + imazamox	70	0.7 (0.0)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.2)	0.9 (0.3)	0.7 (0.0)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	1.0 (0.4)
Sodium-acifluorfen + clodinafop	196	0.9 (0.4)	1.0 (0.4)	0.8 (0.1)	0.8 (0.1)	1.0 (0.4)	1.0 (0.5)	0.8 (0.1)	0.9 (0.2)	0.8 (0.2)	0.9 (0.3)	0.8 (0.1)	1.1 (0.8)
Sodium-acifluorfen + clodinafop	245	0.8 (0.1)	0.9 (0.3)	0.8 (0.1)	0.8 (0.1)	0.9 (0.4)	1.0 (0.5)	0.7 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	1.0 (0.5)
Oxyfluorfen	150	0.8 (0.1)	0.8 (0.1)	0.7 (0.0)	0.7 (0.0)	0.9 (0.3)	0.9 (0.3)	0.7 (0.0)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)
Hand weeding at 25 DAS	-	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.8 (0.1)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.8 (0.2)
Control	-	1.5 (1.7)	1.2 (1.0)	1.1 (0.7)	1.0 (0.6)	1.5 (1.8)	1.2 (1.0)	1.0 (0.6)	1.1 (0.6)	1.3 (1.3)	1.3 (0.7)	0.9 (0.4)	1.5 (1.8)
LSD (p=0.05)		0.25	0.23	0.13	0.11	0.11	0.16	0.08	0.14	0.17	0.09	0.08	0.17

*Figures in parentheses are original value

Effect on group-wise weeds at 30 and 50 DAS

The density and biomass of weeds were significantly (p<0.05) influenced by weed management treatments during both the years (**Table 5**). Un-weeded control plots exhibited higher densities of grassy weeds at 30 DAS and 50 DAS. The lowest density of grassy weeds was recorded with hand weeding at 25 DAS followed by quizalofop at 75 g/ha. Among the different herbicides, quizalofop 75 g/ha consistently provided effective control of grassy weeds during both sampling times and years, followed by quizalofop 60 g/ha. At 50 DAS, higher densities were observed with sodium acifluorfen + clodinafop 196 g/ha, imazethapyr + imazamox 56 g/

Table 3. Grasses and sedges density and biomass at 50 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture (2017 and 2018)

