International Journal of Plant & Soil Science

Volume 35, Issue 19, Page 1778-1784, 2023; Article no.IJPSS.104838
ISSN: 2320-7035

The Use of Herbicides to Control Weeds in Soybean Crops (*Glycine max* L. Merrill)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i193728

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/104838

Original Research Article

Received: 22/06/2023
Accepted: 27/08/2023
Published: 09/09/2023

ABSTRACT

An experiment was conducted at 'The Research Farm, College of Agriculture, Tikamgarh, during the *kharif* season, 2016-17. The field was mainly infested with monocot weeds like *Brachiaria ramosa, Commelina benghalensis, Cyperus rotundus* and *Echinochloa crusgalli*. Dicot weeds *Digera arvensis, Phyllanthus niruri* and *Mollugo pentaphylla* were less dominant in the soybean ecosystem. The treatments comprised of pre-emergence herbicides; clomazone @ 1 kg/ha, pendimethalin @ 1 kg/ha and alachlor @ 1 kg/ha and post-emergence herbicides; imazethapyr @

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75 g/ha, imazethapyr + imazamox @ 70 g/ha, quizalofop-p-ethyl @ 50 g/ha+ chlorimuron-ethyl @ 9 g/ha,quizalofop-p-ethyl @ 50 g/ha, chlorimuron-ethyl @ 9 g/ha, two hand weeding at 20 and 40 DAS and weedy check., dry matter and weed index. It was also found superior in respect of various growth and yield attributes. The highest seed yield (825 kg/ha) and straw yield (1152 kg/ha) of soybean and maximum gross return (₹ 37,611 ha-1) and net return (₹ 23,951 ha-1) were also recorded in imazethapyr + imazamox 70 kg/ha as postemergence with highest B:C ratio of 2.75. It was also found responsible for the highest N, P and K uptake by soybean crops and the lowest uptake of these plant nutrients by weed plants.

Keywords: Imazamox; imazethapyr; pendimethalin; quizalofop-p-ethyl; soybean; weed control.

1. INTRODUCTION

"Soybean (*Glycine max*), is an important oil-yielding rainy season (*Kharif*) crop having multiple uses. It has revolutionized the rural economy and improved the farmers' socio-economic status. Soybean has emerged as a potential crop for changing the ecological position of the farmers in India, particularly in Madhya Pradesh. Although the ecological conditions of the state are congenial for soybean conditions, the yield is substantially low, despite best management practices. Poor weed management practices deprive the crop of nutrients, soil moisture, sunlight, and space, resulting in poor crop growth and yield. The soybean crop grows slowly during the initial period, which results in vigorous growth and proliferation of weeds. In the *Kharif* season, weed competition is one of the most important causes of low yield, estimated at 31-84%" [1]. "Thus, intense weed completion is one of the main constraints for increasing soybean productivity. The weed is not controlled during a critical period of weed crop competition and may reduce soybean yield from 58-85% depending upon type and weed intensity" [2,3]. "Hand weeding is a traditional and effective method of weed control, but untimely and continuous rains and unavailability of labour during peak periods of demand are the main limitations of manual weeding. Therefore, there is a need for alternative methods of reducing the weed load during the early crop growth period of soybean i.e. first 30-45 DAS" [4].

"Several herbicides *viz.,* fluchoralin, pendimethalin, metalochlor, alachlor and trifluralin *etc*. are presently being used for controlling weeds associated with soybean, but these herbicides were found not very effective in controlling many broad-leaved weeds existing in soybean. Recently, some post-emergence herbicides have been found effective in controlling weeds in soybeans" [5]. "Therefore, it is imperative to evaluate the efficacy of suitable early postemergence herbicides, which could be able to control the dominating weeds in soybean fields" [6]. According to Chauhan et al., [7] and Dixit et al., [8] "chlorimuron may be an effective post-emergence herbicide for controlling both sedges and broad-leaved weeds in soybean, but it is not tested under the agroclimatic condition of Jabalpur. Hence, the present investigation was carried out to assess the efficacy of chlorimuron alone and its mixture with quizalofop-p–ethyl against weeds in soybeans" [9,10].

