



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 260-263
Received: 11-10-2025
Accepted: 13-11-2025

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Herbicide efficacy on weed management, yield and profitability of soybean (*Glycine max* L.) under Himalayan conditions

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i12d.4373>

Abstract

A field experiment was conducted during the *kharif* - 2023 at the Agronomy Research Farm, CSK HPKV Palampur to evaluate the efficacy of various herbicides on weed control, productivity, and profitability of soybean. The experiment conducted using a Randomised Block Design with ten treatments, each replicated thrice. The findings revealed that in untreated plots, the weed flora comprised of 66.13% grasses, 13.44% sedges, and 20.43% broad-leaved weeds. Among the treatments, pre-emergence application of sulfentrazone + clomazone at 725 g/ha recorded the lowest weed count and dry weight, followed by pendimethalin + imazethapyr at 800 g/ha which yielded 1430.00 and 1385.33 kg / ha respectively. However, hand-weeding treatment resulted in higher grain yields 1529.67 kg/ha but less return per rupees invested as compared to best herbicide treatments. Hence, the pre-emergence application of sulfentrazone + clomazone was effective in enhancing weed control and economic returns in soybean cultivation under mid-hill conditions.

Keywords: Profitability, productivity, herbicide, soybean, weeds

1. Introduction

Soybean (*Glycine max*) often referred to as the Golden Bean or Miracle Crop is a important oilseed crop known for its high protein content and wide range of applications in food, oil, biofuel and various industrial products (Gandhi, 2009) ^[11]. During 2022-23, global soybean production was 391.17 million tonnes with total area of 135.5 million hectares (Anonymous, 2023a) ^[2]. India ranks fourth in area under cultivation with 13.00 million ha and fifth in production with 13.05 million tonnes. In Himachal Pradesh, soybean is cultivated over 520 hectares with a total production of 410 tonnes and productivity of 799 kg/ha (Anonymous, 2023b) ^[3]. Despite the expansion in cultivation area and total production, the crop continues to face challenges in terms of productivity. One of the major constraints is the infestation of weeds, which compete with the crop for essential resources such as nutrients, moisture, light and space, resulting in yield losses ranging from 20-77% depending on the type of soil, season and weed density (Ahmad *et al.*, 2020; Tehulie *et al.*, 2021; Khan *et al.*, 2021) ^[1, 21, 17]. In addition, weeds interfere with farm operations, serve as hosts for pests and diseases, and lead to contamination of harvested produce. Nutrient depletion due to unchecked weed growth may amount to 33.53 kg N, 15.78 kg P₂O₅, and 72.19 kg K₂O per hectare (Gaikwad and Pawar, 2003) ^[10]. To mitigate such losses due to weeds and enhance crop productivity, the adoption of a cost-effective and sustainable weed management strategy is imperative. Integrated Weed Management (IWM), which incorporates cultural, mechanical and chemical control measures, has gained importance as a viable approach (Chandraker and Paikra, 2015) ^[6]. However, manual weeding remains effective because it is labour-intensive and economically less viable. The judicious use of pre- and post-emergence herbicides in combination with conventional practices has been shown to improve weed control efficiency, reduce biomass, and enhance yields (Chen *et al.*, 2024). Herbicides such as pendimethalin, metribuzin and imazethapyr are currently recommended due to their broad-spectrum efficacy (Bermaiya *et al.*, 2023) ^[5]. Therefore, the

present study was undertaken to evaluate the effectiveness of different herbicide combinations for weed management in soybean.

