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Bio-efficacy of promising herbicides alone and in combination against major weeds in soybean

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Abstract
A field experiment was conducted during rainy (*Kharif*) seasons of 2014 and 2015 at Agriculture Research Station, Kasbe Digraj, Sangli, Mahatma Phule Agricultural University, Maharashtra, India. The dominant broad-leaved weeds in the field were *Commelina benghalensis*, *Acalypha indica*, *Digera arvensis*, *Parthenium hysterophorus*, *Amaranthus viridis* and *Euphorbia geniculata*. Grassy weeds were *Echinochloa colonum*, *Brachiaria reptans*, *Dinebra arabica*, *Digitaria longiflora* and *Cynadon dactylon* and *Cyperus rotundus* as sedge. Results revealed that, pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} recorded significantly lower weed density and weed dry weight at 30 and 45 DAS during *Kharif* 2014 and 2015. Higher weed control efficiency was recorded with pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} at 30 and 45 DAS (86.19 and 82.32 % during *Kharif* 2014 and 88.92 and 85.24% during *Kharif* 2015, respectively). Pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} recorded significantly higher seed yield (1.75 & 1.80 t ha^{-1} during *Kharif* 2014 and 2015, respectively) and which was at a par with application of Imazethapyr @ 100 g a.i. ha^{-1} as post-emergence and twice hand weeded check with highest B:C ratio.

Keywords: Bio-efficacy, herbicides, soybean, weeds, weed control efficiency

Introduction
Soybean (*Glycine max* L.) is mostly grown for oil (20%) and protein (40%) around the world. In India, it is cultivated over 10.84 million hectares area with a production and productivity of 14.68 million tones and 1.35 t ha^{-1}, respectively. In Maharashtra, it is grown over an area of 3.22 million hectares with a production and productivity of 4.67 million tones and 1.45 t ha^{-1}, respectively (Anonymous 2013) [2]. The national productivity of soybean (1.3 t ha^{-1}) is low as compared to world average 2.4 t ha^{-1} (Agarwal *et al.* 2013) [1]. One of the major reasons for lower productivity is abiotic and biotic factors encountered during crop season. Weeds are the major biotic factor responsible for poor soybean yield. Weeds alone are responsible for reduction in seed yield of soybean to the range of 25 to 70% depending upon the weed flora and intensity. Therefore, it is important to keep the soybean crop weed free as far as possible, so as to get higher seed yield (Kewat *et al*. 2000) [8]. Malik *et al*. (2006) [10] have reported 55% soybean yield reduction with broad-leaved weeds (80%), grasses and sedges (20%) infestation throughout the crop season. Hand-weeding is a traditional and effective method of weed control, but it is time consuming and difficult due to unavailability of laborers during peak period of demand. Hence, the only alternative that needs to be explored is the use of herbicide. Newer molecules of herbicides are promising for control of monocotyledonous or dicotyledonous weeds. Further, herbicide mixtures may broaden the window of weed management by broad spectrum weed control (Bineet *et al.* 2001) [4]. Therefore, the present investigation was initiated to assess bio-efficacy of herbicides for effective management of weeds and higher productivity of soybean.

Materials and Methods
A field experiment was conducted at Agriculture Research Station, Kasbe Digraj, Sangli, Mahatma Phule Agricultural University, Maharashtra, India during *Kharif* seasons of 2014 and 2015. Average rainfall of station is 692.4 mm in 49 rainy days. The experiment was laid out in medium deep black soil (0 - 45 cm depth) which was low in available nitrogen (167 kg ha^{-1}) and phosphorus (11.50 kg ha^{-1}) content, and high in available potash content (632 kg ha^{-1}) with pH 8.27. The experiment consisted of eleven treatments *viz.*, Sulfentrazone (28% EC) + Clomazone (30% WP) as PE @ 580, 725 and 870 g a.i. ha^{-1}, Clomazone (50% EC) @ 375 and

