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RESEARCH ARTICLE

Evaluation of post-emergence herbicides for weed management in greengram

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ABSTRACT

A field experiment was conducted to evaluate the bio-efficacy of fomesafen 11.1% w/w + fluazifop-p-butyl 11.1% w/w (25% w/v SL) for control of complex weed flora in greengram and its residual effects on succeeding crop at GBPUA&T, Pantnagar during *Kharif* (rainy) season of 2017 and 2018. The results revealed that post-emergence application of fomesafen + fluazifop-p-butyl 25% SL applied at 250 and 312.5 g/ha being at par were found to be most effective in controlling all type of weeds in greengram. There were no phytotoxic symptoms due to any dose of fomesafen + fluazifop-p-butyl 25% SL. The highest grain yield (1.22 t/ha) was obtained with fomesafen + fluazifop-p-butyl 25% SL applied at 312.5 g/ha closely followed by its lower dose250g/ha (1.21 t/ha) and two hand weeding at 20 and 40 DAS (1.21 t/ha). Propaquizafop 10% EC at 100 g/ha and quizalofop-ethyl 5% EC at 50 g/ha kept as standard checks proved inferior.

Keywords: Bio-efficacy, Fomesafen + fluazifop-p-butyl, Greengram, Phytotoxicity, Standard checks

INTRODUCTION

India is the highest producer as well as consumer of pulses in the world. Greengram with 43.26 million ha is the third important pulse crop of India grown in nearly 8 per cent of the total pulse area of the country. In India, total production of greengram is 2.05 million tons (Anonymous 2021-22). Its seed contains 24.7% protein due to its supply of cheaper protein source, it is designated as "poor man's meat" (Potter and Hotchkiss 1997). Greengram has high digestibility and palatability; its pods are used as green vegetable. Its whole grains and split grains are used as dal and curry. Its green plants, chopped and mixed with other fodders are palatable as feed for animals. It is also used as green manuring crop, which adds nitrogen in addition to humus to the soil. It is a soil protecting crop in rainy season.

Greengram is recommended for cultivation mainly in *Kharif* season under Tarai condition in Uttarakhand, India. Weed infestation is one of the major constraints in greengram cultivation and causes 50 to 90% yield loss (Kumar *et al*. 2006). Competition with the weeds leads to 30 to 80% reduction in grain yield of greengram during summer and *Kharif* seasons while 70-80% during *Rabi* season, respectively. Algotar *et al.* (2015) reported that the weed infestation if not checked within 20 DAS, there would be a severe yield reduction to an extent of 38 per cent in contrast to 20 per cent yield reduction with unchecked weed infestation till 20 DAS in greengram. A first period of 20-40 days after sowing is crucial for crop-weed completion (Pankaj *et al.* 2017). Mechanical practices such as hand weeding and inter–culturing is effective but unavailability of labour and incessant rains during the early crop season normally limit the weeding operations. Therefore, chemical weeding under such circumstances becomes indispensable and can be a cost-effective alternative.

Application of pendimethalin and imazethapyr during pre-emergence (PE) and post-emergence (PoE), respectively, have shown promising results in greengram Singh *et al.* (2015). However, narrow time window of application often makes the PE herbicides less preferred choice among the farmers. Also, application of a single herbicide is often ineffective in controlling diverse weed flora. On the contrary, either ready or tank mixes of compatible herbicides with varying modes of action may ensure effective control of diverse weed flora and check shifting of weed flora complex and herbicide resistance Banerjee *et al.* (2018). In general, there is paucity of information on the impact of new herbicide ready mixes available in Indian market on the performance of monsoon greengram.

Under the above perspectives, the present study was formulated to evaluate the effect of new

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herbicide ready-mixes on weed density and dry matter accumulation, growth and yield of monsoon greengram and the performance of succeeding *Rabi*(mustard) crop in clay loam soil of Pantnagar, Uttarakhand.

