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Effect of post-emergence herbicides on weed dynamics and yield of soybean [*Glycine max* (L.) Merrill]

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Abstract
The present research entitled "Effect of post-emergence herbicides on weed dynamics and yield of soybean [*Glycine max* (L.) Merrill]" was conducted during *kharif*, 2023 at Research cum Instructional Farm, College of Agriculture, Raipur, Chhattisgarh. Experiment was conducted in randomized block design with 3 replications and 8 treatments *viz*, propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} (T_1), fluazifop-P-butyl 11.1% + fomesafen 11.1% SL 250 g a.i. ha^{-1} (T_2), clethodim 25% EC 150 g a.i. ha^{-1} (T_3), flumioxazin 50% SC 125 g a.i. ha^{-1} (T_4), pyroxasulfone 85% WP 127.5 g a.i. ha^{-1} (T_5), haloxyfop-R-methyl 10.5% EC 125 g a.i. ha^{-1} (T_6), hand weeding twice (20 and 40 DAS) (T_7) and weedy check (T_8). Results revealed that growth attributing character *viz*, plant height, number of branches, number of leaves, dry matter accumulation, crop growth rate, leaf area index as well as yield attributing parameters *viz*, number of pod plant^{-1}, number of seeds pod^{-1}, seed index, seed yield, harvest index were found significantly maximum under hand weeding twice (20 and 40 DAS) followed by propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}. Minimum values of above characters were observed in weedy check. Lowest weed density and weed dry matter production was obtained in hand weeding twice (20 and 40 DAS) which was followed by propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}, whereas highest weed density, weed dry matter production and weed index was found under weedy check. In terms of economics, maximum gross return and net return were fetched under hand weeding twice (20 and 40 DAS) followed by propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} but maximum B: C ratio was found under propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} and lowest gross return, net return and B:C ratio were received under weedy check.

Keywords: Post-emergence herbicide**,** hand weeding, propaquizafop 2.5% + imazethapyr 3.75% ME

Introduction
Soybean is the major *kharif* crop and emerged as main oilseed crop in short span of time and posses high nutritive value. It is known to be the richest and cheapest source of protein and oil which are essential for life. It contains about 40-42 percent quality protein, 20-30 percent carbohydrates and 20-22 percent cholesterol free oil. The right growth and yield of soybean are severely impacted by late and inadequate weed control. According to reports, the first 30-45 days after sowing are the important phase for crop weed competition in soybean (Panneerselvam and Lourduraj, 2000) [8]. In addition to yield losses, yield reduction from uncontrolled weeds in soybean has been recorded to range from 30-80%, depending on the type of weeds and length of infestation (Yaduraju, 2002) [10]. Early post-emergence herbicide applied at the 2–5 leaf stage of weeds, is a more effective way of controlling weeds in the soybean crop while dealing with persistent rainy conditions (Malik *et al.* 2006) [5]. Hand weeding is an expensive, time-consuming, and laborious way of traditional weed control. However, because herbicides kill some plants but not others, they cannot completely control weeds when used alone. Farmers mostly use pre-plant and pre-emergence herbicides for weed control in soybean; however, a number of climatic and edaphic conditions diminish their effectiveness. Although hand weeding is a time-tested and successful way of controlling weeds, its main drawbacks include untimely and persistent rains and a shortage of labour during peak hours. The application of post-emergence herbicides is the sole substitute that requires investigation.

These herbicides work well against either dicotyledonous or monocotyledonous weeds, accordingly on screening results conducted on soybeans. Therefore, by using broad-spectrum weed control, their combinations may increase the window for weed management (Bineet *et al.*, 2001) [2].