1000 g a.i. ha^{-1} as PE, Sulfentrazone (48% EC) @ 350 and 360 g a.i. ha^{-1} as PE, Pendimethalin (30% EC) + Imazethapyr (2% EC) @ 960 g a.i. ha^{-1} as PE and Imazethapyr (10% SL) @ 100 g a.i. ha^{-1} as PoE along with hand weeding twice at 20 and 40 days after sowing (DAS) and a weedy check which were replicated thrice in a randomized block design. The gross and net plot size of the experiment were 5 m x 3.6 m and 4.5 m x 2.7 m, respectively. Soybean seed (75 kg ha^{-1}) of variety *'KDS-344'* was sown on 05 July, 2014 and 01 July, 2015 at 45 cm x 5 cm spacing. Crop was applied with recommended dose of fertilizer i.e. 75:50:0 N: P_2O_5:K_2O kg ha^{-1}. Before sowing, the seeds were treated with Carbendazim @ 2.0 g kg^{-1} of seed followed by inoculation with *Rhizobium japonicum* culture @ 5 g kg^{-1} of seed. All the Pre-emergence herbicides were applied just after sowing of soybean while post-emergence herbicides were applied after 15-20 days of sowing (DAS) with knapsack sprayer fitted with flat-fan nozzle using 500 litres of water per hectare.

Data on species wise weed density at 30 and 45 days after sowing (DAS) was recorded using a quadrant of 1m × 1m from three random spots per plot and the average was reported as weed density (m^{-2}). The weeds were oven dried and total weed dry weight was recorded at 30 and 45 DAS and expressed as (g m^{-2}). Data of both weed density and total weed dry weight analyzed statistically using suitable square root transformation. Weed control efficiency measures the efficiency of any weed control treatment in comparison to weedy treatment. To adjudge the efficiency of weed control treatments, weed control efficiency (WCE) was calculated (Das, 2008) [6] as follows:

$$WCE\ (\%) = \frac{DWC\text{-}DWT}{DWC} \times 100$$

(Where, WCE = Weed control efficiency in percent, DWC = Dry weight of weeds in control plot and DWT = Dry weight of weeds in treated plot) Crop was harvested at physiological maturity on 26 October, 2014 and 21 October, 2015. After the harvest, threshing was done and seed yield of each treatment was recorded and expressed as t ha^{-1}. The yield attributes *viz*., number of pods plants^{-1}; number of seeds pod^{-1} and 100 seed weight (g) were recorded. Gross returns, net returns as well as B:C ratio were worked out using prevailing prices of inputs and outputs. The data of each year was analyzed separately. MSTAT was used for statistical analysis of data and means were separated using least significant difference (CD) at p=0.05.

Results and Discussion

Effect on weeds

The experimental field at 30 and 45 days after sowing (DAS) was infested with broad-leaved weeds (41.0 and 43.1% during *Kharif* 2014 and 44.3 and 43.8% during *Kharif* 2015, respectively).

Table 1: Total weed count and percentage of different weed species

Weed species	Total weed count (m^{-2})				Percent (%)			
	Kharif 2014		*Kharif* 2015		*Kharif* 2014		*Kharif* 2015	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
Broad-leaved weeds	100.41	130.42	113.94	138.01	41.0	43.1	44.3	43.8
Grasses	106.46	122.46	106.78	130.84	43.4	40.5	41.6	41.5
Sedges	38.20	49.75	36.21	46.17	15.6	16.4	14.1	14.7
Total	245.07	302.63	256.93	315.02	100.0	100.00	100.00	100.00

The predominant broad-leaved weeds in the field were *Commelina benghalensis*, *Acalypha indica*, *Digera arvensis*, *Parthenium hysterophorus*, *Amaranthus viridis* and *Euphorbia geniculata*. All the weed control treatments caused significant reduction in broad-leaved weed density at both stages 30 and 45 DAS of observations during *Kharif* 2014 and 2015 as compared to weedy check. Application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence, Imazethapyr @ 100 g a.i. ha^{-1} as post-emergence and twice hand weeded check recorded significantly lower broad-leaved weed density compared to other weed control treatments in *Kharif* 2014 and 2015 when observed at 30 and 45 DAS.