MATERIALS AND METHODS

The field experiment was conducted at GBPUA&T, Pantnagar (29°N latitude, 27.3°E longitude and at an altitude of 243.8 m above mean sea level) during *Kharif* season of 2017 and 2018. The climate of Pantnagar is very hot in summers and cold in winters. The soil of the experimental site is clay loam in texture.

Greengram variety "*Pant Mung-5*" was sown manually with 30x10cm planting geometry in a plot size of 5.5m x 3.6m with seed rate of 15 kg/ha. Nine treatment combinations comprised of three doses of fomesafen + fluazifop-p-butyl 25% SL at 187.5, 250, and 312.5 g/ha, fomesafen 25% w/v SL 156.25 g/ha, fluazifop-p-butyl 13.4% EC 156.25 g/ha were compared with quizalofop-ethyl 5% EC at 50 g/ha and propaquizafop 10% EC at 100 g/ha as standard checks, and also twice hand weeding (20 and40 DAS) and weedy check. Herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 500-liter water/ha. Phytotoxicity of Fomesafen + fluazifop-p-butyl 25% SL at 312.5 and 625.0 g/ha was studied on greengram. The experiment was laid out in randomized block design (RBD) with three replications. Thinning was done manually to maintain optimal plant population. Irrigation was applied in the field as per requirement. A recommended dose of fertilizer (20:40:30 kg NPK/ha) was applied as per package of practices of crop for the area.

Category-wise weed count and their dry biomass accumulation and total weed density, total weed dry biomass and weed control efficiency were measured at 07, 14, 21, 28, 42 DAA and at harvest by placing a quadrate of 0.25 m^2 randomly at 3 places in each plot and were subjected to square-root transformation [$\sqrt{x+0.5}$] before analysis. Crop was harvested on November 13, 2018 and left in the field for 5-7 days for sun drying. The number of plants/m^2, pods/plant, 100 grain weight, grain yield and plant height were recorded. Phytotoxic symptoms were recorded at 0, 1, 3, 7, 14 and 28 days after herbicide application at dose of 312.5 and 625 g/ha of fomesafen + fluazifop-p-butyl 25% SL by comparing it with untreated check. Carry over effect of applied herbicides were also observed on succeeding mustard crop. Succeeding mustard crop variety *Kranti* was sown in *Rabi* season of 2017-18 and 2018-19 on 12-12-2017 and 24-11-2018, respectively. Data were analyzed by using standard statistical techniques (STPR package). Treatment means were separated using the least significant difference (LSD) at the 5% level of significance. Differences were considered significant only at p=0.05.

RESULTS AND DISCUSSION

Weed flora

The major weed flora recorded in weedy check plots in greengram crop consisted of *Eleusine indica, Echinochloa colona, Digitaria sanguinalis, Dactyloctenium aegyptium* and *Panicum maximum* among grassy weeds: *Mollugo stricta*, *Celosia argentea, Phyllanthus niruri, Eclipta alba, Digera arvensis* and *Amaranthus viridis* as broadleaf weeds (BLWs) and *Cyperus rotundus* and *Cyperus iria* as sedges (Khairnar *et al*. 2015) also reported the similar findings.

