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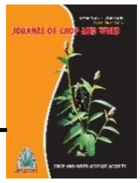

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Weed management in soybean using early post emergence herbicide in lateritic soil and residual effects of herbicide in succeeding crops

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ABSTRACT

A study was conducted to establish an appropriate weed management strategy through ready-mix early post-emergence herbicides for soybean production in lateritic belt of West Bengal (India). The experiment was conducted for two consecutive years i.e., 2017-18 and 2018-19 in a field located at Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Sriniketan, Birbhum, West Bengal (N 23^{0}39.823', E 87^{0}37.972'). The early post-emergence application of fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 10 days after soybean sowing recorded minimum weed population and dry weight as well as showed good weed control efficacy, higher yield with good soybean safety. However, weed-free treatment produced tallest plant, greater yield attributing characters, and yield that was comparable to fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was again at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} The application of ready-mix formulation of early post emergence herbicide may be incorporated into the weed management programme for sustainable soybean production, and there wouldn't be any residual effects on succeeding crops.

Keywords: Chlorimuron-ethyl fenoxaprop, fomesafen, early post emergence and soybean

Soybean [*Glycine max* (L.) Merill], also known as 'wonder crop' possesses global importance. In India, it is cultivated in an 8.53 million ha area with an annual production of 9.43 million tonnes (FAOSTAT, 2021). However, soybean productivity in India is significantly less than that in USA. There are several reasons for low productivity. Out of these, weed has paramount importance. As soybean is a wet season crop, it must contend with fierce crop weed competition, while it is actively growing. Depending on the weed species and their density, inadequate weed control can reduce soybean yields as high as 43% in the untreated control (Reddy *et al*., 2013). Although weeds are an issue during the crop cycle, keeping a weed-free environment during the critical time (the first 45 days after planting) is crucial (Hosmath, 2014). The production potential of the crop cannot be realized fully, if weeds are not controlled within the critical period of crop-weed competition. Effective weed management in soybean cultivation is crucial to protect soybean growth and productivity from weed competition during the growing seasons. Soybean is susceptible to weed interference since the seeds are sown with wider spacing for encouraging to produce more branches and to allow the canopy to expand fully during the late growth stage (Hock *et al*., 2006). The late canopy closure permits weeds to be established more quickly in soybean field than in other crops (Harder *et al*., 2007). To efficiently manage weed infestations in soybean field, various weed management methods, including hand weeding, herbicide application, tillage practices, and crop rotation are used in combination (Vivian *et al*., 2013). Manual weeding and hoeing are typically used to control weeds in soybean fields. Hand weeding is the most popular weed management technique (Shukla *et al*., 2022). However, hand weeding becomes difficult due to shortage of labour,

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especially during the peak of crop weed competition and also now a days, it is not economically much viable due to high labour costs. Because of severe and persistent rain, weeding equipment and implements are exceptionally scarce during *kharif* season (Jadhav and Kashid, 2019). Due to the increased cost of cultivation and depletion of the resource base, manual weeding and mechanical weed control methods may not be efficient and effective (Kumar *et al*., 2018; Adigun *et al*., 2018). Hence, there is a need to evaluate the new herbicide molecules for successful control of annual grass and broadleaved weed flora in soybean. So, fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME is a new molecule that reportedly kills the post-emergence weeds in soybean. In context of all these information, the current study has been carried out by using post emergence herbicide with the goal of determining its impact on weed and growth of the soybean crop.

MATERIALS AND METHODS

The field experiments were conducted in 2017-18 and 2018-19 in soybean fields at Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum, West Bengal (N $23^{0}39.823'$, E $87^{0}37.972'$). During the entire growing season (*kharif*), soybean was grown in rainfed conditions. The respective total rainfall during the growing season was 751.4 mm in 2017-18 and 836.9 mm in 2018-19 (Indian Meteorological Department, Sriniketan). The soil of the experimental field was sandy loam (Ultisol) in texture with slightly acidic pH (6.07), organic carbon 0.48%, available nitrogen concentration of 167.1 kg ha^{-1} (Alkaline permanganate method by Subbiah and Asija, 1956), available phosphorus (P) concentration of 6.2 mg kg^{-1} (Olsen's calorimeter method by Olsen *et al*., 1954) and available potassium concentration of 83.4 mg kg^{-1} (0.1 N Ammonium acetate extractable K method; Jackson, 1973).