Table 2: Effect of weed control treatments on weed density in soybean

Treatment	Broad-leaved weeds (m^{-2})				Grasses (m^{-2})				Sedges (m^{-2})			
	Kharif 2014		*Kharif* 2015		*Kharif* 2014		*Kharif* 2015		*Kharif* 2014		*Kharif* 2015	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
T_1- Sulfentrazone + Clomazone @ 580 g a.i. ha^{-1} as PE	3.06 (8.37)	3.48 (11.14)	3.32 (9.99)	3.57 (11.76)	3.02 (8.12)	3.23 (9.42)	3.28 (9.74)	3.66 (12.43)	2.26 (4.10)	2.43 (4.89)	1.93 (2.74)	2.24 (4.03)
T_2-Sulfentrazone + Clomazone @ 725 g a.i. ha^{-1} as PE	2.29 (4.24)	2.89 (7.38)	2.52 (5.33)	2.93 (7.56)	2.24 (4.03)	2.75 (6.54)	2.48 (5.16)	2.83 (7.02)	1.96 (2.86)	2.19 (3.78)	1.83 (2.34)	2.05 (3.22)
T_3-Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as PE	2.06 (3.24)	2.61 (5.82)	2.08 (3.32)	2.61 (5.81)	2.00 (3.02)	2.36 (4.56)	2.17 (3.72)	2.52 (5.34)	1.69 (1.85)	1.83 (2.36)	1.66 (1.77)	1.82 (2.32)
T_4-Clomazone @ 375 g a.i. ha^{-1} as PE	3.78 (13.28)	4.21 (16.69)	3.92 (14.40)	4.35 (17.91)	4.03 (15.24)	4.27 (17.23)	3.78 (13.32)	4.17 (16.43)	2.60 (5.78)	2.83 (7.00)	2.61 (5.80)	2.79 (6.78)
T_5-Sulfentrazone @ 350 g a.i. ha^{-1} as PE	3.20 (9.22)	3.78 (13.27)	3.52 (11.41)	3.75 (13.09)	3.71 (12.75)	3.93 (14.47)	3.42 (10.67)	3.75 (13.08)	1.97 (2.87)	2.50 (5.24)	1.99 (2.98)	2.26 (4.12)
T_6-Clomazone @ 1000 g a.i. ha^{-1} as PE	3.59 (11.89)	3.92 (14.39)	3.71 (12.73)	4.19 (16.57)	3.77 (13.22)	4.00 (14.99)	3.23 (9.45)	3.61 (12.03)	2.52 (5.33)	2.77 (6.67)	2.62 (5.89)	2.70 (6.31)
T_7-Sulfentrazone @ 360 g a.i. ha^{-1} as PE	3.19 (9.15)	3.62 (12.10)	3.36 (10.27)	3.64 (12.23)	3.44 (10.84)	3.58 (11.84)	3.35 (10.25)	3.73 (12.95)	1.82 (2.33)	2.45 (5.00)	1.90 (2.62)	2.25 (4.05)
T_8-Pendimethalin + Imazethapyr @ 960 g a.i. ha^{-1} as PE	2.98 (7.86)	3.40 (10.56)	3.17 (9.02)	3.46 (10.98)	3.00 (7.98)	3.16 (8.97)	3.16 (8.97)	3.60 (11.98)	2.23 (3.98)	2.25 (4.06)	1.89 (2.56)	2.22 (3.94)

