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Efficacy of New Generation Herbicides in Soybean (*Glycine max.* L)

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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 at Agricultural Research Station, Adilabad, Telangana during *Kharif*, 2022 to assess the efficacy of new generation herbicides in soybean (*Glycine max.* L). The experiment was laid out in randomized block design with 11 treatments and replicated thrice. Results revealed that among herbicidal treatments, pre-emergence application of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* post-emergence of Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1} recorded lowest weed density, biomass, weed index and higher weed control

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efficiency, seed and haulm yield. It was followed by pre-emergence application of Imazethapyr 2% EC + Pendimethalin 30% EC mix @ 960 g ha^{-1} *fb* post-emergence Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1}.

Keywords: Glycine max. L; herbicides; yield; weed control.

1. INTRODUCTION

In India, oilseed crops constitute the second largest agricultural produce, next to cereals. Among oilseeds, soybean is a major oilseed crop worldwide due to its adaptability to various geographical areas, unique chemical composition and numerous uses. Its versatility allows for its utilization in feed production, as a food source and in non-edible industries [1].

In India, soybean is cultivated in an area of 12.27 million hectares with a production of 12.99 million tonnes and productivity of 1059 kg ha^{-1} [2]. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Telangana are the important soybean growing states in India; Adilabad, Kamareddy, Nizamabad, Nirmal and Sangareddy are the major soybean growing districts of Telangana [3].

"Among different production factors limiting soybean productivity, weeds are considered to be major one as the yield reduction due to uncontrolled weed is about 84%" Kachroo *et al*. [4]. "Being a *kharif* season crop it is heavily infested with grasses, broad-leaved and sedges weeds which compete for light, food, water and space and ultimately reduce the crop yield [4]". Farmers commonly use preemergence herbicides for weed control in soybean. The weeds emerging later cause significant reduction in yield. Therefore, identified of ideal pre and post emergence herbicide mixtures is crucial for effective and timely control of weeds in soybean and for enhancing yields.

2. MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station, Adilabad, Telangana during *Kharif*, 2022 on black soil, neutral in nature (pH 7.35), having EC 0.19 dSm^{-1}, medium in organic carbon (0.67%) and low in available nitrogen (100.8 kg ha^{-1}), medium in phosphorus (47.4 kg ha^{-1}) and high in potassium (426 kg ha^{-1}). The experiment was laid out in randomized block design with 11 treatments and replicated thrice. Soybean variety JS-335 was sown with a seed rate of 65 kg ha^{-1}, maintaining 45 x 10 cm spacing at 5 cm depth. The crop was fertilized with 50:60:20 kg ha^{-1} Nitrogen, Phosphorous and Potassium, respectively in the form of urea DAP, MOP and seed inoculated with *Brady Rhizobium c*ulture @ 200 g/8 kg. Pre-emergence (PE) application of herbicides was done at 2 days after sowing (DAS) and post-emergence (PoE) at 20 DAS using 500 liters of water/ha as spray fluid with flat fan nozzle fitted knapsack sprayer (Table 1). The observations on weed density (no.m^{-2}), weed dry weight (g m^{-2}) and weed control efficiency (%) at 15, 30 and 45 DAA were recorded. Weeds were counted using a quadrant of 0.25 square meter (0.5 x 0.5 m).

Weed control efficiency (WCE) was calculated as per the following formula Mani *et al*. [5].

$$WCE\ (\%) = \frac{(DM_C - DM_T)}{DM_C} \times 100$$

Where in, DM_C = Dry matter of weeds in the un-weeded check (control)

DM_T = Dry matter of weeds in the treatment imposed plot

Weed index (WI) was calculated as per the following formula [6].

$$WI\ (\%) = \frac{X-Y}{X} \times 100$$

Where in,

X: Grain yield from weed-free check or maximum yield treatment
Y: Grain yield from treatment for which weed index is to be calculated

3. RESULTS AND DISCUSSION

3.1 Effect on Weeds

The principal weed flora observed in the experimental site were *Cynodon dactylon, Echinichloa colonum, Dactyloctenium aegyptium*,