The experiment was designed in a Randomized Block Design with three replications. Soybean variety 'Pusa 20' was sown on June 8, 2017 for first year and on June 6, 2018 for second year maintaining the row to row spacing of 40 cm and plant to plant spacing 10 cm at 75 kg seed ha^{-1}. A total of 40 kg N through urea, 80 kg P_2O_5 through SSP and 25 kg K_2O through MOP were applied per hectare basis to the crop as basal. The ten treatments comprised of early post emergence herbicide formulation fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME in different doses (187, 234 and 280 g ha^{-1}) along with chlorimuron ethyl 25% WP at 9 g ha^{-1}, Fenoxaprop-p-ethyl 9.3% w/w EC at 103 g ha^{-1}, imazethapyr 10% SL at 100 g ha^{-1} and fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL at 222 g ha^{-1}. All the herbicides were sprayed as early-post emergence at 10 days after sowing (DAS). The herbicides were applied using a Knapsack sprayer with a flat-fan nozzle that was adjusted to deliver 500 L ha^{-1}. Hand weeding (15 and 30 DAS) was also included twice in the experiment besides the weed free and un-weeded control (weedy check). All the recommended improved package of practices of soybean was followed in this experiment including the general plant protection measures.

The efficacy of the tested herbicides was evaluated at 15 and 30 days after herbicide application (DAA). At each sampling period, three quadrates of 50 × 50 cm were placed randomly in each plot to determine the density and biomass of weeds. Weeds were uprooted manually, identified and counted into three groups viz., grasses, sedges, and broad-leaved. Weed samples were then sun-dried for 24 hours and then oven-dried at $70^{o}C$ for 72 hours. The dry weight of weeds was recorded separately with precise electronic balance to compare the efficacy of different herbicidal treatments in terms of weed control efficiency (Mani *et al*., 1973; Das, 2008) and weed index (Gill and Kumar, 1969)

Residual study of tested herbicides was done on succeeding rapeseed (cv. B9) during 2017-18 and lentil (cv. Subrata) during 2018-19. The crops were sown in the same experimental plot previously used for soybean crop without disturbing the previous field lay-out. Seeds were sown after treating with *Trichoderma viride* @ 4 g kg^{-1} (Liebigs Agro Chem Pvt. Ltd., Kolkata) at a spacing of 30 × 10 cm. All the recommended improved package of practices were followed in rapeseed and lentil. The germination percentage along with the yield was recorded for both the succeeding crops during harvesting and presented in Table 4.

All data were analyzed through analysis of variance (ANOVA) using standard variance techniques suggested by Gomez and Gomez (1984). Before statistical analysis, the data on density of weeds and dry weight of data were subjected to square root ($\sqrt{x+0.5}$) transformation to improve the homogeneity of the variance (ANOVA). The significant treatment effect was judged with the help of 'F' test at the 5% level of significance.

RESULTS AND DISCUSSION

Weed flora in experimental site

The experimental field was infested with weeds belonging to three different groups. There was a total of six major different species of weeds, including *Commelina benghalensis*, *Phyllanthus niruri*, and *Eclipta alba* among the broad-leaved weeds and major grassy weeds included *Dactyloctenium aegyptium*, *Cynodon dactylon* as well as *Cyperus sp*. among the sedge were the predominant weed floras during the cropping period.

Effect on weed density

Results revealed significant differences among the herbicidal treatments on weed density of various species at 15 DAA (Days after herbicide application) and 30 DAA (Table 1). Maximum weed density of all species was recorded in weedy check plots due to uninterrupted growth of weeds as no weed control measures were taken. The herbicide - fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME gave better result in controlling all the weed species very effectively and its efficacy was more with higher doses. Better efficacy was obtained from - fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} and was at par with the lower dose at 234 g ha^{-1}. The lowest weed density was recorded in the treatment hand weeding twice at 15 and 30 DAS and weed free treatment in both 15 DAA and 30 DAA, which might be due to elimination of all categories of weeds during the course of hand weeding. Among the herbicidal treatments, lowest density of *Commelina benghalensis* was recorded with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} followed by fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} in both the observation and highest population was recorded with Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL in both the observation. The density of *Phyllanthus niruri* population was observed to be the lowest at fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} among herbicidal treatments which was at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1}. At 15 DAA, the population of *Eclipta alba* was lowest in the treatment fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} and imazethapyr 10% SL at 100 g ha^{-1}. During the observation of 30 DAA, lowest population noted in fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was at par with both the treatments fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} and chlorimuron ethyl 25% WP at 9 g ha^{-1}. Among the grasses, lowest density of *Dactyloctenium aegyptium* was recorded under fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1}. The treatment fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 280 g ha^{-1} indicated lowest population of *Cynodon dactylon* for both 15 and 30 DAA, which was at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1}, chlorimuron ethyl 25% WP at 9 g ha^{-1} and imazethapyr 10% SL at 100 g ha^{-1}. The sedge, *Cyperus sp*. was observed to be the lowest at fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was statistically at par with fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} and chlorimuron ethyl 25% WP at 9 g ha^{-1}. The results were in conformity with the findings of Sharma *et al*. (2017), Gidesa and Kebede (2018), and Patel *et al*. (2021).

