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RESEARCH ARTICLE

Evaluation of weed management efficacy of post-emergence herbicides in blackgram under semi-arid Alfisols

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ABSTRACT

The efficacy of a post-emergence herbicides in managing weeds in blackgram was evaluated during summer and rainy *(Kharif)* seasons of 2016 at University of Agricultural Sciences (UAS), GKVK, Bangalore, India. The experiments were laid in RCBD with three replications comprising of nine treatments. Major weed species observed were: *Cyperus rotundus, Eleuisine indica, Dactyloctenium aegyptium, Borreria articularis, Echinochloa colona, Commelina benghalensis, Euphorbia geniculata, Phyllanthus niruri.* The post-emergence application (PoE) of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 100 g/ha) has attained significantly higher seed and haulm yield of blackgram (1305 and 2088 kg/ha, respectively) in summer 2016 and (1519 and 2253 kg/ha, respectively) in *Kharif* 2016, followed by sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (165 + 80 and 123.75 + 60 g/ha) (1192 and 1808 kg/ha, respectively) in summer 2016 and (1425 and 2095 kg/ha, respectively) in *Kharif* 2016. Similarly the weed control efficiency in summer and kharif 2016 was higher with sodium acifluorfen + clodinafop-propargyl (330 + 160 g/ha) PoE (93.20 and 91.0%, respectively) and it was followed by sodium acifluorfen + clodinafop-propargyl (206.25 + 100 g/ha) PoE (89.51 and 90.24%, respectively) when compared to weedy check. The increased yield was mainly due to a significant reduction in weed density and biomass, without any phytotoxicity to succeeding finger millet crop under semi-arid Alfisols.

Keywords: Blackgram, Bio-efficacy, Clodinafop-propargyl, Economics, Sodium acifluorfen, Weed management

INTRODUCTION

The pulses contribute significantly to the dietary protein in different regions in India. The pulses also maintain soil fertility through the process of biological nitrogen fixation (BNF) in the soil, while being a rich source of protein to the human population. Thus, the pulses play a vital role in furthering sustainable agriculture under rainfed condition. Among different pulses, blackgram which is also known as urd bean, is a rich source of protein and carbohydrates. Blackgram is grown as a subsidiary crop because of less inputs and lower management given to the crop at all soil and agro-climatic conditions. However, the weeds are severe threat to the blackgram crop growth as they compete with crop for the limited resources like water, nutrient, light and space leading to a significant reduction in growth and seed yield of blackgram (Upasani *et al*. 2017), which range from 43.2 to 64.1% during *Kharif* (Chand *et al*. 2004, Rathi *et al*. 2004) and 46.0 to 53.0 % during summer season (Bhandari *et al*. 2004, Kumar and Tewari 2004).

Weed management with conventional hand weeding was observed to be highly expensive among different weed control methods due to the non-availability and increased cost of labour at some of the most important and critical stages of the crop weed competition. In addition, the unusual and incessant rains make it difficult to enter into the fields for hand weeding. Hence, the timely control of weeds in blackgram using herbicides would be preferable and the use of post-emergent herbicides could be better option for the control of weeds during the early stages of the crop growth. The present study was undertaken to evaluate the efficacy of different post-emergent herbicides for efficient management of weeds in blackgram for attaining profitable yields under semi-arid Alfisols.

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MATERIALS AND METHODS

Field experiments were conducted during rainy *(Kharif)* 2016 and summer 2016 seasons at the University of Agricultural Sciences, GKVK, Bangalore. Blackgram (Rashmi variety) was sown at a spacing of 30 × 10 cm in both summer and *Kharif* seasons. The summer crop was sown on 1st February and harvested on 28th April 2016. The *Kharif* crop was sown on 20th July and harvested on 20th October 2016. The post-emergence application (PoE) of herbicides was done at 22 days after seeding (DAS) using 500 litres of water per ha with flat fan nozzle attached to the knapsack sprayer. The study was conducted with 9 treatments arranged in a Randomized block design with 3 replications. The nine treatments include: sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (sodium acifluorfen + clodinafop-propargyl) 330 + 160 g /ha PoE; sodium acifluorfen + clodinafop-propargyl 206.25+100 g/ha PoE; sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE; sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE; sodium acifluorfen 165 g/ha PoE; clodinafop-propargyl 80 g/ha PoE; propaquizafop 100 g/ha PoE; hand weeding twice 20 and 45 DAS and weedy check (untreated).

