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Enhancing productivity and cost-effectiveness of groundnut (*Arachis hypogaea*) through novel herbicide use in Gujarat plains of India

C S PRAHARAJ[1]*, AARADHANA CHILWAL[1], KEVAL HIRAPARA[1], KIRAN REDDY[1] and SHANMUKA ADUPA[1]

ICAR-Indian Institute of Groundnut Research, Junagadh, Gujarat 362 015, India

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ABSTRACT

Appropriate weed management in groundnut (*Arachis hypogaea* L.) with an efficient herbicide plays a crucial role for effective weed control, reducing crop-weed competition and ultimately enhances crop productivity. Therefore, the present study was carried out to evaluate new pre-emergence (PE) and post-emergence (PoE) herbicides in comparison to traditional methods during rainy (*kharif*) season 2022 and spring-summer 2023 at ICAR-Indian Institute of Groundnut Research, Junagadh, Gujarat on groundnut variety 'TG 37A'. The study involved nine treatment combinations, laid out in a randomised complete block design under field conditions. Results indicated that the treatment diclosulam @26 g/ha as PE and fenoxaprop-p-ethyl @78 g/ha as PoE was efficient in terms of efficient weed control and higher yield. This treatment resulted in higher pod yield of 2,682 kg/ha in rainy season 2022 and 3,245 kg/ha in spring-summer 2023 compared to national average yield (2 t/ha), showing an increment of 22.5 and 13.1%, respectively over recommended manual weed control with intercultural operation during the respective seasons. Furthermore, net economic returns, based on selling price of both pod and haulm yields, were also increased tremendously (30.5% during rainy season and 14.7% during spring-summer) with a corresponding surge in benefit-cost ratios (31.2% in the former and 8.74% in latter season) under this treatment compared to manual weed control. Other crop and weed growth attributes (weed control efficiency, weed index, nodulation and NPK uptake by the crop) followed the similar trend as that of the pod yield. The study concluded that groundnut crop can be more remunerative through need-based use of both pre- and post-emergence novel herbicides.

Keywords: Diclosulam, Economics, Fenoxaprop-p-ethyl, Weed control efficiency, Weed index

Groundnut (*Arachis hypogaea* L.) is a globally significant crop, mainly cultivated in the tropics and subtropics since its domestication in Peru around 3,900 BC. Known as both a grain legume and vegetable oil crop, it has high oil (49.24%) and protein (25.80%) content, making it vital for both smallholders and large-scale producers. In India, it is referred to as the 'poor man's almond' (USDA 2017). The crop is grown on 5.76 mha, producing 11.94 mt with a yield of 2,073 kg/ha. Gujarat alone accounts for 34.10% of the country's area and 43.72% of production, with yields of 2,657 kg/ha (DA&FW 2025).

Weed infestation is a major constraint in groundnut cultivation, especially during the first 40 days when the crop grows slowly and forms pods underground, making it highly sensitive to weed competition (Kumar and Rana 2004, Malik *et al.* 2010). Uncontrolled weeds can reduce yields by 30–60% (Everman *et al.* 2008). Manual, mechanical and chemical methods are used for weed control. Hand weeding is effective and has increased yields up to 2.42 times in Tamil Nadu (Meyyappan and Kathiresan 2005), but it is limited by labour shortages and high costs. Mechanical weeders improve efficiency and can cover about 1 ha/day (Tajuddin 2006), though they may damage shallow roots (Lal *et al.* 2016). Due to these challenges, herbicides are becoming a preferred option. They offer timely and broad-spectrum weed control and help address labour scarcity (Amosun and Aduramigba-Modupe 2016). However, identifying safe, effective herbicides remains essential for improving groundnut productivity.

Given the challenges posed by rain, labour shortages and groundnut's underground pods, this study aimed to evaluate new pre-emergence (PE) and post-emergence (PoE) herbicides in comparison to traditional methods. The research focused on weed management, crop productivity, nutrient uptake and profitability. By identifying effective herbicide combinations, the study seeks to provide long-term, environmentally sustainable and economically viable solutions for season-long weed control in groundnut cultivation, benefiting farmers in the country as a whole and Gujarat plains in particular.

[1]ICAR-Indian Institute of Groundnut Research, Junagadh, Gujarat. *Corresponding author email: cspraharaj@hotmail.com

MATERIALS AND METHODS

Site description: The field experiment was carried out at ICAR-Indian Institute of Groundnut Research, Junagadh (21.31°N, 70.36°E; at an elevation of 60 m amsl), Gujarat during rainy (*kharif*) season 2022 and spring-summer 2023. The site is categorised under the Southern Saurashtra Agro-climatic Region of Gujarat and is further classified under Gujarat Plain and Hill Region of India. The climate of this area is semi-arid with an annual average rainfall of about 80–100 cm (mostly during rainy season with very meagre amount received during *rabi*/spring/summer seasons). The soil of experimental site was calcareous medium black clay (*Vertic Stochrept*) with an alkaline soil *p*H of 8.24.

