Plant Archives Vol. 25, No. 1, 2025 pp. 757-763 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.114

BIO-EFFICACY EVALUATION OF HERBICIDES ALONE AND MIXTURES ON WEED DYNAMICS, GROWTH, YIELD AND ECONOMICS OF SOYBEAN (*GLYCINE MAX* L. MERRILL) AND THEIR RESIDUAL EFFECT ON SUCCEEDING WHEAT

Uditi Dhakad[1]*, Chaman K. Jadon[2], S.L. Yadav[3] and S.N. Meena[4]

[1]College of Agriculture, Agriculture University, Kota - 324 001, Rajasthan, India.

[2]Agricultural Research Station, Ummedganj, Kota, Rajasthan, India.

*Corresponding author E-mail : uditi1303@gmail.com

(Date of Receiving-04-12-2024; Date of Acceptance-24-02-2025)

ABSTRACT

A field experiment was conducted at the Research Farm of Agricultural Research Station, Kota, during the *kharif* season of 2021 to assess the effectiveness of newer ready-mix post-emergence herbicides for controlling weeds in soybean. Additionally, the study aimed to examine their impact on growth, yield parameters, economic aspects, and residual effects on the subsequent wheat crop. The findings revealed that the post-emergence ready-mix herbicide containing fomesafen + fluazifop-p-butyl @ 220 g *a.i.*/ha exhibited significant superiority in reducing the density of grassy, broad-leaved, and sedge weeds, as well as weed dry matter and nutrient depletion by weeds. This treatment demonstrated the highest weed control efficiency (85.41% and 79.97% at 30 and 60 DAS, respectively) compared to other treatments. Moreover, the application of fomesafen + fluazifop-p-butyl at 220 g *a.i.*/ha resulted in significantly higher values for yield attributes and yields, including seed, straw, and biological yield (1760 kg/ha, 2364 kg/ha, and 4124 kg/ha, respectively), followed by propaquizafop + imazethapyr at 125 g *a.i.*/ha (1730 kg/ha, 2323 kg/ha, and 4053 kg/ha) and sodium acifluorfen + clodinafop propargyl at 245 g *a.i.*/ha (1628 kg/ha, 2204 kg/ha, and 3832 kg/ha). The application of fomesafen + fluazifop-p-butyl at 220 g *a.i.*/ha also resulted in the maximum net return (₹ 55008/ha) and benefit:cost ratio (2.30). No phytotoxic symptoms were observed on the soybean crop, and there was no residual effect on the succeeding wheat crop due to the different herbicides applied in the preceding soybean crop.

Key words : Bio-efficacy, Residual effect, Succeeding, Weed control, Weed dynamics.

Introduction

Soybean [*Glycine max* (L.) Merrill] has emerged as a promising protein and oilseed crop globally, boasting wide adaptability and high yield potential compared to other oilseed and pulse crops during the *kharif* season. In India, soybean cultivation covered an area of 11.84 million hectares in 2020, yielding 10.45 million tonnes (Anonymous, 2021). Rajasthan contributed 11.29 lakh hectares to this cultivation, producing 10.94 lakh tonnes with a productivity of 969 kg/ha (Anonymous, 2020-21). However, soybean productivity in Rajasthan lags behind that of Madhya Pradesh (1231 kg/ha), Maharashtra (1132 kg/ha), India (1192 kg/ha) and the global average (2491 kg/ha) (World Market and Trade USDA, 2022). As a rainfed crop, soybean faces significant challenges from weed competition during its growth. Common weeds such as *Echinochloa crusgalli*, *Echinochloa colona*, *Commelina benghalensis*, *Panicum dichotomiflorum*, *Polygonum* spp., *Aeschynomene indica*, *Digitaria sanguinalis*, *Eleusine aegyptium* and *Cyperus* spp. are prevalent in soybean fields. Weeds can cause yield reductions ranging from 30% to 80% in soybean (Gupta *et al*., 2006) and the extent of nutrient loss due to weeds varies depending on factors such as the crop, location, and level of weed control. Inadequate weed control

contributes to reduced fertilizer efficiency and productivity. Managing weeds in soybean cultivation, particularly during the *kharif* season, is challenging due to unpredictable rainfall, soil conditions during rainy periods, and a shortage of timely labor. Herbicide mixtures offer a solution by providing broad-spectrum weed control. While various herbicide experiments have been conducted, there is a pressing need for dynamic evaluations of the bio-efficacy of newer herbicides available for soybean-based cropping systems.