Materials and Methods

A field experiment was conducted at Research cum Instructional Farm, College of Agriculture, Raipur, Chhattisgarh. In the experimental field, the soil had clayey (*vertisols*) texture, was neutral (pH 7.61), contained 0.45% soil organic carbon, low nitrogen (214 kg ha^{-1}), medium phosphorus (13.90 kg ha^{-1}) and high potassium (380.87 kg ha^{-1}). Experiment was conducted in randomized block design with 3 replications and 8 treatments *viz*, propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}, fluazifop-P-butyl 11.1% + fomesafen 11.1% SL 250 g a.i. ha^{-1}, clethodim 25% EC 150 g a.i. ha^{-1}, flumioxazin 50% SC 125 g a.i. ha^{-1}, pyroxasulfone 85% WP 127.5 g a.i. $ha^{-1}$and haloxyfop-R-methyl 10.5% EC 125 g a.i. ha^{-1} applied as post emergence at 20 DAS, hand weeding twice (20 and 40 DAS) and weedy check. All the herbicides were applied by manually operated knapsack sprayer fitted with flat fan nozzle. The species-wise weed population was recorded by the least-count quadrat (0.25 m^2) method. Similarly, the weed biomass was recorded and weed-control efficiency was calculated accordingly.

Results and Discussion

Effect on weeds

Different weed species observed in experimental field were *Bracharia eruciformis, Cynodon dactylon, Parthenium hysterophorus, Merremia emarginata, Phyllanthus niruri,* and *Digera arvensis.* Results showed that weed management practices markedly reduced crop-weed competition. The experimental data (Table 1 & 2) revealed that hand weeding twice (20 and 40 DAS) resulted in the lowest density of total weed (7.33 m^{-2}) *fb* propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} (26.67 m^{-2}) at 60 DAS compared to weedy check (83.67 m^{-2}). At 60 DAS, minimum dry matter of total weeds were recorded under hand weeding twice (20 and 40 DAS) *fb* propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}. Maximum weed control efficiency was observed with hand weeding twice (20 and 40 DAS) *fb* propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}. The higher weed control efficiency under these treatments could be attributed to the lower weed population and total weed dry matter as well. These results were similar with the findings of Sandil *et al.* (2015) [9] and Bagotiya *et al.* (2018) [1].

Effect on crop

Results (Table 3) revealed that hand weeding twice (20 and 40 DAS) recorded maximum number of branches $plant^{-1}$, leaf area $plant^{-1}$ (cm^2), dry matter accumulation (g $plant^{-1}$), number of pods $plant^{-1}$ and 100 seed weight (g). The maximum seed yield (1802.85 kg ha^{-1}) was recorded under hand weeding twice (20 and 40 DAS) but among the chemical weed management treatments, significantly maximum seed yield (1561.97 kg ha^{-1}) was observed under propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1}. Among the overall treatment's maximum stover yield was observed under hand weeding twice (20 and 40 DAS) *fb* propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} (3793.33 and 3537.91 kg ha^{-1} respectively). It is established fact that least crop weed competition during the early phase of crop growth exerts an important regulatory function on complex process of yield formation due to better availability of water, space and nutrient to the crop plant. It also helps in improving aeration and nutrient uptake by plant resulting in higher metabolic activity. The better expression of yield attributes in herbicide and manually weeded plots might be due to poor resurgence frequency and growth of weeds in these treatments. Hence, weeds were unable to compete with the crop plants for different growth factors. Improvement in yield attributes occurred when weeds were controlled in the early growth stages particularly during critical growth period either manually or chemically, which scaled down competition and created congenial micro-environment for better establishment and growth of the crop. Similar results were reported by Kalyani *et al.* (2023) [4].

Economics

Minimum net monetory returns (6991 ₹) was fetched under weedy check plots as a result of lower seed and stover yields. However, hand weeding twice (20 and 40 DAS) and propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} was found more rumenerativeas they fetched higher net monetary returns (44963 ₹ and 39589 ₹) and benefit-cost ratio 2.6 and 2.6 respectively). The low investment under propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} and fluazifop-P-butyl 11.1% + fomesafen 11.1% SL 250 g a.i. ha^{-1} as post emergence applied with good economic yield might be the reason for higher net monetary return and benefit cost ratio over clethodim 25% EC 150 g a.i. ha^{-1}, flumioxazin 50% SC 125 g a.i. ha^{-1}, pyroxasulfone 85% WP 127.5 g a.i. ha^{-1} and haloxyfop-R-methyl 10.5% EC 125 g a.i. ha^{-1}. Similar finding was also reported by Panda *et al.* (2015) [7] and Nagre *et al.* (2017) [6].