The observations on weed density (no./m^2) of different species were collected in a quadrat of 50 × 50 cm on 20, 45, 65 DAS and at harvest. The weeds collected were used for determining weed dry weight (biomass) per m^2 at 20, 45, 60 DAS and at harvest. The measurements on herbicide efficiency index (HEI) and weed control index (WCI) were calculated at the harvest of blackgram. The observations collected in each of the season on the weed density and biomass have been transformed using the square-root transformation. The weed control efficiency (WCE) at harvest was calculated. The observations on seed yield (kg/ha) and haulm yield (kg/ha) were recorded at harvest in each of the treatment during summer and kharif seasons of this study.

Herbicide efficiency index (HEI) and Weed control efficiency (WCE) of different treatments were also calculated as per the formula suggested by Krishnamurthy *et al*. (1975) and Walia (2003), respectively.

$$\text{HEI} = \frac{\text{Yield of treated plot} - \text{Yield in Control}}{\text{Yield in Control}}$$

$$\text{WCE} = \frac{\text{Weed dry weight in control} - \text{Weed dry weight in treated}}{\text{Weed dry weight in control}} \times 100$$

After the harvest of the greengram crop, the residual crop finger millet was grown to know the phytotoxicity effect on succeeding crop.

The differences between 9 treatments in influencing the seed yield were tested based on the Analysis of Variance (ANOVA) in each year and also pooled over years. The treatments were compared for superiority based on the Duncan's Multiple Range Test (DMRT) at $p < 0.05$ and $p < 0.01$ level of significance (Gomez and Gomez 1984)