Materials and Methods

During the *kharif* 2021, a field experiment was conducted on soybean [*Glycine max* (L.) Merrill] at the Agricultural Research Station, Ummedganj, Kota, situated at 25°13' N latitude, 75°25' E longitude and 258 m above mean sea level. This area falls under Agro-climatic Zone V of Rajasthan, known as the Humid South Eastern Plain. Among different weed control measures, the experiment evaluated six ready-mix post-emergence herbicides at two different doses for effective weed management in soybean: propaquizafop + imazethapyr at 93.75 g *a.i.*/ha and 125 g *a.i.*/ha, sodium acifluorfen + clodinafop propargyl at 183.7 g *a.i.*/ha and 245 g *a.i.*/ha, and fomesafen + fluazifop-p-butyl at 165 g *a.i.*/ha and 220 g *a.i.*/ha. The experiment followed a randomized block design (RBD) with three replications. Soybean variety JS 20-34 was sown with a tractor-drawn seed drill, spaced 30 cm apart and at a depth of 2-3 cm, using a seed rate of 80 kg/ha. Seed treatment with 1 g/kg carbendazim was carried out. Fertilizers such as urea, single super phosphate (SSP) and muriate of potash (MOP) were applied at recommended rates (20:40:40 kg/ha) and drilled at a depth of 8-12 cm during sowing. Post-emergence herbicides were applied at 16 days after sowing (DAS) using a 0.1% non-ionic surfactant and a knapsack sprayer with flat fan nozzles with 500 liters of water/ha used per treatment.

Weed counts were observed at 30, 60 DAS and at harvest, with grassy, broad-leaved weeds and sedges counted separately and expressed as no./m². Weed control efficiency (WCE) was calculated using the formula Weed Control Efficiency (%) = (DMC-DMT)/ DMC×100, where DMC represents dry matter content of the control and DMT represents dry matter content of the treatment. Plant stands per meter row length, plant height (cm), dry matter accumulation (g/plant), number of branches, nodules per plant, dry weight of nodules, pods per plant, seeds per pod, 1000-seed weight (g), seed, straw and biological yield (kg/ha), harvest index, oil content (%) and protein content (%) were also recorded.

Phytotoxicity studies on soybean were conducted visually at various intervals after herbicide application. Succeeding wheat (Raj 4037) was sown at the same site for residual studies. Economic analysis was performed to determine the most profitable treatment, taking into account net return/ha and rupees per rupee invested. The cost of cultivation for each treatment was determined based on inputs used per hectare.

Results and Discussion

Effect on weed density, weed dry matter, nutrient depletion by weeds and weed control efficiency

During the *kharif* season, grassy weeds such as *Echinochloa colonum*, *E. crusgalli*, *Cyanodon dactylon*, *Eleusine indica* and broad-leaved weeds including *Celosia argentea*, *Digera arvensis*, *Commelina benghalensis* and *Trianthema portulacastrum* were predominant in soybean fields. *Cyperus rotundus* was the sole sedge weed identified, constituting 9.4% of the weed population. All herbicidal treatments significantly reduced total weed density and weed dry matter compared to the weedy check at 30, 60 days after sowing (DAS) and at harvest. The application of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL at 220 g *a.i.*/ha, followed closely by propaquizafop 2.5% + imazethapyr 3.75% at 125 g *a.i.*/ha and sodium aciflourfen + clodinafop-propargyl at 245 g *a.i.*/ha, resulted in significant reduction in weed density, weed dry matter, and nutrient (N, P and K) depletion by weeds at 30, 60 DAS, and at harvest. Among all herbicides, the ready-mix post-emergence fomesafen 11.1% + fluazifop-p-butyl 11.1% SL at 220 g *a.i.*/ha exhibited the highest weed control efficiency (85.41%, 79.97% and 77.39% at 30, 60 DAS, and at harvest, respectively). Even lower doses of these herbicide mixtures were significantly superior to the weedy check, effectively suppressing weed growth and providing favorable conditions for crop development. The efficiency of different post emergence herbicides has been also reported for clodinafop-propargyl by (Meena *et al*., 2012), fluazifop-p-butyl (Jhadav and Gade, 2012), propaquizafop (Panda *et al*., 2015; Vaghasia *et al*., 2014) against grassy weeds in soybean. Consequently, these treatments reduced the density of later-emerging weeds and minimized weed dry matter accumulation during the crop growth period, thereby decreasing nutrient depletion by weeds. The weedy check plot exhibited the highest nutrient depletion by weeds at harvest, with 14.69 kg N, 6.73 kg P and 11.67 kg K/ha, significantly higher than other treatments. Similar findings regarding reduced nutrient uptake by weeds under different weed control measures in soybean have been reported by Harisha *et*

Table 1 : Effect of weed control measures on total weed density, weed dry matter and weed control efficiency in soybean.

