Indian Journal of Weed Science (2025) **57**(1): 146–149
http://dx.doi.org/10.5958/0974-8164.2025.00024.3

RESEARCH NOTE

Efficacy of post-emergence application of haloxyfop-R-methyl on weed control, yield and economics of soybean

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Received: 11 April 2024 | Revised: 9 February 2025 | Accepted: 13 February 2025

ABSTRACT

A field experiment was conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India), during the *Kharif* (rainy) season of 2022. The experiment was laid out in a randomized block design with three replications and eight treatments to identify the ideal rate of herbicide for optimum weed control in soybean. Among the herbicidal treatments, the application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) at the rate of 164.1 g/ha as PoE 20 days after sowing (DAS) was found effective in controlling a broad spectrum of weeds with minimum dry weight of weeds and highest mean weed control efficiency (48%) among all the treatments. The same treatment also recorded the maximum seed yield (1.50 t/ha), net monetary return (₹ 50149/ha), and the benefit-cost ratio (1.37) and thus, found to be an economically viable approach to control diverse weed flora in soybean.

Keywords: Economics, Haloxyfop-R-methyl, Herbicide, Weed flora, Yield

Weed infestation is viewed as a persistent and complicated limitation in soybean cultivation because it interferes with soybean growth and development by competing with it for nutrients, water, light, and space. Due to its slow early vegetative growth, it is very susceptible to weeds in the early stages of its growth (Meena *et al.* 2009). Therefore, the first 30-45 days after sowing (DAS) is the most critical period for weed competition. If weeds are not controlled during this crucial phase, there might be losses of 20 to 84 per cent (Gharde *et al.* 2018, Kumar *et al.* 2022). In general, manually hand weeding is the most effective method of weed control, but due to the non-availability of sufficient labour during peak periods, its time-consuming nature and being a costly affair, it is an uneconomical method of weed control (Vijayakumar *et al.* 2023). Chemical weed control seems to offer greater convenience, saves time, more cost-effective, and ensures a weed-free environment during the initial stages of crop growth (Keerthi *et al.* 2022). Post-emergence herbicides, such as haloxyfop-R-methyl, imazethapyr, fomesafen, bentazone, propaquizafop, quizalofop-p-ethyl, chlorimuron *etc.* are narrow spectrum in nature. Haloxyfop and quizalofop are effective against grassy weeds. Acetachlor is most effective against grassy as well as broad-leaved weeds (Kumar *et al.* 2008). In the recent past, haloxyfop-R-methyl is reported to control grassy weeds in soybean effectively, but the information on its efficacy and doses are very meagre in the literature. Therefore, in order to find out the optimum rate of its application this study was done.

A field experiment is conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The experiment is conducted using a randomized block design, consisting of three replications and eight treatments, *viz.* haloxyfop-r-methyl 10.5% w/w EC (BCSPL sample) 105.0 g/ha, haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 131.3 g/ha; haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha; haloxyfop-R-methyl 10.5% w/w EC (market sample) 105.0 g/ha; haloxyfop-R-methyl 10.5% w/w EC (market sample)131.3 g/ha; propaquizafop 10% EC75.0 g/ha, weed free plot and untreated control (weedy check). All the post-emergence herbicides are applied at 20 days after sowing (DAS). The experimental field's soil is typical Indo-Gangetic alluvium (Entisol), well-drained and has moderate soil fertility with a bulk density of 1.4 Mg/m^3, near neutral pH of 7.3, low organic carbon (0.3%), low available nitrogen (210.3 kg/ha), medium available phosphorus (18.1 kg/ha) and medium available potassium (176.9 kg/ha). The soybean variety JS 20-98 is sown in the furrow on

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27th June 2022 with a row to rows pacing of 45 X 10 cm. Uniform dose of 23.5:60:20 NPK kg/ha and 20 kg/ha sulphur as the basal dose is applied before the sowing of soybean and the crop is harvested on 22nd of October 2022. A total of 1200.4 mm of rainfall is received intermittently during the crop period. The data regarding density (no./m^2) and dry weight (g/m^2) of weeds are recorded at 30, 45and 60 days after the application of herbicide (DAA). The weed samples were collected from two spots in each plot with the help of 0.5 m^2 quadrate and the data is converted for one m^2 area. In each quadrate weeds are counted and cut close to the soil surface and then collected for drying in the sun followed by drying in the oven at 70^o C for 2 days. Dried samples of weeds are weighted separately to assess dry matter accumulation. Data transformation for weed density and weed dry weight is done with the help of square root transformation. Weed control efficiency (WCE) is calculated using following formula (Amare *et al.* 2014);

$$\text{WCE (\%)} = \frac{W_C - W_T}{W_C} \times 100$$

Where, WDC = weed dry matter from the control plot (untreated), WDT = weed dry matter from treated plot. The weed control efficiency (%) is calculated at 30 and 45 DAA for different treatments based on dry matter production over the weedy check plot.