Treatment	Dose (g/ha)	Grasses										Sedge	
		E. colona		*C. dactylon*		*D. sanguinalis*		*P. flavidum*		*D. retroflexa*		*C. rotundus*	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Weed density (no./m^2)													
Imazethapyr	80	1.8	3.0	1.3	1.7	1.7	1.6	1.5	1.8	1.7	1.9	0.9	1.2
		(2.7)*	(8.7)	(1.3)	(2.3)	(2.3)	(2.0)	(1.7)	(2.7)	(2.3)	(3.0)	(0.3)	(1.0)
Imazethapyr	100	1.2	2.2	1.1	1.2	1.3	1.2	1.1	1.3	1.5	1.3	0.7	0.9
		(1.0)	(4.3)	(0.7)	(1.0)	(1.3)	(1.0)	(0.7)	(1.3)	(1.7)	(1.3)	(0.0)	(0.3)
Quizalofop	60	0.9	1.3	0.9	1.4	1.2	1.2	1.1	1.3	1.1	1.2	1.8	2.0
		(0.3)	(1.3)	(0.3)	(1.7)	(1.0)	(1.0)	(0.7)	(1.3)	(0.7)	(1.0)	(2.7)	(3.3)
Quizalofop	75	0.7	0.9	0.7	0.7	0.9	0.9	0.7	0.9	0.9	1.1	1.7	1.8
		(0.0)	(0.3)	(0.0)	(0.0)	(0.3)	(0.3)	(0.0)	(0.3)	(0.3)	(0.7)	(2.3)	(2.7)
Imazethapyr + imazamox	56	1.7	2.1	1.3	1.7	1.2	1.3	1.6	1.6	1.9	2.1	1.2	1.3
		(2.3)	(4.0)	(1.3)	(2.3)	(1.0)	(1.3)	(2.0)	(2.0)	(3.0)	(4.0)	(1.0)	(1.3)
Imazethapyr + imazamox	70	1.5	1.8	1.1	1.3	1.1	1.0	1.2	1.2	1.3	1.5	0.9	1.1
		(1.7)	(2.7)	(0.7)	(1.3)	(0.7)	(0.7)	(1.0)	(1.0)	(1.3)	(1.7)	(0.3)	(0.7)
Sodium-acifluorfen +	196	1.9	2.0	1.8	2.0	1.5	1.5	1.7	1.9	1.9	1.9	1.9	1.7
clodinafop		(3.0)	(3.7)	(2.7)	(3.3)	(1.7)	(1.7)	(2.3)	(3.0)	(3.0)	(3.0)	(3.0)	(2.3)
Sodium-acifluorfen +	245	1.7	1.8	1.5	1.7	0.9	1.3	1.1	1.5	2.0	1.7	1.5	1.3
clodinafop		(2.3)	(2.7)	(1.7)	(2.3)	(0.3)	(1.3)	(0.7)	(1.7)	(3.3)	(2.3)	(1.7)	(1.3)
Oxyfluorfen	150	1.6	1.8	1.3	1.7	1.3	1.7	1.9	2.0	1.8	1.9	1.1	1.5
		(2.0)	(2.7)	(1.3)	(2.7)	(1.3)	(2.3)	(3.0)	(3.7)	(2.7)	(3.0)	(0.7)	(1.7)
Hand weeding at 25 DAS	-	0.7	1.1	0.7	0.9	0.7	0.9	0.7	1.3	0.7	1.3	0.7	1.7
		(0.0)	(0.7)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(1.3)	(0.0)	(1.3)	(0.0)	(2.3)
Control	-	3.0	3.2	2.3	2.5	3.0	2.1	2.1	2.9	2.4	2.4	2.0	2.2
		(8.7)	(9.7)	(5.0)	(5.7)	(8.3)	(4.0)	(4.0)	(8.0)	(5.3)	(5.3)	(3.7)	(4.3)
LSD (p=0.05)		0.43	0.50	0.43	0.54	0.40	0.49	0.43	0.53	0.40	0.55	0.30	0.40
Weed biomass (g/m^2)													
Imazethapyr	80	1.6	2.1	1.4	1.5	1.4	1.4	0.9	1.3	1.3	1.5	0.9	0.9
		(2.0)	(3.8)	(1.6)	(1.6)	(1.4)	(1.5)	(0.4)	(1.2)	(1.3)	(1.7)	(0.3)	(0.3)
Imazethapyr	100	1.1	1.6	1.1	1.1	1.2	1.1	0.8	1.1	1.3	1.1	0.7	0.8
		(0.8)	(2.2)	(0.9)	(0.8)	(1.0)	(0.8)	(0.1)	(0.8)	(1.1)	(0.7)	(0.0)	(0.1)
Quizalofop	60	0.9	1.1	0.9	1.2	1.1	1.1	0.8	1.1	1.0	1.0	1.7	1.1
		(0.3)	(0.8)	(0.4)	(1.1)	(0.7)	(0.7)	(0.1)	(0.8)	(0.5)	(0.6)	(2.5)	(0.8)
Quizalofop	75	0.7	0.9	0.7	0.7	0.8	0.8	0.7	0.8	0.8	1.0	1.6	1.1
		(0.0)	(0.4)	(0.0)	(0.0)	(0.2)	(0.3)	(0.0)	(0.2)	(0.2)	(0.5)	(2.2)	(0.7)
Imazethapyr + imazamox	56	1.2	1.6	1.2	1.4	1.1	1.3	0.9	1.2	1.3	1.7	1.2	0.9
		(1.0)	(2.0)	(0.9)	(1.5)	(0.7)	(1.1)	(0.4)	(0.9)	(1.1)	(2.3)	(0.9)	(0.3)
Imazethapyr + imazamox	70	1.1	1.4	1.0	1.2	0.9	0.9	0.8	1.0	1.0	1.3	0.8	0.8
		(0.8)	(1.5)	(0.5)	(1.0)	(0.3)	(0.5)	(0.2)	(0.4)	(0.6)	(1.1)	(0.2)	(0.2)
Sodium-acifluorfen +	196	1.5	1.5	1.6	1.5	1.2	1.3	1.0	1.3	1.4	1.4	1.8	1.0
clodinafop		(1.6)	(1.9)	(2.1)	(1.8)	(1.0)	(1.3)	(0.4)	(1.1)	(1.5)	(1.6)	(2.8)	(0.5)
Sodium-acifluorfen +	245	1.4	1.3	1.3	1.3	0.8	1.2	0.8	1.1	1.4	1.3	1.5	0.9
clodinafop		(1.4)	(1.2)	(1.3)	(1.3)	(0.2)	(1.0)	(0.2)	(0.7)	(1.6)	(1.3)	(1.8)	(0.4)
Oxyfluorfen	150	1.4	1.6	1.3	1.4	1.1	1.5	1.0	1.3	1.4	1.4	1.1	1.0
		(1.5)	(1.9)	(1.2)	(1.5)	(0.6)	(1.6)	(0.6)	(1.1)	(1.6)	(1.6)	(0.8)	(0.4)
Hand weeding at 25 DAS	-	0.7	0.9	0.7	0.9	0.7	0.9	0.7	1.1	0.7	1.0	0.7	1.1
		(0.0)	(0.4)	(0.0)	(0.3)	(0.0)	(0.3)	(0.0)	(0.7)	(0.0)	(0.4)	(0.0)	(0.6)
Control	-	3.4	2.5	2.0	2.1	2.3	1.9	1.1	1.7	2.0	2.0	1.9	1.4
		(11.1)	(5.6)	(3.4)	(3.8)	(4.8)	(3.2)	(0.7)	(2.5)	(3.4)	(3.6)	(3.2)	(1.4)
LSD (p=0.05)		0.33	0.33	0.39	0.40	0.27	0.37	0.11	0.28	0.25	0.36	0.26	0.14