Treatments	Total weeds			Total weed dry matter accumulation (g/plant)			Weed control Efficiency %		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Weedy check	8.15*	15.93*	14.09*	410.66	779.15	578.69	0.00	0.00	0.00
2 HW 20 & 40 DAS	2.40	4.19	6.44	18.90	60.93	47.77	95.43	91.95	91.63
Pendimethalin 1.0 kg PE	5.18	10.55	10.41	111.16	347.92	306.56	72.48	54.52	46.76
Imazethapyr 100 g/ha PoE	4.66	9.49	9.93	103.99	279.13	239.64	74.39	63.34	58.33
Fluthiacet methyl 12.5 g/ha PoE	6.52	12.46	11.36	210.51	437.36	350.05	48.30	42.33	38.55
Clodinafop-propargyl 60 g/ha PoE	5.40	11.59	10.95	231.91	459.23	359.88	43.05	40.12	37.20
Fomesafen250 g/ha PoE	6.43	12.45	11.39	209.23	437.09	353.70	48.56	42.69	37.86
Fluazifop-p-butyl 250 g/ha PoE	5.37	11.56	11.01	232.25	432.35	359.09	43.62	43.33	37.91
Propaquizafop 50 g/ha PoE	5.38	11.65	11.14	232.78	459.66	364.09	42.93	40.00	36.51
Pendi. + Imaz. 960 g/ha PE	4.21	9.46	9.81	96.35	283.35	255.59	76.47	62.29	55.31
Propaqf. + Imaz. 93.7 g/ha PoE	5.02	9.03	9.59	109.87	268.28	208.64	73.28	64.80	63.58
Propaqf. + Imaz.125 g/ha PoE	3.95	6.61	8.04	61.63	155.87	134.50	84.87	79.64	76.40
Sod. Acif. + Clodina.P.183.7 g/ha PoE	5.13	9.19	9.66	113.25	276.06	212.43	72.27	63.84	62.85
Sod. Acif. + Clodina.P.245 g/ha PoE	4.08	6.80	8.14	64.14	161.51	137.15	84.36	78.80	75.84
Fomsaf. + Fluazi.FB165 g/ha PoE	5.06	9.08	9.43	109.97	268.16	204.85	73.07	64.80	64.01
Fomsf. + Fluazi.FB 220 g/ha PoE	3.84	6.43	7.74	59.34	155.07	129.72	85.41	79.97	77.39
LSD (P=0.05)	0.46	0.53	0.87	27.19	63.12	47.04	5.18	6.05	6.14

*Values are $\sqrt{x+0.5}$ transformed.

al. (2021).

Effect on soybean crop

Growth parameters

All herbicidal treatments using PoE (RM) significantly enhanced the growth parameters of soybean crops compared to the weedy control, evident at all growth stages (30, 60 DAS, and at harvest) as shown in Table 2. During the kharif season, weeds tend to outpace crop growth, leading to competition for solar radiation and nutrients (Jadon *et al.*, 2019). Consequently, under weedy conditions, soybean plants struggle to attain optimal height, with the tallest observed at 30 DAS in the weedy check (23.93 cm). However, at 60 DAS and harvest, herbicide-treated plots exhibited greater plant height due to effective weed population and growth control. Additionally, all weed control measures resulted in increased periodic dry matter production of the crop, branches per plant, pods per plant, nodules per plant, and dry weight of nodules across various growth stages (Table 2). The superiority of readymix applications was because of better control of both type of weeds *viz.*, monocots and dicots, which resulted in reduced weed competition with crop to a greater extent. The superiority of readymix applications over individual one is soybean have been also reported by various scientists *viz.*; Bhimwal *et al.* (2018), Mangraj *et al.* (2021) (pendimethalin + imazethapyr); Jha *et al.* (2014), Harithavardhni *et al.* (2018) (sodium acifluorfen + clodinafop propargyl); Kadam *et al.* (2020) and Sondhia *et al.* (2018).

