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Performance of herbicides on effective weed management in soybean (*Glycine max*) crop

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ABSTRACT

Field experiment was conducted to study the efficacy of different post-emergence herbicides in the soybean (*Glycine max* (L.) Merr.). The selected herbicides were applied individually or in combination in soybean. A series of experiments were conducted during 2013 to 2017. Application of quizalofop-p-ethyl + chlorimuron ethyl and fenoxaprop-p-ethyl + chlorimuron ethyl along with surfactant at 15 days after sowing (DAS) were found effective herbicides for control of broad leaf weed and grasses in soybean crop. It was observed that post-emergence application of quizolofop-p-ethyl (50 g a.i.) + chlorimuron ethyl (6 g a.i./ha) significantly reduce the weed population (8/m^2), weed dry matter (2.3), weed index (0) and highest weed control efficiency (92.9%) and grain yield (1.77 t/ha) at 45 DAS followed by fenoxaprop-p-ethyl (50 g a.i.) + chlorimuron ethyl (6 g a.i./ha) compared to other treatments. Application of quizolofop-p-ethyl (50 g a.i.) + chlorimuron ethyl (6 g *a.i.*/ha) was found to minimize the loss (44.06%) caused by weeds and there by improve the uptake of water, air, and nutrition by the crop plants. Further, application of quizalofop-p-ethyl + chlorimuron ethyl + surfactant enhanced the number of nodule/plant (52.00), nodule diameter (5.00 mm) and nodule weight (187.2 mg/plant) followed by fenoxaprop-p-ethyl + chlorimuron ethyl + surfactant as compared to other treatments. Highest yield was recorded in the plants treated with quizalofop-p-ethyl + chlorimuron ethyl + surfactant in combination compared to other treatments. Quizalofop-p-ethyl and fenoxaprop-p-ethyl + chlorimuron ethyl along with surfactant were found to highly comparable in terms of price and yield compared to other methods of weed control including hand weeding. This combination can be recommended for the control of both broad and narrow leaf weed the soybean crop.

Key words: Economics, Herbicide, Soybean , Weeds, Yield

Soybean [*Glycine max* (L.) Merr.] is one of the most important leguminous crops which contain about 40% protein and 18% oil. In India, it is being cultivated in 11.39 million ha with an annual production of 13.7 million tons (www.iisrindore.gov.in 2016). Globally, weeds represent one of the major constraints in soybean production and causes substantial yield losses (31- 84%) in soybean crop (Kachroo *et al*. 2003). The degree of yield losses in soybean largely depend on the type of weed flora, their density and duration of competition for nutrient, water, light and space. Manual and mechanical weeding has been reported to control the weeds in soybean. Manual and mechanical weeding was found to effective but it is costly and time consuming. Many a time manual and mechanical weeding is not possible due to unfavorable weather conditions and less availability of labour force in the agriculture. Due to these factors, they have been least preferred in the current scenario of low-input agriculture. Therefore, as alternative of manual and mechanical weeding, several herbicides have been tested and used for the control of weeds in many crops including soybean. The selective herbicides have proven their role in the weed management system. Further, the importance of surfactants in the herbicide application has been well documented. They increase the retention of droplets on the leaf surface as most of herbicide droplets bounce off from the leaf surface during spraying and lowering the herbicide efficacy (Penner 2000, Young and Hart 1998). Therefore, improvement in the retention capacity of droplets with surfactant could be an approach to increase the herbicide performance and to reduce doses (Kudsk 2008). However, there is lack of information on use of crop specific herbicides, their doses, time and method of application and lack of knowledge make them less effective. Keeping in view of the above facts and considering the importance of the problem, the present investigation was undertaken with the objective to perform the different herbicides available in the market individually or in combination for effective

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control of weeds in soybean crop.

MATERIALS AND METHODS

Experimental set up

A series of field experiments were conducted in soybean (*cv*. JS-9305) at Instructional farm, Krishi Vigyan Kendra, Panna during the year 2013-14 to 2016-17. The soil was medium black, natural reaction 7.5 pH and low in OC (0.41%). The nitrogen, phosphorus and potassium content were 240, 17 and 360 kg/ha, respectively. The experiment was conducted in a randomized block design. Treatments were: Control, imazethapyr, fenoxaprop-p-ethyl, quizalofop-p-ethyl, fenoxaprop-p-ethyl + chlorimuron ethyl, quizalofop-p-ethyl + chlorimuron ethyl, imazethapyr + surfactant, fenoxaprop-p-ethyl + chlorimuron ethyl + surfactant, quizalofop-p-ethyl + chlorimuron ethyl + surfactant.