*Figures in parentheses are original value

ha and oxyfluorfen 150 g/ha. The other herbicides resulted in lower densities of grassy weeds, although their efficacy was compared to hand weeding and quizalofop 75 g/ha. Similar to density, the highest biomass recorded in un-weeded control plots during both sampling times and years. Lower biomass of grassy weeds was observed in plots subjected to hand weeding followed by quizalofop at 75 g/ha. The other herbicides at tested doses resulted in lower biomass of grassy weeds, although their effects were less pronounced compared to hand weeding.

Hand weeding at 25 DAS resulted in the lowest density of BLWs, followed by oxyfluorfen 150 g/ha and imazethapyr 100 g/ha. Other weed management treatments also effectively controlled BLWs, although their efficacy was comparatively lower than hand weeding. Hand weeded plots recorded the lowest biomass of BLWs followed by imazethapyr 100 g/ha and imazethapyr + imazamox 70 g/ha. The other weed management practices also significantly reduced the biomass of BLWs, although their effectiveness was lower than hand weeded plots during both years.

In 2017, at 50 DAS, sedges were absent in hand weeded plots and plots treated with imazethapyr 100 g/ha, while in 2018, the lowest density and biomass of sedges were recorded with imazethapyr 100 g/ha followed by imazethapyr + imazamox 70 g/ha. The

Table 4. Broad-leaved weeds density (no./m^2) and biomass (g/m^2) at 50 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture (2017 and 2018)