Experimental details and crop management: The experimental design was laid out in a randomised complete block design (RCBD) with four replications and nine treatments. Treatments included T_1, Weedy check; T_2, Hand weeding + interculture; T_3, Diclosulam 26 g/ha as PE *fb* clethodim 180 g/ha as PoE; T_4, Diclosulam 26 g/ha as PE *fb* fenoxaprop-p-ethyl 78 g/ha as PoE; T_5, Oxyflourfen 200 g/ha as PE *fb* clethodim 180 g/ha as PoE; T_6, Oxyflourfen 200 g/ha as PE *fb* fenoxaprop-p-ethyl 78 g/ha as PoE; T_7, Pre-mix pendimethalin + imazethapyr 450 g/ha each as PE; T_8, Oxyflourfen 200 g/ha as PE *fb* quizalofop ethyl 50 g/ha as PoE; and T_9, Weed free. The treatment T_9 was included in spring-summer 2023 trial for precise information on maximum realised yield in absence of weed competition in life cycle. Treatments T_3 to T_8 also included an interculture at around 40 days after emergence (DAE) for aeration.

Variety 'TG 37A', belonging to Spanish Bunch habit group, was planted in both the seasons in a plot size of 30 m^2. In 2022, the experiment was sown during last week of June and harvested during last week of October. While in 2023, experiment was sown during 2nd week of February with pre-sowing irrigation, followed by other good agricultural practices (GAPs) and harvested during 1st week of June. The crop was raised following standard recommended practices. Seed treatment with *Rhizobium* along with IGR 6 or IGR 40 @1.25 kg/ha and PGPR 'NutBoost' @1.25 kg/ha was done by mixing thoroughly with the seed and drying in shade before sowing. A seed rate of 120 kg/ha with spacing of 30 cm × 10 cm was used; FYM @5 t/ha along with 25:50:25 kg NPK/ha was applied [100% nitrogen and phosphorus and 50% potassium as basal and the remaining 50% potassium at 45 days after sowing (DAS)], along with gypsum @500 kg/ha in two splits (50% basal and 50% at 45 DAS). Additionally, foliar spray of multi-micronutrient mixture (Grade IV) @25 g/15 L of water was applied at flowering and pod formation stages. For biological control, *Trichoderma viride* @2.5 kg/ha mixed with 500 kg FYM/ha was applied to the soil.

Pre-emergence herbicides were applied within 48 h of sowing and post-emergence herbicides were applied at 20–25 DAE with knapsack sprayer at the rate 500 L/ha and under normal soil moisture condition. The observations pertaining to growth and yield attributes including those related to weeds and production economics were computed during the study seasons. Correlation analysis was also made to understand the link between the various traits studied for effective weed control in groundnut. The weed control efficiency (WCE) and weed index (WI) for a specific treatment were calculated as under:

$$\text{WCE (\%)} = \frac{\text{Weed population in weedy check plot} - \text{Weed population in treated plot}}{\text{Weed population in control weedy plot}} \times 100$$

$$\text{WI (\%)} = \frac{\text{Yield in weed free plot-Yield in weedy plot}}{\text{Yield in weed free plot}} \times 100$$

Statistical analysis: The data obtained under different treatments with respect to various parameters were subjected to Analysis of Variance (ANOVA) using the general linear model (GLM procedure) of SPSS 16.0 software package (IBM 2016). The means (± standard error of mean) were tested for significant difference by using Tukey's b test. The mean data of both seasons were subjected to square-root transformation $\left(\sqrt{(x+0.5)}\right)$ for species, category-wise weed density and dry weight because of larger variability. The correlation between pod yield and weed parameters was assessed and corresponding graphs were generated using SPSS 16.0 software (IBM 2016). Each attribute was analysed statistically and results were interpreted appropriately based on the significance in terms of value compared to control or others.

RESULTS AND DISCUSSION

Yield parameters: Significant effects of weed control treatments on groundnut yield and yield attributes were evident in both seasons. During the rainy season of 2022, diclosulam 26 g/ha as PE followed by fenoxaprop-p-ethyl 78 g/ha as PoE (T_4) produced the highest pod yield (2,682 kg/ha), haulm yield (4,744 kg/ha), biological yield (7,426 kg/ha) and kernel yield (1,900 kg/ha) (Table 1). The next best treatment was T_6 which recorded pod yield of 2,525 kg/ha and kernel yield of 1,763 kg/ha. The superior performance of these treatments might be attributed to improved weed suppression which enhanced yield attributes such as pods/plant, 100-kernel weight and shelling percentage.

During spring-summer 2023, the highest yields were observed under weed free (T_9) with pod yield, haulm yield, biological yield and kernel yield of 3,375 kg/ha, 4,009 kg/ha, 7,385 kg/ha and 2,671 kg/ha, respectively (Table 2). The T_4 was the next best treatment, showing only a 3.9% reduction in pod yield and 5.0% reduction in kernel yield compared to T_9. In comparison to manual weeding (T_2), T_4 recorded a 13.1% increase in pod yield, demonstrating its higher efficacy. The consistent superiority of T_4 across both seasons highlights its robust performance in reducing weed competition and improving yield traits.