Yield attributes and yields

The weed control treatments notably enhanced the number of pods per plant, 1000 seed weight, seed yield, straw yield, and biological yield compared to the weedy control (Tables 3 and 4). This effect was particularly pronounced when incorporating a mixture of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL, sodium acifluorfen 16.5% EC + clodinafop-propargyl 8% EC and propaquizafop 2.5% + imazethapyr 3.75%. The reduced weed infestation in these treatments resulted in lower nutrient depletion and decreased competition for growth resources. Consequently, these herbicides exhibited higher values for pods per plant (ranging from 43.7 to 58.9) and 1000 seed weight (132.1 to 137.1 g), although no significant differences were noted for seeds per pod. The improved expression of yield attributes in herbicide-treated plots may be attributed to the lower resurgence frequency and growth of weeds in these treatments. Various authors *viz.*, Habimana *et al.* (2013), Panda *et al.* (2015) and Ahirwar *et al.* (2018) also observed significant effect of weed control in increasing yield attributes of soybean.

The treatments involving fomesafen 11.1% + fluazifop-p-butyl 11.1% SL, sodium acifluorfen 16.5%

Table 2 : Effect of weed control measures on plant stand, plant height and dry matter accumulation in soybean.

Treatments	Plant stand (no./mrl)		Plant height (cm)				Dry matter accumulation (g/plant)			
	30 DAS	Harvest	30 DAS	45 DAS	60 DAS	Harvest	30 DAS	45 DAS	60 DAS	Harvest
Weedy check	12.20	10.87	23.93	40.53	51.00	51.50	0.88	2.92	9.46	11.75
2 HW 20 & 40 DAS	12.33	12.27	22.87	39.27	48.77	58.27	2.09	7.17	20.47	30.91
Pendimethalin 1.0 kg PE	12.07	11.27	21.90	31.00	37.63	44.10	1.23	4.50	12.65	15.95
Imazethapyr 100 g/ha PoE	11.53	11.40	21.63	31.20	36.13	44.33	1.37	4.64	13.36	18.09
Fluthiacet methyl 12.5 g/ha PoE	12.00	11.40	21.13	30.60	37.23	44.60	1.14	3.83	13.32	17.86
Clodinafop-propargyl 60 g/ha PoE	12.47	11.87	21.27	32.43	37.23	44.37	1.13	4.01	12.75	18.53
Fomesafen250 g/ha PoE	12.33	12.00	21.77	31.83	38.17	44.57	1.19	4.26	12.58	19.00
Fluazifop-p-butyl 250 g/ha PoE	12.00	11.40	20.67	31.20	38.73	46.63	1.15	4.38	13.05	18.46
Propaquizafop 50 g/ha PoE	12.07	11.90	21.03	30.80	37.03	45.03	1.15	3.83	12.74	17.12
Pendi. + Imaz. 960 g/ha PE	11.93	11.53	21.30	30.00	42.17	46.53	1.38	4.43	13.01	17.69
Propaqf. + Imaz. 93.7 g/ha PoE	12.07	11.87	20.33	32.63	42.90	48.37	1.32	4.46	14.57	23.61
Propaqf. + Imaz.125 g/ha PoE	12.60	12.20	22.33	35.13	46.03	54.97	1.83	6.00	17.42	27.44
Sod. Acif. + Clodina.P.183.7 g/ha PoE	12.20	11.33	20.63	32.67	43.47	47.93	1.58	4.28	14.54	23.50
Sod. Acif. + Clodina.P.245 g/ha PoE	12.33	11.80	21.97	34.50	45.87	54.37	1.80	5.94	17.27	27.28
Fomsaf. + Fluazi.FB165 g/ha PoE	12.27	11.73	21.53	32.87	44.00	48.77	1.56	4.69	14.63	24.11
Fomsf. + Fluazi.FB 220 g/ha PoE	12.13	11.80	22.77	35.53	46.20	55.80	1.87	6.04	17.51	27.72
LSD (P=0.05)	NS	NS	NS	3.29	5.84	6.06	0.18	0.90	2.53	3.19

Table 3 : Effect of weed control measures on yield attributes of soybean.

