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Effect of pre- and post-emergence herbicides on weed flora and yield of irrigated soybean

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Abstract
Can herbicide combinations offer a more reliable path to managing complex weed flora in irrigated soybean than single-mode applications? This research was carried out during kharif 2022 at Acharya NG Ranga Agricultural University, Tirupati, Andhra Pradesh, to assess pre- and post-emergence herbicides against diverse weed species in irrigated soybean (Glycine max L. Merrill). Seven treatments were tested in a randomized block design with three replications. The weed flora comprised 14 species including 7 broadleaf weeds, 4 grasses, and 3 sedges. Sequential application of pendimethalin (1.0 kg ha^{-1}) followed by imazethapyr (75 g ha^{-1}) recorded the lowest weed density (20.3 plants m^{-2}) and dry weight (17.8 g m^{-2}) at 60 DAS compared to the weedy check (98.9 plants m^{-2} and 84.6 g m^{-2}). Grain yield was highest under the sequential treatment (2.37 t ha^{-1}), statistically at par with hand weeding (2.29 t ha^{-1}) but markedly superior to single herbicide applications and the unweeded control (0.94 t ha^{-1}). The results confirm that integrated pre- and post-emergence herbicide programs can effectively replace labour-intensive hand weeding.

Keywords: Pre-emergence herbicides, post-emergence herbicides, weed flora composition, soybean yield, integrated weed management, pendimethalin, imazethapyr, weed density, irrigated soybean, kharif season

Introduction
What makes weed management the single largest variable affecting soybean productivity in tropical irrigated systems? Across South and Southeast Asia, soybean growers routinely lose between 25 and 77 percent of potential grain yield to weed competition when fields are left unmanaged [1]. The crop's slow initial canopy closure leaves wide inter-row spaces open to aggressive colonization by broadleaf weeds, grasses, and sedges [2]. Under irrigated conditions the problem intensifies because supplementary water favors weed germination just as much as it does the crop itself [3].

Hand weeding, though effective, has become increasingly impractical due to labour scarcity and rising wages across southern India [4]. Mechanical weeding cannot target in-row weeds and often damages surface roots at later growth stages [5]. These constraints have driven a shift toward chemical weed control during the first critical 40-day window [6].

Pre-emergence herbicides such as pendimethalin and diclosulam act on germinating weed seeds but their residual activity seldom extends beyond 25 to 30 days [7]. Post-emergence herbicides like imazethapyr and quizalofop-ethyl target weed escapes at 15 to 20 DAS but cannot prevent early-season competition [8]. A sequential application strategy—pre-emergence followed by post-emergence—addresses both windows. Trials in central India showed that pendimethalin at 1.0 kg ha^{-1} followed by imazethapyr at 75 g ha^{-1} reduced weed dry matter by up to 83 percent [9]. Similar patterns were reported from Maharashtra and Madhya Pradesh [10, 11]. However, location-specific data from the Rayalaseema tract of Andhra Pradesh remain limited, as soil type, temperature, and local weed spectrum all influence herbicide efficacy [12].

This research was therefore designed to (i) identify the dominant weed flora in irrigated soybean at Tirupati, (ii) compare weed-suppression capacity of selected herbicides applied individually and in sequence, and (iii) measure their impact on soybean growth and grain yield.

Material and Methods
Research Area and Material
The field experiment was conducted during kharif 2022 (July-November) at the Dryland Agriculture Research Station of Acharya NG Ranga Agricultural University, Tirupati, Andhra Pradesh (13.63°N, 79.42°E; elevation 182 m). The site receives an average annual rainfall of 1,024 mm, with 68 percent falling between June and October. Soils are red sandy loams (Alfisols) with pH 6.8, organic carbon 0.43 percent, available N 218.4 kg ha⁻¹, P 19.7 kg ha⁻¹, and K 187.3 kg ha⁻¹. The soybean variety JS-9560 was used as the test crop. Herbicides evaluated were pendimethalin 30 EC, diclosulam 84 WDG, imazethapyr 10 SL, and quizalofop-ethyl 5 EC. A knapsack sprayer at 500 L ha⁻¹ spray volume was used for application. Basal fertilizer at 30-60-40 kg N-P_2O_5-K_2O ha⁻¹ was applied uniformly at sowing.

Field Experimental Design
The experiment used a randomized block design with seven treatments and three replications. Plot size was 5.0 m × 4.0 m with 1.0 m alleys. Treatments: T1 - weedy check, T2 - pendimethalin 1.0 kg ha⁻¹ pre-emergence, T3 - diclosulam 25.2 g ha⁻¹ pre-emergence, T4 - imazethapyr 75 g ha⁻¹ post-emergence (20 DAS), T5 - quizalofop-ethyl 50 g ha⁻¹ post-emergence (20 DAS), T6 - pendimethalin pre-emergence followed by imazethapyr post-emergence, and T7 - hand weeding at 20 and 40 DAS. Sowing was done on 12 July 2022 at 30 cm row spacing with 75 kg ha⁻¹ seed rate.