The enhanced shelling percentage, seed index and pods/plant under T_4 can be attributed to reduced crop-weed competition, which facilitated greater synthesis and translocation of metabolites, leading to better pod development (Grey and Prostko 2015). These findings align

Table 1 Yield economics in groundnut under different weed control treatments during rainy season 2022

Treatments	Pod yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Kernal yield (kg/ha)	HI (%)	Net returns (₹/ha)	BCR
T_1	885^{e}	2,788^{b}	3,674^{c}	569^{f}	24.1^{d}	21,503^{e}	0.77^{f}
T_2	2,189^{d}	4,738^{a}	6,926^{b}	1,471^{e}	31.6^{c}	95,617^{d}	2.40^{e}
T_3	2,434^{b}	4,527^{a}	6,961^{b}	1,675^{c}	35.0^{ab}	1,08,094^{c}	2.65^{d}
T_4	2,682^{a}	4,744^{a}	7,426^{a}	1,900^{a}	36.2^{a}	1,24,796^{a}	3.15^{a}
T_5	2,465^{bc}	4,609^{a}	7,074^{b}	1,730^{bc}	34.8^{ab}	1,10,286^{b}	2.70^{d}
T_6	2,525^{b}	4,476^{a}	7,001^{b}	1,763^{b}	36.1^{a}	1,15,153^{b}	2.92^{b}
T_7	2,369^{c}	4,568^{a}	6,936^{b}	1,645^{d}	34.2^{b}	1,07,138^{c}	2.77^{cd}
T_8	2,480^{b}	4,600^{a}	7,080^{b}	1,723^{bcd}	35.0^{ab}	1,12,728^{bc}	2.85^{bc}
Significance	**	***	***	**	***	***	***

*, Significant at p<0.05; **, Significant at p<0.01; ***, Significant at p<0.001; Means within each column under a parameter having different superscript small letters are significantly different. HI, Harvest index; BCR, Benefit:cost ratio.

Treatment details are given under Materials and Methods.

with Singh *et al.* (2001), who reported increased pod yield due to efficient mobilisation of photosynthates. Although manual weeding and intercultural operations (T_2) showed good yield potential, they were inferior to T_4. The positive effects of hand weeding on soil aeration and weed reduction have been reported previously by Singh *et al.* (2009) and Jha and Soni (2013). Diclosulam has been evaluated for its effectiveness in enhancing yields in various crops, particularly groundnut and soybean. In groundnut, a study demonstrated that pre-emergence application of diclosulam at 20 g/ha, combined with hand weeding, significantly reduced weed density and increased pod yield by 48.8% compared to unweeded control (Subramanyam *et al.* 2020). However, another study indicated that diclosulam did not affect yields in eight groundnut cultivars when applied before planting, showing less than 5% visible injury and no impact on disease incidence or yield metrics (Bailey *et al.* 2000). In soybean, diclosulam effectively controlled specific weed species but did not significantly influence overall yield compared to other herbicides (Reddy 2000, Oliviera *et al.* 2002). Additionally, a weeding composition containing diclosulam showed improved herbicidal activity and potential yield enhancement due to its synergistic effects.

Economics of cultivation: Treatment T_4 recorded the highest net returns (₹1,24,796/ha) and benefit-cost ratio (BCR) (3.15) in the rainy season of 2022 (Table 1**)**. The next best treatment was T_6. While, the manual weed control strategy (T_2) was not remunerative due to higher labour costs.

Table 2 Yield and economics in groundnut under different weed control treatments in spring-summer 2023

Treatments	Pod yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Kernal yield (kg/ha)	HI (%)	Net returns (₹/ha)	BCR
T_1	1,102^{f}	1,709^{e}	2,810^{f}	788^{f}	39.2^{e}	31,140^{f}	1.74^{f}
T_2	2,870^{c}	3,685^{b}	6,555^{c}	2,210^{c}	43.8^{bc}	1,40,115^{c}	4.12^{c}
T_3	3,126^{b}	3,797^{b}	6,923^{b}	2,114^{d}	45.1^{ab}	1,51,802^{b}	4.15^{bc}
T_4	3,245^{ab}	3,821^{ab}	7,067^{ab}	2,538^{b}	45.9^{a}	1,60,655^{ab}	4.48^{a}
T_5	2,006^{d}	2,614^{d}	4,621^{e}	1,475^{f}	43.4^{c}	81,501^{e}	2.69^{e}
T_6	2,149^{d}	2,852^{c}	5,001^{d}	1,620^{e}	43.0^{cd}	93,163^{d}	3.02^{d}
T_7	2,830^{c}	3,632^{b}	6,462^{c}	2,169^{c}	43.8^{bc}	1,36,715^{c}	3.99^{c}
T_8	1,810^{e}	2,531^{d}	4,342^{e}	1,307^{g}	41.7^{d}	71,681^{e}	2.54^{e}
T_9	3,375^{a}	4,009^{a}	7,385^{a}	2,671^{a}	45.7^{a}	1,65,939^{a}	4.36^{ab}
Significance	**	***	***	***	***	***	***

*, Significant at p<0.05; **, Significant at p<0.01; ***, Significant at p<0.001; Means within each column under a parameter having different superscript small letters are significantly different. HI, Harvest index; BCR, Benefit:cost ratio.