The seed-cum-fertidril was used to sow the seeds in lines with a planting distance of 45 × 10 cm. The sowing was done in the IInd fortnight of June during 2013-14 and 2016-17. The recommended dose of fertilizers (20:60:20 N,P,K kg/ha) were applied during sowing and no herbicide were applied in the check plots. Further, sufficient soil moisture was maintained at the time of herbicide spray. The herbicides were sprayed at 20 days after sowing (DAS) using knapsak sprayer fitted with flat fan nozzle (500 l/ha).

Sampling and analysis

Five plants from each plot were randomly uprooted along with a soil core at 45 DAS. Roots were washed properly and removed the adhering soil. Nodules were separated from the roots, counted and recorded the average diameter. Dry weights of plants and nodules were determined. The quadrate sampling was done to record the weed density at 45 DAS and harvest stage. For this, quadrate was placed randomly at five places in each plot and counted the weed species present in each plot. The percent composition of weed flora was recorded and compared with check plot. The weed biomass was recorded from different plots at 60 DAS. The weeds were first sun dried, thereafter kept in paper bags and finally dried in hot air oven at 60 ^{o}C for 48 hr. Dry weight of each sample was recorded.

RESULTS AND DISCUSSION

Weed spectrum

The major weeds were *Echinochloa colona* (16.2%), *Commelina benghalensis* (15.7%), *Commelina communis* (14.25%), *Eupharbia geniculata* (9.37%), *Euphorbia hirta* (8.9%), *Cynodon dactylon* (6.9%), *Echinochloa crusgallis* (6.7%), *Cyperus rotundus* (6.5%), *Corochorus acutangulus* (6%), *Cyperus iria* (3.3%), *Parthenium hysterophrous* (2.9%) and *Abolmuscus maschtus* (3.1%) at 45 DAS.

Effect of herbicide on weed population and density

Effects of different herbicides and their combination was explored for effective management of weed flora, growth, yield attributes and yield of Soybean (Table 1 & 2). The maximum weed intensity and weed dry weight were recorded in weedy check plot as compared to rest of the treatments across the years under investigation. However, the lowest weed counts/intensity and weed dry weights were observed in weed free treatment. The dry matter of weeds in weedy check plot was the maximum because of higher weed intensity and its dominance in utilizing the sunlight, nutrients, moisture, CO_2 *etc*. These results are in close conformity with those of Dhonde *et al*. (2009) and it was reduced drastically in all the other treatments (Table 1).

Table 1 Effect of herbicides application on nodulation and their dry weight and plant height at 45 DAS and weed parameter in soybean crop at 60 DAS

Treatment	Plant height (cm)	Nodule no.	Nodule diameter (mm)	Nodule dry weight (mg)/plant	Weed density (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Weed index (%)
Control	55	34	4.0	102	109	32.7	-	88.9
Imazethapyr75 g a.i./ha	56	37	4.2	118.4	65	18.98	41.5	41.7
Fenoxaprop p ethyal 50g a.i./ha	57	39	4.2	124.8	63	18.6	43.1	31.7
Quizalofop-p-ethyl 50g a.i./ha	56	40	4.2	128	59	17.3	47.1	19.8
Fenoxaprop p ethyl + Chlorimuron ethyl 50g+6g a.i./ha	59	42	4.5	151.2	32	9.3	71.5	17.6
Quizalofop-p-ethyl+ Chlorimuron ethyl 50g+6g/ a.i./ha	59	48	4.5	172.8	28	8.2	74.9	14.0
Imazethapyr + surfactant 75 g/ha+1250 ml/ha	62	48	4.5	172.8	9	2.6	92.0	5.0
Fenoxaprop p ethyal + Chlorimuron ethyl +surfactant 50g+6g a.i./ha+1250 ml/ha	63	51	4.8	183.6	10	2.9	92.1	2.1
Quizalofop-p-ethyl + Chlorimuron ethyl + surfactant 50g+6g a.i./ha+1250 ml/ha	64	52	5.0	187.2	8	2.32	92.9	-
LSD (P=0.05)	4.03	5.7	0.65	4.4	5.0	1.5	-	-

Table 2 Effect of different herbicides on yield and yield attributes and economics of soybean cultivation