Treatments	Branches/plant			Nodules /plant	Dry weight of nodules	Pods/ plant	Seeds /pod	Test weight (g)
	30 DAS	60 DAS	Harvest					
Weedy check	1.00	1.13	1.20	31.14	38.45	20.1	2.30	109.4
2 HW 20 & 40 DAS	1.27	3.20	3.60	57.33	89.05	67.3	2.67	137.5
Pendimethalin 1.0 kg PE	1.20	1.60	1.73	39.00	47.56	29.7	2.40	121.3
Imazethapyr 100 g/ha PoE	1.27	1.80	1.87	44.00	48.77	40.1	2.37	131.8
Fluthiacet methyl 12.5 g/ha PoE	1.20	1.60	1.93	40.00	47.56	36.5	2.37	128.5
Clodinafop-propargyl 60 g/ha PoE	1.13	1.60	1.87	39.80	48.88	38.5	2.30	126.7
Fomesafen250 g/ha PoE	1.20	2.20	1.87	40.40	48.07	39.4	2.33	128.2
Fluazifop-p-butyl 250 g/ha PoE	1.13	2.07	1.87	41.00	48.57	39.3	2.30	128.2
Propaquizafop 50 g/ha PoE	1.20	1.60	1.80	39.20	55.65	33.5	2.30	129.2
Pendi. + Imaz. 960 g/ha PE	1.20	1.80	2.07	44.40	56.36	40.8	2.33	132.5
Propaqf. + Imaz. 93.7 g/ha PoE	1.20	1.93	2.50	42.40	64.76	43.7	2.37	132.1
Propaqf. + Imaz.125 g/ha PoE	1.33	2.53	3.27	51.80	74.58	57.7	2.60	136.8
Sod. Acif. + Clodina.P.183.7 g/ha PoE	1.27	1.67	2.40	44.40	63.75	42.8	2.30	130.6
Sod. Acif. + Clodina.P.245 g/ha PoE	1.27	2.53	3.33	51.20	77.61	57.7	2.57	136.4
Fomsaf. + Fluazi.FB165 g/ha PoE	1.23	1.87	2.47	43.80	63.85	44.5	2.50	131.4
Fomsf. + Fluazi.FB 220 g/ha PoE	1.30	2.60	3.33	52.10	78.32	58.9	2.60	137.1
LSD (P=0.05)	NS	0.45	0.46	5.15	5.69	6.77	NS	7.25

EC + clodinafop-propargyl 8% EC and propaquizafop 2.5% + imazethapyr 3.75% at both higher and lower doses were significantly superior in enhancing seed yield, straw yield, and biological yield over the weedy control. This superiority could be linked to improved weed control, creating favorable growth conditions such as increased nutrient availability, moisture, light and other factors for the crop plants, ultimately resulting in enhanced growth

Table 4 : Effect of weed control measures on total nutrient uptake, yield and economics of soybean.

Treatments	Total nutrient uptake by soybean (seed+straw)			Seed yield (kg/ha)	Straw yield (kg/ha)	Net return (Rs/ha)	B: C ratio
	N (kg/ha)	P (kg/ha)	K (kg/ha)				
Weedy check	56.1	5.60	32.81	626	977	6751	0.31
2 HW 20 & 40 DAS	189.7	17.33	97.51	1970	2636	52988	1.50
Pendimethalin 1.0 kg PE	85.6	8.42	47.20	970	1328	19178	0.78
Imazethapyr 100 g/ha PoE	103.7	9.94	55.67	1145	1551	27747	1.17
Fluthiacet methyl 12.5 g/ha PoE	97.7	9.66	53.47	1113	1510	26413	1.12
Clodinafop-propargyl 60 g/ha PoE	93.8	9.25	52.07	1072	1454	24139	1.01
Fomesafen250 g/ha PoE	97.8	9.57	53.40	1103	1496	25981	1.10
Fluazifop-p-butyl 250 g/ha PoE	88.9	8.76	49.00	1014	1378	20207	0.80
Propaquizafop 50 g/ha PoE	91.9	9.15	50.75	1053	1435	23753	1.01
Pendi. + Imaz. 960 g/ha PE	100.2	9.72	54.48	1127	1527	25286	1.00
Propaqf. + Imaz. 93.7 g/ha PoE	126.6	12.16	68.68	1407	1897	37779	1.49
Propaqf. + Imaz.125 g/ha PoE	160.4	14.97	84.63	1730	2323	51243	1.94
Sod. Acif. + Clodina.P.183.7 g/ha PoE	121.0	11.55	66.19	1340	1808	36504	1.54
Sod. Acif. + Clodina.P.245 g/ha PoE	152.3	14.12	80.83	1628	2204	49051	2.04
Fomsaf. + Fluazi.FB165 g/ha PoE	127.6	12.19	69.60	1413	1905	39874	1.69
Fomsf. + Fluazi.FB 220 g/ha PoE	165.0	15.24	86.92	1760	2364	55008	2.30
LSD (P=0.05)	14.6	1.34	7.76	180.7	238.2	7436	0.31