2. MATERIALS AND METHODS

The field was infested with location-specific weeds representative of this area. All herbicides were combined and applied 14 Days after sowing (DAS) in 500 litres of water per ha with a knapsack sprayer using a flat fan nozzle. Before sowing, the seed was treated with Thiram 2.5 g/kg of seed, followed by inoculation with *Rhizobium japonicum* culture at 5 g/kg of seed. Soybean variety 'JS-20-29' was sown @ 80 kg/ha on 18 July with a row spacing of 30 cm in 2016. A full dose of major plant nutrients (20 kg N+ 60 kg P2O5 + 20 kg K2O/ha) was applied as basal application through urea, SSP and Muriate of potash during sowing. "All the fertilizers were applied manually at the time of sowing in the furrows about 3 cm below the seed. The species-wise weed population was recorded by the least count quadrate (0.25 m × 0.25 m) method at 45 DAS, whereas the weed biomass was recorded at harvest and weed control efficiency was calculated accordingly. Observations on grain yield and yield attributing parameters viz., pods/plant, seeds/pod, seed index and harvest index were recorded at harvest" [6]. The experiment was laid down in randomized block design replicated thrice with ten weed control treatments comprised of:

T_1 - Clomazone @ 1 kg/ha,
T_2- Pendimethalin @1kg/ha,

T_3-Alachlor @ 1 kg/ha,
T_4- imazethapyr@ 75 g/ha,
T_5 -Imazethapyr + Imazamox @ 70 g/ha,
T_6 - Quizalofop-p-ethyl @ 50 g/ha,
T_7- Chlorimuron-ethyl @ 9 g/ha,
T_8 - Quizalofop-p-ethyl @ 50 g/ha + Chlorimuron-ethyl 9 g/ha,
T_9- Hand weeding (20 and 40 DAS),
T_{10}- Weedy check.

2.1 Weed Control Efficiency (WCE)

It is the efficiency of treatment expressed in percent for controlling weeds compared to the weedy check. It was worked out based on the following formula as suggested by (Mallikarjun et al*.,* 2014).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where,

WCE = weed control efficiency
DWC =dry weight of weeds in weedy check plot
DWT = dry weight of weeds in the treated plot

2.2 Harvest Index (HI)

It refers to the ratio of economic yield (seed yield) to the biological (seed + stover) yield under a particular treatment and it is expressed in percentage. It was computed by using the following formula.

$$\textbf{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

Economic yield = Seed yield
Biological yield = Seed yield + Stover yield

2.3 Leaf Area Index (LAI)

The leaf area of leaves from five selected plants drawn for biomass observation was used for measuring leaf area. The leaf area index (LAI) was determined plot-wise for each observation in all plots by using the following formula:

$$\textbf{LAI} = \frac{\text{Total leaf area (A)}}{\text{Ground area covered (P)}}$$

Where,

A = leaf area (m^{-2})
P = Ground area (m^{-2})

2.4 Harvest Index (HI)

It refers to the ratio of economic yield (seed yield) to the biological (seed + stover) yield under a particular treatment and it is expressed in percentage. It was computed by using the following formula (Nichiporovich, 1967).