Effect of herbicides on weed density and weed dry weight at 21 and 42 DAA

Application of various weed control treatments had significant effect over the density of weeds at 21 and 42 DAA. The efficacy of fomesafen + fluazifop-p-butyl 25% SL was further improved with the corresponding increase in the rates of application from 187.0 to 312.5 g/ha or higher rate 312.5 g/ha and proved superior over other herbicidal treatments. *Eleusine indica, Echinochloa colona, Digitaria sanguinalis, Dactyloctenium aegyptium, Trianthema monogyna, Digera arvensis, Amaranthus viridis, Eclipta alba* and *Cyperus iria* were completely controlled with application of Fomesafen + Fluazifop-p-butyl 25% SL at 312.5 and 250.0 g/ha. However, at 21 and 45 DAA the density of *Panicum maximum, Mollugo stricta, Celosia argentea, Phyllanthus niruri* and *Cyperus rotundus* was not completely controlled by Fomesafen + Fluazifop-p-butyl 25% SL applied at any doses but these are also effective in reducing the density (**Table 1-4**). On other hand, standard checks quizalofop ethyl 5% EC 50 g/ha PoE and propaquizafop 10% EC 100 g/ha as PoE caused more reduction in the density and dry weight of all type weeds as compared to weedy check plots. However, twice hand weeding at 20 and 40 DAS reduced the density and dry weight of weeds to the maximum extent over herbicidal treatments due to elimination of all sort of weeds during the course of hand weeding (Das 2008) except Fomesafen + Fluazifop-p-butyl 25% SL at 312.5 and 250.0 g/ha in the present study.

Fluazifop-p-butyl, and Fomesafen alone being selective for a certain set of weeds (Oliveria Junior 2011) did not provide satisfactory control of total weeds.

Total weed density, total weed dry biomass and weed control efficiency

Among the different herbicidal treatments, the lowest total weed density was recorded with fomesafen + fluazifop-p-butyl 25% SL at 312.5 g/ha and was significantly superior to rest of the herbicidal treatments, at all the stages of crop growth (**Table 5**). The lowest total weed dry biomass and highest weed control efficiency was recorded with application of Fomesafen + fluazifop-p-butyl 25% SL 312.5 g/ha followed by fomesafen + fluazifop-p-butyl 25% SL 250.0 g/ha amongst different herbicidal treatments at all the stages (**Table 5**). Weed-control efficiency

Table 1. Effect of different treatments on weed density and dry weight of grassy weed and sedges at 21 DAA (pooled data of two year)

Treatment	Dose (g/ha)	Grassy weeds										Sedges			
		Eleusine indica		*Echinochloa colona*		*Panicum maximum*		*Dactyloctenium aegyptium*		*Digitaria sanguinalis*		*Cyperus rotundus*		*Cyperus iria*	
		Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight
Fomesafen + fluazifop-p-butyl	187.5	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.1 (9.3)	1.8 (2.3)	1.2 (0.7)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)	6.0 (35.3)	2.8 (6.7)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	250	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.2 (4.0)	1.3 (0.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.5 (11.3)	1.9 (2.6)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	312.5	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	1.2 (0.5)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.8 (7.3)	1.7 (1.9)	1.0 (0.0)	1.0 (0.0)
Fomesafen	156.25	5.4 (31.3)	3.7 (14.3)	2.8 (7.3)	2.7 (6.3)	4.7 (21.3)	2.5 (5.3)	4.5 (19.3)	2.5 (5.3)	3.3 (10.7)	2.2 (3.9)	3.0 (8.0)	1.8 (2.3)	1.0 (0.0)	1.0 (0.0)
Fluazifop-p-butyl	156.25	1.5 (2.7)	1.0 (0.1)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.1)	4.3 (18.0)	2.7 (6.3)	4.3 (17.3)	2.6 (5.8)	6.4 (40.7)	2.9 (7.5)	1.0 (0.0)	1.0 (0.0)
Quizalofop-ethyl	50	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.6 (2.0)	1.3 (0.7)	1.2 (0.7)	1.1 (0.4)	1.0 (0.0)	1.0 (0.0)	4.8 (22.7)	2.7 (6.4)	3.6 (14.7)	2.5 (6.3)
Propaquizafop	100	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.8 (13.3)	2.2 (3.7)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.2 (0.7)	3.7 (12.7)	2.6 (5.6)	3.0 (10.7)	2.0 (3.6)
Hand weeding (20&40DAS)	-	3.9 (15.3)	2.2 (3.9)	1.6 (2.0)	1.4 (1.2)	2.6 (6.0)	1.6 (1.7)	3.1 (8.7)	2.2 (3.8)	3.9 (14.7)	2.6 (5.7)	5.3 (26.7)	2.6 (5.7)	2.8 (8.0)	1.9 (2.9)
Weedy check	-	7.6 (60.7)	5.3 (28.1)	3.4 (10.7)	3.4 (10.9)	6.3 (40.7)	3.8 (14.0)	5.2 (26.0)	3.2 (9.4)	5.6 (30.7)	3.2 (9.2)	7.0 (48.0)	3.2 (9.6)	5.8 (37.3)	3.8 (14.5)
LSD (p=0.05)	-	1.19	0.69	0.43	0.27	0.88	0.47	0.46	0.20	0.19	0.23	0.53	0.19	1.32	0.68