Weed flora: The experimental plot contains diverse species of weed flora, *viz.* sedges (*Cyperus rotundus* (L.), *Cyperus esculentus* (L.) and *Fimbristylis miliacea*), monocots (*Echinochloa colona* (L.) Link, *Paspalum distichum Berg.* and *Cynodon dactylon* (L.) Pers.), and dicots (*Phyllanthus niruri* (L.), *Phyllanthus virgatus, Eclipta alba* (L.) Hassk, *Lindernia procumbens, Parthenium hysterophorus* (L.), *Cyanotis axillaris* and *Euphorbia hirta*). The density of sedges was much higher than that of monocots followed by dicots. Among all the weed flora, *Cyperus esculentus* (L.) was found to be predominant weed followed by *Cyperus rotundus* (L.), *Parthenium hysterophorus* (L.) and *Lindernia procumbens.*

Weed density: The weed density was found lower at 30 DAA but increased substantially at 45 DAA and again decreased at 60 DAA irrespective of the species (**Table 1**). The density of sedges and monocot weed species successively decreased after the application of post-emergence herbicides and the density of dicot weed species was not affected by the herbicidal application. The density of monocot weed species was found to consecutively decrease by the application of herbicide at all the stages of crop growth (30, 45 and 60 DAA). Weed free treatment recorded lower weed density irrespective of the species. The application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1g/ha reported the lowest monocot weed density among all the herbicidal treatments. In the case of sedges, the herbicidal application significantly reduced the weed flora at the initial stage but at later stages, its density increased. At all the rates of application, the haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) was found to be broad-spectrum herbicide control led by all sorts of weed species. Nainwal *et al.* (2010) reported that haloxyfop-R-methyl 10% EC 100 g/ha was found to be effective in controlling monocot weed species. Singh *et al.* (2023) also reported similar results.

Weed dry matter: The weed dry weight of the dicot was increased successively after the application of

Table 1. Weed density (no./m^2) as influenced by different weed control treatments

Treatment	Sedges			Monocot			Dicot			Total		
	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA
Haloxyfop-R-methyl 10.5% w/w	16.4	20.13	14.39	2.15	0.71	0.97	6.72	7.33	5.19	9.35	14.70	7.91
EC (BCSPL sample) 105.0 g/ha	(268.30)	(404.71)	(206.67)	(4.13)	(0.00)	(0.44)	(44.67)	(53.30)	(26.48)	(86.92)	(215.49)	(62.05)
Haloxyfop-R-methyl 10.5% w/w	15.92	21.14	15.35	1.86	0.71	0.71	7.84	8.11	4.69	9.61	15.54	8.15
EC (BCSPL sample) 131.3 g/ha	(252.89)	(446.20)	(235.11)	(2.94)	(0.00)	(0.00)	(60.94)	(65.24)	(21.52)	(91.85)	(241.07)	(65.85)
Haloxyfop-R-methyl 10.5% w/w	15.83	18.55	14.28	2.65	1.69	0.71	6.94	7.51	5.03	9.24	13.75	7.80
EC (BCSPL sample) 164.1 g/ha	(249.93)	(343.69)	(203.56)	(6.51)	(2.36)	(0.00)	(47.73)	(55.85)	(24.76)	(84.88)	(188.70)	(60.31)
Haloxyfop-R-methyl 10.5% w/w	15.98	19.01	15.76	2.01	0.71	0.71	6.94	7.12	4.20	9.26	13.93	8.18
EC (market sample) 105.0 g/ha	(254.79)	(360.88)	(248.00)	(3.53)	(0.00)	(0.00)	(47.72)	(50.25)	(17.14)	(85.31)	(193.61)	(66.46)
Haloxyfop-R-methyl 10.5% w/w	16.07	18.88	13.40	2.76	1.86	0.71	7.44	7.71	5.19	9.55	14.02	7.49
EC (market sample) 131.3 g/ha	(257.64)	(356.11)	(179.11)	(7.11)	(2.96)	(0.00)	(54.84)	(58.90)	(26.48)	(90.63)	(196.07)	(55.59)
Propaquizafop 10% EC 75.0 g/ha	17.09	19.85	16.51	2.65	1.30	0.97	7.01	7.04	4.85	9.77	14.44	8.71
	(291.41)	(393.44)	(272.00)	(6.52)	(1.18)	(0.44)	(48.67)	(49.00)	(23.05)	(94.96)	(207.97)	(75.28)
Weed free	10.79	13.89	11.39	3.34	3.72	2.22	4.09	6.02	4.49	6.20	10.42	6.48
	(116.02)	(192.57)	(129.33)	(10.66)	(13.31)	(4.44)	(16.23)	(35.79)	(19.62)	(37.97)	(108.15)	(41.44)
Untreated control (weedy check)	18.46	21.85	17.25	6.39	6.84	5.05	8.33	8.93	6.04	11.20	16.23	9.67
	(340.43)	(476.90)	(296.93)	(40.30)	(46.30)	(25.00)	(68.82)	(79.23)	(35.99)	(124.93)	(262.77)	(92.95)
LSD (p=0.05)	2.32	2.56	1.95	1.52	2.21	1.58	1.32	0.88	0.77	1.47	0.62	0.40