2. Materials and Methods

2.1 Experimental site and weather

A field experiment was conducted at the Research Farm of the Department of Agronomy, College of Agriculture, CSKHPKV, Palampur, during the *kharif* season of 2023. The Research Farm situated in North-West Himalaya at 32° 6' N latitude, 76° 3' E longitude and an elevation of 1290.8 AMSL. The soil texture was silty clay loam and acidic in nature (pH 5.6) with an EC of 0.10 dS/m. The soil was high in organic carbon content (0.65%), with low nitrogen (278.6 kg/ha), medium phosphorus (24.6 kg/ha) and potassium (236.5 kg/ha) availability. The region receives an annual rainfall of 2000-2500 mm where 80% of precipitation occurs during the monsoon season i.e., June to September. Temperature varies between 16.4 to 20.9 °C from March to April and 27 to 30 °C from May to June. The relative humidity in the region ranges between 46 to 84%.

2.2 Experiment and treatment details

The experiment was laid out in a randomized complete block design with three replications. The soybean variety 'Harit Soya' was sown with 45 x 10 cm crop planting geometry in a plot size of 8.10 m x 2.30 m with a seed rate of 75 kg/ha on June 21, 2023. The experiment consisted of ten treatments, out of which the first four treatments were applied as pre-emergence, i.e. diclosulam, pendimethalin + imazethapyr, sulfentrazone + clomazone and diclosulam + Pendimethalin; the next four treatments were applied as post-emergence i.e. fluazifop-p-butyl + fomesafen, bentazone, sodium acifluorfen + clodinafop propargyl and imazethapyr + propaquizafop, alongside two hand weeding at 20 and 40 DAS treatments and a weedy check. The crop was grown totally under rainfed conditions. Thinning and gap filling were done manually to maintain an optimum plant population. A recommended dose of fertilizer 20:60:20 (NPK/ha) was applied as a basal application through urea, single super phosphate (SSP) and murate of potash (MOP) as per the package of practices of the crop for the area. All the pre-emergence herbicides were applied the next day after the sowing and post-emergence herbicides were applied 20 DAS using a knapsack sprayer fitted with a flat fan nozzle, utilizing a spray volume of 750 litres per hectare.

2.3 Observations

Data on weed count and dry weight data were collected from two randomly selected spots using a 0.25 m x 0.25 m quadrat at 60 days after sowing (DAS) and were expressed as number/m² and g/m², respectively. The sampled weeds were then categorized into grasses, sedges and broad-leaved. Category-wise weed density was determined by counting and then weed dry weight was measured by sun drying for two days, followed by oven drying at 70 °C for 48 hours. Due to wide variability in weed count and dry weight data, square root transformation ($\sqrt{x+1}$) was applied for statistical analysis (Gomez and Gomez, 1984)^[12]. Weed control efficiency (WCE) was also estimated at 60 DAS by using the formula suggested by Bajjiya *et al.* 2025^[4].

$$\text{Weed control efficiency (\%)} = \frac{\text{Dry weight of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in control plot}} \times 100$$

Weed control efficiency was calculated on a dry matter basis

and grain yield recorded in kg per plot was standardized to 12-14% moisture and then weight was converted into kg/ha. Net return was obtained for each treatment by subtracting the cost of cultivation from gross return and was expressed as ₹/ha and net return per rupee invested was calculated by dividing net returns obtained by individual treatment by the cost of cultivation.

3. Results and Discussion

3.1 Weed count and weed control efficiency

The weed flora in the experimental field comprised of grasses, sedges and broad-leaved weeds among which grasses were predominant including *Polygonum* spp., *Echinochloa colona*, *Digitaria sanguinalis* and *Panicum dichotomiflorum*. In sedge, *Cyperus difformis* was predominate and *Bidens Pilosa*, *Commelina benghalensis* and *Ageratum conyzoides* were the most prevalent broad-leaved weeds. Similar findings were also reported by Meena *et al.* (2020)^[19].

