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Efficacy of Sulfentrazone 39.6% and Pendimethalin as a Pre Emergence Application against Weed Spectrum of Soybean (*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.

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ABSTRACT

A field experiment was conducted during *Kharif* season of 2017 at the Research Farm, College of Agriculture, Jabalpur, Madhya Pradesh. The seven treatments comprising of four doses of sulfentrazone (180, 360, 540 and 720 g/ha), application of pendimethalin (750 g/ha) as pre emergence, hand weeding twice at 20 and 40 days after sowing (DAS) including weedy check, were laid out in randomized block design with 3 replications. Results revealed that, *Echinochloa colona* (28.24%) was the dominant weed species closely followed by *Commelina communis* (24.42%). However, other monocot weed like *Cyperus rotundus (*15.56%) and dicots like *Phyllanthus niruri* (19.34%) and *Euphorbia hirta* (12.44%) were also found associated with soybean in less numbers. Application of T4- sulfentrazone at 720 g/ha as pre emergence arrested the weed

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growth remarkably and proved superior to its lower dose (180 g/ha) and application of pendimethalin 750 g/ha. The poor crop-weed competition due to effective control of weeds under this treatment resulted in higher weed control efficiency. Pre-emergence application of T4- sulfentrazone at 720 g/ha recorded maximum grain yield and was at par with other individual herbicides. Similarly, higher net returns and benefit: cost ratio were recorded in T4- sulfentrazone at 720 g/ha fb T3- sulfentrazone at 540 g/ha. It may be inferred from the present investigation that these herbicidal treatments could be used effectively as an alternative for controlling weeds and obtaining optimum seed yield of soybean.

Keywords: Growth parameters; seed yield; soybean; sulfentrazone; weed control.

1. INTRODUCTION

Soybean (*Glycine max* L. Merrill) is a native of North-eastern China belongs to the family *Fabaceae*. Soybean was introduced to India during 1880 AD. Soybean is one of the important pulse and oilseed crops of India. It grows well during the *kharif* or monsoon, season (July-October) in the dry land areas of peninsular India [1]. It is known as "Golden bean" and miracle crop of 20th century. It contains about 20% oil and 40–42% high-quality protein as compared to 20–25% in other legumes [2]. In India it is grown in 10.50 million hectares with the production of 9.50 million tonnes. Madhya Pradesh is a leading state in India for cultivation of soybean, where it is grown in 5.01 million hectares with the total production of 4.20 million tonnes. But the productivity is 838 kg/ha which is far below than its yield potential *i.e.* 2500 kg/ha [3]. Its seeds are also used to make protein-rich goods such as soy milk, soy cheese (paneer), soy sauce, and soy flour [4]. Soybean leaves residual nitrogen equivalent to 35-40 kg/ha for the succeeding crop, which contributes in soil fertility improvement.

There are various factors which are responsible for lower productivity of soybean in the state but weeds are the major culprit which causes more yield reduction [5]. Weeds are a key challenge to maintaining increased crop production because they compete for nutrients, moisture, solar radiation, and space with crops [6]. Weed problems differ based on crop, agro-ecological factors, growth season, and management practices [7]. Weeds also serve as an alternate host for certain insect pests and disease-causing pathogens [8]. Weeds are the most significant biological constraints, accounting for over 34% of global yield loss, compared to 18% and 16% for insect pests and diseases, respectively, in essential field crops such as rice [9,10], wheat [11,12], maize, soybean, and cotton. The ecological conditions of the state are congenial for cultivation of soybean but the yield is substantially low, due to infestation of weeds. In *kharif* season due to continuous rains, there will be high weed infestation and high weed competition is one of the most important causes of yield loss in soybean and is estimated to be 22-77 per cent [13,14].

In modern agriculture, intensive use of herbicides is gaining popularity in recent years because of easy and timely application, lower cost and effectiveness in controlling weeds [15]. Herbicides are often used to increase crop production in circumstances when manpower is limited and expensive [16]. Chemical weed management has been proven beyond question to be more cost-efficient than manual weeding [17,18]. Manual weeding, although efficient in reducing weed competition, but it has various disadvantages, including a lack of sufficient labour during peak periods, high labour costs, and being time-consuming [19,20]. Herbicide use should be thoroughly investigated to build a herbicide-based weed management strategy for soybean in the area of Central India in order to attain a higher soybean yield and a better economic return from weed control. However, no research has been conducted to design a herbicide-based weed management strategy that is both successful and cost-efficient for soybean cultivation in the region. As a result, the aim of this research was to develop an effective and cost-effective weed management strategy for soybean production in Central India using pre-emergence herbicides. Thus, a field experiment was carried out to evaluate the performance of sulfentrazone herbicides in weed management.

