Indian Journal of Agronomy **70** (4): 489–493 (December 2025)
DOI: 10.59797/ija.v70.i4.5675

Research Communication

Optimizing post-emergence herbicide rates for enhanced growth, symbiotic efficiency and weed management in soybean (*Glycine max*)

PARVEEN KUMAR[1], HARPREET KAUR VIRK[2], MANPREET SINGH[3] AND SIMRANPREET SINGH BOLA[4]

Punjab Agricultural University, Ludhiana, Punjab 141 004

Received: December 2024; Revised accepted: November 2025

ABSTRACT

The field experiment was carried out at Punjab Agricultural University, Ludhiana and Dr. J.C. Bakhshi Regional Research Station, Abohar, Punjab, India, during *kharif* (rainy season) 2021, in a randomized complete block design with 12 treatments [imazethapyr 75 g/ha, propaquizafop + imazethapyr at 75, 100, and 125 g/ha, clodinafop propargyl + sodium acifluorfen at 147, 196, and 245 g/ha, imazamox + imazethapyr at 42, 56 and 70 g/ha, two hand weedings (HW) at 20 and 40 DAS and weedy check] with three replications. Results revealed that 2-hand weedings (HW) significantly increased number & dry weight of nodules and leghaemoglobin content compared to the weedy check. Among post-emergence herbicides, imazamox + imazethapyr (70 g/ha) applied at 15–20 DAS produced the number and dry weight of nodules/plant, as well as the leghaemoglobin content statistically comparable to HW. The lowest weed density and dry weight were recorded under two HW at both locations, with imazamox + imazethapyr (70 g/ha) showing comparable effectiveness. Chlorophyll content remained unaffected by most herbicide treatments, though high doses reduced it marginally due to phytotoxicity. Maximum plant height and shoot dry matter accumulation were observed with two HW, followed by imazamox + imazethapyr (70 g/ha) at 15-20 DAS, which provided effective weed control and enhanced crop growth by reducing competition. The findings suggest that imazamox + imazethapyr at 70 g/ha is a viable alternative to manual weeding for soybean under labour scarcity.

Key words: Herbicides, Post-emergence, Soybean, Symbiotic parameters, Weed density, Weeds dry weight

Soybean [*Glycine max* (L.) Merrill] is a versatile legume crop known for its high protein and oil content, making it a critical source of food, feed and industrial products globally. Soybean seeds are a rich source of protein (36–43%) and oil (18–24%), high in polyunsaturated fatty acids, especially Omega-6 and Omega-3. The crop is also essential for soil health, as it can fix atmospheric nitrogen through symbiotic relationships with rhizobia. Global soybean production in 2023 reached 348.8 million tonnes across 133.7 million hectares, with an average yield of 2607 kg per hectare. In India, soybean was cultivated on 12.0 million hectares, producing 12.7 million tonnes and achieving an average yield of 1063 kg/ha (FAOSTAT, 2024).

Weeds significantly impact soybean yield, causing reductions of 50–76% by competing for vital resources like light, water, and nutrients, while also serving as habitats for pests (Gharde *et al*., 2018; Virk *et al*., 2018). In 2018, weed-related losses in Indian soybean farming were estimated at USD 1,559 million (Gharde *et al.,* 2018). While traditional methods like inter-culturing are frequently employed, factors such as limited labour availability and excessive rainfall complicate efficient weed control, making the use of herbicides a more practical solution (Matloob *et al.,* 2020). Therefore, an experiment was conducted to study the effect of post-emergence herbicides on symbiotic parameters, growth and weeds in soybean under diverse agro-climatic environments.