Treatment	Dose (g/ha)	*P. minima*		*E. alba*		*E. geniculata*		*A. sessilis*		*T. portulcastrum*		*C. communis*		*M. polymorpha*	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Weed density (no./m^2)															
Imazethapyr	80	1.7 (2.3)*	2.0 (3.3)	0.9 (0.3)	1.3 (1.3)	0.7 (0.0)	0.7 (0.0)	1.7 (2.3)	1.9 (3.0)	0.9 (0.3)	1.2 (1.0)	0.9 (0.3)	1.6 (2.0)	-	2.0 (3.7)
Imazethapyr	100	1.3 (1.3)	1.7 (2.3)	0.7 (0.0)	0.9 (0.3)	0.7 (0.0)	0.7 (0.0)	1.3 (1.3)	1.7 (2.3)	0.7 (0.0)	0.9 (0.3)	0.7 (0.0)	1.1 (0.7)	-	1.6 (2.0)
Quizalofop	60	2.4 (5.3)	2.5 (5.7)	1.7 (2.3)	1.8 (2.7)	1.7 (2.3)	1.8 (2.7)	2.0 (3.3)	2.0 (3.3)	2.0 (3.3)	2.1 (4.0)	1.9 (3.0)	1.7 (2.3)	-	3.5 (12.0)
Quizalofop	75	2.3 (4.7)	2.1 (4.0)	1.5 (1.7)	1.7 (2.3)	1.5 (1.7)	1.6 (2.0)	1.7 (2.3)	1.6 (2.0)	1.8 (2.7)	1.8 (2.7)	1.7 (2.3)	1.7 (2.3)	-	3.6 (12.3)
Imazethapyr + imazamox	56	1.2 (1.0)	1.3 (1.3)	1.3 (1.3)	1.5 (1.7)	1.2 (1.0)	1.5 (1.7)	1.6 (2.0)	1.6 (2.0)	1.8 (2.7)	1.9 (3.0)	1.5 (1.7)	1.6 (2.0)	-	2.3 (5.0)
Imazethapyr + imazamox	70	1.1 (0.7)	1.1 (0.7)	1.1 (0.7)	1.1 (0.7)	0.9 (0.3)	0.9 (0.3)	1.3 (1.3)	1.2 (1.0)	1.3 (1.3)	1.3 (1.3)	0.9 (0.3)	0.9 (0.3)	-	1.8 (2.7)
Sodium-acifluorfen + clodinafop	196	1.2 (1.0)	1.3 (1.3)	1.2 (1.0)	1.5 (1.7)	1.2 (1.0)	1.2 (1.0)	1.6 (2.0)	1.8 (2.7)	1.9 (3.0)	2.0 (3.7)	1.3 (1.3)	1.8 (2.7)	-	2.4 (5.3)
Sodium-acifluorfen + clodinafop	245	0.9 (0.3)	1.1 (0.7)	1.1 (0.7)	1.2 (1.0)	0.9 (0.3)	0.9 (0.3)	1.5 (1.7)	1.5 (1.7)	1.7 (2.3)	1.6 (2.0)	0.9 (0.3)	1.5 (1.7)	-	1.9 (3.3)
Oxyfluorfen	150	1.1 (0.7)	1.6 (2.0)	1.2 (1.0)	1.7 (2.3)	0.9 (0.3)	1.7 (2.3)	1.3 (1.3)	1.8 (2.7)	1.8 (2.7)	1.8 (2.7)	1.1 (0.7)	1.6 (2.0)	-	2.0 (3.7)
Hand weeding at 25 DAS	-	0.7 (0.0)	1.3 (1.3)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	1.2 (1.0)	0.7 (0.0)	1.2 (1.0)	0.7 (0.0)	1.2 (1.0)	-	1.2 (1.0)
Control	-	1.9 (3.0)	2.4 (5.3)	1.8 (2.7)	2.0 (3.7)	1.7 (2.3)	1.9 (3.0)	2.2 (4.3)	2.3 (4.7)	2.0 (3.7)	2.5 (5.7)	2.0 (3.7)	2.1 (4.0)	-	3.9 (15.0)
LSD (p=0.05)		0.46	0.39	0.41	0.41	0.37	0.34	0.44	0.36	0.32	0.44	0.39	0.47		0.53
Weed biomass (g/m^2)															
Imazethapyr	80	1.4 (1.4)	1.6 (2.1)	0.9 (0.4)	0.9 (0.3)	0.7 (0.0)	0.7 (0.0)	2.0 (3.6)	1.3 (1.3)	0.9 (0.3)	1.0 (0.4)	0.8 (0.1)	1.1 (0.6)	-	1.2 (0.9)
Imazethapyr	100	1.2 (0.9)	1.4 (1.6)	0.7 (0.0)	0.8 (0.1)	0.7 (0.0)	0.7 (0.0)	1.6 (2.1)	1.2 (1.0)	0.7 (0.0)	0.8 (0.1)	0.7 (0.0)	0.8 (0.1)	-	1.0 (0.6)
Quizalofop	60	1.7 (2.4)	1.8 (2.8)	1.7 (2.4)	1.1 (0.7)	1.7 (2.4)	1.2 (0.9)	2.1 (3.7)	1.3 (1.3)	1.7 (2.4)	1.6 (2.0)	1.2 (0.9)	1.1 (0.6)	-	1.7 (2.4)
Quizalofop	75	1.6 (2.1)	1.7 (2.3)	1.5 (1.6)	1.0 (0.5)	1.5 (1.8)	1.1 (0.6)	1.8 (2.8)	1.1 (0.8)	1.6 (2.0)	1.3 (1.2)	1.1 (0.7)	1.1 (0.7)	-	1.7 (2.5)
Imazethapyr + imazamox	56	1.0 (0.6)	1.1 (0.8)	1.2 (1.0)	1.0 (0.4)	1.2 (0.8)	1.0 (0.5)	1.4 (1.6)	1.2 (1.0)	1.4 (1.5)	1.3 (1.3)	1.0 (0.4)	1.0 (0.6)	-	1.3 (1.1)
Imazethapyr + imazamox	70	0.9 (0.4)	1.3 (1.5)	0.9 (0.4)	0.8 (0.1)	0.8 (0.2)	0.8 (0.1)	1.3 (1.2)	1.0 (0.4)	1.1 (0.7)	1.0 (0.5)	0.8 (0.1)	0.8 (0.1)	-	1.1 (0.7)
Sodium-acifluorfen + clodinafop	196	1.0 (0.6)	1.1 (0.8)	1.1 (0.9)	1.0 (0.4)	1.2 (1.0)	0.9 (0.3)	1.7 (2.3)	1.1 (0.8)	1.5 (1.7)	1.4 (1.4)	0.9 (0.4)	1.1 (0.8)	-	1.4 (1.3)
Sodium-acifluorfen + clodinafop	245	0.8 (0.2)	1.0 (0.4)	1.1 (0.7)	0.9 (0.3)	0.9 (0.3)	0.8 (0.1)	1.6 (2.0)	1.0 (0.5)	1.4 (1.5)	1.2 (0.9)	0.8 (0.1)	1.0 (0.4)	-	1.2 (1.0)
Oxyfluorfen	150	1.0 (0.5)	1.3 (1.2)	1.2 (1.0)	1.0 (0.6)	0.9 (0.4)	1.0 (0.6)	1.4 (1.9)	1.2 (1.0)	1.6 (2.1)	1.3 (1.1)	0.8 (0.2)	1.1 (0.6)	-	1.3 (1.1)
Hand weeding at 25 DAS	-	0.7 (0.0)	1.1 (0.7)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.9 (0.4)	0.7 (0.0)	1.0 (0.5)	0.7 (0.0)	0.9 (0.3)	-	0.9 (0.3)
Control	-	1.6 (1.9)	1.7 (2.4)	1.8 (2.9)	1.3 (1.1)	1.8 (2.9)	1.2 (0.9)	2.5 (6.0)	1.8 (2.9)	1.9 (3.1)	1.8 (2.6)	1.3 (1.1)	1.5 (1.8)	-	1.7 (2.4)
LSD (p=0.05)		0.29	0.43	0.37	0.15	0.34	0.14	0.45	0.23	0.28	0.22	0.14	0.16		0.21