2. MATERIALS AND METHODS

A field experiment was conducted at the Research Farm, College of Agriculture, Jabalpur, Madhya Pradesh during *Kharif* season of the year 2017 in randomized block design with seven treatments replicated thrice. The experimental site was located at 23^0 09' North latitude and 79^0

58' East longitudes with an altitude of 411.78 meters above the mean sea level with average annual rainfall of 890 mm. The soil of experimental field was clayey in texture, neutral in reaction with pH 7.2 with medium available N (365 kg/ha), medium P (16.34 kg/ha) and high in K (327.16 kg/ha). The gross and net plot sizes were 5.0 m x 3.6 m and 4.0 m x 2.7 m, respectively. The soybean variety *'JS 20-29'* was sown at 45cm X 5cm spacing on 17th July, 2017. The rows were opened with the help of pick axe and later sowing was done for each plot using a seed rate of 70 kg/ha. Treatment consist of recommended practice of weed control hand weeding twice and pre emergence application of sulfentazone at different doses at 180, 360, 540 & 750 g/ha and pendimethalin 750 g/ha as pre emergence application. Hand weeding was practiced at 20 and 40 DAS (twice). Herbicides were applied with knapsack sprayer through 500 liter of water per hectare. Sulfentrazone and Pendimethalin were applied as pre emergence at 1-2 DAS. The fertilizer dose of 20 kg N and 60 kg P per hectare was applied to crop through urea and single super phosphate as half of N and whole P at the time of sowing and remaining half of N was applied at 30 days after sowing. Protective irrigations were given to crop whenever dry spells appeared during the crop growth. Other plant protection practices for disease and pest control were also applied in similar manner for all the treatments. Observations on weed density, weed dry weight and weed control efficiency were recorded at 30 days after application (DAA). The crop was harvested on October 28, 2017 when the foliage of the soybean plants turned yellowish brown to brown in color and started to fall down. The weed control efficiency was calculated by using the following formula:

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

(Where, WCE = Weed control efficiency in percent, DWC = Dry matter weight of weed in control plot and DWT = Dry matter weight of weed in treated plot).

The data obtained on various observations were tabulated and subjected to statically analysis by using the techniques of the analysis of variance (ANOVA). Critical difference at 5% level of significance was determined for each character to compare the differences among treatment means. The data on weed count and weed biomass were subjected to square root transformation i.e. before carrying out analysis of variance and comparisons were made on transformed values only.

3. RESULTS AND DISCUSSION

3.1 Effect on Weeds

In the experimental field, *Echinochloa colona* (28.24%) was the rampant weed closely followed by *Commelina communis* (24.42%). However, other monocot weed like *Cyperus rotundus* (15.56%) and dicot weeds like *Phyllanthus niruri* (19.34%) and *Euphorbia hirta* (12.44%) were also present in less numbers with soybean in weedy check plots. Weedy check plots receiving no weed control had significantly higher weed density than all the herbicidal treatments including hand weeding treatment (Table 1). Among the herbicidal treatments, activity of sulfentrazone at the lowest dose (180 g/ha) as pre emergence was not well marked against most of the weeds, but when it was applied between 360 to 720 g/ha as pre emergence, controlled most of the associated weeds. Weedy check had the highest weed biomass, which reduced significantly when weeds were controlled either chemically or mechanically (Table 2). The lowest weed biomass was recorded under hand weeding treatment, which proved significantly superior to all the herbicidal treatments. Similar views were also endorsed by Arsenijevic et al. [21]. Among the herbicidal treatments, application of sulfentrazone at 360, 540 and 720 g/ha as pre emergence arrested the weed biomass production remarkably as well as application of pendimethalin (750 g/ha) and proved superior to its lower dose (180 g/ha).

Weed control efficiency at 30 days after application is presented through Fig. 1. Among different herbicide treatments, T4- Sulfentrazone at 720 g/ha recorded significantly higher weed control efficiency (89.53 %) as followed by T3- Sulfentrazone at 540 g/ha and T2- Sulfentrazone at 360 g/ha. However, highest weed control efficiency was recorded with hand weeding treatment. Weedy check treatment recorded the lowest weed control efficiency. Kanatas et al. [22] also reported similar findings.