T_9-Imazethapyr @ 100 g a.i. ha^{-1} as PoE	2.19 (3.78)	2.73 (6.45)	2.17 (3.70)	2.74 (6.53)	2.18 (3.76)	2.45 (4.98)	2.27 (4.16)	2.64 (5.96)	1.75 (2.05)	1.93 (2.72)	1.73 (2.01)	1.97 (2.88)
T_{10}-Hand weeding twice (20 and 40 DAS)	1.50 (1.24)	1.42 (1.01)	1.52 (1.32)	1.44 (1.08)	1.44 (1.08)	1.36 (0.85)	1.46 (1.12)	1.39 (0.92)	1.43 (1.05)	1.32 (0.75)	1.44 (1.08)	1.30 (0.70)
T_{11}-Weedy check	5.40 (28.14)	5.71 (31.61)	5.78 (32.45)	5.96 (34.49)	5.24 (26.42)	5.44 (28.61)	5.59 (30.22)	5.81 (32.70)	2.65 (6.00)	2.88 (7.28)	2.72 (6.42)	2.97 (7.82)
SEm ±	0.08	0.09	0.08	0.09	0.10	0.10	0.11	0.11	0.06	0.07	0.06	0.07
CD (P=0.05)	0.24	0.27	0.25	0.27	0.29	0.31	0.34	0.33	0.18	0.21	0.19	0.22

Data in parentheses are original weed density values; Data was subjected to square root transformation ($\sqrt{x+1}$). DAS: Days after sowing

Among the different herbicide treatments, application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence recorded significantly lower broad-leaved weed density at 30 and 45 DAS (3.24 and 5.82 m^{-2} during *Kharif* 2014 and 3.32 and 5.32 m^{-2} during *Kharif* 2015, respectively) compared to other herbicide treatments and was on-par with post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1} (Table 2). Further, weedy check recorded significantly higher weed population of broad-leaved weeds during both seasons at both stages 30 and 45 DAS of observations.

The experimental field at 30 and 45 days after sowing (DAS) was infested with grassy weeds (43.4 and 40.5% during *Kharif* 2014 and 41.6 and 41.5% during *Kharif* 2015, respectively). The predominant grassy weeds in field were *Echinochloa colonum*, *Brachiaria reptans*, *Dinebra arabica*, *Digitaria longiflora* and *Cynadon dactylon*. Application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence, Imazethapyr @ 100 g a.i. ha^{-1} as post-emergence and twice hand weeded check found to be significantly superior treatment which recorded lowest population of grassy weeds over rest of the treatments. Among the different herbicide treatments, application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence recorded significantly lower grassy weed density at 30 and 45 DAS (3.02 and 4.56 m^{-2} during *Kharif* 2014 and 3.72 and 5.34 m^{-2} during *Kharif* 2015, respectively) compared to other herbicide treatments and was on-par with post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}. Highest population of grassy weeds was recorded in weedy check during *Kharif* 2014 and 2015 when observed at 30 and 45 DAS.

The experimental field at 30 and 45 DAS was infested with sedges (15.6 and 16.4% during *Kharif* 2014 and 14.1 and 14.7% during *Kharif* 2015, respectively). Application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence, Imazethapyr @ 100 g a.i. ha^{-1} as post-emergence and twice hand weeded check were found equally efficient in controlling the sedges in soybean. However, among the different herbicide treatments, application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as pre-emergence recorded significantly lower density of sedges at 30 and 45 DAS (1.85 and 2.36 m^{-2} during *Kharif* 2014 and 1.77 and 2.32 m^{-2} during *Kharif* 2015, respectively) compared to other herbicide treatments and was on-par with post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}. Weedy check recorded significantly higher sedges population as compared to other weed controlling treatments during both seasons when observed at 30 and 45 DAS. Many researchers have reported lower weed densities in soybean with the use of herbicides like Sulfentrazone by Vidrine *et al*. (1996) [14]; Niekamp *et al.* (2001) [13]; Krausz *et al.* (2003) [9] and Clomazone by Werling and Bhuler, (1988) [15] and Pendimethalin by Nayak *et al.* (2000) [12]; Chauhan *et al.* (2002) [5] and Imazethapyr by Meena *et al.* (2011) [11].

Pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1}, post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1} and twice hand weeded check found to be significantly superior over rest of the treatments in controlling the weeds and recorded least total dry weight of weeds at both stages 30 and 45 DAS of observations during *Kharif* 2014 and 2015. Further, weedy check recorded significantly higher total dry weight of weeds as compared to other weed control treatments during both seasons when observed at 30 and 45 DAS. Twice hand weeded check recorded highest weed control efficiency at 30 and 45 DAS during both seasons.

Table 3: Total weed dry weight and weed control efficiency as influenced by different treatments in soybean

Treatment	Total weed dry weight (g m^{-2})				WCE (%)			
	Kharif 2014		*Kharif* 2015		*Kharif* 2014		*Kharif* 2015	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
T_1- Sulfentrazone + Clomazone @ 580 g a.i. ha^{-1} as PE	2.24 (4.03)	3.02 (8.13)	2.29 (4.24)	3.16 (8.97)	73.50	68.23	74.40	70.95
T_2-Sulfentrazone + Clomazone @ 725 g a.i. ha^{-1} as PE	2.00 (3.01)	2.66 (6.09)	1.99 (2.97)	2.70 (6.29)	80.23	76.20	82.03	79.65
T_3-Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as PE	1.76 (2.10)	2.35 (4.53)	1.68 (1.83)	2.36 (4.56)	86.19	82.32	88.92	85.24
T_4-Clomazone @ 375 g a.i. ha^{-1} as PE	2.66 (6.05)	3.49 (11.18)	2.70 (6.30)	3.79 (13.35)	60.22	56.33	61.91	56.78
T_5-Sulfentrazone @ 350 g a.i. ha^{-1} as PE	2.42 (4.86)	3.19 (9.17)	2.47 (5.12)	3.51 (11.33)	68.05	64.18	69.04	63.32
T_6-Clomazone @ 1000 g a.i. ha^{-1} as PE	2.51 (5.29)	3.35 (10.20)	2.57 (5.61)	3.65 (12.32)	65.22	60.14	66.08	60.12
T_7-Sulfentrazone @ 360 g a.i. ha^{-1} as PE	2.30 (4.28)	3.00 (8.01)	2.32 (4.39)	3.23 (9.41)	71.88	68.71	73.45	69.54
T_8-Pendimethalin + Imazethapyr @ 960 g a.i. ha^{-1} as PE	2.19 (3.80)	2.92 (7.51)	2.18 (3.75)	3.10 (8.64)	75.02	70.66	77.32	72.03
T_9-Imazethapyr @ 100 g a.i. ha^{-1} as PoE	1.82 (2.31)	2.51 (5.32)	1.81 (2.29)	2.54 (5.43)	84.83	79.21	86.18	82.42
T_{10}-Hand weeding twice (20 and 40 DAS)	1.38 (0.91)	1.37 (0.88)	1.39 (0.92)	1.36 (0.86)	94.04	96.58	94.42	97.23

T_{11}-Weedy check	4.03 (15.21)	5.16 (25.60)	4.19 (16.55)	5.65 (30.89)	-	-	-	-
SEm ±	0.08	0.10	0.08	0.11	-	-	-	-
CD (P=0.05)	0.23	0.31	0.25	0.33	-	-	-	-

Data in parentheses are original total weed dry weight values; Data was subjected to square root transformation ($\sqrt{x+1}$). DAS: Days after sowing

Among the different herbicide treatments, pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} recorded higher weed control efficiency at 30 and 45 DAS (86.19 and 82.32 % during *Kharif* 2014 and 88.92 and 85.24% during *Kharif* 2015, respectively) and it was followed by post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1} (Table 3).