The field study was conducted at Punjab Agricultural University, Ludhiana (30°54'N latitude, 75°48'E longitude) and Dr. J.C. Bakhshi Regional Research Station, Abohar (30°14'N latitude,74°20'E longitude) during *kharif* (rainy season) 2021. At Ludhiana, average maximum and minimum temperatures were 38.0°C and 15.6°C and total

Based on a part of M.Sc. Thesis of the first author submitted to the Punjab Agricultural University, Ludhiana, Punjab in 2021 (unpublished)

[2]Corresponding author's Email: hkmand@pau.edu
[1]M.Sc. Research Scholar; [4]Ph.D. Scholar, Department of Agronomy; [2]Senior Agronomist (Soybean), Department of Plant Breeding and Genetics; [3]Senior Agronomist, Dr. J.C. Bakhshi Regional Research Station, Abohar, Punjab Agricultural University, Ludhiana, Punjab 141 004

rainfall received was 770.6 mm. At Abohar, average maximum and minimun temperatures were 41.8°C and 17.1°C and total rainfall received was127.8 mm. The soils of Ludhiana and Abohar had a pH of 7.3 and 7.1, electrical conductivity 0.11 and 0.37 dS/m, organic carbon 0.22% and 0.38%, available nitrogen 120.4 and 92.2 kg/ha, available potassium 274.3 and 267.2 kg/ha, available phosphorus 45.7 and 13.5 kg/ha, respectively. The experiment was conducted in a randomized complete block design with 12 treatments of imazethapyr 10% SL 75 g/ha, propaquizafop 2.5% + imazethapyr 3.75% ME at 75, 100 and 125 g/ha, clodinafop propargyl 8% + sodium acifluorfen 16.5% EC at 147, 196 and 245 g/ha, imazamox 35% + imazethapyr 35% WG at 42, 56 and 70 g/ha, two hand weedings (HW) at 20 and 40 days after sowing (DAS) and weedy check with three replications. Plot size at both sites was 6.0 m × 3.6 m (21.6 m²). Post-emergence herbicides were applied 20 DAS using a power sprayer with 375 L/ha water and a flat fan nozzle. Manual weeding was done with *khurpa* in the two HW treatment, while weeds in the control plots were allowed to grow undisturbed through the season. Soybean variety 'SL 958' was sown on 4 June and 10 June, 2021 at Abohar and Ludhiana, respectively, using a seed rate of 75 kg/ha at a row spacing of 45 cm. At sowing, 31.25 kg/ha nitrogen (46% N) and 60 kg/ha phosphorus (16% PO) were applied through urea and single superphosphate.

Data on nodule count/plant was recorded by selecting five plants per plot at both 60 and 90 DAS. Nodules were carefully detached, counted, and dried at 60°C until reaching a consistent weight, which was recorded per plant. The leghaemoglobin concentration in fresh, pink nodules from Ludhiana was measured at 60 and 90 DAS using the Wilson and Reisenauer (1963) method. Data on weed density were recorded at 30 and 60 DAS from the quadrat of 50 cm × 50 cm from each plot and then converted to weed species count per m^2. After counting, all the weeds were oven dried for taking dry weight of weeds at 30 and 60 DAS and expressed as kg/ha. Data on chlorophyll content in leaves were calculated by the method given by Witham *et al.* (1971) from the experimental field of Ludhiana at 30 and 60 DAS. Plant height was recorded from randomly selected five plants from each plot at harvest and shoot dry matter accumulation was recorded by cutting the plants from the 0.5 m row length and after sun drying, samples were kept in a hot air oven at 60°C till constant weight and were expressed as kg/ha. Data were statistically analyzed with ANOVA using standard Randomised Block Design based on the procedure of Cochran and Cox (1967). The comparisons were made at a 5 per cent level of significance. Data on weed density were transformed using square root transformation.