Effect on weed dry weight

Results in table 1and 2 indicated that the dry weed weight recorded at 15 DAA and 30 DAA under weed management showed significant differences. At the first and second observations, i.e., 15 DAA and 30 DAA, it was observed (Table 2) that all the weed management treatments significantly recorded lowest dry weight of weed over the weedy check (control). It was also observed that the gradual increase in the doses of the herbicide fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME recorded lowest dry weight of weeds, which might be due to better controlling of all categories of weeds, which were more or less equally effective to chlorimuron Ethyl 25% WP and better than the fenoxaprop-p-ethyl 9.3% w/w EC and fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL. Similar work was reported by Pundas *et al*., (2018). However, the maximum dry weight of all categories was recorded in weeded check control treatment, and the minimum was recorded under fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} treatment. Significant variations in weed density and dry weed weight were recorded due to different weed management practices. Significantly, the highest weed density and dry weed weight were recorded in the weedy check. It could be due to poor weed control favoring the grand growth of weeds. This conforms to the finding of Patel *et al*. (2018) and Patel *et al*. (2021). Weed-free and hand-weeding at 15 and 30 DAS recorded the lowest weed dry weight.

Weed Control Efficiency (WCE)

Weed control efficiency indicates the extent of effectiveness of weed biomass reduction by weed control treatments over weedy check (control). Different weed control treatments significantly influenced weed control efficiency. During the cropping period, among the herbicidal treatments, fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} exhibited higher weed control efficiency irrespective of the types of weed as: for *Commelina benghalensis* (86.22% and 83.33%), *Phyllanthus niruri* (85.22% and 82.33%), *Eclipta alba* (88.30% and 85.48%), *Dactyloctenium aegyptium* (85.32% and 82.32%), *Cynodon dactylon* (85.18% and 83.80%) and *Cyperus sp.* (84.58% and 82.80%) at 15 DAA and 30 DAA respectively as compared to weedy check (Table 3). Variation in weed control efficacies have been mainly attributed to the weed composition and size (Dhakad, 2022), the relative rate of weed growth (Song *et al*., 2020) and their susceptibility to herbicides (Besançon, 2022) at the time of spraying under field conditions.

Effect on soybean

Plant height at harvest

The mean data on plant height at harvest were statistically analyzed and presented in Table 4. It showed that herbicidal treatments recorded significantly higher plant height over the weedy check (control) plot. Average longest plants (65.63cm) were noticed after application of fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} which was at par with weed free plot. In the control treatment (weedy check), the plants exhibited stunted growth. This is attributed to the crop weed competition during the early phases of plant growth and development, which hinders access to essential resources like water, light, nutrients, and space. The maximum plant height is due to the effectiveness of herbicides in reducing weed density and their dry weights (Table 1 and 2) providing a congenial crop environment to grow without competition for the growth factors like water, nutrients and light for a longer period, therefore more photosynthesis, which helps to increase in plant height. This result corroborates with the findings of Shati (2014).