Table 1. Details of the treatments

Treatment No.	Treatment details
T_1	PE of Imazethapyr 2% EC (+) Pendimethalin 30% EC @ 960 g ha^{-1} *fb* intercultivation at 20-25 DAS
T_2	PE of Pyroxasulfone 85 % WDG @ 127.5 g ha^{-1} *fb* intercultivation at 20-25 DAS
T_3	PE of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* intercultivation at 20-25 DAS
T_4	PE of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* PoE Sodium acifluorfen 16.5% EC (+) Clodinafop propargyl 8% EC @ 250 g ha^{-1}
T_5	PE of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* PoE Fluazifop-p-butyl 11.1% w/w (+) Fomesafen 11.1% w/w SL @ 250 g ha^{-1}
T_6	PE of Imazethapyr 2% EC (+) Pendimethalin 30% EC @ 960 g ha^{-1} *fb* PoE Sodium acifluorfen 16.5% EC (+) Clodinafop propargyl 8% EC @ 250 g ha^{-1}
T_7	PE of Imazethapyr 2% EC (+) Pendimethalin 30% EC @ 960 g ha^{-1} *fb* PoE Fluazifop-p-butyl 11.1% w/w (+) Fomesafen 11.1% w/w SL @ 250 g ha^{-1}
T_8	PE of Pyroxasulfone 85 % WDG @ 127.5 g ha^{-1} *fb* PoE Sodium acifluorfen 16.5% EC (+) Clodinafop propargyl 8% EC @ 250 g ha^{-1}
T_9	PE of Pyroxasulfone 85 % WDG @ 127.5 g ha^{-1} *fb* PoE Fluazifop-p-butyl 11.1% w/w (+) Fomesafen 11.1% w/w SL 250 g ha^{-1}
T_{10}	Weed-free (Intercultivation at 20-25 DAS) *fb* hand weeding at 40 DAS)
T_{11}	Un-weeded control

Table 2. Effect of weed control treatments on weed parameters, weed control efficiency and weed index

Treatments	Weed density (per m^2)			Weed dry weight (g per m^2)			WCE (%)	Weed
	15 DAA	30 DAA	45 DAA	15 DAA	30 DAA	45 DAA	45 DAA	index (%)
T_1	4.70 (21.64)	5.36 (28.24)	5.44 (29.13)	3.93 (15.01)	4.37 (18.68)	5.47 (29.46)	72.31	40.7
T_2	5.75 (32.61)	5.46 (29.40)	6.59 (38.54)	4.51 (19.87)	4.47 (19.49)	5.39 (28.51)	72.17	47.7
T_3	4.06 (15.99)	5.01 (24.61)	4.76 (22.15)	3.59 (12.39)	4.20 (17.14)	4.23 (17.42)	82.95	26.1
T_4	4.23 (17.43)	5.69 (31.88)	5.05 (25.09)	3.66 (12.94)	5.03 (24.85)	4.38 (18.72)	81.70	28.4
T_5	3.93 (14.93)	4.90 (23.55)	4.46 (19.48)	3.46 (11.53)	4.00 (15.58)	3.92 (14.84)	85.51	14.2
T_6	4.97 (24.27)	6.94 (47.62)	5.30 (27.63)	4.08 (16.15)	5.08 (25.34)	4.61 (20.81)	79.66	37.0
T_7	4.60 (20.74)	4.97 (24.24)	4.67 (21.31)	3.92 (14.9)	4.30 (17.57)	4.17 (16.87)	83.50	21.5
T_8	6.37 (40.04)	7.14 (50.42)	6.58 (42.80)	4.41 (19.03)	5.42 (28.87)	5.59 (30.70)	70.00	45.8
T_9	5.65 (34.97)	6.55 (42.51)	5.44 (29.16)	4.28 (17.83)	5.70 (32.07)	5.39 (28.58)	72.07	41.7
T_{10}	2.89 (7.83)	3.54 (12.02)	3.45 (11.43)	2.86 (7.68)	3.31 (10.45)	3.12 (9.25)	90.95	-
T_{11}	8.97 (79.93)	10.40 (107.63)	11.46 (130.89)	6.74 (44.97)	8.57 (72.92)	10.15 (102.47)		56.3
S. Em. $\pm$	0.24	0.21	0.32	0.15	0.19	0.31		
CD (P=0.05)	0.59	0.57	0.85	0.40	0.51	0.71		