3.2 Effect on the Crop

Weed control treatments significantly affected the growth parameter (branches per plant) at 30 DAS (Table 3). Weedy check plots had the minimum number of branches per plant (1.54)

Table 1. Influence of herbicides treatments on the density of weeds (no/m^2) at 30 DAA in soybean

Treatments	Echinochloa colona	Cyperus rotundus	Commelina communis	Phyllanthus niruri	Euphorbia hirta
T1- Sulfentrazone 180 g/ha	4.56 (20.33)	3.39 (11.00)	3.89 (13.00)	3.98 (14.67)	2.92 (8.00)
T2- Sulfentrazone 360 g/ha	3.72 (13.33)	2.61 (6.33)	3.28 (10.33)	3.24 (11.65)	2.86 (6.00)
T3- Sulfentrazone 540 g/ha	3.57 (12.33)	2.41 (5.33)	2.96 (8.34)	3.13 (11.00)	2.67 (5.67)
T4- Sulfentrazone 720 g/ha	3.13 (9.33)	2.20 (4.32)	2.11 (4.00)	2.68 (10.33)	1.68 (4.33)
T5- Pendimethalin 750 g/ha	4.10 (16.33)	2.91 (8.00)	3.48 (11.67)	3.67 (13.00)	2.54 (6.67)
T6- Weedy check	6.07 (36.33)	4.42 (19.00)	5.61 (31.00)	4.95 (24.00)	3.67 (13.00)
T7- Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.11	0.06	0.13	0.08	0.09
CD at 5%	0.35	0.17	0.40	0.25	0.28

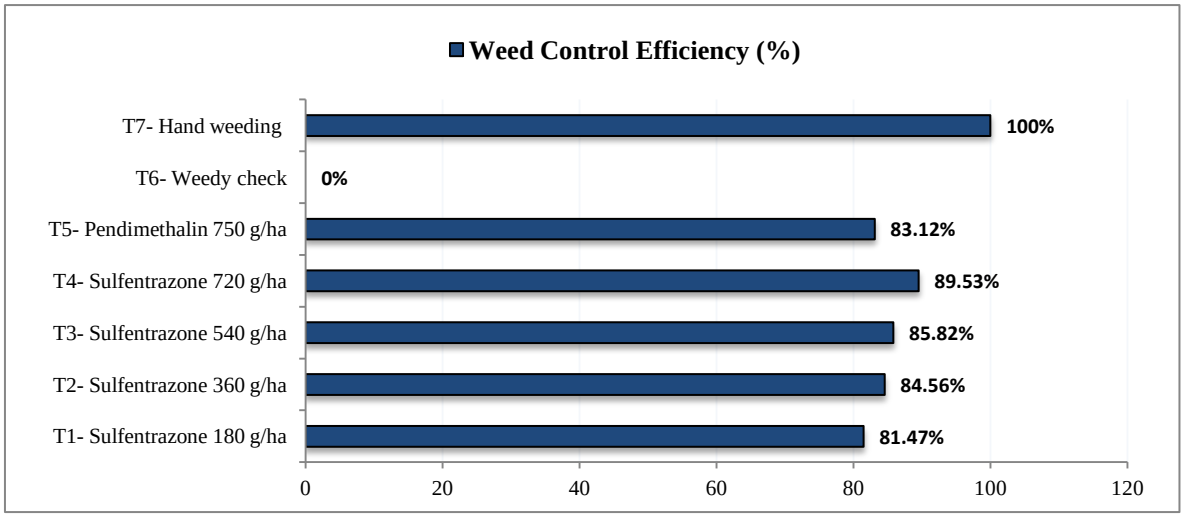

Fig. 1. Influence of different herbicides treatments on weed control efficiency at 30 DAA

which increased appreciably in plots receiving weed control treatments. The pre emergence application of T4-sulfentrazone 720 g/ha registered maximum number of branches/plant (1.99) followed by application of T3-Sulfentrazone 540 g/ha and 360 g/ha and the minimum (1.78) was recorded with T5- Pendimethalin 750 g/ha whereas at par with T2 - Sulfentrazone 360 g/ha and T3-Sulfentrazone 540 g/ha treatments. However hand weeding twice had the maximum (2.13) branches/plant, which was superior to other treatments.