At both locations, treatment of two HW significantly increased number and dry weight of nodules per plant at 60 DAS compared to the weedy check (Table 1). While post-emergence herbicides generally reduced nodule counts, treatments with propaquizafop + imazethapyr (125 g/ha) and imazamox + imazethapyr (70 g/ha) applied at 15-20 DAS produced nodule numbers statistically comparable to HW at Ludhiana. At Abohar, the application of imazamox + imazethapyr (56 and 70 g/ha) at 15-20 DAS also achieved similar results to HW. Increase in nodulation with HW could be attributed to enhanced aeration around the roots (Verma and Kushwaha, 2020). Similarly, Raghavendra *et al.* (2017) observed a decline in nodule formation with herbicide use, suggesting an antagonistic effect on nodulation. Application of imazamox + imazethapyr (70 g/ha) at 15-20 DAS produced comparable dry weights to HW at both 60 and 90 DAS. The maximum leghaemoglobin content at 60 DAS was achieved with two HW, which was statistically similar to application of propaquizafop + imazethapyr (125 g/ha) and imazamox + imazethapyr (70 g/ha). Mawalia *et al.* (2016) also reported increased nodule dry weight with pre-emergence pendimethalin and post-emergence imazethapyr + imazamox treatments. Maji *et al.* (2020) also reported that effective weed management with imazamox + imazethapyr could enhance leghaemoglobin content by improving photosynthate availability.

The predominant weed species recorded at Ludhiana among grasses were *Digitaria sanguinalis, Dactyloctenium aegyptium, Commelina benghalensis, Acrachne racemosa*; broadleaved weeds were *Trianthema portulacastrum*; and sedges were *Cyperus rotundus*. The predominant weed species recorded at Abohar among grasses were *Digitaria sanguinalis, Dactyloctenium aegyptium*; broadleaved weeds were; *Trianthema portulacastrum, Digera arvensis*: and sedges were *Cyperus rotundus*. At both the locations, two HW recorded the lowest total weed population at 30 and 60 DAS (Table 2). At 30 DAS, two HW significantly reduced total weed population and dry weight than weedy check and other herbicidal treatments. At 60 DAS, two HW recorded the lowest total weed population and dry weight, which was, however, statistically at par with application of imazamox + imazethapyr 70 g/ha at 15-20 DAS.

Among the post-emergence herbicides, application of imazamox + imazethapyr 70 g/ha at 15-20 DAS effectively controlled weeds, followed by propaquizafop + imazethapyr 125 g/ha at 15-20 DAS. The density of weeds at Abohar was lower than Ludhiana, which was due to the reason that higher rainfall was recorded at Ludhiana as compared to Abohar, which was favourable for the growth of weeds. Bhimwal *et al.* (2019) reported that application of propaquizafop + imazethapyr 75 + 75 g/ha at 21 DAS

Table 1. Effect of different post-emergence herbicides on symbiotic parameters

Treatment	Number of nodules/ plant				Dry weight of nodules (mg/plant)				Leghaemoglobin content (mg/g fresh weight of nodules) at Ludhiana	
	60 DAS		90 DAS		60 DAS		90 DAS		60 DAS	90 DAS
	LDH	ABH	LDH	ABH	LDH	ABH	LDH	ABH		
Imazethapyr 75 g/ha	31.3	18.7	76.8	46.8	100.7	51.3	291.3	233.0	2.80	4.23
Propaquizafop + imazethapyr 75 g/ha	31.0	19.7	49.3	40.0	83.0	42.3	216.5	174.7	2.63	3.90
Propaquizafop + imazethapyr 100 g/ha	32.6	20.2	57.3	43.0	86.3	49.8	284.4	223.8	3.03	4.33
Propaquizafop + imazethapyr 125 g/ha	45.5	23.2	85.9	64.7	92.0	71.5	319.7	261.7	3.20	4.90
Clodinafop propargyl + sodium acifluorfen 147 g/ha	19.3	13.1	45.9	33.0	97.7	43.2	144.8	106.5	2.46	4.00
Clodinafop propargyl + sodium acifluorfen 196 g/ha	21.6	13.2	62.9	43.9	100.3	49.8	145.0	114.7	2.60	4.36
Clodinafop propargyl + sodium acifluorfen 245 g/ha	39.9	21.1	66.2	48.6	101.3	78.3	182.1	142.4	2.63	4.60
Imazamox + imazethapyr WG 42 g/ha	28.3	25.2	69.8	62.2	110.7	56.5	249.9	210.9	2.76	4.70
Imazamox + imazethapyr WG 56 g/ha	43.8	33.7	85.5	67.5	135.7	85.0	293.0	249.6	2.83	4.76
Imazamox + imazethapyr WG 70 g/ha	46.0	34.2	90.4	80.2	143.3	109.4	398.7	334.3	3.30	5.18
Two hand weedings at 20 and 40 DAS	49.0	36.8	103.2	87.5	161.3	128.2	469.8	418.2	3.56	5.56
Weedy check	28.0	17.5	60.3	47.3	95.3	57.8	167.6	146.0	2.93	4.33
SEm±	1.5	1.3	6.5	5.9	6.6	7.2	32.5	35.8	0.11	0.14
CD (P=0.05)	5.1	4.4	19.6	18.4	19.8	21.2	96.3	99.7	0.38	0.46