Note: Figures in parenthesis are transformed values, square root transformation $\sqrt{x+0.5}$ was used for statistical analysis

Digitaria sanguinalis, *Cyperus rotundus*, *Commelina bengalensis*, *Amaranthus viridis, Digera arvensis, Parthenium hysterophorus,* and *Euphorbia hirta.* All the weed management practices significantly affected the weed density and weed dry weight at 15, 30 and 45 DAA in comparison to un-weeded control (Table 2).

3.2 Weed Density (No. m^{-2}) and Dry Weight (g m^{-2})

At 15, 30 and 45 days after application (DAA), among different weed management practices weed free treatment (intercultivation at 20-25 DAS *fb* hand weeding at 40 DAS) maintained its superiority and registered lowest total weed density and weed dry weight (2.89 m^{-2} and 2.86 g m^{-2}), (3.54 m^{-2} and 3.31 g m^{-2}) and (3.45 m^{-2} and 3.12 g m^{-2}), respectively.

Among the herbicide treatments, lowest total weed density and dry weight at 15 DAA was recorded with pre-emergence T_5 (PE) application of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* post emergence of Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1} (3.93 m^{-2} and 3.46 g m^{-2}) and were on par with T_3 (4.06 m^{-2} and 3.59 g m^{-2}) and T_4 (4.23 m^{-2} and 3.66 g m^{-2}) respectively.

At 30 DAA, T_5 (PE) application of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* PoE Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1} was registered lowest total weed density and weed dry weight (4.90 m^{-2} and 4.00 g m^{-2}) and which was on par with T_7 (4.97 m^{-2} and 4.30 g m^{-2}), T_3 (5.01 m^{-2} and 4.20 g m^{-2}), T_1 (5.36 m^{-2} and 4.37 g m^{-2}) and T_2 (5.46 m^{-2} and 4.47 g m^{-2}) respectively.

Similar to 15 and 30 DAA, at 45 DAA, T_5 (PE) application of Diclosulam 84% WDG @ 26 g ha^{-1} *fb* PoE Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1} was registered lowest total weed density and weed dry weight (4.46 m^{-2} and 3.92 g m^{-2}) and which was on par with T_7 (4.67 m^{-2} and 4.17 g m^{-2}), T_3 (4.76 m^{-2} and 4.23 g m^{-2}), T_4 (5.05 m^{-2} and 4.38 g m^{-2}) and T_6 (5.30 m^{-2} and 4.61 g m^{-2}) respectively.

While, the highest total weed density and dry weight was recorded with unweeded control (8.97 m^{-2} and 6.74 g m^{-2}) (10.40 m^{-2} and 8.57 g m^{-2}) and (11.46 m^{-2} and 10.15 g m^{-2}) respectively. The treatments that consisted of diclosulam has controlled weeds effectively due to longer half-life period and pendimethalin and imazethapyr applied as PE reduced weed density and produced lower weed dry weight due to dual mode of action of herbicides. Imazethapyr which acted as inhibitor of three branched-chain amino-acids and pendimethalin which killed weeds by inhibiting cell division and cell elongation. Fluazifop-p-butyl and fomesafen applied as PoE reduced weed density and dry weight of weeds due to dual mode of action of herbicides. Fomesafen inhibits lipid synthesis and also fatty acid elongation. Fluazifop-p-butyl inhibits acetyl CoA carboxylase. Similar results were also reported by Singh et al. [7], Kumar et al. [8], Charitha et al. [9] and Mehriya et al. [10].