Treatment	No. of pods/ plant	Days to 50% flowering	Test weight (g)	Yield (t/ha)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	C:B ratio
Control	15.0	52	104	0.99	19000	29700	10700	1:1.6
Imazethapyr 75 g a.i./ha	20.0	52	104	1.32	20100	39600	19500	1:1.9
Fenoxaprop p ethyl 50g a.i./ha	21.0	52	105	1.42	20100	42600	22500	1:2.1
Quizalofop-p-ethyl 50g a.i./ha	23.0	48	105	1.56	20500	46800	26300	1:2.3
Fenoxaprop p ethyl + Chlorimuron ethyl 50g+6g a.i./ha	23.5	48	105	1.59	20500	47700	27200	1:2.3
Quizalofop-p-ethyl+ Chlorimuron ethyl 50g+6g a.i./ha	24.0	46	104	1.62	20500	48600	28100	1:2.4
Imazethapyr + surfactant 75 g a.i./ha+1250 ml/ha	25.5	46	106	1.68	20750	50400	29650	1:2.4
Fenoxaprop p ethyl + Chlorimuron ethyl +surfactant 50g+6g a.i./ha+1250 ml/ha	26.0	45	107	1.73	20750	51900	31150	1:2.5
Quizalofop-p-ethyl + Chlorimuron ethyl + surfactant 50g+6g a.i./ha+1250 ml/ha	26.5	45	107	1.77	20750	53100	32350	1:2.6
LSD (P=0.05)	1.8		4.9	0.15	-	-	-	-

Significantly higher weed control efficiency (WCE) and long lasting effects of quizalofop-ethyl 50g a.i/ha + chlorimuron ethyl 6g a.i./ha reduced weed dry matter might be due to broad spectrum activity of herbicides. It affects establishment of both narrow and broad leaf weeds and quizalofop-p-ethyl and inhibit the activity of the acetyl-CoA carboxylase enzyme, which is necessary for fatty acid synthesis in grassy weeds. The effects of quizalofop for controlling grassy weeds in soybean were in confirmation with the earlier results reported by Pandey *et al.* (2007). It inhibit the fatty acid synthesis and chlorimuron ethyl to inhibit the process of cell division of meristemtic tissues as a result of which food reserves of treated plants are used up rapidly, causing slow growth relatively and killing process start and weeds dried rapidly (Das 2015). This integration of both of the herbicide quizalofop-p-ethyl (50 g a.i./ha) + chlorimuron ethyl (6g a.i./ha) and fenoxaprop -p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6g a.i./ha) followed by imazethapyr (75g a.i./ha) along with surfactants at 50 DAS resulted effective weed control (Basu and Sengupta 2012).

Maximum WCE (92.90%) was recorded in the plots treated with quizalofop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6g a.i./ha) which was superior than rest of the treatments. Application of quizalofop-p-ethyl (50g a.i./ha) and fenoxaprop p-ethyl (50g a.i./ha) PoE in combination with chlorimuron-ethyl (6g a.i./ha) PoE along with surfactant (1250 ml/ha) resulted in highest WCE (92 and 92.9%, respectively) and the lowest weed index (5 and 2.1%, respectively) at 15-20 DAS. However, application of quizalofop-p-ethyl (50g a.i./ha) and chlorimuron-ethyl (6g a.i./ha) PoE resulted WCE (74.9 and 14, respectively) as compared to control (0 and 88%, respectively) at 15-20 DAS. These combinations of herbicides along with surfactant have proved more effective than integration of other molecule. As surfactants have been found to reduce the dose of herbicides and increase the retention capacity of droplets and thereby increase the WCE (Singh *et al.* 2008, Walia *et al*. 2010).

Nodulation

The applied herbicides did not show adverse effect on the number, diameter and dry weight of root nodules formed in the soybean at 45 DAS (Table 2). These results are in agreement with the Kishinevsky *et al.* (1998). The integration of both quizalofop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6g a.i./ha) with surfactant (1250 ml/ha) and fenoxaprop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6 g a.i./ha) with surfactant (1250 ml/ha) were reported to enhanced the nodule number and significant increase in nodule dry weight as compared to weedy check. Maximum nodule number, nodule diameter and nodule dry weight was recorded with weed free check treatment, being significantly more of 8.8-52.8%, 5-25% and 16.1-83.5% over weedy check, respectively. Such beneficial effects of herbicides on nodule parameter may be due to effective weed control and minimizing the crop weed competition resulted better plant and nodule growth (Chandel and Saxena 2001). Further, the increased plant growth and development might be due to the herbicides treatments as they improve better nodulation and N_2 fixation. Further, the herbicides may have stimulatory effect and thereby increased the nodule dry weight significantly (Billore *et al*. 2001).