Seed yield and haulm yield

The mean data on seed yield and haulm yield at harvest were also presented in Table 4. The weedy check (control) treatment recorded lowest seed and haulm yield over weed control plot, where weeds were allowed to grow throughout crop growth period. This result indicated that weed competition with soybean can cause significant reduction in yield potential. Whereas, among the herbicidal treatment, fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 280 g ha^{-1} (T_3) recorded significantly highest grain yield (1317 kg ha^{-1}) and haulm yield (2498 kg ha^{-1}) over the weedy check (control) plot, but it was at par with treatment fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at 234 g ha^{-1} (T_2). It is to note that all weed management treatments recorded significantly higher values of both seed and stover yield over the weedy check. This might be due to the effective suppression of weeds resulting in adequate availability resources like nutrients, light, moisture, space by the crop and lesser crop-weed competition during critical crop growth period. A similar positive response of soybean to applied herbicide i.e., fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME has been reported by Patel *et al*. (2021).

Weed index

Maximum reduction in yield (32.81%) due to weed competition occurred in weedy check plots, where weeds were not controlled at all throughout the crop season. Application of fomesafen + fenoxaprop + chlorimuron-ethyl (ready-mix) at 280 g ha^{-1} recorded lower yield reduction (2.44%) due to less weed competition and was superior over other treatments, except hand weeding twice that recorded no reduction due to absence of crop-weed competition. The effective control of weeds under combined application of fomesafen + fenoxaprop + chlorimuron-ethyl (ready-mix) at 280 g ha^{-1} could be assigned to the reason for superior weed control efficiency. Similar results were recorded in case of rest of the herbicidal treatments by Mishra *et al*. (2016).

Economics of different treatments

On the basis of present cost of inputs and market selling price of soybean (Rs.46 kg^{-1}), the Incremental Cost Benefit Ratio (ICBR) was worked out to interpret the economics of different treatments. The data presented in Table 5 indicated that Chlorimuron Ethyl 25% WP was the most economically viable treatment recording ICBR as 9.4 due its less amount, which stands 1st rank amongst all the treatments. The next treatment in descending order in respect of ICBR i.e., fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 234 g ha^{-1} which stands in 2nd rank (5.29) followed by fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 280 g ha^{-1} in 3rd rank (4.82), fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME at 234 g ha^{-1} at 187 g ha^{-1} in 4th rank (3.46), imazethapyr 10% SL at 100 g ha^{-1} in 5th rank (2.47), fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL at 222 g ha^{-1} in 6th rank (1.87) and fenoxaprop-p-ethyl 9.3% w/w EC at 103 g ha^{-1} in 7th rank (1.85).

Effect on succeeding crop

Germination percentage and seed yield of rapeseed and lentil crop were recorded as succeeding crop (Table 4). The recorded data did not show any significant variation among the treatments used in the previous soybean crop. The seed yield data (Table 4) also did not vary significantly among the treatments, where the fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME was used in different doses at 187, 234, and 280 g ha^{-1} on the previous crop. This might be due to negligible or no carry over effect of fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME on succeeding crops. In our experiment, we did not find any phytotoxicity on soybean crop with application of fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at higher dose. Similar results were also reported by Patel *et al*. (2021).

Table 1: Effect of treatments on weed population at different days after herbicides application