$$\textbf{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

Economical yield = Seed yield
Biological yield = Seed yield + stover yield

3. RESULTS AND DISCUSSION

Effect on weed flora predominant weed species observed in the experimental field consisted of grassy weeds *viz. Brachiaria ramosa, Commelina benghalensis, Cynodon dactylon, Cyperus rotundus, Echinochloa crusgalli, and broad leaved weeds*. *Digera arvensis,Mollugo pentaphylla* and *Phyllanthus niruri*. The weeds' population and dry matter accumulation were recorded at 15, 30, 45, and 60 DAS and harvest stages. Herbicides significantly reduced weed intensity at all crop growth stages. Pre-emergence application of clomazone@ 1 kg/ha, alachlor @ 1 kg/ha and pendimethalin @ 1 kg/ha recorded a lower number of weeds per m^{-2} and post-emergence application ofimazethapyr + imazamox @ 70 g/ha, imazethapyr @ 75 g/ha, quizalofop-p-ethyl @ 50 g/ha + chlorimuron-ethyl @ 9g/ha which is on par withquizalofop-p-ethyl @ 50 g/ha, chlorimuron-ethyl @ 9g/ha and control recorded highest weed number at 45 DAS. Higher numbers of weeds per m^2 were recorded in control at all the stages. All treatments effectively decreased the weed infestation compared to control. Whereas, dry matter of weeds also showed similar results as the number of weeds per m^2. Low weed dry matter accumulation was recorded in the treatments of pre-emergence herbicides clomazone @ 1 kg/ha and post-emergence herbicides imazethapyr + imazamox @ 70 g/ha, quizalofop-p-ethyl @ 50 g/ha + chlorimuron-ethyl @ 9 g/ha and imazethapyr @ 75 g/ha, followed by quizalofop-p-ethyl @ 50 g/ha,alachlor@ 1 kg/ha, pendimethalin @ 1 kg/ha and chlorimuron-ethyl @ 9 g/ha (Table 1). The lowest weed index and highest weed control efficiency was found in imazethapyr + imazamox @ 70 g/ha, quizalofop-p-ethyl @ 50 g/ha + chlorimuron-ethyl @ 9 g/ha and imazethapyr @ 75 g/ha [11,12].

Table 1. Effect of different herbicidal doses against weed intensity in soybean 45 DAS

Treatment	*Cyperus rotundus*	*Echinochloa crusgalli*	*Cynadon dactylon*	*Commelina benghalensis*	*Brachiaria ramosa*	*Phyllanthus niruri*	*Digera arvensis*	*Mollugo pentaphylla*
T_1 - Clomazone @ 1 kg/ha	19.94 (4.50)	15.66 (4.01)	3.55 (1.99)	3.44 (1.98)	3.44 (1.97)	4.89 (2.32)	3.00 (1.85)	1.77 (1.45)
T_2 - Pendimethalin @ 1 kg/ha	23.00 (4.84)	17.00 (4.14)	5.33 (2.41)	3.14 (1.88)	4.11 (2.14)	4.72 (2.28)	3.22 (1.90)	2.00 (1.54)
T_3 - Alachlor @ 1 kg/ha	21.50 (4.69)	16.44 (4.09)	5.67 (2.48)	3.44 (1.98)	4.22 (2.16)	4.55 (2.24)	3.22 (1.93)	1.89 (1.54)
T_4 - Imazethapyr @ 75 g/ha	16.50 (4.11)	12.89 (3.63)	2.55 (1.75)	1.61 (1.44)	1.89 (1.51)	2.55 (1.74)	1.11 (1.26)	0.77 (1.13)
T_5 - Imazethapyr + Imazamox @ 70 g ha^{-1}	12.67 (3.62)	4.55 (2.12)	2.44 (1.71)	1.00 (1.17)	1.55 (1.43)	1.67 (1.46)	0.22 (0.83)	0.66 (1.07)
T_6 - Quizalofop-p-ethyl @ 50 g/ha	18.33 (4.32)	6.22 (2.57)	2.44 (1.68)	3.55 (2.00)	1.55 (1.42)	9.33 (3.13)	4.11 (2.14)	5.22 (2.39)
T_7 - Chlorimuron-ethyl @ g/ha	32.67 (5.76)	28.00 (5.32)	6.50 (2.68)	1.55 (1.41)	7.22 (2.77)	2.33 (1.68)	0.72 (1.10)	1.00 (1.18)
T_8 - Quizalofop-p-ethyl @ 50 g/ha + Chlorimuron-ethyl 9g/ha	18.33 (4.33)	8.00 (2.91)	3.11 (1.87)	1.78 (1.50)	2.11 (1.60)	2.67 (1.77)	1.44 (1.30)	1.00 (1.22)
T_9 - Hand weeding (20 & 40 DAS)	1.33 (1.27)	0.00 (0.71)	0.67 (1.05)	0.00 (.0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T_{10} - Weedy check	36.00 (6.04)	34.33 (5.90)	6.33 (2.61)	5.44 (2.43)	8.67 (3.03)	9.22 (3.11)	5.44 (2.44)	5.00 (2.34)
SEm±	0.24	0.31	0.13	0.15	0.14	0.11	0.16	0.15
CD (P=0.05)	0.70	0.94	0.37	0.45	0.40	0.33	0.49	0.47