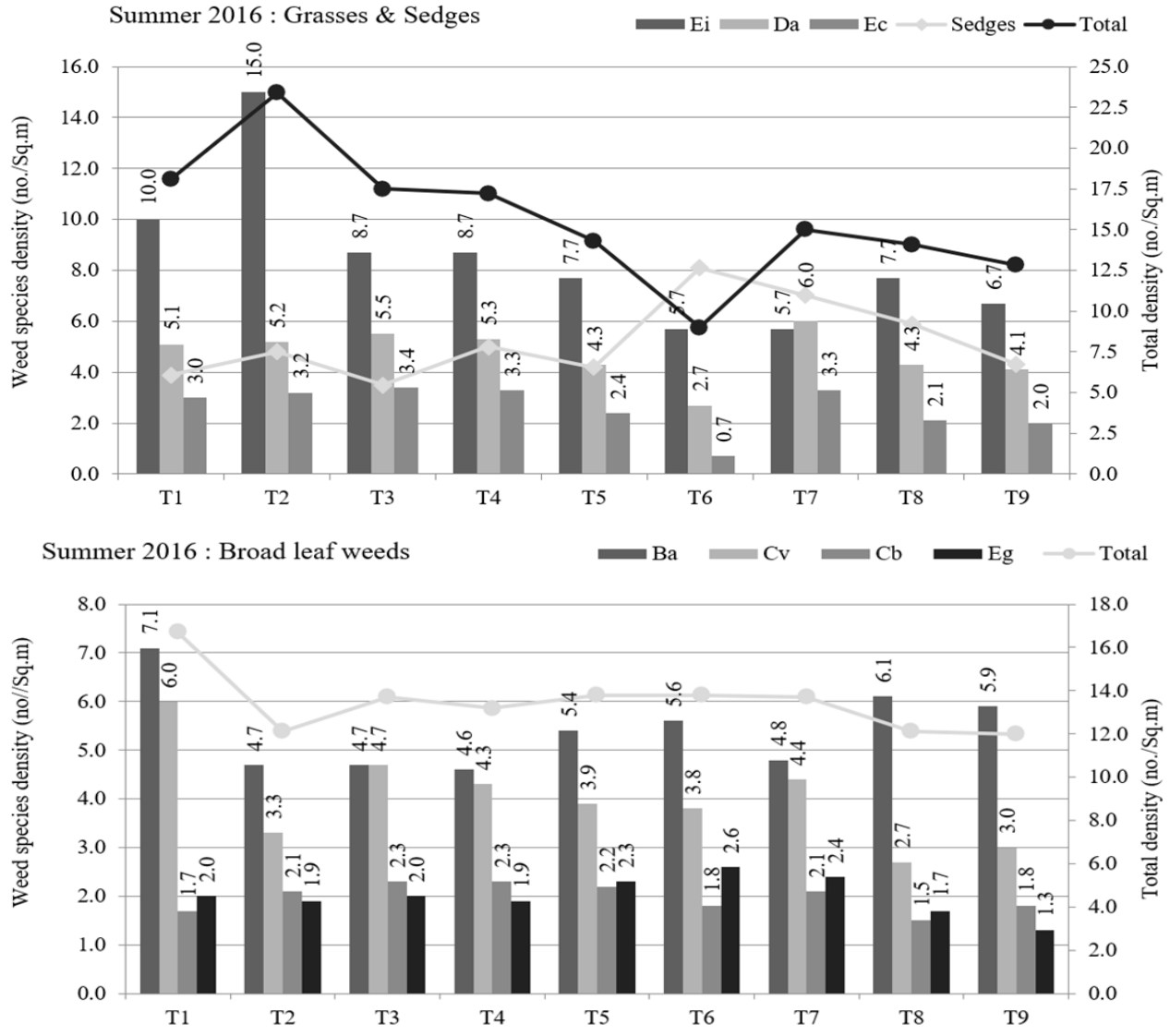
RESULTS AND DISCUSSION

Weed flora

The weed flora observed in this study comprised of: *Cyperus rotundus,* the sedge; *Eleusine indica*, *Dactyloctenium aegyptium*, *Echinochloa colona* amongst grasses, *Borreria articularis*, *Cleome viscosa*, *Phyllanthus niruri*, *Commelina benghalensis*, *Euphorbia geniculata*, *Alternenthara* spp., *etc*. among broad-leaved weeds. A few other weeds observed in lesser numbers were *Amaranthus viridis*, *Cleome monophylla* and *Acanthospermum hispidum.*

During summer 2016, the sedges density ranged from 3.5 to 8.1 per m^2 with mean of 5.2/m^2. Among different grasses, *E. indica* density ranged from 5.7 to 15.0/m^2 with mean of 8.4/m^2, while *D. aegyptium* density ranged from 2.7 to 6.0/m^2 with mean of 4.7/ m^2. *E. colona* density ranged from 0.7 to 3.4/m^2 with mean of 2.6/m^2, while the total weed species density of all the 3 grasses ranged from 9.0 to 23.4/m^2 with mean of 15.7/m^2 (**Figure 1**). Among broad-leaved weeds, *B. articularis* ranged from 4.6 to 7.1/m^2 with mean of 5.4/m^2, while *C. viscose* ranged from 2.7 to 6.0/m^2 with mean of 4.0/m^2. *C. benghalensis* ranged from 1.5 to 2.3/m^2 with mean of 2.0 per, while *E. geniculata* ranged from 1.3 to 2.6/m^2 with mean of 2.0/m^2. The total of all broad-leaved weeds ranged from 12.0 to 16.7/m^2 with mean of 13.5/m^2, while the grand total of all sedges, grasses and broad-leaved weeds ranged from 30.1 to 40.3/m^2 with mean of 34.5 /m^2. (**Figure 1**).

During *Kharif* 2016, the sedges density ranged from 4.8 to 9.1/m^2 with mean of 6.8/m^2 (**Figure 2**). Among grasses, *E. indica* density ranged from 12.3 to 17.3/m^2 with mean of 14.6/m^2, while *D. aegyptium* density ranged from 5.1 to 8.2/m^2 with mean of 7.1/ m^2. *E. colona* density ranged from 2.9 to 5.0/m^2 with mean of 3.8/m^2, while the total grasses weed species density ranged from 20.8 to 29.9/m^2 with mean of 25.5/m^2. Among broad-leaved weeds, *B. articularis* density ranged from 6.5 to 10.7/m^2 with mean of 8.0/ m^2, while *C. viscose* density ranged from 4.2 to 6.0/ m^2 with mean of 4.9/m^2. *P. niruri* density ranged from 2.0 to 2.8/m^2 with mean of 2.2/m^2, while *C.*