Treatments	Dose (g ha^{-1})	*Commelina benghalensis* (No. m^{-2})		*Phyllanthus niruri* (No. m^{-2})		*Eclipta alba* (No. m^{-2})		*Dactyloctenium aegyptium* (No. m^{-2})		*Cynodon dactylon* (No. m^{-2})		*Cyperus sp.* (No. m^{-2})	
		15 DAA	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**
T_1	187	1.34 (1.31)	1.55 (1.9)	1.58 (1.99)	1.82 (2.82)	1.51 (1.78)	1.65 (2.22)	1.55 (1.92)	1.64 (2.19)	1.63 (2.15)	1.69 (2.37)	1.9 (3.11)	1.98 (3.41)
T_2	234	1.25 (1.07)	1.3 (1.19)	1.36 (1.35)	1.57 (1.98)	1.37 (1.37)	1.42 (1.5)	1.39 (1.42)	1.43 (1.54)	1.34 (1.30)	1.47 (1.66)	1.75 (2.55)	1.69 (2.39)
T_3	280	1.21 (0.95)	1.28 (1.14)	1.31 (1.23)	1.5 (1.74)	1.34 (1.28)	1.36 (1.35)	1.3 (1.2)	1.38 (1.4)	1.33 (1.26)	1.41 (1.5)	1.68 (2.34)	1.63 (2.2)
T_4	9	1.29 (1.16)	1.44 (1.57)	1.58 (1.99)	1.8 (2.73)	1.38 (1.39)	1.45 (1.61)	1.44 1.58)	1.54 (1.86)	1.38 (1.42)	1.5 (1.76)	1.79 (2.7)	1.74 (2.56)
T_5	103	1.56 (1.94)	1.72 (2.47)	2.15 (4.12)	2.32 (4.9)	2.02 (3.6)	2.18 (4.28)	1.45 (1.59)	1.52 (1.82)	1.35 (1.34)	1.42 (1.53)	1.85 (2.92)	1.86 (2.96)
T_6	100	1.28 (1.13)	1.42 (1.51)	1.53 (1.85)	1.75 (2.58)	1.39 (1.43)	1.62 (2.11)	1.48 (1.69)	1.55 (1.92)	1.45 (1.62)	1.62 (2.11)	2.02 (3.57)	2.05 (3.71)
T_7	222	1.52 (1.81)	1.77 (2.63)	2.21 (4.36)	2.54 (5.95)	1.71 (2.44)	1.86 (2.97)	1.42 (1.52)	1.5 (1.76)	1.43 (1.55)	1.56 (1.93)	1.89 (3.07)	2.00 (3.51)
T_8	-	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_9	-	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}	-	2.15 (4.15)	2.48 (5.64)	3.26 (10.11)	4.11 (16.44)	2.49 (5.73)	2.97 (8.31)	3.11 (9.19)	3.37 (10.85)	2.95 (8.21)	3.62 (12.62)	3.39 (10.98	3.81 (13.99)
SEm (±)		**0.04**	**0.04**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.03**	**0.04**	**0.07**
LSD (0.05)		**0.11**	**0.10**	**0.14**	**0.12**	**0.11**	**0.12**	**0.11**	**0.09**	**0.09**	**0.09**	**0.12**	**0.20**
CV (%)		**4.75**	**4.12**	**4.86**	**4.86**	**4.29**	**4.31**	**4.33**	**3.59**	**3.29**	**3.52**	**3.95**	**6.44**
F Stat Value		**136.1**	**226.8**	**269.9**	**269.9**	**222.1**	**222.2**	**327.2**	**526.0**	**515.2**	**631.1**	**340.0**	**160.1**

Note: Figures in parentheses are the original values. The data was transformed to SQRT (x +0.5) before analysis.

T_1 to T_3-Fomesafen 12.5% + fenoxaprop 10% + Chlorimuron ethyl 0.9% ME, T_4- Chlorimuron Ethyl 25% WP, T_5- Fenoxaprop-p-ethyl 9.3% w/w EC, T_6-Imazethapyr 10% SL, T_7-Fluazifop-p-butyl 11.1% w/w + Fomesafen 11.1% w/w SL, T_8- Hand weeding at 15 & 30 DAS, T_9- Weed Free, T_{10}- Weedy check (Control)

Table 2: Effect of treatments on weed dry weight at different days after herbicides application