Treatment details are given under Materials and Methods.

In the spring-summer 2023 season, T_9 resulted in the highest net return (₹1,65,939/ha), followed closely by T_4 (₹1,60,655/ha) and T_3 (₹1,51,802/ha). However, the BCR was highest for T_4 (4.48), followed by T_9, with no significant difference between these two treatments (Table 2). T_4 resulted in 14.66% increase in net return and 8.74% increase in BCR compared to manual weed control (T_2), confirming its economic feasibility.

The weed-free treatment while resulting in the highest yield, was the most-costly due to the extensive labour requirements for weed control, which significantly raised production costs. In contrast, the diclosulam + fenoxaprop treatment (T_4) led to higher economic return and a better BCR due to reduced weeding costs and increased yield. This aligns with findings of Olayinka and Etejere (2015) where the weedy check treatment showed the lowest economic returns due to the adverse impact of uncontrolled weeds on crop growth and yield. The diclosulam + fenoxaprop treatment proved to be a more cost-effective alternative, especially in situations where labour availability is limited and optimisation of production costs is a priority (Rohit and Narayan 2018).

Weed parameters: Weed parameters recorded at different crop growth stages were significantly influenced by weed control treatments in both seasons (Fig. 1). During the rainy season of 2022, T_4 recorded the lowest weed count and weed dry weight at 45, 60 and 90 DAE followed by T_6 (Table 3). WCE under T_4 improved steadily from 63.5% at 45 DAE to 83.8% at 90 DAE. A similar pattern was observed during spring-summer 2023 (Table 4) where the T_9 had the lowest weed density followed by T_4 and T_6. In T_4, WCE increased from 55.5% at 45 DAE to 82.8% at 90 DAE. The WI was lowest in T_4 (3.8%) and T_3 (7.3%), while the highest WI (67.4%) occurred in the T_1 (weedy check).

Combined analysis of the rainy season (2022) and spring-summer season (2023) (Tables 3 and 4) highlights the superior efficacy of diclosulam + fenoxaprop (T_4) in controlling monocot and dicot weeds. Similar variations in weed flora composition under different management practices have been reported by Ravichandran *et al.* (2021), emphasising the importance of selecting herbicides based on prevailing weed communities. In 2022, T_4 recorded the lowest relative monocot density (22.19%) and dicot density (44.76%) at 45 DAS and 24.23% monocots and 44.97% dicots at 90 DAS. In 2023, monocot density was 22.25% and dicot density was 46.25% at 45 DAS, while at 90 DAS, these were 21.74% and 50.71%, respectively. Although sedge control was slightly lower (33.05% in 2022 and 31.50% in 2023), T_4 still outperformed treatments such as T_2 and Oxyflourfen PE fb clethodim PoE. At harvest, T_4 significantly reduced the relative densities of *Echinochloa colonum*, *Dactyloctenium aegyptium*, *Digera arvensis*, *Commelina benghalensis* and *Cyperus rotundus* due to diclosulam's early suppression and fenoxaprop's selective post-emergence grass control.

Diclosulam 26 g/ha PE effectively reduced crop-weed competition due to its broad-spectrum soil and foliar activity (Golubev 2021). Its mode of action, ALS inhibition, prevents the synthesis of branched-chain amino acids, causing stunted weed growth (Adhikary *et al.* 2016). Fenoxaprop-p-ethyl complements this by inhibiting ACCase activity and controlling late-emerging grasses (Anuj *et al.* 2019). The combination treatment (T_4), thus, sustained effective weed suppression throughout the critical period of weed competition in groundnut, typically 4–8 weeks after emergence (Krishnamurthy *et al.* 1981), thereby reducing weed interference and ensuring better crop growth and yield.

Many studies have shown that diclosulam, when applied as pre-emergence can control a wide range of weeds such as common lambsquarters, common ragweed and *Eclipta* with up to 100% efficacy and it effectively manages morning glory species and prickly sida with control rates exceeding 80% (Price and Wilcut 2002). Additionally, diclosulam's efficacy is enhanced when used in combination with other herbicides like metolachlor, providing consistent high yields and net returns in peanut production (Price *et al.* 2002). The herbicide's performance is also notable in greenhouse settings, where it effectively controls *Ipomoea grandifolia* and *Sida rhombifolia*, especially when applied directly to the soil, even at lower doses (Carbonari *et al.* 2008). Overall, diclosulam, particularly when integrated