Herbicide application treatments significantly reduced weed count and dry weight with higher weed control efficiency (WCE) at 60 DAS as compared to the weedy check (Table 1). Pre-emergence application of sulfentrazone + clomazone at 725 g/ha recorded significantly lower count and dry weight with corresponding WCE values of 96.14% for grasses, 92.19% for sedges and 97.77% for broadleaved weeds over the rest of the herbicide treatments. This treatment remained statistically at par with pendimethalin + imazethapyr at 800 g/ha, which showed WCE of 92.36, 91.13 and 91.49 for grasses, sedge and broad-leaved weeds, respectively and handweeding twice, which recorded the highest WCE of 96.84, 96.90 and 100% for the respective weed categories. Imazethapyr + propaquizafop at 125 g/ha also exhibited effective control, with WCE values of 88.90% (grasses), 84.49% (sedges) and 89.55% (broad-leaved). Conversely, the least effective treatments included diclosulam and fluazifop-p-butyl + fomesafen, which exhibited comparatively lower weed suppression and WCE values. The weedy check recorded the significantly highest weed count and dry weight, confirming the necessity of timely and effective weed control measures. These findings are closely consistent with those of Deshmukh *et al.* (2014a)^[8] and Wanjari *et al.* (2022)^[22] reported superior weed control and crop yield with pre-emergence application of sulfentrazone + clomazone and pendimethalin + imazethapyr in soybean. Similar trends were also observed by Das *et al.* (2021)^[7] reported that hand weeding twice remains one of the most effective methods for managing broad-spectrum weed flora with near-complete control (100%) of broad-leaved species.

3.2 Yield and profitability

The data revealed that the seed yield of soybean was significantly influenced by different herbicide treatments and all the treatments were significantly superior to the weedy check. Among herbicide treatments, pre-emergence application of sulfentrazone + clomazone at 725 g/ha recorded significantly higher grain yield of 1430 kg/ha which was statistically at par with pendimethalin + imazethapyr at 800 g/ha (1385.33 kg/ha). In contrast, the lowest seed yield among herbicide treatments was observed with diclosulam at 26 g/ha (900.33 kg/ha), while weedy check recorded the minimum seed yield (835.00 kg/ha). Hand weeding recorded higher yield of soybean surpassing the all herbicide treatments. The superior performance of the hand weeding treatment could be attributed to effective removal of weed competition, thereby improving crop access to light, nutrients, moisture, and space, which led to better expression of yield attributes. These findings are in conformity with Gulaiya *et*

al. (2023)^[13], Manjunath and Hosmath (2016)^[18] and Kamble *et al.* (2017)^[16]. The percent increase in seed yield over the weedy check is 83.40% with hand weeding and 71.21% with application of sulfentrazone + clomazone at 725 g/ha. This yield enhancement may be ascribed to effective weed suppression, which resulted in improved nutrient uptake, greater leaf area development, enhanced photosynthetic activity, and better translocation of assimilates from source to sink. Similar beneficial effects of herbicide-based weed control on soybean productivity have been reported by Jha *et al.* (2014)^[14] and Kadam *et al.* (2018)^[15].

3.3 Economics

From an economic perspective, all herbicide treatments and manual weeding were superior to the weedy check. The highest net return (₹86,170 /ha) was obtained with the pre-emergence

application of sulfentrazone + clomazone at 725 g/ha, followed by hand weeding twice (₹85,540/ha), pendimethalin + imazethapyr at 800 g/ha (₹83,150 /ha), and imazethapyr + propaquizafop at 125 g/ha (₹77,065 /ha). The lowest net return (₹37,020 /ha) was recorded under the weedy check. In terms of profitability, sulfentrazone + clomazone showed the highest benefit-cost ratio (2.03), followed by pendimethalin + imazethapyr (2.00) and imazethapyr + propaquizafop (1.85). Although hand weeding twice resulted in higher gross and net returns, its net return per rupee invested (1.64) was comparatively lower due to higher labour costs. These results underscore the economic viability and cost-effectiveness of herbicide-based weed management strategies over manual weeding in soybean cultivation, and are in agreement with the findings of Deshmukh *et al.* (2014b)^[9].