**Figures within parentheses are √(x+0.5) transformed values*

Table 2. Effect of different herbicidal doses against dry weight of weed (g/m^2) in soybean at 45 DAS

Treatment	*Cyperus rotundus*	*Echinochloa crusgalli*	*Cynadon dactylon*	*Commelina benghalensis*	*Brachiaria ramosa*	*Phyllanthus niruri*	*Digera arvensis*	*Mollugo pentaphylla*
T_1 - Clomazone @ 1 kg/ha	30.79 (5.59)	19.11 (4.42)	0.76 (1.12)	6.72 (6.72)	3.33 (1.94)	1.27 (1.33)	5.90 (2.53)	0.26 (0.87)
T_2 - Pendimethalin @ 1 kg/ha	34.56 (5.91)	26.29 (5.17)	1.32 (1.37)	6.13 (2.57)	3.56 (2.01)	1.16 (1.29)	7.13 (2.76)	0.40 (0.94)
T_3 - Alachlor @ 1 kg/ha	32.44 (5.73)	25.32 (5.06)	1.27 (1.33)	6.29 (2.60)	3.83 (2.08)	1.02 (1.23)	6.90 (2.72)	0.34 (0.92)
T_4 - Imazethapyr @ 75 g/ha	15.59 (4.00)	5.95 (2.50)	0.56 (1.03)	2.42 (1.70)	2.27 (1.66)	0.75 (1.12)	2.54 (1.74)	0.16 (0.81)
T_5 - Imazethapyr + Imazamox @ 70 g ha^{-1}	6.33 (2.61)	2.15 (1.62)	0.50 (1.00)	1.00 (1.22)	1.22 (1.31)	0.45 (0.97)	0.28 (0.88)	0.08 (0.76)
T_6 - Quizalofop-p-ethyl @ 50 g/ha	14.91 (3.92)	4.74 (2.29)	0.58 (1.04)	4.54 (2.24)	1.44 (1.39)	4.27 (2.18)	7.26 (2.78)	1.53 (1.42)
T_7 - Chlorimuron-ethyl @ g/ha	47.02 (6.89)	33.79 (5.83)	3.19 (1.92)	1.99 (1.57)	6.10 (2.57)	0.77 (1.12)	1.11 (1.27)	0.15 (0.81)
T_8 - Quizalofop-p-ethyl @ 50 g/ha + Chlorimuron-ethyl 9 g/ha	7.39 (2.79)	6.16 (2.58)	0.73 (1.11)	2.18 (1.64)	2.17 (1.63)	0.78 (1.13)	1.62 (1.45)	0.41 (0.95)
T_9 - Hand weeding (20 & 40 DAS)	0.82 (1.14)	0.20 (0.84)	0.08 (0.76)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T_{10} - Weedy check	56.18 (7.52)	61.89 (7.87)	4.13 (2.15)	11.90 (3.52)	6.64 (2.67)	6.33 (2.60)	8.22 (2.95)	1.70 (1.48)
SEm±	0.20	0.21	0.05	0.08	0.07	0.07	0.07	0.04
CD (P=0.05)	0.60	0.63	0.14	0.24	0.20	0.20	0.21	0.12

**Figures within parentheses are √(x+0.5) transformed values*

Table 3. Effect of different weed control treatments on various growth and yield attributing characters, yield and economics of soybean