*Figures in parentheses are original value

weed management treatments caused reduced density and biomass of sedges (**Table 6**).

Over time, an increasing density of grasses, especially *D. sanguinalis*, *D. retroflexa*, and *C. dactylon*, was observed under ZT, indicating a change in weed flora from BLWs to grasses, and from annuals to perennials. These species, capable of vegetative reproduction, thrive in undisturbed soils and escape PE and early PoE herbicide applications due to delayed emergence under crop residues. This delay leads to late weed flushes and increased seed production, enriching the seed bank (Choudhary and Kumar 2019, Mishra *et al.* 2019). Herbicides are essential in CA, but crop residues can reduce their efficacy by intercepting the spray, limiting soil contact (Mobli *et al.* 2020). Consequently, escape weeds like *C. iria* persist. The reliance only on PE or early PoE herbicides may worsen weed problems. Effective weed control in CA is critical in the initial 2–3 years to prevent seed bank buildup. Integrated weed management, including timely herbicide application and residue management, is essential (Sims *et al.*

Table 5. Weed densities and biomass of grassy and broad-leaved weeds at 30 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture

Treatment	Dose (g/ha)	Weed density (no./m²)				Weed biomass (g/m²)			
		Grasses		Broad-leaved		Grasses		Broad-leaved	
		2017	2018	2017	2018	2017	2018	2017	2018
Imazethapyr	80	1.8(2.7)*	2.9(8.0)	2.1(4.0)	2.8(7.3)	1.5(1.8)	1.9(3.3)	1.4(1.5)	1.5(1.6)
Imazethapyr	100	1.5(1.7)	2.2(4.3)	1.8(2.7)	2.1(4.0)	1.2(0.9)	1.6(1.9)	1.1(0.8)	1.2(0.8)
Quizalofop	60	1.1(1.0)	1.6(2.3)	4.9(24.0)	5.5(30.0)	0.7(0.0)	1.2(0.9)	2.4(5.1)	2.4(5.0)
Quizalofop	75	0.7(0.0)	0.9(0.3)	4.7(21.3)	5.2(27.0)	0.7(0.0)	0.8(0.1)	2.1(4.1)	2.1(4.0)
Imazethapyr + imazamox	56	2.1(4.0)	2.5(5.7)	2.5(5.7)	3.2(9.7)	1.7(2.4)	1.6(2.2)	1.3(1.2)	1.5(1.7)
Imazethapyr + imazamox	70	1.7(2.3)	1.9(3.0)	1.6(2.7)	2.3(5.0)	1.4(1.5)	1.3(1.1)	1.0(0.6)	1.3(1.3)
Sodium-acifluorfen + clodinafop	196	2.0(3.7)	2.5(5.7)	2.5(5.7)	3.5(12.0)	2.0(3.7)	1.7(2.5)	1.4(1.4)	1.7(2.3)
Sodium-acifluorfen + clodinafop	245	1.8(2.7)	1.9(3.3)	1.9(3.3)	2.8(7.3)	1.4(1.6)	1.3(1.2)	1.1(0.8)	1.4(1.5)
Oxyfluorfen	150	1.5(1.7)	1.7(2.3)	1.8(3.0)	1.9(3.3)	1.2(1.0)	1.1(0.6)	1.0(0.6)	1.1(0.7)
Hand weeding at 25 DAS	-	0.7(0.0)	1.3(1.3)	0.7(0.0)	1.4(1.7)	0.7(0.0)	0.8(0.2)	0.7(0.0)	0.9(0.3)
Control	-	3.3(10.3)	4.0(15.7)	5.0(24.3)	6.1(37.3)	3.1(8.9)	2.5(5.6)	2.6(6.5)	2.5(5.7)
LSD (p=0.05)		0.49	0.57	0.65	0.59	0.37	0.33	0.24	0.24