and higher dry matter production. The highest seed yield (1760 kg/ha), straw yield (2364 kg/ha) and biological yield (4124 kg/ha) were observed with the ready-mix post-emergence application of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL at a rate of 220 g *a.i.*/ha. The results so obtained for seed yield corroborates with the findings of Harisha *et al.* (2021) and Patel *et al.* (2021).

Quality parameters and nutrient uptake

Weed control treatments resulted in a significant increase in the protein content of soybean seeds compared to the weedy control, although they did not bring about significant changes in improving the oil content (Table 3). Among the herbicidal mixtures, fomesafen 11.1% + fluazifop-p-butyl 11.1% SL applied at a rate of 220 g *a.i.*/ ha exhibited the highest protein content in seeds (40.76%) compared to all other treatments. The application of ready-mix herbicides significantly enhanced the uptake of nitrogen (N), phosphorus (P) and potassium (K) by the crop compared to the weedy control. Specifically, the ready-mix of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL at a rate of 220 g *a.i.*/ha recorded significantly higher total N (165.0 kg/ha), P (15.24 kg/ha), and K (86.92 kg/ha), statistically comparable to propaquizafop 2.5% + imazethapyr 3.75% at 125 g *a.i.*/ha and sodium acifluorfen 16.5% EC + clodinafop-propargyl 8% EC at 245 g *a.i.*/ha, in comparison to the other herbicidal treatments. These results are in agreement with the findings of Kumbar *et al.* (2018), Bhimwal *et al.* (2018) and Harisha *et al.* (2021) and Patel *et al.* (2021).

Economics

Maximum net returns of ` 55008/ha with B: C ratio of 2.30 was fethched with the application of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL 220 g *a.i.*/ha, closely followed by propaquizafop 2.5% + imazethapyr 3.75 % 125 g *a.i.*/ha 125 g *a.i.*/ha (` 42043/ha & 1.59) and sodium acifluorfen 16.5% EC + clodinafop-propargyl 8% EC 245 g *a.i.*/ha (` 40322/ha & 1.67) which was significantly higher than lower doses and weedy check (` 2881/ha & 0.13). The higher B:C ratio achieved under superior treatments might be due to higher seed yield and higher returns per rupee investment (Table 3). Results of the present investigation corroborate the finding of Harithavardhini *et al.* (2016) and Patel *et al.* (2021).

Effect on soybean crop phytotoxicity

No phytotoxic symptoms such as wilting, vein clearing, necrosis, epinasty, or hyponasty were observed with any of the herbicide mixtures. This indicates that the tested herbicide combinations were selective towards soybean crops and can be safely utilized.

Patel *et al.* (2021) reported no phytotoxicity of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL at a rate of 220 g *a.i.*/ha on soybean. Bagotiya *et al.* (2018) noted that while sodium acifluorfen + clodinafop-propargyl and

Table 5 : Residual effect of weed control measures on succeeding wheat crop.