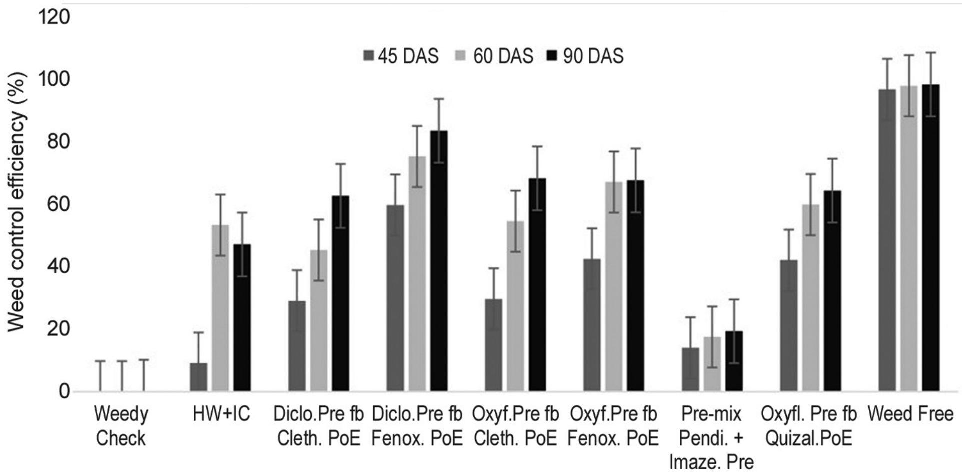

Fig. 1 Weed control efficiency (%) in each herbicide treatment at various crop growth stages (mean of two seasons).
DAS, Days after sowing; Diclo, Diclosulam; Cleth, Clethodim; Oxyfl, Oxyfluorfen; Fenox, Fenoxaprop p-ethyl; Pendi, Pendimethalin; Imaze, Imazethapyr; Quizal, Quizalopfop ethyl; HW, Hand weeding; IC, Interculture; Pre, Pre-energence; PoE, Post emergence.
Error bars represent standard error of mean.

Table 3 Effect on weed attributes under different weed control treatments during rainy season 2022

Treatments	Weed count (No./m^2)			Weed dry wt. (g/m^2)			WCE (%)			Relative density at 45 DAS (%)			Relative density at 60 DAS (%)			Relative density at 90 DAS (%)			Relative density of major weed flora at harvest (%)				
	45 DAE	60 DAE	90 DAE	45 DAE	60 DAE	90 DAE	45 DAE	60 DAE	90 DAE	Mono-cot	Dicot	Sedge	Mono-cot	Dicot	Sedge	Mono-cot	Dicot	Sedge	EC	DE	DA	CB	CR
T_1	10.5^{e} (110.3)	11.3^{e} (126.5)	12.2^{e} (148.5)	8.2^{e} (66.1)	10.6^{g} (112.8)	11.8^{f} (138.9)	-	-	-	23.47	50.20	26.33	26.50	50.64	22.86	35.03	50.44	14.53	12.81	12.08	15.63	14.86	23.44
T_2	8.5^{d} (72.0)	7.6b^{c} (58.0)	8.9^{c} (78.3)	7.5^{d} (56.5)	7.3^{d} (52.1)	8.6^{d} (73.2)	13.8^{f}	53.5^{c}	47.3^{c}	27.27	46.82	25.91	23.95	51.41	24.64	25.75	52.81	21.44	7.96	7.88	12.29	10.96	17.73
T_3	7.7^{e} (58.3)	8.1^{c} (66.0)	7.1^{b} (50.0)	6.5^{c} (41.9)	8.0^{e} (63.6)	7.3^{c} (52.9)	36.6^{d}	43.4^{d}	61.9^{b}	23.25	45.78	30.97	24.74	45.91	29.35	24.78	49.56	25.66	4.69	6.13	12.27	10.74	14.53
T_4	5.4^{a} (29.3)	5.1^{a} (26.0)	4.4^{a} (19.0)	4.9^{a} (24.0)	5.4^{a} (28.4)	4.8^{a} (22.5)	63.5^{a}	74.9^{a}	83.8^{a}	22.19	44.76	33.05	22.43	50.47	27.10	24.23	44.97	30.80	3.91	7.36	12.08	9.61	16.43
T_5	7.3^{bc} (52.3)	7.8^{b} (60.8)	6.7^{b} (44.3)	6.5^{c} (41.2)	7.2^{d} (50.8)	6.8^{bc} (46.4)	37.3^{cd}	54.8^{c}	66.5^{b}	24.74	47.73	27.53	28.39	48.24	23.37	29.47	54.10	16.43	12.01	9.73	14.49	13.50	20.81
T_6	6.9^{b} (47.5)	7.3^{b} (53.0)	6.6^{b} (43.5)	6.0^{b} (35.8)	6.3^{b} (40.1)	6.5^{b} (42.7)	45.9^{b}	64.5^{b}	69.1^{b}	23.86	47.96	28.18	26.43	49.43	24.14	25.00	51.56	23.44	12.75	9.78	14.78	12.51	21.66
T_7	8.7^{d} (74.5)	10.2^{d} (103.8)	11.0^{d} (121.5)	7.3^{d} (52.2)	9.8^{f} (95.0)	10.6^{e} (112.7)	20.5^{e}	15.^{6e}	18.7^{d}	23.66	46.99	29.35	27.78	50.69	21.53	25.77	53.37	20.86	7.98	9.38	14.06	11.11	20.44
T_8	7.0^{b} (48.3)	7.2^{b} (52.0)	6.6^{b} (43.0)	6.2^{b} (37.7)	6.9^{c} (47.3)	7.3^{c} (52.8)	42.7^{bc}	57.8^{c}	62.0^{b}	24.18	47.14	28.68	25.00	55.00	20.00	26.60	55.67	17.73	8.70	9.66	14.16	11.33	20.86
Significance	**	***	***	***	***	***	*	***	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*, Significant at $p<0.05$; **, Significant at $p<0.01$; ***, Significant at $p<0.001$; Means within each column under a parameter having different superscript small letters are significantly different. Figures in parenthesis are original values, while the other values are square root transformed values for comparison. WCE, Weed control efficiency; DAE, Days after emergence, EC, *Echinochloa colonum*; DE, *Dactyloctenium aegyptium*; DA, *Digera arvensis*; CB, *Commelina benghalensis*; CR, *Cyperus rotundus*; DAS, Days after sowing. Treatment details are given under Materials and Methods.