DAS: Days after sowing; Value in parentheses were original and transformed to square root ($\sqrt{x+1}$) for analysis; Density (no./m^2); Dry weight (g/m^2)

Table 2. Effect of different treatments on weed density and dry weight of broad-leaved weed at 21 DAA (pooled data of two year)

Treatment	Dose (g/ha)	Broad-leaved weeds													
		Mollugo stricta		*Trianthema monogyna*		*Celosia argentea*		*Digera arvensis*		*Amaranthus viridis*		*Phyllanthus niruri*		*Eclipta alba*	
		Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight
Fomesafen + fluazifop-p-butyl	187.5	3.3 (10.0)	1.4 (1.0)	2.5 (5.3)	1.9 (2.7)	2.7 (6.7)	2.2 (4.3)	1.4 (1.3)	1.3 (0.9)	1.0 (0.0)	1.0 (0.0)	2.0 (3.3)	1.4 (1.0)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	250	2.3 (4.7)	1.2 (0.3)	1.2 (0.7)	1.1 (0.3)	1.8 (2.7)	1.5 (1.5)	1.2 (0.7)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)	1.6 (2.0)	1.2 (0.6)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	312.5	2.1 (4.0)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.4 (1.1)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)
Fomesafen	156.25	2.0 (3.3)	1.2 (0.4)	2.2 (4.0)	1.7 (2.1)	2.2 (4.0)	1.8 (2.3)	1.0 (0.0)	1.0 (0.0)	2.1 (4.0)	1.5 (1.5)	2.7 (6.7)	1.5 (1.2)	1.0 (0.0)	1.0 (0.0)
Fluazifop-p-butyl	156.25	3.8 (14.7)	1.5 (1.5)	2.6 (6.7)	2.1 (3.7)	3.8 (13.3)	2.6 (6.8)	4.5 (19.3)	2.6 (5.8)	2.9 (8.0)	1.7 (1.9)	2.7 (6.7)	1.8 (2.4)	1.4 (1.3)	1.4 (1.1)
Quizalofop-ethyl	50	4.0 (17.3)	1.6 (1.5)	3.6 (12.0)	2.7 (6.5)	4.4 (18.0)	2.7 (7.2)	4.2 (16.7)	2.5 (5.3)	2.7 (6.7)	1.7 (1.9)	2.7 (6.7)	1.6 (1.8)	1.4 (1.3)	1.4 (1.2)
Propaquizafop	100	3.7 (14.7)	1.5 (1.3)	2.5 (5.3)	1.9 (2.8)	4.6 (20.0)	2.5 (5.7)	4.3 (18.0)	2.5 (5.5)	2.5 (5.3)	1.6 (1.7)	3.0 (8.0)	1.8 (2.2)	1.4 (1.3)	1.4 (1.1)
Hand weeding (20&40DAS)	-	3.1 (11.0)	1.3 (0.8)	2.0 (3.3)	1.7 (2.0)	3.1 (8.7)	2.2 (4.1)	3.7 (12.7)	2.9 (7.9)	1.7 (2.7)	1.3 (0.7)	2.4 (4.7)	1.3 (0.7)	1.0 (0.0)	1.0 (0.0)
Weedy check	-	4.7 (23.3)	2.1 (3.6)	4.6 (20.0)	3.9 (14.4)	5.4 (28.7)	3.5 (11.9)	5.4 (28.7)	3.4 (10.3)	3.4 (11.3)	2.3 (4.4)	3.8 (14.0)	2.1 (3.7)	1.8 (2.7)	1.7 (2.3)
LSD (p=0.05)	-	1.09	0.22	0.62	0.43	0.50	0.75	0.51	0.34	0.72	0.30	0.66	0.31	0.42	0.36