The yield attributing traits namely pods per plant was superior under hand weeding plots receiving two hand weeding at 20 and 40 DAS than weedy check, but seeds per pod were mostly similar in all the treatments (Table 3). Excellent growth and development of soybean plants under weed free environment during critical period of crop growth might have resulted in superior yield attributes under hand weeding treatment as compared to weedy check, which had severe weed competition from early growth stages and ultimately resulted into most inferior yield attributes. Application of sulfentrazone at 360, 540 and 720 g/ha as pre emergence produced

better yield attributing characters (pods per plant) compared to T5- pendimethalin 750 g/ha on account of maximum reduction in weed growth coupled with no inhibitory effects on soybean plants. Whereas, poor weed control under T1- Sulfentrazone 180 g/ha, T5- Pendimethalin 750 g/ha and T6- weedy check have produced inferior yield attributes. Verma et al. [23] also recorded higher branches per plant and number of pods per plant under effective weed-management practices in soybean.

Table 2. Influence of herbicides treatments on the dry weight of weeds (g/m^2) at 30 DAA in soybean

Treatments	Echinochloa colona	Cyperus rotundus	Commelina communis	Phyllanthus niruri	Euphorbia hirta
T1- Sulfentrazone 180 g/ha	2.20 (4.37)	3.39 (11.00)	2.66 (6.55)	2.22 (4.44)	2.09 (3.87)
T2- Sulfentrazone 360 g/ha	1.99 (3.47)	3.22 (9.85)	2.41 (5.31)	2.05 (3.72)	1.83 (2.840
T3- Sulfentrazone 540 g/ha	1.93 (3.23)	3.13 (9.30)	2.31 (4.86)	1.96 (3.34)	1.71 (2.41)
T4- Sulfentrazone 720 g/ha	1.70 (2.38)	2.54 (5.97)	2.11 (3.94)	1.83 (2.85)	1.56 (1.94)
T5- Pendimethalin 750 g/ha	2.06 (3.77)	3.32 (10.50)	2.54 (5.95)	2.12 (4.00)	1.95 (3.32)
T6- Weedy check	6.97 (48.17)	7.65 (57.98)	5.06 (25.06)	3.46 (11.47)	4.58 (20.45)
T7- Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.07	0.04	0.04	0.04	0.04
CD at 5%	0.22	0.12	0.12	0.11	0.14

Table 3. Influence of different herbicides treatments on growth parameters, yield attributing characters and yield of soybean

Treatments	Number of branches/plant	Number of pods/plant	Seed yield (kg/ha)	Harvest index (%)
T1- Sulfentrazone 180 g/ha	1.76	34.48	1222.45	30.82
T2- Sulfentrazone 360 g/ha	1.79	39.34	1365.54	31.46
T3- Sulfentrazone 540 g/ha	1.82	46.51	1498.25	33.01
T4- Sulfentrazone 720 g/ha	1.99	47.41	1508.44	33.31
T5- Pendimethalin 750 g/ha	1.78	36.68	1263.49	31.18
T6- Weedy check	1.54	29.25	767.24	27.28
T7- Hand weeding	2.13	50.02	1606.00	34.34
SEm±	0.05	0.80	38.99	-
CD at 5%	0.16	2.48	120.21	-

Table 4. Influence of different herbicides treatments on economics of soybean

Treatments	Cost of cultivation (Rs/ha)	Gross monetary returns (Rs/ha)	Net return (Rs/ha)	B:C ratio
T1- Sulfentrazone 180 g/ha	28010	40029	12019	1.43
T2- Sulfentrazone 360 g/ha	28348	44624	16276	1.57
T3- Sulfentrazone 540 g/ha	29248	49027	19779	1.68
T4- Sulfentrazone 720 g/ha	28798	48737	19939	1.69
T5- Pendimethalin 750 g/ha	29848	41325	11477	1.38
T6- Weedy check	27048	25446	-1602	0.94
T7- Hand weeding	39048	52053	13005	1.33