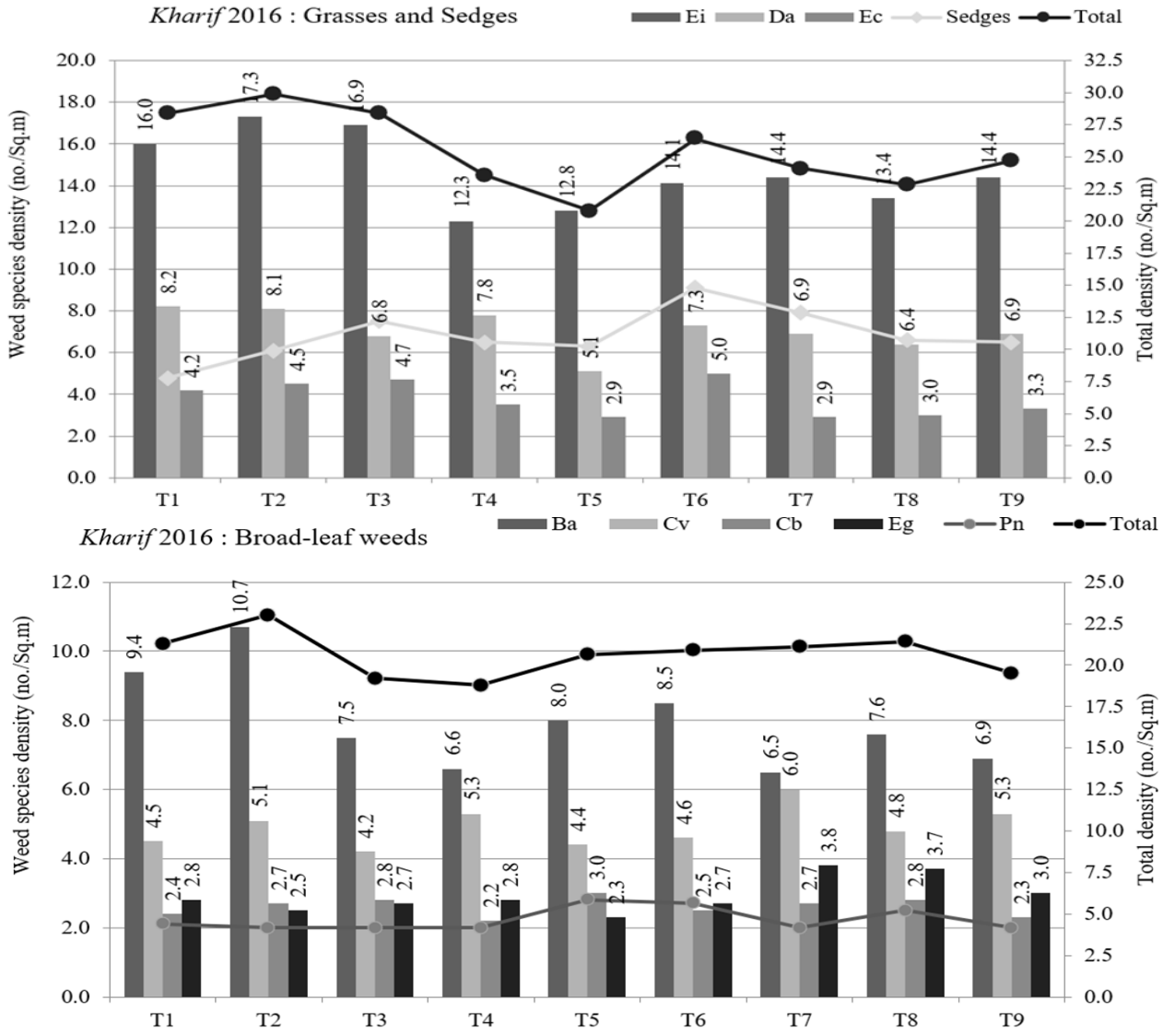
T_1: Sodium acifluorfen + clodinafop-propargyl (123.75 + 60 g/ha); T_2: Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha); T_3: Sodium acifluorfen + clodinafop-propargyl (206.25 + 100 g/ha); T_4: Sodium acifluorfen (165 g/ha); T_5: Clodinafop-propargyl (80 g/ha); T_6: Propaquizafop; T_7: Hand weeding twice at 20 and 45 DAS; T_8: Weedy check (untreated); and T_9: Sodium acifluorfen + clodinafop-propargyl (330+160 g/ha); EI = *Eleusine indica*; DA = *Dactyloctenium aegyptium*; EC = *Echinochloa colona*; BA = *Borreria articularis*; CV = *Cleome viscosa*; CB = *Commelina benghalensis*; EG = *Euphorbia geniculate*; PN = *Phyllanthus niruri*