recorded the lowest density of weeds, which was significantly lower than weedy check and other herbicidal treatments. Similar results were reported by Prachand *et al.* (2015) and they observed that application of premix imazethapyr + imazamox 0.080 kg ha^{-1} was effective in controlling weeds. Reduction in dry weight of weeds was recorded with application of imazethapyr + imazamox 70 g ha^{-1} with 1000 ml of adjuvant in soybean (Mishra *et al.,* 2013). The reduction in dry weight of weeds with imazamox + imazethapyr 70 g/ha at 15–20 DAS might be due to combined effect of both the herbicides, which had longer effect on weed control and brought significant decrease in dry weight of weeds as compared to weedy check. Komal *et al.* (2015) also reported that imazethapyr + imazamox 60 g/ha at 20 DAS + hand weeding at 40 DAS gave significant higher reduction in weed dry weight as compared to weedy check.

Application of post-emergence herbicides did not affect chlorophyll content significantly (Table 3). However, at high dose of herbicides, chlorophyll content was decreased, which could be due to its phytotoxic effects on crop. At both locations, the maximum plant height was observed under two HW, which was, however, statistically at par with the application of imazamox + imazethapyr 56 and 70 g/ha at 15–20 DAS. Higher plant height in the treatments of two HW and imazamox + imazethapyr than weedy check might be resulted from the favourable growing conditions brought by the lower crop-weed competition, whereas, the lowest plant height in weedy check might be resulted from the competitive stress for the available resources (Singh 2005). Post-emergence application of imazamox + imazethapyr 70 g/ha recorded higher plant height than other treatments could be due to better control of the weeds during the initial growth period of the crop which resulted in lower crop-weed competition and better availability of sunlight, space, water and nutrients to the crop in the absence of weeds. Yadav *et al.* (2017) also reported higher plant height with the application of imazethapyr + imazamox 70 g/ha at 21 DAS than weedy check in soybean. Similar results were also recorded in soybean with the application of imazethapyr + imazamox 35 + 35 g/ha at 30 DAS (Rupareliya *et al.,* 2020).

At Ludhiana, the maximum shoot dry matter accumulation was recorded in two HW, which

Table 2. Effect of different post-emergence herbicides on dry weight of weeds in soybean