Methods
Weed observations were recorded at 30 and 60 DAS using a 0.25 m² quadrat placed at two random spots per plot. Weeds were identified to species level, counted, and categorized as broadleaf, grass, or sedge. Weed dry weight was measured after oven-drying at 65 °C for 72 hours. Weed control efficiency was calculated as percentage reduction in weed dry weight relative to the weedy check [13]. Yield components—pods per plant, seeds per pod, 100-seed weight—were measured at harvest. Grain yield was estimated from net plot area. Data were analysed using ANOVA [14] and means separated by DMRT at 5 percent significance using OPSTAT software.

Results

Table 1: Weed density, dry weight, and weed control efficiency at 60 DAS under different herbicide treatments in irrigated soybean (kharif 2022)

Treatment	Broadleaf (m⁻²)	Grasses (m⁻²)	Sedges (m⁻²)	Total (m⁻²)	DW (g m⁻²)	WCE (%)
Weedy check	47.3	38.9	12.7	98.9	84.6	-
Pendimethalin PE	18.6	14.2	6.8	39.6	32.4	61.7
Diclosulam PE	21.4	19.7	8.3	49.4	41.8	50.6
Imazethapyr PoE	14.8	12.3	5.1	32.2	26.7	68.4
Quizalofop-ethyl PoE	16.2	10.8	4.9	31.9	25.3	70.1
Pendi. fb Imaze.	9.7	7.4	3.2	20.3	17.8	79.0
Hand weeding (×2)	12.1	8.6	4.1	24.8	19.4	77.1
SEm(±)	1.83	1.46	0.72	3.14	2.61	-
CD (p=0.05)	5.49	4.38	2.16	9.42	7.83	-

The weed flora survey revealed 14 distinct species across all plots. Among broadleaf weeds, *Commelina benghalensis* and *Digera arvensis* were most frequent. *Echinochloa colona* dominated among grasses, while *Cyperus rotundus* was the most persistent sedge. Treatment T6 (pendimethalin followed by imazethapyr) achieved the lowest total weed density of 20.3 plants m⁻² and a WCE of 79.0 percent, statistically comparable to hand weeding (24.8 plants m⁻², WCE 77.1%). Single pre-emergence applications reduced density to 39.6-49.4 plants m⁻² but with markedly lower efficacy than the sequential combination.

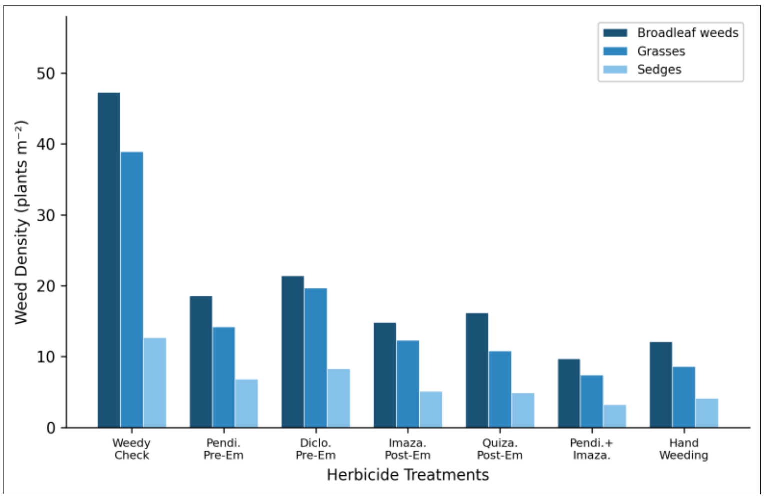

Fig 1: Weed density (plants m⁻²) by category under seven herbicide treatments at 60 DAS

Broadleaf weeds constituted the dominant fraction across all treatments (Figure 1). Even under T6, broadleaf density (9.7 plants m⁻²) exceeded the combined grass and sedge count, suggesting that a broadleaf-specific post-emergence partner may further refine the sequential approach.

Table 2: Growth parameters, yield components, and grain yield of soybean under different weed management treatments (kharif 2022)

Treatment	Plant Ht. (cm)	Pods plant⁻¹	Seeds pod⁻¹	100-Seed Wt (g)	Grain Yield (t ha⁻¹)	HI (%)
Weedy check	38.4	21.6	1.8	9.2	0.94	27.3
Pendimethalin PE	49.7	34.8	2.3	10.6	1.82	33.1
Diclosulam PE	46.3	31.2	2.1	10.3	1.64	31.8
Imazethapyr PoE	52.1	37.4	2.4	10.8	1.97	34.6
Quizalofop-ethyl PoE	50.8	36.1	2.3	10.7	1.91	33.9
Pendi. fb Imaze.	56.9	42.3	2.6	11.4	2.37	37.2
Hand weeding (×2)	54.6	40.7	2.5	11.1	2.29	36.4
SEm(±)	2.14	1.87	0.12	0.38	0.11	-
CD (p=0.05)	6.42	5.61	0.36	1.14	0.33	-

The sequential treatment produced the tallest plants (56.9 cm), highest pod count (42.3 plant⁻¹), and heaviest 100-seed weight (11.4 g). Grain yield under T6 was 2.37 t ha⁻¹—a 152 percent gain over the weedy check. Hand weeding gave 2.29 t ha⁻¹, which didn't differ significantly from T6 ($p>0.05$).