DAA- days after the application of herbicide, *Data subjected to x + 0.5 Square root transformation and figure in parentheses are the original value herbicides and was found unaffected by treatment (**Table 2**). The dry weight of monocot weeds was decreased after the application of treatments at all the dates of observation (30, 45 and 60 DAA). Plots with higher weed dry weight resulted from higher weed infestation. Among all the treatments, the weedy check plot recorded the highest weed dry weight of all the weed species at all the dates of observations while, weed free plot recorded the lowest weed dry weight (Panda *et al.* 2015). The post-emergence application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) at different rates resulted in maximum dry weight of monocot weeds at all the dates of observations (30, 45 and 60 DAA). The post-emergence application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha recorded lower dry weight of sedges at 30 DAA and haloxyfop-r-methyl 10.5% w/w EC (market sample) 131.3 g/ha recorded lower dry weight of sedges at 45 and 60 DAA among all the herbicidal treatments and this result was confirmed with the findings of Singh *et al.* (2010).

Weed control efficiency: Although, the weed-free plot resulted in highest weed control efficiency (87.79%), the post-emergence application of propaquizafop 10% EC 75.0 g/ha recorded higher weed control efficiency (46.61%) at 30 DAA. Similar results were reported by Bhadauria *et al.* (2012), Gupta *et al.* (2016) and Kumar *et al.* (2018). At 45 DAA, haloxyfop-R-methyl 10.5% w/w EC (market sample) 105.0 g/ha (53.18%) followed by haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha (52.55%) recorded higher weed control efficiency as it offered greater reduction of sedges, dicot and monocot weed species and found superior over other treatments with conformity of the findings of Singh *et al.* (2010) and Singh *et al.* (2023).

Seed yield: The data on seed yield revealed a significant influence of various treatments (**Table 3**).

Table 2. Weed dry weight (g/m^2) as influenced by different weed control treatments

Treatment	Sedges			Dicot			Monocot			Total		
	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA	30 DAA	45 DAA	60 DAA
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 105.0 g/ha	8.86 (78.07)	11.74 (137.40)	7.69 (58.59)	3.07 (8.92)	3.97 (15.24)	2.65 (6.50)	1.76 (2.59)	0.71 (0.00)	0.88 (0.27)	4.89 (23.42)	6.36 (39.92)	4.19 (17.08)
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 131.3 g/ha	8.59 (73.28)	11.52 (132.32)	8.69 (75.04)	3.31 (10.47)	3.97 (15.27)	2.95 (8.20)	1.32 (1.23)	0.71 (0.00)	0.71 (0.00)	4.83 (22.83)	6.27 (38.76)	4.72 (21.74)
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha	8.35 (69.29)	10.38 (107.31)	7.68 (58.44)	3.00 (8.49)	3.65 (12.86)	2.88 (7.80)	2.29 (4.76)	1.42 (1.51)	0.71 (0.00)	4.71 (21.66)	5.70 (32.04)	4.26 (17.68)
Haloxyfop-R-methyl 10.5% w/w EC (market sample) 105.0 g/ha	8.96 (79.86)	10.17 (102.88)	8.70 (75.11)	2.57 (6.10)	3.89 (14.61)	2.64 (6.45)	1.42 (1.52)	0.71 (0.00)	0.71 (0.00)	4.75 (22.07)	5.67 (31.61)	4.62 (20.81)
Haloxyfop-R-methyl 10.5% w/w EC (market sample) 131.3 g/ha	8.59 (73.37)	9.67 (93.10)	7.09 (49.82)	2.69 (6.72)	4.62 (20.86)	2.96 (8.29)	2.27 (4.66)	1.72 (2.47)	0.71 (0.00)	4.70 (21.62)	5.81 (33.28)	4.06 (15.96)
Propaquizafop 10% EC 75.0 g/ha	8.40 (69.99)	10.78 (115.78)	8.46 (71.07)	2.76 (7.12)	3.72 (13.33)	2.72 (6.90)	1.60 (2.07)	1.59 (2.02)	0.88 (0.27)	4.58 (20.46)	5.90 (34.36)	4.55 (20.17)
Weed free	3.73 (13.41)	5.84 (33.58)	5.38 (28.41)	1.17 (0.86)	1.88 (3.05)	1.72 (2.47)	2.32 (4.87)	2.81 (7.38)	1.69 (2.34)	2.28 (4.68)	3.41 (11.09)	2.99 (8.43)
Untreated control (weedy check)	9.24 (84.90)	12.22 (148.83)	9.36 (87.03)	3.90 (14.69)	5.31 (27.69)	3.46 (11.46)	6.89 (46.92)	8.92 (79.08)	4.73 (21.86)	6.23 (38.33)	8.25 (67.51)	5.64 (31.30)
LSD (p=0.05)	0.35	0.48	0.47	0.14	0.18	0.14	0.15	0.09	2.31	0.22	0.32	0.20