Treatment	Weed density (number/m^2)				Dry weight of weeds (kg/ha)			
	30 DAS		60 DAS		30 DAS		60 DAS	
	LDH	ABH	LDH	ABH	LDH	ABH	LDH	ABH
Imazethapyr 75 g/ha	12.6 (158.7)	10.2 (104.0)	8.6 (73.3)	6.8 (45.3)	624	552	2,995	2,819
Propaquizafop + imazethapyr 75 g/ha	13.8 (189.3)	11.1 (122.7)	9.4 (88.0)	8.4 (69.3)	787	567	3,467	3,020
Propaquizafop + imazethapyr 100 g/ha	13.0 (169.3)	10.4 (108.0)	8.1 (65.3)	7.3 (52.0)	712	507	2,387	2,153
Propaquizafop + imazethapyr 125 g/ha	12.1 (146.7)	9.9 (97.3)	6.5 (41.3)	5.5 (29.3)	680	483	1,258	1,126
Clodinafop propargyl + sodium acifluorfen 147 g/ha	12.6 (158.7)	10.8 (116.0)	9.5 (89.3)	7.9 (61.3)	873	637	4,177	3,480
Clodinafop propargyl + sodium acifluorfen 196 g/ha	11.9 (141.3)	10.2 (104.0)	8.4 (70.7)	6.3 (38.7)	820	553	3,153	2,680
Clodinafop propargyl + sodium acifluorfen 245 g/ha	11.5 (130.7)	9.8 (96.0)	7.5 (56.0)	5.7 (32.0)	760	520	2,787	2,573
Imazamox + imazethapyr WG 42 g/ha	12.0 (144.0)	9.5 (89.3)	8.3 (68.0)	7.1 (49.3)	693	547	3,147	2,913
Imazamox + imazethapyr WG 56 g/ha	11.2 (125.3)	9.0 (80.0)	7.0 (48.0)	6.5 (41.3)	627	440	2,720	2,260
Imazamox + imazethapyr WG 70 g/ha	10.4 (106.7)	8.2 (66.7)	5.4 (28.0)	4.6 (20.0)	527	393	880	760
Two hand weedings at 20 and 40 DAS	5.1 (25.3)	3.7 (13.3)	4.9 (22.7)	4.3 (18.7)	311	217	417	353
Weedy check	15.3 (233.3)	12.1 (146.7)	18.2 (330.7)	14.2 (200.0)	970	893	4,593	3,880
SEm±	0.2	0.4	0.5	0.3	42	35	191	173
CD (P=0.05)	0.6	1.2	1.3	0.8	123	103	584	518

Original data on weed density given in parentheses were subjected to square root transformation $\sqrt{x+0.5}$ before analysis

was, however, statistically at par with imazethapyr 75 g/ha, propaquizafop + imazethapyr 125 g/ha and imazamox + imazethapyr 70 g/ha at 15–20 DAS (Table 3). At Abohar, the maximum shoot dry matter accumulation was recorded in two HW, which was, however, statistically at par with application of imazethapyr 75 g/ha, propaquizafop + imazethapyr 125 g/ha and imazamox + imazethapyr 56 & 70 g/ha at 15–20 DAS and significantly higher than the other treatments. The higher shoot dry matter accumulation was observed with application of imazamox + imazethapyr 70 g/ha at 15–20 DAS, which could be possibly due to effective weed control (Table 2) resulted the lower crop-weed competition and thereby, creating congenial environment for the crop growth and establishment (Deshkari *et al.,* 2019; Jadon *et al.,* 2019). The lower shoot dry matter accumulation was noticed in weedy check at both locations, which might be due to severe crop-weed competition and lesser control of weeds. The higher shoot dry matter accumulation was observed at Ludhiana than Abohar, which might be resulted due to higher rainfall and better distribution over the cropping period. The higher shoot dry matter production was also observed in soybean with the application of imazethapyr + imazamox 75 g/ha at 15 DAS than weedy check (Jadon *et al.,* 2019).

It can be concluded that post-emergence application of imazamox + imazethapyr 70 g/ha applied at 15–20 DAS was most effective, providing comparable results to HW while minimizing weed-crop competition and maintaining crop growth where manual weeding is not feasible.

Table 3. Effect of different post-emergence herbicides on chlorophyll content, plant height and shoot dry matter of soybean