*Figures in parentheses are original value

Table 6. Weed densities and biomass of grassy, broad-leaved weeds and sedges at 50 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture

Treatment	Dose (g/ha)	Grasses		Broad-leaved		Sedges	
		2017	2018	2017	2018	2017	2018
Weed density (no./m²)							
Imazethapyr	80	3.3(10.3)*	4.4(18.7)	2.5(5.7)	3.8(14.3)	0.9(0.3)	1.2(1.0)
Imazethapyr	100	2.4(5.3)	3.0(9.0)	1.8(2.7)	2.9(8.0)	0.7(0.0)	0.9(0.3)
Quizalofop	60	1.8(3.0)	2.6(6.3)	4.5(19.7)	5.8(32.7)	1.8(2.7)	2.0(3.3)
Quizalofop	75	1.1(0.7)	1.4(1.7)	4.0(15.3)	5.3(27.7)	1.7(2.3)	1.8(2.7)
Imazethapyr + imazamox	56	3.2(9.7)	(3.813.7)	3.2(9.7)	4.1(16.7)	1.2(1.0)	1.3(1.3)
Imazethapyr + imazamox	70	2.4(5.3)	2.8(7.3)	2.3(4.7)	2.7(7.0)	0.9(0.3)	1.1(0.7)
Sodium-acifluorfen + clodinafop	196	3.6(12.7)	3.9(14.7)	3.1(9.3)	4.3(18.3)	1.9(3.0)	1.7(2.3)
Sodium-acifluorfen + clodinafop	245	3.0(8.3)	3.3(10.3)	2.5(5.7)	3.3(10.7)	1.5(1.7)	1.3(1.3)
Oxyfluorfen	150	3.3(10.3)	3.9(14.3)	2.7(6.7)	4.3(17.7)	1.1(0.7)	1.5(1.7)
Hand weeding at 25 DAS	-	0.7(0.0)	2.1(4.0)	0.7(0.0)	2.4(5.3)	0.7(0.0)	1.7(2.3)
Control	-	5.6(31.3)	5.8(32.7)	4.5(19.7)	6.5(41.3)	2.0(3.7)	2.2(4.3)
LSD (p=0.05)		0.50	0.55	0.40	0.48	0.30	0.40
Weed biomass (g/m²)							
Imazethapyr	80	2.7(6.7)	3.2(9.9)	2.5(5.8)	(5.7)	0.9(0.3)	0.9(0.3)
Imazethapyr	100	2.1(4.0)	2.4(5.3)	1.9(3.0)	(3.5)	0.7(0.0)	0.8(0.1)
Quizalofop	60	1.6(2.1)	2.1(4.0)	3.8(14.3)	(10.7)	1.7(2.5)	1.1(0.8)
Quizalofop	75	1.0(0.5)	1.3(1.4)	3.4(11.0)	(8.6)	1.6(2.2)	1.1(0.7)
Imazethapyr + imazamox	56	2.1(4.1)	2.9(7.8)	2.5(6.0)	(5.7)	1.2(0.9)	0.9(0.3)
Imazethapyr + imazamox	70	1.7(2.4)	2.2(4.4)	1.9(3.0)	(3.5)	0.8(0.2)	0.8(0.2)
Sodium-acifluorfen + clodinafop	196	2.7(6.7)	2.8(7.6)	2.7(6.8)	(5.9)	1.8(2.8)	1.0(0.5)
Sodium-acifluorfen + clodinafop	245	2.3(4.7)	2.4(5.4)	2.3(4.8)	(3.7)	1.5(1.8)	0.9(0.4)
Oxyfluorfen	150	2.5(5.6)	2.9(7.7)	2.6(6.1)	(6.0)	1.1(0.8)	1.0(0.4)
Hand weeding at 25 DAS	-	0.7(0.0)	1.6(2.1)	0.7(0.0)	(2.1)	0.7(0.0)	1.1(0.6)
Control	-	4.9(23.4)	4.4(18.6)	4.3(17.9)	(14.2)	1.9(3.2)	1.4(1.4)
LSD (p=0.05)		0.41	0.40	0.32	0.38	0.26	0.14

*Figures in parentheses are original value

2018). Uniform crop residue placement with sufficient thickness (≥4 t/ha) suppresses weeds by blocking light and altering soil microclimate, with possible allelopathic effects. The effectiveness of mulch also depends on residue type and decomposition rate, which can affect soil fertility and weed emergence (Choudhary and Bhagawati 2019).