Treatments	Plant stand (no./mrl) at 45 DAS	Plant height (cm) at 45 DAS	Dry matter (g/plant) at 45 DAS	Tillers/mrl (No.)	Grains/ear (No.)	1000 seed wt (g)	Seed yield kg/ha	Straw yield kg/ha	Protein content (%)
Weedy check	32.1	34.6	24.36	120.3	34.4	44.01	4029	5375	11.32
2 HW 20 & 40 DAS	32.5	36.0	25.79	139.7	37.4	44.74	4743	5819	12.49
Pendimethalin 1.0 kg PE	32.2	35.6	24.55	125.0	35.3	44.58	4458	5611	11.76
Imazethapyr 100 g/ha PoE	31.7	35.6	24.65	124.3	35.4	44.53	4455	5562	11.88
Fluthiacet methyl 12.5 g/ha PoE	31.4	35.5	24.78	124.3	35.5	44.57	4434	5628	11.73
Clodinafop-propargyl 60 g/ha PoE	31.8	35.5	24.74	123.7	35.4	44.52	4370	5613	11.53
Fomesafen250 g/ha PoE	32.2	35.0	24.65	124.7	35.4	44.50	4356	5535	11.67
Fluazifop-p-butyl 250 g/ha PoE	32.5	34.8	24.69	123.7	35.2	44.20	4421	5541	11.59
Propaquizafop 50 g/ha PoE	32.1	34.9	24.82	124.0	35.2	44.11	4443	5510	11.67
Pendi. + Imaz. 960 g/ha PE	31.9	35.3	23.91	124.0	35.1	44.07	4421	5544	11.59
Propaqf. + Imaz. 93.7 g/ha PoE	31.8	35.4	25.30	129.0	37.0	44.10	4405	5648	11.65
Propaqf. + Imaz.125 g/ha PoE	31.2	35.7	25.34	132.0	37.0	44.60	4545	5690	12.22
Sod. Acif. + Clodina.P.183.7 g/ha PoE	32.1	35.3	25.26	126.3	37.0	44.11	4421	5661	11.73
Sod. Acif. + Clodina.P.245 g/ha PoE	31.2	35.8	25.30	131.3	37.1	44.62	4597	5685	12.32
Fomsaf.+Fluazi.FB 165 g/haPoE	31.5	35.3	25.21	126.7	37.0	44.10	4512	5679	11.67
Fomsf. + Fluazi.FB 220 g/ha PoE	31.2	36.0	25.55	138.7	37.1	44.68	4610	5717	12.44
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

propaquizafop 2.5% + imazethapyr at 125 g *a.i.*/ha induced some leaf yellowing and temporary growth cessation in soybean, the crop plants recovered within 6-7 days with no adverse impact on crop yield. The results are in conformity with the findings of Patel *et al.* (2021) did not observe phytotoxicity of fomesafen + fluazifop-p-butyl on soybean crop.

Residual effect on succeeding wheat crop

The herbicidal treatments administered to the preceding soybean crop did not exhibit any residual effects on the subsequent wheat crop, as evidenced by consistent growth parameters, yield attributes and overall yield. This was probably a consequence of faster rate of degradation of herbicides in the soil within the time frame of the crop duration in which they were applied.

Bhimwal *et al.* (2018) who have reported that succeeding wheat and chickpea crops were not affected by herbicides applied in soybean due to their residual effect. Choudhary *et al.* (2018) found that growth and yield of succeeding wheat, chickpea and mustard after soybean were not influenced significantly due to carryover effect of herbicides applied to soybean *viz*. fomesafen + fluazifop-p-butyl, sodium acifluorfen + clodinafop-propargyl and propaquizafop + imazethapyr mixtures.

Conclusion

Based on the results of the field experiment, it can be inferred that various post-emergence herbicide treatments effectively managed a broad spectrum of weeds in soybean fields, leading to increased crop yield compared to fields without herbicide application. Among these treatments, the combination of fomesafen (11.1%) and fluazifop-p-butyl (11.1%) in a ready-mix formulation at a rate of 220 g active ingredient per hectare demonstrated superior weed control performance. This particular mixture resulted in the lowest weed density and dry matter, along with high weed control efficiencies of 85.41%, 79.97% and 77.39% at 30, 60 days after sowing (DAS) and during harvest, respectively. Moreover, it caused minimal nutrient depletion by weeds (3.32 kg NPK/ha, 1.41 kg NPK/ha, and 2.51 kg NPK/ha) while enhancing total nutrient uptake by the crop (165.0 kg NPK/ha, 15.24 kg NPK/ha,

and 86.92 kg NPK/ha), resulting in increased oil yield (349.1 kg/ha), protein yield (717.6 kg/ha) and seed yield (1760 kg/ha). Additionally, it provided the maximum net return (55008/ha) and a favorable benefit-to-cost ratio (2.30) compared to other treatments. Close behind were treatments involving propaquizafop (2.5%) combined with imazethapyr (3.75%) at 125 g active ingredient per hectare and sodium acifluorfen (16.5%) combined with clodinafop-propargyl (8%) at 245 g active ingredient per hectare, which showed similar efficacy without causing any adverse effects on soybean crops or leaving residual impacts on subsequent wheat crops.

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