Table 4 Effect on weed attributes under different weed control treatments during spring-summer 2023

Treatments	Weed count (No./m^2)			Weed dry wt. (g/m^2)			WCE (%)			Weed index (%)	Relative density at 45 DAS (%)			Relative density at 60 DAS (%)			Relative density at 90 DAS (%)			Relative density of major weed flora at harvest (%)				
	45 DAE	60 DAE	90 DAE	45 DAE	60 DAE	90 DAE	45 DAE	60 DAE	90 DAE		Mono-cot	Dicot	Sedge	Mono-cot	Dicot	Sedge	Mono-cot	Dicot	Sedge	EC	DE	DA	CB	CR
T_1	8.97^{f} (80.0)	10.07^{i} (101.0)	10.41^{h} (108.0)	7.11^{e} (50.06)	10.07^{h} (101.0)	11.09^{g} (122.63)	-	-	-	67.4^{h}	16.66	56.67	26.67	28.24	59.63	12.13	29.26	57.29	13.45	16.67	12.58	18.85	23.33	23.33
T_2	5.80^{c} (33.3)	5.87^{d} (34.0)	6.21^{d} (38.3)	6.95^{e} (47.76)	6.93^{e} (47.63)	8.10^{e} (65.2)	4.47^{e}	52.89^{e}	46.75^{e}	15.0^{d}	25.28	49.24	25.48	26.32	57.89	15.79	21.15	61.54	17.31	6.81	6.91	15.29	12.57	17.02
T_3	3.80^{b} (12.7)	4.61^{c} (20.7)	4.96^{c} (24.3)	6.31^{d} (39.33)	7.35^{f} (53.5)	6.75^{d} (45.23)	21.45^{d}	47.05^{e}	63.14^{d}	7.3^{c}	22.42	48.14	29.44	26.19	49.05	24.76	25.12	49.88	25.00	6.25	3.85	15.20	11.7	16.56
T_4	3.22^{b} (10.0)	4.06^{b} (16.0)	4.44^{b} (19.3)	4.75^{b} (22.20)	5.03^{b} (25.03)	4.64^{b} (21.13)	55.70^{b}	75.32^{b}	82.82^{b}	3.8^{b}	22.25	46.25	31.50	23.71	49.00	27.29	21.74	50.71	27.55	5.74	4.92	14.58	11.46	15.18
T_5	7.10^{e} (50.0)	7.95^{f} (62.7)	8.08^{g} (64.7)	6.29^{d} (39.16)	6.84^{e} (46.33)	6.13^{c} (37.1)	2195.^{b}	54.09^{e}	69.75^{c}	40.6^{f}	23.62	50.63	25.75	32.77	52.20	15.03	30.37	54.45	15.18	11.4	8.38	16.67	14.75	25.00
T_6	6.78^{de} (45.7)	7.26^{g} (52.3)	7.51^{f} (56.0)	5.58^{c} (30.66)	5.60^{c} (31.0)	6.49^{cd} (41.8)	38.87^{c}	69.40^{c}	65.82^{d}	36.3^{e}	22.47	51.80	25.73	26.67	52.50	20.83	25.41	53.28	21.31	10.6	9.94	17.55	15.38	21.31
T_7	6.28^{cd} (39.0)	6.34^{e} (39.7)	6.80^{e} (45.7)	6.84^{e} (46.33)	9.03^{g} (81.16)	9.93^{f} (98.13)	7.57^{e}	19.36^{f}	19.90^{f}	16.2^{d}	22.73	49.09	28.18	23.81	56.67	19.52	26.75	54.78	18.47	7.64	7.29	15.38	13.83	17.31
T_8	7.25^{e} (52.3)	7.97^{h} (63.0)	8.38^{g} (69.7)	5.46^{c} (29.26)	6.24^{d} (38.40)	6.44^{cd} (41.1)	41.28^{c}	61.68^{d}	66.41^{cd}	46.3^{g}	24.69	49.26	26.05	26.00	55.56	18.44	26.06	56.91	17.03	7.98	7.01	16.39	14.01	18.47
T_9	1.51^{a} (2.0)	1.56^{a} (2.0)	1.49^{a} (1.7)	1.43^{a} (1.66)	1.65^{a} (2.33)	1.68^{a} (2.33)	96.49^{a}	97.69^{a}	98.11^{a}	0.0^{a}	32.26	41.61	26.13	0.00	80.00	20.00	16.67	50.00	33.33	3.85	0	11.26	9.27	13.45
Significance	***	***	***	**	***	***	***	***	**	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*, Significant at $p<0.05$; **, Significant at $p<0.01$; ***, Significant at $p<0.001$; Means within each column under a parameter having different superscript small letters are significantly different. Figures in parenthesis are original values, while the other values are square root transformed values for comparison. WCE, Weed control efficiency; DAE, Days after emergence; EC, *Echinochloa colonum*; DE, *Dactyloctenium aegyptium*; DA, *Digera arvensis*; CB, *Commelina benghalensis*; CR, *Cyperus rotundus*; DAS, Days after sowing. Treatment details are given under Materials and Methods.