Days to 50% flowering

The results shows that application of quizalofop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6 g a.i./ha) + surfactant 1250 (ml/ha) and fenoxaprop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl (6g a.i./ha) + surfactant (1250 ml/ha) resulted the lowest number of days to 50% flowering (Table 2). The early flowering could be attributed to less weed competition for nutrients leading to early growth and development. No weeding plots recorded the highest number of days to 50% flowering. The observations supports the study conducted earlier by Odeleye *et al*. (2007) and Lamptey *et al.* (2015). They reported that flowering of soybean always delayed significantly in the fields haveing

high weed density and high weed interference affect the growth and development of the soybean.

Effect on crop

The maximum plant height (64 cm) was recorded in the plots treated with quizalofop-p-ethyl + chlorimuron ethyl + surfactant followed by fenoxaprop-p-ethyl + chlorimuron ethyl + surfactant (63cm), imazethapyr + surfactant (62 cm) and quizalofop-p-ethyl + chlorimuron ethyl treatments (59 cm) compared to weedy check plots (55 cm) at 45 DAS. Similarly, the highest number of pods per plant (26.5) and test weight (107 g) were recorded in above mentioned treatment and these values higher than other herbicide treatments including weedy check. Among the herbicides alone or in combination of two herbicides at 60 DAS, quizalofop-p-ethyl + chlorimuron ethyl + surfactant recorded the highest values of pods/plant (26.5) and test weight (107g) followed by application of fenoxaprop-p-ethyl (50g a.i) + clorimuron-ethyl (6g a.i./ha) along with surfactant (26 and 107 g, respectively). Although, the number of pods/plant and test weight (weight of 1000 seeds) are varietal characters but tremendous weed infestation caused stress to the crop plants with respect to nutrients, moisture, sunlight, space and other various aspects which are directly related to physiological processes of crop plants and they enforced the crop to have less number of pods/plant and test weight. It was evidenced from the results obtained in the weedy check plots (Meena *et al*. 2010).

The maximum seed yield (1.77 t/ha) was obtained within the plots treated with quizalofop-p-ethyl + chlorimuron ethyl + surfactant (50g+6g a.i./ha+1250 ml/ha) which was significantly higher than weedy check plot (990 kg/ha) and other treatments. The lowest seed yields was recorded in weedy check plots might be due to the high weeds density since the beginning of crop emergence and resulted great competition with crop plants for nutrients, moisture and/ sunlight. However, amongst the set of combined herbicide treatments, the maximum seed yield was recorded in quizalofop-p-ethyl (50g a.i.) + chlorimuron-ethyl (6g a.i./ ha) PoE followed by fenoxaprop-p-ethyl (50g a.i./ha) PoE + chlorimuron-ethyl (6g a.i. /ha) PoE (1.73 t/ha). Higher grain yields in these treatments is might be due to effective weed control as reflected in lower weed dry matter, higher WCE, better plant growth and yield attributes (Table 2). It can be explained in the light of the facts that these treatments control the weeds effectively, therefore more nutrients available to crop and consequently encouraged higher concentration of nutrients and more yields. This variation in weed control could be due to infestation of various weed species and climatic conditions including rainfall distribution pattern. These findings are in concurrence with the earlier workers (Jha and Soni 2013; Habimana *et al*. 2013b; Basu and Sengupta 2012).

Economic evaluation

Higher gross returns (₹ 39600-53100) and net returns (₹ 19500-32350/ha) were obtained from improved weed management practices compared to control (₹ 29700) and (₹ 10700/ha), respectively (Table 2). The returns per rupee investment were accordingly higher in improved weed management practices (1:2.3 to 1:2.6) as compared to control plot (1:1.6).

It can be concluded that application of quizalofop-p-ethyl and fenoxaprop-p-ethyl (50g a.i./ha) + chlorimuron-ethyl at (6 g/ha) + surfactant (1250 ml/ha) was found to mere effective followed by imazethapyr at (75 g/ha) + surfactant (1250 ml/ha) at 15-20 DAS resulted in higher grain yield of soybean.

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