3.3 Seed Yield

Seed yield under particular treatments is the resultant of complex phenomenon, which not only depends on the genetic constitution of the crop plants but also on the production technology adopted there in. Weed caused considerable damage to the crop depending upon the associated weed species, their relative density, duration of crop-weed competition etc. and their cumulative effect reflected in terms of reduced crop yield [24]. The seed yield was lowest (767.0 kg/ha) in the plots receiving no weed control (weedy check) due to severe competition stress from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the minimum seed yield. All the treated plots receiving either manual weeding or herbicidal treatments produced higher yields over weedy check. Hand weeding treatment produced the maximum seed yield (1606.0 kg/ha) and proved its superiority over all the treatments (Table 3). The crop under hand weeded plots attained lush growth due to elimination of weeds from inter and intra rows besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and consequently the highest yield [25,26]. Emmiganur and Hosmath [27] also reported that hand weeding as an effective method of weed control for achieving the maximum yield of soybean. Among the herbicidal treatments, application of T4- Sulfentrazone 720 g/ha as pre emergence attained the higher seed yield (1508.44 kg/ha) because of relatively low competition stress and better yield attributes However, this treatment proved superior over of sulfentrazone at lower rate (180, 360 g/ha) as well as higher rates (540 g/ha) and T5- Pendimethalin (750 g/ha). Thereby, produced inferior yield attributing traits leading to lower seed yields due to more weed stress. Similar result was opined by Vidrine et al. [28], Vyas and Jain [29]

3.4 Harvest Index

It is the ratio between economic and biological yield expressed in percentage and it varied due to different weed control treatments (Table 3). Hand weeding treatment had the maximum harvest index (34.34%) over herbicidal treatments, being the lowest (27.28%) under weedy check receiving no weed control measures. Maximum partitioning of photosynthates towards the production of haulm rather than seeds under weedy check may be assigned the reason for the lowest harvest index. Among the herbicidal treatments, combined application of T4- Sulfentrazone 720 g/ha applied as pre emergence curbed weed menace effectively and had higher coefficient of partitioning of photosynthates in sink (seed) from the source and consequently the harvest index values were higher under this treatment. Similar findings were reported by Halvankar et al. [30].

3.5 Economics

Cost of cultivation play an important role in deciding the acceptability of any treatments by the farmers. It is obvious from the data that hand weeding treatment receiving two hand weeding at 20 and 40 DAS, required maximum variable cost (Rs. 12000 /ha), which is not affordable by the poor farmers and at the same time the availability of labourers during peak period is also not certain (Table 3). All sulfentrazone treatments receiving pre emergence application from 180 to 720 g/ha and T5- pendimethalin 750 g/ha needed less variable cost (Rs. 528-2538 /ha) over hand weeding twice. Thus, use of sulfentrazone and pendimethalin for control of weeds seems to be cheaper from farmers view point. The gross monetary returns (GMR) was minimum (Rs. 25446 /ha) under weedy check because of the lowest seed and haulm yields. But, it was increased to a maximum level (Rs. 52053 /ha) under hand weeding closely followed by application of sulfentrazone at 720, 540, and 360 g/ha (Rs. 48737, 49027 and 44623 /ha respectively) and pendimethalin at 750 g/ha (Rs. 41325 /ha). All the plots receiving either hand weeding or herbicidal treatments fetched greater GMR than weedy check because of increased seed and haulm yields of soybean. The net monetary returns (NMR) was only Rs. 1602 /ha when weeds were not controlled by any means, but increased to a maximum level (Rs. 19939 /ha) when weeds were controlled by application of T4- Sulfentrazone 720 g/ha closely followed by application of T3- Sulfentrazone 540 g/ha (Rs. 19779 /ha). The low investment under application of T3- Sulfentrazone 720 g/ha as pre emergence good economic yield might be the reason for higher NMR over other treatments sulfentrazone (180, 360, 720 g/ha) and pendimethalin 750 g/ha and the advantage of higher GMR under hand weeding was nullified due to higher variable cost for control of weeds (Rs. 12000 /ha). The benefit-cost ratio represents the profitability of the

treatment with each rupee of investment. It is remarkable to note that the application of T4- Sulfentrazone 720 g/ha as pre emergence was found more remunerative (1.69) than other herbicidal treatments including hand weeding. Our findings are accordance with those of Krausz and Young [31].

4. CONCLUSION

In conclusion, the investigation revealed that application of T4- Sulfentrazone 720 g/ha was effective weed controller in soybean. T4- Sulfentrazone 720 g/ha attained higher values of growth parameters, yield attributing traits, seed yield of soybean and found more remunerative as received higher values of NMR and B:C ratio compared to other treatments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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