DAS: Days after sowing; Value in parentheses were original and transformed to square root ($\sqrt{x+1}$) for analysis; Density (no./m^2); Dry weight (g/m^2)

(WCE) based on total dry weight varied significantly amongst the treatments. This is due to broad-spectrum control of weeds by fomesafen + fluazifop-p-butyl (Oliveria Junior 2011).

Among the different herbicidal treatments, the lowest total weed density, total weed dry biomass and highest weed control efficiency were recorded with fomesafen + fluazifop-p-butyl 25% SL at 312.5 g/ha and was significantly superior to rest of the herbicidal treatments, at all the stages of crop growth (**Table 5**).

Effect of weed control treatments on various agronomic indices in greengram

The values of weed indices like weed control efficiency (WCE), herbicide efficiency index (HEI) and weed persistency index (WPI) were inferior in weedy checks plots (**Table 5**). But ready-mix application of fomesafen + fluazifop-p-butyl 25% SL at 250 and 312.5 g/ha recorded superior values of WCE, HEI and WPI. Application of propaquizafop 100 g/ha and fomesafen 25% 156.25 g/ha also

Table 3. Effect of different treatments on weed density and dry weight of grassy weed and sedges at 42 DAA (pooled data of two year)

Treatment	Dose (g/ha)	Grassy weeds										Sedges			
		Eleusine indica		*Echinochloa colona*		*Panicum maximum*		*Dactyloctenium aegyptium*		*Digitaria sanguinalis*		*Cyperus rotundus*		*Cyperus iria*	
		Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight
Fomesafen + fluazifop-p-butyl	187.5	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.9 (7.3)	2.4 (4.8)	1.3 (1.3)	1.4 (1.5)	1.2 (0.7)	1.2 (0.4)	4.7 (22.0)	2.0 (3.1)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	250	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.9 (2.0)	1.5 (1.6)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.6 (6.0)	2.0 (3.0)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	312.5	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.5 (1.3)	1.5 (1.4)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.2 (4.0)	1.9 (2.5)	1.0 (0.0)	1.0 (0.0)
Fomesafen	156.25	4.1 (18.7)	4.0 (19.3)	2.2 (4.0)	3.9 (14.7)	2.4 (10.7)	3.3 (10.0)	4.0 (15.3)	3.5 (11.5)	4.8 (22.7)	3.3 (10.2)	4.1 (16.0)	1.9 (2.7)	1.0 (0.0)	1.0 (0.0)
Fluazifop-p-butyl	156.25	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.5 (1.3)	1.3 (0.8)	4.0 (15.3)	3.9 (13.9)	3.5 (11.3)	2.9 (7.8)	5.6 (30.7)	2.1 (3.5)	1.0 (0.0)	1.0 (0.0)
Quizalofop-ethyl	50	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.7 (4.0)	1.8 (2.3)	1.2 (0.7)	1.2 (0.5)	1.0 (0.0)	1.0 (0.0)	4.5 (20.0)	2.1 (3.4)	2.3 (4.7)	1.8 (2.5)
Propaquizafop	100	1.6 (2.0)	1.6 (2.0)	1.0 (0.0)	1.0 (0.0)	2.2 (4.7)	2.3 (4.6)	1.2 (0.7)	1.2 (0.5)	1.2 (0.7)	1.2 (0.4)	3.9 (14.0)	2.1 (3.3)	2.1 (4.7)	1.6 (2.1)
Hand weeding (20&40DAS)	-	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.3 (2.0)	1.3 (0.7)	3.9 (14.7)	3.1 (9.5)	3.8 (13.3)	3.5 (11.1)	3.3 (10.0)	1.9 (2.7)	1.0 (0.0)	1.0 (0.0)
Weedy check	-	5.9 (36.0)	7.2 (59.0)	2.9 (7.3)	4.9 (22.9)	1.8 (16.7)	3.9 (14.5)	5.0 (24.0)	4.5 (19.3)	5.8 (32.7)	4.9 (23.1)	6.2 (37.3)	2.6 (6.0)	3.7 (13.3)	2.7 (6.2)
LSD (p=0.05)	-	1.04	1.48	0.12	0.38	NS	0.52	0.63	0.66	0.47	0.34	0.58	0.23	0.71	0.41