These results were in conformity with the findings of Fisher *et al.* (2001) [7] who stated that the application of Sulfentrazone + Clomazone 0.28 + 0.84 kg ha^{-1} as pre-emergence effectively controls many broadleaf weeds, grasses and sedges including morning glory (*Ipomoea* spp.), pigweeds (*Amaranthus* spp.), crabgrass (*Digitaria* spp.), yellow (*Cyperus esculentus*) and purple nutsedges (*Cyperus rotundus*) as compared to cultivated check in tobacco. The effectiveness of pre and post-emergence herbicides was found to be equal for managing weeds in soybean (Billore *et al*. 1999) [3].

Yield attributes and economics

Highest seed yield (1.92 & 1.95 t ha^{-1} during *Kharif* 2014 and 2015, respectively) was recorded in twice hand weeded check which was significantly higher over rest of the treatments and was on-par with pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} and post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}. Among the different herbicide treatments, pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} recorded significantly higher seed yield (1.75 & 1.80 t ha^{-1} during *Kharif* 2014 and 2015, respectively) and which was at a par with application of Imazethapyr @ 100 g a.i. ha^{-1} (Table 4). The yield enhancement due to weed control treatments was to the tune of (23.53 to 125.88% during *Kharif* 2014 and 20.00 to 116.67% during *Kharif* 2015, respectively) over weedy check. Further, weedy check recorded significantly lower seed yield (0.85 and 0.90 t ha^{-1} during *Kharif* 2014 and 2015, respectively) as compared to other weed control treatments. Number of pods plant^{-1} was highest (45.7 and 46.3 during *Kharif* 2014 and 2015, respectively) in twice hand weeded check and was on-par with pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} and post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}. Lowest pods plant^{-1} was recorded in weedy check plot during *Kharif* 2014 and 2015. No. of seeds pod^{-1} and 100 seed weight (g) were not significantly different among treatments.

Table 4: Yield attributes and economics of soybean as influenced by various treatments

Treatment	No. of pods plant^{-1}		No. of seeds pod^{-1}		100 seed weight (g)		Seed yield (t ha^{-1})		Gross returns (x10^3 `ha^{-1})		B:C ratio	
	Kharif 2014	*Kharif* 2015	*Kharif* 2014	*Kharif* 2015	*Kharif* 2014	*Kharif* 2015	*Kharif* 2014	*Kharif* 2015	*Kharif* 2014	*Kharif* 2015	*Kharif* 2014	*Kharif* 2015
T_1-Sulfentrazone + Clomazone @ 580 g a.i. ha^{-1} as PE	41.3	42.0	3.00	3.33	11.88	12.10	1.35	1.39	40.89	43.72	1.82	1.89
T_2-Sulfentrazone + Clomazone @ 725 g a.i. ha^{-1} as PE	42.3	43.3	3.33	3.66	11.90	12.15	1.42	1.46	43.01	45.92	1.89	1.97
T_3-Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} as PE	44.7	45.3	3.33	3.66	12.50	12.95	1.75	1.80	53.01	56.61	2.31	2.40
T_4-Clomazone @ 375 g a.i. ha^{-1} as PE	34.7	35.3	3.00	3.00	11.85	12.05	1.05	1.08	31.80	33.87	1.44	1.48
T_5-Sulfentrazone @ 350 g a.i. ha^{-1} as PE	38.3	39.7	3.00	3.33	12.10	12.35	1.25	1.29	37.86	40.45	1.71	1.75
T_6-Clomazone @ 1000 g a.i. ha^{-1} as PE	38.0	39.0	3.33	3.00	11.98	12.00	1.22	1.24	36.95	38.89	1.64	1.68
T_7-Sulfentrazone @ 360 g a.i. ha^{-1} as PE	40.0	40.4	3.00	3.66	12.20	12.25	1.30	1.33	39.38	41.71	1.77	1.79
T_8-Pendimethalin + Imazethapyr @ 960 g a.i. ha^{-1} as PE	42.7	43.3	3.33	3.66	12.10	12.50	1.38	1.42	41.80	44.57	1.85	1.88
T_9-Imazethapyr @ 100 g a.i. ha^{-1} as PoE	44.3	44.5	3.33	3.66	12.45	12.70	1.65	1.72	49.98	54.04	2.18	2.25
T_{10}-Hand weeding twice (20 and 40 DAS)	45.7	46.3	3.66	3.66	12.60	12.92	1.92	1.95	58.16	61.39	1.81	1.83
T_{11}-Weedy check	28.0	30.3	2.66	3.00	11.65	12.05	0.85	0.90	25.75	28.17	1.29	1.34
SEm ±	0.80	0.90	0.32	0.34	0.28	0.30	0.09	0.10	-	-	-	-
CD (P=0.05)	2.40	2.70	NS	NS	NS	NS	0.27	0.31	-	-	-	-