Treatment	Chlorophyll content (mg/g fresh weight of leaf tissue) at LDH		Plant height at harvest (cm)		Shoot dry matter at harvest (kg/ha)	
	30 DAS	60 DAS	LDH	ABH	LDH	ABH
Imazethapyr 75 g/ha	1.22	1.33	96.0	107.3	6,117	6,330
Propaquizafop + imazethapyr 75 g/ha	1.27	1.42	97.1	101.0	5,271	5,621
Propaquizafop + imazethapyr 100 g/ha	1.08	1.31	99.3	107.3	5,545	5,948
Propaquizafop + imazethapyr 125 g/ha	1.04	1.14	99.6	110.0	6,240	6,599
Clodinafop propargyl + sodium acifluorfen 147 g/ha	1.20	1.37	93.0	95.7	4,845	5,439
Clodinafop propargyl + sodium acifluorfen 196 g/ha	1.13	1.31	94.3	102.3	5,223	5,638
Clodinafop propargyl + sodium acifluorfen 245 g/ha	1.05	1.10	96.6	105.3	5,506	6,143
Imazamox + imazethapyr WG 42 g/ha	1.21	1.43	96.1	105.7	5,538	6,131
Imazamox + imazethapyr WG 56 g/ha	1.15	1.29	103.6	108.3	5,876	6,479
Imazamox + imazethapyr WG 70 g/ha	1.06	1.19	105.7	113.7	6,504	6,992
Two hand weedings at 20 and 40 DAS	1.37	1.83	108.6	120.7	6,849	7,141
Weedy check	1.25	1.32	89.6	93.7	4,746	5,390
SEm±	0.01	0.03	2.9	3.3	302	271
CD (P=0.05)	NS	NS	8.5	10.6	916	843

LDH: Ludhiana and ABH: Abohar

REFERENCES

Cochran, W.G. and Cox, G.M. 1967. *Experiment Designs.* Asia publishing House, New Delhi, India.

Deshkari, S.M., Pagar, P.C., Dangore, S.T., Babhulkar. V.P. and Mendhe, H.S. 2019. Effect of weed management on growth, yield and economics of soybean. *Journal of Soils and Crops* **29**: 194–199.

FAOSTAT. 2024. Food and Agriculture Organization of the United Nations. Statistical database. Retrieved from https://www.fao.org/faostat.

Gharde, Y., Singh, P.K., Dubey, R. and Gupta, P.K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection* **107**: 12–18.

Jado, C.K., Dashora, L.N., Meena, S.N. and Singh, P. 2019. Growth, yield and quality of soybean (*Glycine max* (L.) Merr.) as influenced by weed management and fertility levels in vertisols of S-E Rajasthan. *International Journal of Bio-resource and Stress Management* **10**: 177–180.

Maji, S., Reja, M.H., Nath, R., Bandopadhyay, P. and Dutta, P. 2020. Herbicidal management in monsoon green gram (*Vigna radiata* (L.) Wilczek) and its effect on the following rapeseed (*Brassica campestris* L. var. Yellow Sarson) in the Indo-Gangetic plains of Eastern India. *Journal of the Saudi Society of Agricultural Sciences* **19**: 499–509.

Matloob, A., Safdar, M.E., Abbas, T., Aslam, F., Khaliq, A., Tanveer, A. and Chadhar, A. R. 2020. Challenges and prospects for weed management in Pakistan: A review. *Crop Protection* **134**: 104,724.

Mawalia, A.K., Kumar, S. and Rana, S.S. 2016. Herbicide combinations for control of complex weed flora in garden pea. *Indian Journal of Weed Science* **48**: 48–52.

Raghavendra, K.S., Gundappagol, R.C. and Santosh, G.P. 2017. Impact of post-emergence herbicides on soil microorganisms, nodulation and yield of chickpea. *International Journal of Chemical Studies* **5**: 1,016–1,023.

Verma, L. and Kushwaha, H.S. 2020. Evaluation of different herbicides against weeds in mungbean (*Vigna radiata* L.). *Legume Research* **43**: 866–871.

Virk, H.K., Singh, S. and Sharma, P. 2018. Efficacy of post-emergence herbicides for weed control in soybean. *Indian Journal of Weed Science* **50**(2): 182–185.

Wilson, D.O. and Reisenauer, H.M. 1963. Determination of leghemoglobin in legume nodules. Analytical Biochemistry **6**: 27–30.

Witham, F.H., Blaydes, D.F. and Devlin, R.M. 1971. *Experiments in Plant Physiology*, Van Nostrand, New York.