Based on the result obtained in the present investigation, it can be concluded that propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} found more effective and remunerative compared to applied among all the herbicide treatments.

Table 1: Total and species wise weed density (No. m^{-2}) at 60 DAS as influenced by different weed management practices

Weed management practices	Dose (g a.i. ha^{-1})	Weed density species wise (No. m^{-2})						
		Parthenium hysterophorus	*Bracharia erusiformis*	*Merremia emarginata*	*Phyllanthus niruri*	*Cynodon dactylon*	*Digera arvensis*	Total
Propaquizafop 2.5% + Imazethapyr 3.75% ME	120	3.35	3.07	1.86	1.05	1.58	1.22	5.20
		(11.00)	(9.00)	(3.00)	(0.67)	(2.00)	(1.00)	(26.67)
Fluzifop-P-butyl 11.1% + Fomesafen 11.1% SL	250	3.48	3.48	1.86	1.35	1.74	1.34	5.67
		(11.67)	(11.67)	(3.00)	(1.33)	(2.67)	(1.33)	(31.67)
Clethodim 25% EC	150	4.62	2.18	2.47	2.00	1.39	2.11	6.38
		(21.00)	(4.33)	(5.67)	(3.67)	(1.67)	(4.00)	(40.33)
Flumioxazin 50% SC	125	4.34	5.04	1.93	1.77	1.81	1.46	7.37
		(18.33)	(25.00)	(3.33)	(2.67)	(3.00)	(1.67)	(54.00)
Pyroxasulfone 85% WP	127.5	3.89	4.01	1.81	1.76	1.65	1.64	6.41
		(14.67)	(15.67)	(3.00)	(2.67)	(2.33)	(2.33)	(40.67)
Haloxyfop-R-methyl 10.5% EC	125	4.25	2.01	2.46	1.86	1.34	1.95	5.93
		(17.67)	(3.67)	(5.67)	(3.00)	(1.33)	(3.33)	(34.67)
Hand weeding at 20 & 40 DAS	-	1.74	1.56	1.10	1.00	1.07	0.88	2.77
		(2.67)	(2.00)	(1.00)	(0.67)	(0.67)	(0.33)	(7.33)
Weedy check	-	5.53	5.84	2.59	2.27	1.93	2.32	9.17
		(30.67)	(33.67)	(6.33)	(4.67)	(3.33)	(5.00)	(83.67)
SEm±	-	0.29	0.18	0.25	0.19	0.22	0.16	0.25
CD (P=0.05)	-	0.87	0.54	0.76	0.59	0.68	0.50	0.76

Table 2: Total and species wise weed dry matter accumulation (g m^{-2}) at 60 DAS as influenced by different weed management practices