Treatments	Dose (g ha^{-1})	***Commelina benghalensis*** **(g m^{-2})**		***Phyllanthus niruri*** **(g m^{-2})**		***Eclipta alba*** **(g m^{-2})**		***Dactyloctenium aegyptium*** **(g m^{-2})**		***Cynodon dactylon*** **(g m^{-2})**		***Cyperus sp.*** **(g m^{-2})**	
		15 DAA	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**	**15 DAA**	**30 DAA**
T$_1$	187	0.95 (0.39)	1.03 (0.57)	1.15 (0.83)	1.33 (1.28)	1.01 (0.52)	1.11 (0.74)	1.39 (1.43)	1.69 (2.37)	1.11 (0.73)	1.24 (1.03)	1.38 (1.41)	1.56 (1.92)
T$_2$	234	0.9 (0.3)	0.98 (0.45)	1.06 (0.63)	1.23 (1.00)	0.92 (0.35)	1.01 (0.53)	1.21 (0.98)	1.46 (1.62)	1.07 (0.63)	1.15 (0.83)	1.24 (1.05)	1.37 (1.4)
T$_3$	280	0.87 (0.26)	0.94 (0.39)	1.02 (0.54)	1.17 (0.86)	0.89 (0.29)	0.97 (0.43)	1.16 (0.84)	1.41 (1.5)	1.02 (0.53)	1.09 (0.7)	1.18 (0.89)	1.3 (1.2)
T$_4$	9	0.94 (0.38)	1.02 (0.53)	1.09 (0.69)	1.28 (1.13)	1.00 (0.49)	1.08 (0.66)	1.33 (1.27)	1.64 (2.2)	1.10 (0.7)	1.20 (0.95)	1.28 (1.14)	1.42 (1.52)
T$_5$	103	1.06 (0.63)	1.17 (0.87)	1.32 (1.24)	1.55 (1.9)	1.25 (1.07)	1.4 (1.45)	1.37 (1.39)	1.67 (2.29)	1.1 (0.71)	1.19 (0.92)	1.31 (1.22)	1.47 (1.67)
T$_6$	100	0.93 (0.36)	1.03 (0.56)	1.10 (0.71)	1.27 (1.11)	1.00 (0.5)	1.07 (0.65)	1.44 (1.59)	1.8 (2.76)	1.15 (0.83)	1.29 (1.17)	1.4 (1.46)	1.57 (1.98)
T$_7$	222	1.07 (0.64)	1.17 (0.87)	1.34 (1.3)	1.59 (2.03)	1.25 (1.07)	1.38 (1.41)	1.39 (1.44)	1.7 (2.42)	1.1 (0.71)	1.23 (1.01)	1.3 (1.19)	1.46 (1.64)
T$_8$	-	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T$_9$	-	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T$_{10}$	-	1.55 (1.92)	1.7 (2.38)	2.03 (3.63)	2.34 (4.96)	1.73 (2.49)	1.87 (2.98)	2.5 (5.74)	3.01 (8.56)	2.03 (3.62)	2.2 (4.32)	2.51 (5.79)	2.73 (6.97)
SEm (±)		**0.02**	**0.02**	**0.03**	**0.03**	**0.02**	**0.02**	**0.04**	**0.05**	**0.03**	**0.02**	**0.02**	**0.03**
LSD (0.05)		**0.05**	**0.05**	**0.09**	**0.09**	**0.05**	**0.05**	**0.11**	**0.14**	**0.08**	**0.06**	**0.06**	**0.08**
CV (%)		**3.18**	**3.00**	**4.62**	**3.91**	**2.66**	**2.78**	**4.72**	**5.02**	**3.98**	**2.59**	**2.79**	**3.14**
F Stat Value		**181.1**	**237.3**	**148.7**	**245.0**	**354.7**	**365.4**	**188.8**	**195.7**	**202.7**	**518.2**	**554.2**	**462.2**

Note: Figures in parentheses are the original values. The data was transformed to SQRT (x +0.5) before analysis.

Table 3: Effect of treatments on weed control efficiency (%) at different days after herbicides application

Treatments	Dose (g ha^{-1})	*Commelina benghalensis*		*Phyllanthus niruri*		*Eclipta alba*		*Dactyloctenium aegyptium*		*Cynodon dactylon*		*Cyperus sp.*	
		15 DAA	30 DAA	15 DAA	30 DAA	15 DAA	30 DAA	15 DAA	30 DAA	15 DAA	30 DAA	15 DAA	30 DAA
T_1	187	78.97	76.12	76.85	74.06	78.89	75.11	74.78	72.17	79.65	76.21	75.59	72.40
T_2	234	84.39	80.67	82.65	79.70	85.78	82.23	82.65	80.76	82.38	80.68	81.71	79.83
T_3	280	86.22	83.33	85.22	82.33	88.30	85.48	85.32	82.32	85.18	83.80	84.58	82.80
T_4	9	80.13	77.56	80.84	77.05	80.05	77.97	77.71	74.13	80.46	78.00	80.23	78.11
T_5	103	66.42	63.10	65.71	61.34	56.85	51.31	75.62	72.94	80.37	78.56	78.78	76.02
T_6	100	80.71	76.59	80.45	77.49	79.79	78.14	71.75	67.13	76.97	72.81	74.90	71.59
T_7	222	66.27	62.91	63.66	58.89	56.41	52.73	74.62	71.48	80.57	76.50	79.17	76.33
T_8	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
T_9	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
T_{10}	-	--	--	--	--	--	--	--	--	--	--	--	--
SEm (±)		**1.47**	**1.38**	**2.03**	**1.32**	**1.30**	**1.22**	**1.62**	**2.00**	**1.49**	**1.00**	**0.95**	**1.06**
LSD (0.05)		**4.37**	**4.10**	**6.03**	**3.92**	**3.87**	**3.62**	**4.81**	**5.93**	**4.43**	**2.96**	**2.81**	**3.15**
CV(%)		**3.43**	**4.32**	**4.78**	**3.22**	**3.11**	**3.00**	**3.77**	**4.80**	**3.37**	**2.31**	**2.17**	**2.49**
F Stat Value		**374.6**	**419.6**	**196.6**	**461.8**	**512.8**	**592.1**	**299.3**	**194.0**	**356.1**	**783.5**	**877.2**	**687.8**