Table 1: Effect of different herbicide treatments on weed count and dry weight at 60 DAS in soybean

Sr. No.	Treatment	Dose (g/ha)	Weed count (No./m ²)			Weed dry weight (g/m ²)			WCE (%)		
			Grasses	Sedges	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges	Broad-leaved
T ₁	Diclosulam	26	9.78 (94.67)	4.28 (17.33)	5.96 (34.67)	4.20 (16.64)	2.07 (3.31)	3.22 (9.39)	45.17	51.11	34.56
T ₂	Pendimethalin + imazethapyr (RM)	800	3.78 (13.33)	1.82 (2.67)	1.67 (2.67)	1.81 (2.29)	1.23 (0.53)	1.20 (0.53)	92.45	92.17	96.31
T ₃	Sulfentrazone + clomazone (RM)	725	3.37 (10.67)	1.67 (2.67)	1.41 (1.33)	1.46 (1.17)	1.19 (0.48)	1.13 (0.32)	96.14	92.91	97.77
T ₄	Diclosulam + pendimethalin (TM)	25.2+750	7.00 (48.00)	3.20 (9.33)	3.95 (14.67)	2.89 (7.41)	1.66 (1.76)	2.45 (5.01)	75.58	74.00	65.09
T ₅	Fluazifop-p-butyl + Fomesafen (RM)	250	9.07 (81.33)	3.93 (14.67)	5.36 (28.00)	3.83 (13.81)	1.92 (2.72)	2.99 (7.95)	54.50	59.82	44.60
T ₆	Bentazone	960	8.05 (64.00)	3.78 (13.33)	4.42 (18.67)	3.36 (10.29)	1.81 (2.29)	2.65 (6.03)	66.10	66.17	57.98
T ₇	Sodium acifluorfen + clodinafop propargyl (RM)	245	7.55 (56.00)	3.37 (10.67)	4.24 (17.33)	3.11 (8.69)	1.73 (2.03)	2.49 (5.23)	71.37	70.01	63.55
T ₈	Imazethapyr + propaquizafop (RM)	125	4.72 (21.33)	2.24 (4.00)	2.54 (6.67)	2.28 (4.21)	1.32 (0.75)	1.80 (2.56)	86.13	88.92	82.16
T ₉	2 HW at 20 & 40 DAS	-	2.71 (8.00)	1.41 (1.33)	1.00 (0.00)	1.37 (0.96)	1.09 (0.21)	1.00 (0.00)	96.84	96.90	100.00
T ₁₀	Weedy check	-	12.83 (164.00)	5.86 (33.33)	7.18 (50.67)	5.60 (30.35)	2.79 (6.77)	3.92 (14.35)	0.00	0.00	0.00
	SE(m±)		0.28	0.20	0.26	0.10	0.06	0.14	-	-	-
	CD (P=0.05)		0.84	0.59	0.76	0.29	0.16	0.40	-	-	-

Table 2: Effect of different herbicide treatments on grain yield and economics of soybean

Particulars	Dose	Seed yield (kg/ha)	Net returns	Net return per rupee invested
Diclosulam	26 g/ha	900.33	40600	1.00
Pendimethalin + imazethapyr (RM)	800 g/ha	1385.33	83150	2.00
Sulfentrazone + clomazone (RM)	725 g/ha	1430.00	86170	2.03
Diclosulam + pendimethalin (TM)	25.2+750g/ha	1200.00	66365	1.59
Fluazifop-p-butyl + fomesafen (RM)	250 g/ha	968.67	46303	1.13
Bentazone	960 g/ha	1035.33	52240	1.28
Sodium acifluorfen + clodinafop propargyl (RM)	245 g/ha	1104.33	58760	1.45
Imazethapyr + propaquizafop (RM)	125 g/ha	1318.00	77065	1.85
2HW at 20 and 40 DAS	-	1529.67	85540	1.64
Weedy check	-	835.00	37020	0.97

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