Weed management practices	Dose (g a.i. ha^{-1})	Weed density species wise (No. m^{-2})							
		Parthenium hysterophorus	*Bracharia erusiformis*	*Merremia emarginata*	*Phyllanthus niruri*	*Cynodon dactylon*	*Digera arvensis*	Total	WCE (%)
Propaquizafop 2.5% + Imazethapyr 3.75% ME	120	4.39	2.14	2.01	0.82	1.41	1.19	5.44	69.52
		(18.79)	(4.17)	(3.58)	(0.20)	(1.49)	(0.93)	(29.15)	
Fluzifop-P-butyl 11.1% + Fomesafen 11.1% SL	250	4.57	2.37	1.98	1.19	1.42	1.31	5.76	65.74
		(20.37)	(5.22)	(3.47)	(0.94)	(1.55)	(1.23)	(32.78)	
Clethodim 25% EC	150	5.64	1.74	2.78	2.02	1.31	1.90	7.05	48.59
		(31.32)	(2.58)	(7.22)	(3.61)	(1.23)	(3.23)	(49.19)	
Flumioxazin 50% SC	125	5.50	3.40	2.34	1.52	1.60	1.54	7.23	45.88
		(29.74)	(11.11)	(5.08)	(1.85)	(2.07)	(1.93)	(51.78)	
Pyroxasulfone 85% WP	127.5	4.91	2.66	2.34	1.76	1.53	1.66	6.53	55.95
		(23.62)	(6.75)	(5.01)	(2.59)	(1.86)	(2.32)	(42.15)	
Haloxyfop-R-methyl 10.5% EC	125	5.09	1.68	2.39	1.77	1.27	1.84	6.35	58.37
		(25.50)	(2.38)	(5.21)	(2.66)	(1.12)	(2.96)	(39.84)	
Hand weeding at 20 & 40 DAS	-	0.99	1.27	1.14	0.83	0.81	0.81	1.91	96.55
		(0.48)	(1.13)	(1.16)	(0.21)	(0.16)	(0.16)	(3.30)	
Weedy check	-	7.64	3.93	2.99	2.33	1.89	2.53	9.81	-
		(57.89)	(15.21)	(8.48)	(4.97)	(3.25)	(5.88)	(95.67)	
SEm±	-	0.12	0.23	0.22	0.12	0.13	0.14	0.17	-
CD (P=0.05)	-	0.37	0.69	0.66	0.35	0.39	0.43	0.50	-

Table 3: Growth and yield attributes of soybean as influenced by different weed management practices

Weed management practices	Dose (g a.i. ha^{-1})	No. of branches $plant^{-1}$	Leaf area $plant^{-1}$ (cm^2)	Dry matter accumulation (g $plant^{-1}$)	No. of pods $plant^{-1}$	100 seed weight	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Propaquizafop 2.5% + Imazethapyr 3.75% ME	120	6.40	915.62	15.69	86.67	11.35	1561.97	3537.91	44963	2.6
Fluzifop-P-butyl 11.1% + Fomesafen 11.1% SL	250	6.27	789.62	13.41	73.00	11.22	1453.54	3359.93	39589	2.4
Clethodim 25% EC	150	5.27	516.25	9.60	60.00	10.12	1050.33	2991.00	20718	1.7
Flumioxazin 50% SC	125	4.80	487.25	8.82	55.00	9.95	1009.18	2986.33	18261	1.6
Pyroxasulfone 85% WP	127.5	5.53	606.85	10.15	62.67	10.40	1086.08	3014.67	19800	1.6
Haloxyfop-R-methyl 10.5% EC	125	6.13	774.79	12.58	67.00	10.56	1137.15	3032.33	25124	1.9
Hand weeding	-	8.00	1002.69	19.43	102.00	12.73	1802.85	3793.33	53776	2.6
Weedy check	-	3.50	378.22	6.24	40.00	8.39	712.96	2653.33	6991	1.3
SEm±	-	0.28	41.86	1.33	5.13	0.49	80.99	95.40	-	-
CD (P=0.05)	-	0.84	126.95	4.04	15.56	1.47	245.66	289.36	-	-

Conclusion

In conclusion, the study demonstrates that effective weed management significantly impacts both crop yield and economic returns. Hand weeding twice at 20 and 40 DAS and the application of propaquizafop 2.5% + imazethapyr 3.75% ME 120 g a.i. ha^{-1} substantially reduced weed density and dry matter, resulting in optimal crop growth and yield attributes. This approach not only enhanced seed yield but also achieved the highest stover yield and net monetary returns. Compared to other treatments, this herbicide combination proved to be more cost-effective and beneficial. Overall, managing weeds early and effectively, whether manually or chemically, fosters better crop establishment and economic viability, aligning with previous findings and reinforcing its efficacy as a preferred weed management strategy.

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