Table 5 Nutrient uptake by groundnut under weed control treatments during spring-summer 2022–23

Treatments	Uptake (kernel) (kg/ha)			Uptake (haulm) (kg/ha)			Total uptake (Kernel + haulm) (kg/ha)		
	N	P	K	N	P	K	N	P	K
T_1	16.7[f]	1.61[e]	3.06[i]	21.8[g]	1.73[e]	8.69[f]	38.5[f]	3.35[f]	11.75[g]
T_2	54.4[c]	5.04[c]	10.8[d]	61.1[c]	4.43[c]	21.1[bc]	115.5[c]	9.47[c]	31.92[c]
T_3	61.3[b]	6.35[b]	11.6[c]	67.4[b]	5.47[b]	20.9[bc]	128.7[b]	11.8[b]	32.45[c]
T_4	67.7[ab]	6.04[b]	12.6[b]	69.7[b]	5.26[b]	22.3[b]	137.3[b]	11.3[b]	34.83[b]
T_5	33.4[de]	3.27[d]	5.99[g]	37.9[e]	2.78[d]	13.7[de]	71.3[de]	6.05[d]	19.64[f]
T_6	36.7[d]	3.41[d]	7.07[f]	39.7[e]	3.22[d]	15.0[d]	76.4[d]	6.63[d]	22.07[e]
T_7	51.3[c]	4.97[c]	8.87[e]	57.0[d]	4.55[c]	20.4[c]	108.2[c]	9.52[c]	29.22[d]
T_8	28.0[e]	2.78[d]	5.18[h]	34.9[f]	2.77[d]	12.9[e]	62.9[e]	5.56[e]	18.04[f]
T_9	72.6[a]	7.41[a]	14.4[a]	75.4[a]	6.21[a]	24.2[a]	148.0[a]	13.6[a]	38.56[a]

*, Significant at $p<0.05$; **, Significant at $p<0.01$; ***, Significant at $p<0.001$; Means within each column under a parameter having different superscript small letters are significantly different. N, Nitrogen; P, Phosphorus; K, Potassium.

Treatment details are given under Materials and Methods.

with other herbicides, offers a robust solution for weed management, contributing to enhanced crop yields (Bailey and Wilcut 2002).

Nutrient (NPK) uptake: An appraisal of data (Table 5) indicated that total uptake of NPK, contributed by total uptake in kernel and haulm, were significantly influenced by different weed management treatments in spring-summer 2023. Significantly higher total uptake of NPK (148.0, 13.6 and 38.56 kg/ha) were analysed under the weed free check (T_9) respectively, followed by T_4 and T_3. In contrast, the lowest total uptake of NPK (38.46, 3.35 and 11.75 kg/ha) was noticed under the higher crop-weed competition plots i.e. T_1.