DAS: Days after sowing; Value in parentheses were original and transformed to square root ($\sqrt{x+1}$) for analysis; Density (no./m^2); Dry weight (g/m^2)

Table 4. Effect of different treatments on weed density and dry weight of broad-leaved weed at 42 DAA (pooled data of two year)

Treatment	Dose (g/ha)	Broad-leaved weeds													
		Mollugo stricta		*Trianthema monogyna*		*Celosia argentea*		*Digera arvensis*		*Amaranthus viridis*		*Phyllanthus niruri*		*Eclipta alba*	
		Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight	Density	Dry weight
Fomesafen + fluazifop-p-butyl	187.5	2.9 (7.3)	1.4 (1.0)	1.6 (2.0)	1.9 (2.7)	3.1 (8.7)	2.2 (4.3)	1.5 (2.0)	1.3 (0.9)	1.0 (0.0)	1.0 (0.0)	2.4 (4.7)	1.4 (1.0)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	250	2.7 (6.7)	1.2 (0.3)	1.0 (0.0)	1.1 (0.3)	2.4 (4.7)	1.5 (1.5)	1.4 (1.3)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)	2.0 (3.3)	1.2 (0.6)	1.0 (0.0)	1.0 (0.0)
Fomesafen + fluazifop-p-butyl	312.5	2.4 (4.7)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	1.4 (1.1)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.6 (2.0)	1.1 (0.3)	1.0 (0.0)	1.0 (0.0)
Fomesafen	156.25	3.1 (8.7)	1.2 (0.4)	1.4 (1.3)	1.7 (2.1)	2.2 (4.0)	1.8 (2.3)	1.0 (0.0)	1.0 (0.0)	2.1 (4.0)	1.5 (1.5)	2.0 (3.3)	1.5 (1.2)	1.0 (0.0)	1.0 (0.0)
Fluazifop-p-butyl	156.25	3.6 (14.7)	1.5 (1.5)	2.5 (5.3)	2.1 (3.7)	4.0 (15.3)	2.6 (6.8)	3.6 (13.3)	2.6 (5.8)	1.8 (2.7)	1.7 (1.9)	2.9 (8.0)	1.8 (2.4)	1.0 (0.0)	1.4 (1.1)
Quizalofop-ethyl	50	3.8 (14.0)	1.6 (1.5)	2.6 (6.0)	2.7 (6.5)	3.5 (12.0)	2.7 (7.2)	3.5 (12.0)	2.5 (5.3)	1.3 (1.3)	1.7 (1.9)	2.8 (7.3)	1.6 (1.8)	1.0 (0.0)	1.4 (1.2)
Propaquizafop	100	4.0 (16.0)	1.5 (1.3)	2.0 (3.3)	1.9 (2.8)	4.4 (18.0)	2.5 (5.7)	3.9 (14.7)	2.5 (5.5)	2.1 (4.0)	1.6 (1.7)	2.7 (7.3)	1.8 (2.2)	1.0 (0.0)	1.4 (1.1)
Hand weeding (20&40DAS)	-	1.7 (2.7)	1.3(0.8)	1.0 (0.0)	1.7 (2.0)	1.4 (1.3)	2.2 (4.1)	3.0 (8.0)	2.9 (7.9)	2.3 (5.3)	1.3 (0.7)	1.4 (1.3)	1.3 (0.7)	1.0 (0.0)	1.0 (0.0)
Weedy check	-	4.9 (24.7)	2.1(3.6)	3.3 (10.0)	3.9 (14.4)	5.1 (25.3)	3.5 (11.9)	4.8 (22.7)	3.4 (10.3)	3.3 (10.0)	2.3 (4.4)	3.8 (13.3)	2.1 (3.7)	1.8 (2.7)	1.7 (2.3)
LSD (p=0.05)	-	1.07	0.22	0.48	0.43	0.59	0.75	0.77	0.34	0.75	0.30	0.80	0.31	0.25	0.36