Effect on weed biomass and weed control efficiency

At both 30 DAS and 50 DAS, hand weeding recorded the lowest weed biomass and highest WCE (95.9–100% and 86–100%, respectively) (**Table 7**). As the crop matured, weed biomass increased, reducing WCE. Under CA, minimal soil disturbance leaves weed seeds near the surface, where they can germinate in favourable conditions, though they are prone to predation. Some seeds exhibit delayed germination or emerge in multiple flushes, especially small-sized seeds that respond rapidly to surface conditions and crop residues (Marble 2015, Choudhary 2016).

Phytotoxicity rating

Oxyfluorfen 150 g/ha showed the highest phytotoxicity (rating 4.7) at 4 DAHA, which diminished completely by the 9th DAHA (**Figure 1**). Sodium-acifluorfen + clodinafop 245 g/ha and 196 g/ha showed moderate phytotoxicity (up to 3.0), and imazethapyr + imazamox 70 g/ha and 56 g/ha showed mild effects (up to 1.5), both resolving by the 7th and 5th DAHA, respectively. Other herbicides were safe for greengram.

Greengram growth and yield attributes

Hand weeding recorded the highest LAI, total biomass and greengram haulm yield and seed yield followed by imazethapyr + imazamox at 70 g/ha (**Table 8**). Yield attributes were also highest in hand-weeded plots. Weed management improved pod number and seeds/pod, depending on herbicide and dose. The hand weeding and selective herbicides like imazethapyr + imazamox improved greengram plant branching, pod formation, haulm yield and seed yield.

Table 7. Total weed biomass and weed control efficiency at 30 and 50 days after seeding (DAS) as influenced by post-emergence herbicides in greengram under conservation agriculture

Treatment	Dose (g/ha)	Total weed biomass (g/m^2)				Weed control efficiency (%)			
		30 DAS		50 DAS		30 DAS		50 DAS	
		2017	2018	2017	2018	2017	2018	2017	2018
Imazethapyr	80	1.9(3.3)*	2.3(4.9)	3.6(12.8)	4.0(15.8)	78.4	56.7	70.9	53.8
Imazethapyr	100	1.5(1.7)	1.8(2.8)	2.7(7.0)	3.1(8.9)	88.6	75.7	84.0	73.9
Quizalofop	60	2.4(5.1)	2.5(5.9)	4.4(18.9)	4.0(15.4)	67.0	47.5	57.2	54.9
Quizalofop	75	2.1(4.1)	2.1(4.1)	3.8(13.7)	3.3(10.6)	73.3	63.9	69.1	69.1
Imazethapyr + imazamox	56	2.0(3.6)	2.1(4.0)	3.4(11.0)	3.8(13.9)	76.4	64.5	75.1	59.4
Imazethapyr + imazamox	70	1.6(2.0)	1.7(2.4)	2.4(5.5)	2.9(8.1)	86.8	78.4	87.5	76.5
Sodium-acifluorfen + clodinafop	196	2.3(5.1)	2.3(4.8)	4.1(16.3)	3.8(14.0)	67.1	58.4	63.1	58.9
Sodium-acifluorfen + clodinafop	245	1.7(2.4)	1.8(2.7)	3.4(11.2)	3.2(9.5)	84.3	76.7	74.5	72.4
Oxyfluorfen	150	1.4(1.6)	1.3(1.3)	3.6(12.4)	3.8(14.2)	89.4	88.5	72.2	58.5
Hand weeding at 25 DAS	-	0.7(0.0)	1.0(0.4)	0.7(0.0)	2.3(4.8)	100.0	95.9	100.0	86.0
Control	-	4.0(15.4)	3.4(11.3)	6.7(44.5)	5.9(34.2)	-	-	-	-
LSD (p=0.05)		0.37	0.25	0.38	0.38				

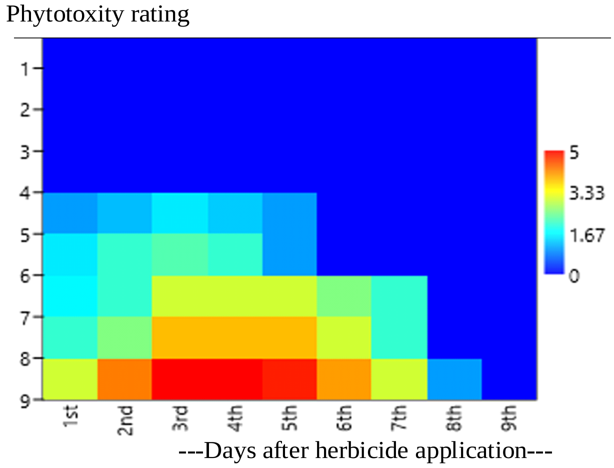
*Figures in parentheses are original value