Maximum gross returns was realized under the twice hand weeded check and it was followed by pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} and post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}. However, among the different weed control treatments, pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} recorded the highest B:C ratio (2.31 and 2.40 during *Kharif* 2014 and 2015, respectively) followed by post-emergence application of Imazethapyr @ 100 g a.i. ha^{-1}.

Conclusion

It may be concluded that pre-emergence application of Sulfentrazone + Clomazone @ 870 g a.i. ha^{-1} was found most effective for control of major weeds in soybean with higher yield and monetary returns.

References

1. Agarwal DK, Billore SD, Sharma AN, Dupare BU, Srivastava SK. Soybean: introduction, improvement and utilization in India-problems and prospectus. Journal of Agricultural Research. 2013; 2(4):293-300.
2. Anonymous. Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India, New Delhi. 2013, 69-70.

3. Billore SD, Joshi OP, Ramesh A. Energy productivity through herbicidal weed control in soybean. Indian Journal of Agricultural Science. 1999; 69(11):770-772.
4. Bineet M, Andani G, Mohamed TA. Herbicide mixture in agriculture: a review. Proceedings of Biennial Conference, Indian Society of Weed Science, held at Bangalore, 2001, 236.
5. Chauhan YS, Bhargava MK, Jain VK. Effect of herbicides on weeds and soybean. Indian Journal of Weed Science. 2002; 34(3&4):213-216.
6. Das TK. Weed science: basics and applications. 1st Edition, Jain Brothers Publishers, New Delhi, 2008, 901.
7. Fisher LR, David Smith W. Effect of sulfentrazone application and combination with clomazone or pendimethalin on weed control and phytotoxicity in flue-cured tobacco. Tobacco Science. 2001; 45:30-34.
8. Kewat ML, Pande J, Yaduraju NJ, Kulshreshtha G. Economic and ecofriendly weed management in soybean. Weed Science. 2000; 32(3&4):135-139.
9. Krausz RF, Young BG. Sulfentrazone enhances weed control of glyphosate in glyphosate-resistant soybean *(Glycine max).* Weed Technology. 2003; 17(2):249-255.
10. Malik RS, Yadav Ashok, Malik RK. Integrated weed management in soybean. Indian Journal of Weed Science. 2006; 38(1&2):65-68.
11. Meena DS, Baldev Ram, Chaman Jadon, Tetarwal JP. Efficacy of imazethapyr on weed management in soybean. Indian Journal of Weed Science. 2011; 43(3&4):169-171.
12. Nayak MP, Vyas MD, Mandloi KS. Efficacy of pendimethalin in soybean (*Glycine max*). Indian Journal of Agronomy. 2000; 45(1):162-165.
13. Niekamp JW, Johnson WG. Weed management with sulfentrazone and flumioxazin in no-tillage soybean (*Glycine max*). Crop Protection. 2001; 20(3):215-220.
14. Vidrine PR, Griffin JL, Jordan DL, Reynolds DB. Broadleaf weed control in soybean (*Glycine max*) with sulfentrazone. Symposium of the weed science society. 1996; 10(4):965-973.
15. Werling VL, Buhler DD. Influence of application time on clomazone activity in no-till soybean (*Glycine max*). Weed Science. 1988; 36(5):629-635.