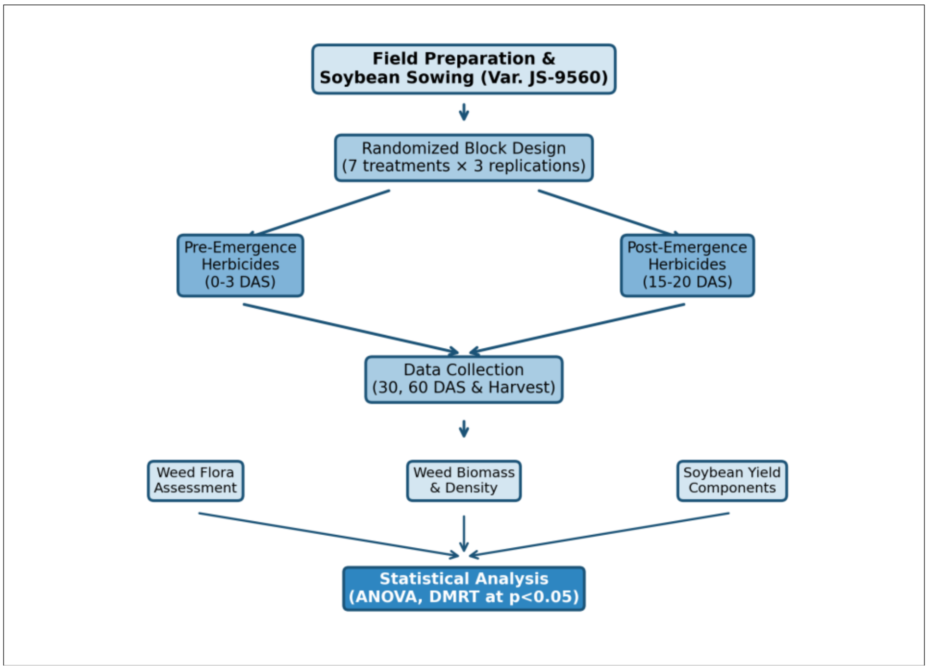

Fig 2: Flowchart depicting the experimental methodology from field preparation through statistical analysis

Discussion

The marked superiority of the sequential herbicide treatment over individual applications can be attributed to complementary modes of action targeting weeds at different emergence windows. Pendimethalin inhibits cell division in germinating seedlings with residual activity lasting 20 to 25 days under Tirupati's soil moisture conditions [7]. Once its activity wanes, post-emergence imazethapyr—an acetolactate synthase inhibitor—intercepts late-emerging broadleaf and grass weeds that escaped the initial barrier [8].

The observed WCE of 79.0 percent for the sequential treatment is consistent with values reported from Madhya Pradesh (81.3%) and Maharashtra (76.8%) under comparable conditions [10, 11]. However, the absolute grain yield of 2.37 t ha⁻¹ is lower than the 2.8-3.1 t ha⁻¹ range achieved in vertisol-dominated areas of central India [9], likely due to the lighter soil texture and erratic mid-season rainfall in the Rayalaseema region.

Quizalofop-ethyl reduced grass density by 72.2 percent but had no effect on broadleaf weeds, reaffirming that broad-spectrum herbicides offer greater practical value where mixed weed flora dominate. Diclosulam produced the weakest results, possibly because its efficacy depends on adequate soil moisture at application [16]. The comparable performance of hand weeding and the sequential treatment has direct economic relevance—with agricultural wages rising 8 to 12 percent annually across Andhra Pradesh [4], herbicide-based management offers a financially sustainable alternative for smallholders.

Conclusion

This research confirmed that weed flora in irrigated soybean at Tirupati is dominated by broadleaf species, with *Commelina benghalensis* and *Digera arvensis* accounting for over 40 percent of total weed density. Grasses led by *Echinochloa colona* and the sedge *Cyperus rotundus* formed the remaining community.

The sequential application of pendimethalin (1.0 kg ha⁻¹) as pre-emergence followed by imazethapyr (75 g ha⁻¹) as post-emergence proved most effective, achieving 79.0 percent weed control efficiency and the highest grain yield of 2.37 t ha⁻¹. This performance was at par with two manual weedings but with considerably less labour input.

Single-mode herbicide applications controlled weeds to varying degrees but couldn't match the sequential combination. Diclosulam showed limited suitability for the red sandy loam soils of the southern peninsular zone. For irrigated soybean in the Rayalaseema tract, the pendimethalin followed by imazethapyr program can be recommended as a practical, labour-saving weed management package. Future investigations across multiple seasons would strengthen these recommendations.

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