DAS: Days after sowing; Value in parentheses were original and transformed to square root ($\sqrt{x+1}$) for analysis; Density (no./m^2); Dry weight (g/m^2)

performed well but the combined application of fomesafen + fluazifop-p-butyl 25% SL at 250 and 312.5 g/ha and twice hand weeding at 20 and 40 DAS proved better for their weed indices.

Yield and yield attributing characters

Yield and yield attributing characters in treated plots were found significantly superior to weedy check (**Table 6**). Among the different weed control treatments, fomesafen + fluazifop-p-butyl 25% SL at 312.5 g/ha was found superior in attaining the yield and yield attributing characters. Yadav *et al.* 2022 and Piragi 2022 were also reported similar findings. The seed index (3.6 g) was recorded highest with twice hand weeding. The average grains/pod (6.8) and pods/plant (34.1) were recorded highest with fomesafen + fluazifop-p-butyl 25% SL at 312.5 g/ha.

Fomesafen + fluazifop-p-butyl 25% SL at higher dose (312.5 g/ha) resulted into highest seed yield (1.30 t/ha), however, it was at par with lower dose 250 g/ha and two hand weeding at 20 and 40 DAS. This might be owing to higher weed control efficiencies of these treatments that reduced the inter-specific competition for resources and allowed the crop to grow to its best potential which in turn positively influenced the biomass production and yield of crop (Lal *et al.* 2017).

Effect on succeeding crop

Phytotoxicity on succeeding mustard crop: No any phytotoxicity systems were observed on mustard crop regarding different doses of herbicides applied on Greengram crop.

Effect of plant population: In succeeding crop, the plant population of Mustard was not influenced significantly due to various weed control treatments applied on greengram.

Effect on yield and yield attributing characters: All yield and yield attributing characters were not influenced significantly due to weed control treatments (**Table 7**) and their differences were statistically non-significant. Application of fomesafen 11.1% w/w + fluazifop-p-butyl 11.1% w/w SL against weeds in greengram during *Kharif* season was observed safe for growing Mustard crop in *Rabi* season.

Conclusions

Fomesafen 11.1% w/w + fluazifop-p-butyl 11.1% w/w 25% SL at 250 to 312.5 g/ha being better than the standard check provided efficient control of complex weed flora in greengram resulted into improved crop productivity and profitability.

Table 5. Effect of different treatments on total weed density, dry weight, WCE, HEI and WPI (pooled data of two year)