Table 4: Effect of treatments on soybean and succeeding crop rapeseed and lentil

Treatments	Dose (g ha^{-1})	Soybean					Rapeseed		Lentil	
		Plant height (cm)	Pods per plant	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Weed index (%)	Germination (%)	Seed yield (kg ha^{-1})	Germination (%)	Seed yield (kg ha^{-1})
T_1	187	56.87	28.7	1136	2366	15.85	84.0	941	86.0	835
T_2	234	62.11	31.6	1290	2438	4.44	85.0	984	85.0	852
T_3	280	65.63	33.8	1317	2498	2.44	85.0	973	87.0	860
T_4	9	61.21	27.4	1149	2394	14.89	85.3	948	84.0	854
T_5	103	60.54	27.3	1082	2322	19.85	85.2	967	85.0	850
T_6	100	60.66	27.2	1073	2278	20.52	85.0	936	86.0	842
T_7	222	57.70	27.4	1046	2247	22.52	85.0	944	85.0	836
T_8	-	62.74	29.3	1075	2295	20.37	86.0	945	87.0	827
T_9	-	66.52	34.3	1350	2533	0.00	84.0	965	85.0	872
T_{10}	-	46.99	19.2	907	2184	32.81	84.0	964	82.0	843
SEm (±)		**0.73**	**0.88**	**20.27**	**71**	**-**	**1.6**	**15.8**	**1.5**	**16.5**
LSD (0.05)		**2.16**	**2.60**	**60.21**	**211**	**-**	**NS**	**NS**	**4.4**	**NS**
CV (%)		**2.10**	**5.30**	**3.08**	**5.22**	**-**	**3.2**	**2.85**	**3.0**	**3.37**
F Stat Value		**57.1**	**23.8**	**44.9**	**2.48**	**-**	**0.18**	**1.04**	**1.01**	**0.65**

Table 5: Incremental Cost Benefit Ratio (ICBR) in response of treatments

Treatments	Quantity of herbicide required per ha (1 Spray)	Market price of herbicide (₹)	Cost of herbicide (1 spray) ₹ ha^{-1}	Labour Charges and rent of hired sprayer (1spray)	Total cost ₹ ha^{-1} (A)	Yield (kg ha^{-1})	Increased yield over control (kg ha^{-1})	Increased yield over control (₹ ha^{-1}) (B)	Net grain over control (C) (B-A) (₹ ha^{-1})	ICBR (C/A)
T_1	800 ml	2200 l^{-1}	1760	600	2360	1136	229	10534	8174	3.46
T_2	1000 ml	2200 l^{-1}	2200	600	2800	1290	383	17618	14818	5.29
T_3	1200 ml	2200 l^{-1}	2640	600	3240	1317	410	18860	15620	4.82
T_4	36 g	13000 kg^{-1}	470	600	1070	1149	242	11132	10062	9.40
T_5	1111 ml	2000 l^{-1}	2222	600	2822	1082	175	8050	5228	1.85
T_6	1000 ml	1600 l^{-1}	1600	600	2200	1073	166	7636	5436	2.47
T_7	1000 ml	1625 l^{-1}	1625	600	2225	1046	139	6394	4169	1.87
T_8	--	--	--	--	7000	1075	168	7728	728	0.10
T_9	--	--	--	--	14000	1350	443	20378	6378	0.46
T_{10}	--	--	--	--	--	907	--	--	--	--
SEm (±)	--	--	--	--	--	**28**	--	--	--	--
LSD (0.05)	--	--	--	--	--	**83**	--	--	--	--

CONCLUSION

From the present investigation it can be concluded that fomesafen 12.5% + fenoxaprop 10% + chlorimuron ethyl 0.9% ME at a rate of 234 g ha^{-1} appeared as effective, productive and economic for managing broad spectrum weeds of soybean and to reduce considerable loss in yield in lateritic soil of West Bengal.

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