DAA- days after the application of herbicide, *Data subjected to $\sqrt{x+0.5}$ Square root transformation and figure in parentheses are the original value

Table 3. Weed control efficiency (WCE) and seed yield and economics of different weed control treatments

Treatment	Weed control efficiency (%)		Seed yield (kg/ha)	Cost of cultivation (₹/ha)	Net monetary returns (₹/ha)	B:C
	30 DAT	45 DAT				
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 105.0 g/ha	38.91	40.87	1305	35261	40368	1.14
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 131.3 g/ha	40.44	42.59	1437	35856	47247	1.32
Haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha	43.49	52.55	1499	36600	50149	1.37
Haloxyfop-R-methyl 10.5% w/w EC (market sample) 105.0 g/ha	42.43	53.18	1381	34993	45000	1.29
Haloxyfop-R-methyl 10.5% w/w EC (market sample) 131.3 g/ha	43.59	50.70	1243	35521	36584	1.03
Propaquizafop 10% EC 75.0g/ha	46.61	49.10	1278	34043	40179	1.18
Weed free	87.79	83.57	1453	45078	38725	0.86
Untreated control (weedy check)	0.00	0.00	965	32238	23667	0.73
LSD (p=0.05)	--	--	65.7	--	--	--

DAT- days after the application of treatments

Among all treatments, the weedy check plot recorded the lowest seed yield, primarily due to severe weed infestation, which suppressed crop growth and negatively impacted key yield parameters such as the number of pods per plant, seeds per pod, and 100-seed weight. These findings align with those reported by Chauhan *et al.* (2012), who emphasized the detrimental effects of unchecked weed competition on crop productivity. Among the herbicidal treatment plots, the post-emergence application of haloxyfop-r-methyl 10.5% w/w EC (BCSPL sample) at 164.1 g/ha resulted in a significantly higher seed yield, closely followed by the weed-free plot and haloxyfop-r-methyl 10.5% w/w EC (BCSPL sample) at 131.3 g/ha. These treatments were statistically at par with other post-emergence herbicides. The enhanced yield in these plots can be attributed to effective weed control during critical crop growth stages, which facilitated vigorous plant growth and improved yield attributes. Similar trends were observed by Sharma *et al.* (2016), who reported that timely weed management significantly boosts crop productivity. Furthermore, the plots that were treated with such herbicides and farmer's practices exhibited superior seed yield due to efficient weed suppression, ensuring optimal resource utilization and robust crop development. These findings are consistent with those of Singh *et al.* (2010), who highlighted the importance of post-emergence herbicides in enhancing crop performance. The overall results underscore the necessity of adopting effective weed management strategies to maximize seed yield and improve farm profitability.

Economics: Weed-free plot required the highest cost of cultivation (₹ 12,000/ha) due to the highest variable cost. The post-emergence application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha recorded higher net monetary return among all the treatments (₹ 50149/ha) followed by the application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 131.3 g/ha (₹ 47247/ha) and haloxyfop-R-methyl 10.5% w/w EC (market sample) 105.0 g/ha (₹ 45000/ha). Among all the treatments, the lowest net monetary return and benefit-cost ratio were recorded under a weedy check plot, while the highest benefit-cost ratio was recorded under post-emergence application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 164.1 g/ha followed by the application of haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) 131.3 g/ha. A similar result was confirmed with the findings of Singh *et al.* (2023) reported similar findings.

Based on the findings of this study, it is advised to apply haloxyfop-R-methyl 10.5% w/w EC (BCSPL sample) as a post-emergence herbicide, at a rate of 164.1 g/ha, around 20 days after sowing. This approach offers both effective broad-spectrum weed control and an economically viable solution for managing weeds in soybean cultivation.

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