Diclosulam along with fenoxaprop-p-ethyl is an effective herbicide combination that enhances nutrient uptake in crops by controlling weeds, thereby improving overall plant health and yield. This weed suppression allows crops like groundnut and fenugreek to access nutrients

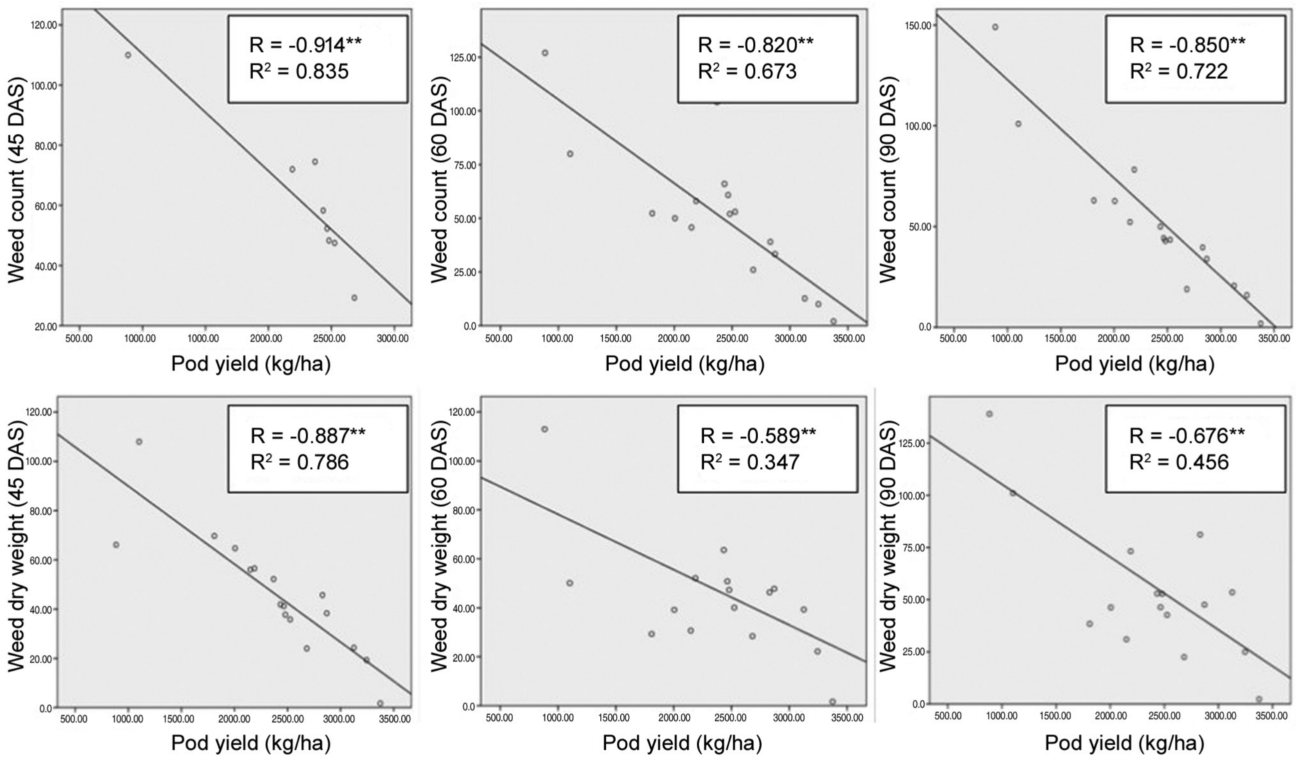

Fig. 2 Correlation of pod yield (kg/ha) with weed count and weed dry weight at different crop growth stages.
**, $p< 0.01$; *, $p< 0.05$; DAS, Days after sowing; R, Pearson correlation coefficient; R^2, Coefficient of determination.

more efficiently, leading to increased yields and better economic returns (Ravichandran *et al.* 2021, Meena *et al.* 2025). Additionally, diclosulam's efficacy is consistent across different soil types, making it a versatile option for weed management (Silva *et al.* 2025). The strategic use of diclosulam can significantly enhance nutrient uptake by reducing weed competition.

Correlation studies: Based on two seasons data, strong negative correlation existed between pod yield and weed parameters (weed count and weed dry weight) at different stages of crop growth, including the critical period of 45 to 60 DAE and physiological maturity at 90 DAE (Fig. 2). The highest (negative) value of correlation coefficient between pod yield with weed count (-0.914) and weed dry weight (-0.887) was observed to be at 45 DAE. It depicts that the most critical stage of crop-weed competition is up to 45 DAE in this Spanish Bunch groundnut cultivar 'TG 37 A' (maturing at about 100–110 days from seed to seed) under Indian subtropical condition. Therefore, efficient weed control during this stage could lead to maximum yield benefits.

The study conclusively demonstrated that the treatment involving 'diclosulam 26 g/ha as PE followed by fenoxaprop-p-ethyl 78 g/ha as PoE' proved to be the most effective, resulting in an average increase of 18% in pod yield and 23.5% in profitability in groundnut cultivation over two seasons of study through controlling total weed flora (grasses, sedges and broadleaved weeds) compared to manual weed control *fb* interculture. These findings highlight the potential of these herbicide treatments to enhance groundnut productivity and economic benefits in the Gujarat plains of India, thereby offering valuable insights for groundnut farmers seeking efficient and cost-effective weed management practices. Future weed control management strategy may be formulated considering factors like weed flora dynamics, total/selective weed control and crop rotation in agriculture production systems.

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