Figure 1. The density of grasses, sedges and broad-leaf weeds under different treatments in blackgram during summer 2016

benghalensis density ranged from 2.2 to 3.0/m^2 with mean of 2.6/m^2 and *E. geniculate* density ranged from 2.3 to 3.8/m^2 with mean of 2.9/m^2. The total broad-leaved weeds density ranged from 18.8 to 23.0/m^2 with mean of 20.6/m^2, while the total of all sedges, grasses and broad-leaved weeds density ranged from 47.6 to 59.0/m^2 with mean of 52.9/m^2 (**Figure 2**).

Effect on weed density

During summer 2016, the total weed density ranged from 5.49 to 6.34/m^2 with mean of 5.86/m^2 at 20 DAS; 3.99 to 7.65/m^2 with mean of 5.25/m^2 at 45 DAS 3.15 to 8.34/m^2 with mean of 4.88/m^2 at 65 DAS and 2.73 to 10.05/m^2 with mean of 5.15/m^2 at harvest of the crop (**Table 1**). During *Kharif* 2016, the weed density ranged from 6.90 to 7.68/m^2 with mean of 7.27/m^2 at 20 DAS; from 5.31 to 8.59/m^2 with mean of 6.40/m^2 at 45 DAS; from 3.49 to 9.67/m^2 with mean of 5.42/m^2 at 65 DAS and from 3.04 to 10.57/m^2 with mean of 5.40/m^2 at harvest of the crop. Based on F-test, the treatments were found to be significantly different at 20, 45, 65 DAS and at harvest in influencing the weed density during both summer 2016 and *Kharif* 2016.



T_1: Sodium acifluorfen + clodinafop-propargyl (123.75 + 60 g/ha); T_2: Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha); T_3: Sodium acifluorfen + clodinafop-propargyl (206.25 + 100 g/ha); T_4: Sodium acifluorfen (165 g/ha); T_5: Clodinafop-propargyl (80 g/ha); T_6: Propaquizafop; T_7: Hand weeding twice at 20 and 45 DAS; T_8: Weedy check (untreated); and T_9: Sodium acifluorfen + clodinafop-propargyl (330+160 g/ha); EI = *Eleusine indica*; DA = *Dactyloctenium aegyptium*; EC = *Echinochloa colona*; BA = *Borreria articularis*; CV = *Cleome viscosa*; CB = *Commelina benghalensis*; EG = *Euphorbia geniculate*; PN = *Phyllanthus niruri*

Figure 2. The density of grasses, sedges and broad-leaved weeds under different treatments in blackgram during *Kharif* 2016

At 45 DAS, sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE recorded a significantly lower weed density (24.9 no./m^2), followed by its application rate of 165 + 80 g/ha and 123.75 + 60 g/ha (29.4 and 29.2 no./m^2). A similar trend of the weed density was observed at 65 DAS and harvest. The significantly lower weed density was found to be due to the combined application of sodium acifluorfen and clodinafop-propargyl, since the sodium acifluorfen was found to effectively control the broad-leaved weeds by inhibiting the enzyme protoporphyrinogen oxidase (PPG) in the weed species and clodinafop-propargyl efficacy was due to its inhibitory action on the enzyme Acetyl co-A carboxylase (Accase) which was found to effectively control the grassy weeds and provided a lower weed density (Rao 2011).