3.3 Weed Control Efficiency (%)

At 45 DAA, the maximum weed control efficiency was registered with intercultivation (20-25 DAS) *fb* hand weeding (40 DAS) (Weed free) (90.95 %) and it was followed by T_5 - (85.51%) and T_7 - (83.50%). Effective weed control resulted in lower weed density and dry weight in these treatments has resulted in higher WCE. Similar findings were reported by Verma and Kushwaha, [11], Patel et al. [12], Reddy et al. [13].

3.4 Weed Index (%)

Lowest weed index was recorded in pre-emergence application of diclosulam 84% WDG @ 26 g ha^{-1} *fb* PoE fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g ha^{-1} (14.2 %) and it was followed by T_7 (21.5%). Better weed control with these treatments resulted in the lowest yield loss and hence, lowest weed index. Unweeded control recorded highest weed index (56.3%) due to non imposition of weed control treatments and uncontrolled weed growth.

3.5 Effect on Crop Growth

Herbicidal combinations offered better control and recorded significantly higher growth parameters and yield attributes and were comparable to weed free treatment. However, weed free treatment was superior over all other treatments.

Table 3. Effect of weed control treatments on yield attributes and yield of soybean

Treatments	Number of branches plant^{-1}	No. of pods Plant^{-1}	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
T_1	4.0	40.2	1545	3831	28.7
T_2	3.5	32.7	1384	3651	27.6
T_3	5.2	45.8	1954	4463	30.5
T_4	4.4	38.9	1886	4259	30.9
T_5	5.6	51.3	2280	4771	32.4
T_6	4.3	35.5	1654	3948	29.6
T_7	5.5	47.8	2089	4530	31.5
T_8	3.8	38.3	1443	3846	27.3
T_9	4.2	42.8	1548	3806	29.1
T_{10}	6.1	63.6	2662	4961	34.9
T_{11}	3.6	27.6	1152	3109	27.0
SEm ±	0.4	4.8	152	349	1.8
CD (P=0.05)	0.9	10	318	730	4.1

Among weed control treatments, intercultivation (20-25 DAS) *fb* hand weeding (40 DAS) weed free registered higher number of branches per plant (6.1) and it was equally superior to T_5 (5.6), T_7 (5.5) and T_3 (5.2). Lower number of branches per plant was recorded with PE of pyroxasulfone 85 % WDG @ 127.5 g ha^{-1} *fb* intercultivation at 20-25 DAS (3.6).

Intercultivation (20-25 DAS) *fb* hand weeding (40 DAS) recorded a higher number of pods plant^{-1} (63.6), seed (2662 kg ha^{-1}) haulm yield (4961 kg ha^{-1}) and harvest index (34.9%) and it was followed by T_5 (51.3, 2280 kg ha^{-1}, 4771 kg ha^{-1} and 32.4 %) and T_7 (47.8, 2089 kg ha^{-1}, 4530 kg ha^{-1} and 31.5 %) respectively. Higher weed control efficiency improved crop growth parameters, pods plant^{-1} and lower weed index in these treatments reflected in higher seed yield. Among all the treatments, the minimum number of pods per plant (27.6), seed yield (1152 kg ha^{-1}), haulm yield (3109 kg ha^{-1}) and harvest index (27%) were recorded under un weeded control. The results are in line with those reported by Singh et al. [14], Singh et al. [7], Kadam et al. [15], Sridhar et al. [16], Mehriya et al. [10] and Aher et al. [17], Charitha et al. [9].

4. CONCLUSION

In soybean pre-emergence application of T_5 - Diclosulam 84% WDG @ 26 g ha^{-1} *fb* post emergence of Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL @ 250 g ha^{-1} and T_7 PE of Imazethapyr 2% EC + Pendimethalin 30% EC @ 960 g ha^{-1}*fb* PoE Fluazifop-p-butyl 11.1% w/w (+) Fomesafen 11.1% w/w SL @ 250 g ha^{-1} offered effective weed control apart from higher yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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