Treatment	Plant height (cm)	LAI (60 DAS)	Plant dry weight (g)	Number of pods/plant	100 seed weight (g)	Seed yield/ plant (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index
T_1 - Clomazone @ 1 kg/ha	33.00	2.57	154.79	10.93	2.47	0.19	644	797	43.80
T_2 - Pendimethalin @ 1 kg/ha	31.43	2.46	148.87	10.52	2.37	0.17	586	763	43.46
T_3 - Alachlor @ 1 kg/ha	32.03	2.51	150.68	10.70	2.40	0.17	630	775	43.64
T_4 - Imazethapyr @ 75 g/ha	34.67	2.81	161.59	11.52	2.63	0.20	713	777	44.08
T_5 - Imazethapyr + Imazamox @ 70 g ha^{-1}	36.62	2.87	177.70	12.67	2.83	0.22	825	1152	45.33
T_6 - Quizalofop-p-ethyl @ 50 g/ha	33.10	2.57	153.76	11.33	2.60	0.18	663	861	43.54
T_7 - Chlorimuron-ethyl @ g/ha	31.00	2.55	154.44	10.66	2.37	0.17	588	755	42.21
T_8 - Quizalofop-p-ethyl @ 50 g/ha + Chlorimuron-ethyl 9g/ha	36.33	2.84	159.53	12.17	2.77	0.19	733	894	44.33
T_9 - Hand weeding (20 & 40 DAS)	38.28	3.09	182.12	13.33	3.13	0.24	1033	1166	47.28
T_{10} - Weedy check	30.00	1.95	129.53	9.85	2.13	0.14	402	583	38.15
SEm±	0.62	0.08	1.45	0.33	0.07	0.01	25	33	0.98
CD (P=0.05)	1.85	0.23	4.29	0.99	0.21	0.02	74	98	2.89

"Hand weeding twice at 20 and 40 DAS gave significantly higher crop biomass and LAI as compared to the other treatments and it was at par with the combined application of chlorimuron+quizalofop-p-ethyl+vit-o-vit @ 9+75+750g/ ha as post- emergence. Application of chlorimuron + quizalofop-p-ethyl (12+50 g/ha) and imazethapyr (75 g/ha) was comparable with chlorimuron + quizalofop-p-ethyl+ vito-vit(9+75+750 g/ha) and significantly superior over weedy check in respect to crop biomass and LAI. The higher crop biomass might be due to better weed control by herbicidal mixture. Whereas a lower rate of chlorimuron (6 g/ha) applied as post-emergence was ineffective in curbing the weed menace and therefore produced inferior crop biomass" [6].

Different weed control treatments significantly affected various growth and yield attributing characters in soybean over control treatment. Taller plants and the highest plant dry matter were observed in the application of imazethapyr + imazamox @ 70 g/ha, quizalofop-p-ethyl @ 50 g/ha + chlorimuron-ethyl @ 9 g/ha and imazethapyr @ 75 g/ha as post-emergence over all the other treatments. This might be due to providing a favourable environment for crops with controlling weeds, which reduces the competition of crops with weeds for space, air, sunlight, moisture and nutrients. A significantly higher number of pods and seed weight per plant were found in imazethapyr + imazamox @ 70 g/ha, quizalofop-p-ethyl @ 50 g/ha + chlorimuron-ethyl @ 9 g/ha and imazethapyr @ 75 g/ha as a post-emergence application over all the other treatments. Similar results were earlier reported by Prachand et al. (2015).

4. CONCLUSION

The study well evaluated the efficacy of chlorimuron alone and its mixture with quizalofop-p–ethyl against weeds in soybeans. It was also discovered to be responsible for the maximum N, P, and K uptake by soybean crops and the lowest N, P, and K uptake by weed plants.

CONFERENCE DISCLAIMER

Some part of this manuscript was previously presented in the conference: 6th International Conference on Strategies and Challenges in Agricultural and Life Science for Food Security and Sustainable Environment (SCALFE-2023) on April 28-30, 2023 in Himachal Pradesh University, Summer Hill, Shimla, HP, India. Web Link of the proceeding: https://www.shobhituniversity.ac.in/pdf/Souvenir-Abstract%20Book-Shimla-HPU-SCALFE-2023.pdf

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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