Treatment	Dose (g/ha)	Total weed density (no./m^2)		Total weed dry weight (g/m^2)		WCE (%)		HEI		WPI	
		21 DAA	42 DAA	21 DAA	42 DAA	21 DAA	42 DAA	21 DAA	42 DAA	21 DAA	42 DAA
Fomesafen + fluazifop-p-butyl	187.5	8.5(72.0)	7.5(56.0)	4.5(19.1)	5.5(29.4)	86.9	86.5	2.79	2.77	0.69	0.65
Fomesafen + fluazifop-p-butyl	250	5.2(26.0)	5.0(24.0)	2.7(6.4)	3.7(13.0)	95.6	93.7	9.94	7.47	0.64	0.67
Fomesafen + fluazifop-p-butyl	312.5	4.1(16.7)	3.9(14.7)	2.2(4.1)	3.0(8.0)	97.2	96.0	16.83	13.26	0.65	0.67
Fomesafen	156.25	10.9(120.0)	10.5(108.7)	6.7(44.9)	9.2(85.1)	69.3	62.1	1.08	0.87	0.98	0.96
Fluazifop-p-butyl	156.25	12.2(148.7)	10.9(118.0)	6.6(42.9)	8.2(66.2)	70.5	69.3	0.95	0.94	0.75	0.69
Quizalofop-ethyl	50	10.9(118.7)	9.1(82.0)	6.3(39.3)	7.1(50.2)	73.0	77.1	1.15	1.37	0.87	0.75
Propaquizafop	100	10.5(110.7)	9.5(90.0)	5.9(33.8)	7.0(47.7)	76.8	77.3	1.49	1.62	0.80	0.65
Hand weeding (20&40DAS)	-	11.2(124.3)	7.7(58.7)	6.5(41.1)	5.9(34.1)	71.8	84.2	-	-	-	-
Weedy check	-	19.6(382.7)	16.6(276.0)	12.1(146.4)	14.9(224.2)	0.0	0.0	-	-	-	-
LSD (p=0.05)	-	1.06	0.88	0.67	0.99						

DAS: Days after sowing; Value in parentheses were original and transformed to square root ($\sqrt{x+1}$) for analysis.

Table 6. Effect of treatment on yield and yield attributes (pooled data of two year)

Treatment	Dose (g/ha)	Plant height (cm)	Plants (no. /m^2)	Yield attributes: Pods / plant	Yield attributes: Grain/ pod	Yield attributes: 100 Seed weight (g)	Seed yield (t/ha)		
							2017	2018	Pooled
Fomesafen + fluazifop-p-butyl	187.5	62.6	42.9	28.1	6.2	3.4	1.13	1.02	1.07
Fomesafen + fluazifop-p-butyl	250	65.2	48.1	30.3	6.2	3.4	1.27	1.14	1.21
Fomesafen + fluazifop-p-butyl	312.5	58.1	50.2	34.1	6.8	3.4	1.33	1.26	1.30
Fomesafen	156.25	67.2	41.4	25.4	5.8	3.3	1.02	1.03	1.02
Fluazifop-p-butyl	156.25	65.0	37.8	27.2	6.3	3.3	0.86	1.03	0.95
Quizalofop-ethyl	50	67.9	39.9	27.0	6.3	3.4	1.00	0.98	0.99
Propaquizafop	100	65.4	39.9	27.9	5.7	3.4	1.04	1.04	1.04
Hand weeding (20 and 40 DAS)	-	65.2	42.4	28.3	6.2	3.6	1.22	1.20	1.21
Weedy check	-	68.5	34.7	23.4	5.6	3.4	0.60	0.77	0.68
LSD (p=0.05)	-	NS	6.87	4.08	0.47	NS	0.34	0.13	0.19

DAS: Days after sowing

Table 7. Effect of treatments on yield and yield attributes of succeeding mustard crop (pooled data of two year)

Treatment	Dose (g/ha)	Plants/ m^2	No. of pods/plant	1000 grain weight (g)	Grain yield (kg/ha)		
					2017	2018	Pooled
Fomesafen + fluazifop-p-butyl	312.5	44.4	118.5	3.1	909	937	923.0
Fomesafen + fluazifop-p-butyl	625	47.7	125.4	3.1	934	990	962.1
Weedy check	-	52.2	130.2	3.3	957	1005	981.1
LSD (p=0.05)	-	NS	NS	NS	NS	NS	NS

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