Table 8. Greengram growth, yield and economics as influenced by post-emergence herbicides under conservation agriculture

Treatment	Dose (g/ha)	Leaf area index		Total plant biomass (g/m^2)		Pods (no./plant)		Seeds (no./pod)		Seed yield (kg/ha)		Haulm yield (kg/ha)		Net returns ($x10^3$ Rs/ha)		B: C	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Imazethapyr	80	3.25	3.16	232.8	225.7	16.9	20.4	10.6	10.8	983	931	1390	1955	26.02	22.85	1.91	1.66
Imazethapyr	100	3.30	3.24	234.2	226.3	19.3	21.7	11.5	11.4	1041	1008	1477	2218	28.52	26.57	2.01	1.81
Quizalofop	60	3.05	3.00	217.1	209.9	14.6	17.9	9.5	9.2	810	787	1267	1972	17.36	15.77	1.47	1.34
Quizalofop	75	3.23	3.16	231.4	222.6	15.8	19.0	10.0	9.8	850	829	1293	2155	18.7	17.20	1.48	1.37
Imazethapyr + imazamox	56	3.39	3.33	240.8	234.9	20.1	23.5	11.7	11.3	1170	1133	1543	2493	34.50	32.80	2.29	2.08
Imazethapyr + imazamox	70	3.41	3.35	242.3	236.3	20.2	23.4	12.0	11.7	1193	1167	1727	2567	35.59	34.12	2.32	2.12
Sodium-acifluorfen + clodinafop	196	3.15	3.08	223.5	216.8	13.9	17.5	9.2	9.4	800	802	1205	1849	16.89	16.31	1.45	1.36
Sodium-acifluorfen + clodinafop	245	3.31	3.25	234.0	228.6	17.2	20.5	11.2	10.9	1007	978	1387	1750	26.16	23.63	1.86	1.66
Oxyfluorfen	150	3.01	2.91	214.0	207.7	13.2	16.3	8.6	8.3	712	698	1193	1174	13.16	10.57	1.29	1.12
Hand weeding at 25 DAS	-	3.49	3.41	247.1	239.2	19.7	24.4	11.9	11.8	1243	1202	1727	2644	33.22	31.23	1.94	1.78
Control	-	2.63	2.56	186.9	180.0	11.0	15.0	8.1	8.1	400	390	1093	988	0.25	-2.36	0.68	0.56
LSD (p=0.05)		0.15	0.16	9.40	8.86	1.73	1.62	0.53	0.46	72.2	70.1	102	141.2	3.24	3.37	0.14	0.14

*Figures in parentheses are original value

Post-emergent herbicide	Dose (g/ha)
Imazethapyr	80
Imazethapyr	100
Quizalofop	60
Quizalofop	75
Imazethapyr + imazamox	56
Imazethapyr + imazamox	70
Sodium-acifluorfen + clodinafop	196
Sodium-acifluorfen + clodinafop	245
Oxyfluorfen	150



The intense colour of the row shows more phytotoxicity ratings, and fading of the colour means getting recoveries.

Figure 1. Phytotoxicity rating as influenced by post-emergence herbicides in greengram under conservation agriculture (mean of two years)

Herbicides like imazethapyr, imazethapyr + imazamox, and acifluorfen + clodinafop effectively suppressed grasses and BLWs, improving yield. Hand weeding eliminated weeds entirely, creating optimal conditions for growth. These findings align with Singh *et al.* (2017) highlighting the importance of early and effective weed control for maximizing yield in greengram. The PoE herbicides provided effective weed control, improving crop yield by enhancing branching and pod formation (**Tables 5–8)**. However, conventional tillage still offers favourable conditions for crop growth (Sangakkara 2004).

Economic return

The highest net returns and B: C were achieved with imazethapyr + imazamox 70 g/ha, followed by its 56 g/ha dose, with no significant difference between them (**Table 8**). Effective weed management led to higher yields, reduced costs, and better economic returns, consistent with findings in RWCS and maize-wheat systems in South Asia (Gathala *et al.* 2013, Nawaz *et al.* 2017).

Conclusion

This study highlighted the potential for enhancing greengram productivity and profitability under CA in the RWCS. Hand weeding achieved the highest seed yield (2.08–2.11 times greater than the un-weeded control) with 86–100% weed control efficiency, but it was not economically viable. In contrast, imazethapyr + imazamox at 70 g/ha offered a sustainable option, providing 76.5–86.8% weed control, nearly doubling yield (1.98–1.99 folds), and achieving a B: C of 2.08–2.53. For long-term success of CA, optimizing crop residue levels and the use of post-emergence herbicide is essential to maximize weed suppression, greengram yield, and farm profitability.

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