Effect on weed biomass

During summer 2016, the weed biomass ranged from 2.59 to 2.95 g/m^2 with mean of 2.76 g/m^2 at 20 DAS; from 2.28 to 4.02 g/m^2 with mean of 2.85 g/m^2 at 45 DAS; from 1.92 to 4.47 g/m^2 with mean of 2.72 g/m^2 at 65 DAS and from 1.78 to 5.42 g/m^2 with mean of 2.87 g/m^2 at harvest of blackgram crop (**Table 2**). During *Kharif* 2016, the weed biomass ranged from

3.19 to 3.52 g/m^2 with mean of 3.35 g/m^2 at 20 DAS; 2.72 to 4.34 g/m^2 with mean of 3.30 g/m^2 at 45 DAS; from 2.01 to 4.94 g/m^2 with mean of 2.93 g/m^2 at 65 DAS and from 2.14 to 6.36 g/m^2 with mean of 3.39 g/m^2 at harvest of the crop. The treatments were found to be significantly different at 45 and 65 DAS and harvest in summer 2016, while they were significantly different at 20, 45, 65 DAS and harvest in influencing the weed biomass.

At 20 DAS, the weed biomass was found to be lower in the control (7.98 g/m^2) *i.e.*, before actually imposing the treatments. At 45 DAS, lower weed biomass was found with sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE (6.88 g/m^2). This was followed by its application rate of 123.75 + 60 g/ha and 165 + 80 g/ha (7.09 and 7.26 g/m^2). At 60 DAS and at harvest of the crop also similar trend was found. The decreased weed biomass with the sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE was mainly because of its effective control of grasses and broad-leaved weeds throughout the crop growth. Similar results were observed by Choudhary *et al*. (2017) and Biswal (2017) in groundnut.

Table 1. Effect of post-emergence application (PoE) of herbicides and other weed control treatments on total weed density (no./m^2) at different days after sowing (DAS) in blackgram during summer 2016 and *Kharif* 2016

Treatment	20 DAS		45 DAS		65 DAS		At Harvest	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
Sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE	6.21(38.8)	7.38(54.4)	5.18(26.8)	6.09(37.1)	3.75(14.1)	4.37 (18.9)	3.21 (10.3)	3.69 (13.6)
Sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE	6.34(40.3)	7.68(59.0)	4.66(21.7)	5.53(30.6)	3.45(11.9)	3.99 (15.9)	3.29 (10.8)	3.44 (11.8)
Sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE	5.88(34.7)	7.42(55.1)	4.23(17.9)	5.15(26.5)	3.3(10.9)	3.65 (13.3)	3.11(9.7)	3.24 (10.5)
Sodium acifluorfen 165 g/ha PoE	5.95(35.4)	6.99(48.9)	6.38(40.7)	7.44(55.3)	6.70(44.9)	7.10 (50.4)	7.57 (57.3)	7.70 (59.3)
Clodinafop-propargyl 80 g /ha PoE	5.68(32.3)	6.90(47.6)	5.83(34.0)	6.76(45.7)	5.48(30.1)	6.08 (37.0)	6.11 (37.3)	6.74 (45.4)
Propaquizafop 100 g/ha PoE	5.55(30.9)	7.51(56.5)	5.79(33.6)	7.16(51.3)	6.04(36.4)	6.60 (43.6)	6.54 (42.8)	6.97 (48.6)
Hand weeding twice 20 and 45 DAS	5.97(35.6)	7.29(53.1)	3.99(15.2)	4.46(20.00)	3.68(13.5)	3.49 (12.2)	4.56 (20.8)	3.04(9.2)
Weedy check	5.66(32.1)	7.13(50.8)	7.65(58.5)	8.59(73.8)	8.34(70.0)	9.67 (93.6)	10.05(101.2)	10.57 (111.7)
Sodium acifluorfen + clodinafop-propargyl 330 + 160 g/ha PoE	5.49(29.1)	7.11(49.6)	4.16(16.3)	5.31(27.2)	3.15(8.9)	3.63(12.2)	2.73(6.5)	3.28(9.8)
LSD (p=0.05)	0.53	0.54	0.34	0.27	0.49	0.24	0.52	0.30
Minimum	5.49	6.90	3.99	4.46	3.15	3.49	2.73	3.04
Maximum	6.34	7.68	7.65	8.59	8.34	9.67	10.05	10.57
Mean	5.86	7.27	5.25	6.26	4.88	5.40	5.15	5.40
SD	0.29	0.26	1.17	1.09	1.84	2.11	2.55	2.68

Data averaged over three replications; Data analyzed using transformation= Square root of (x+1); Data within parentheses are original values

Table 2. Effect of post-emergence application (PoE) of herbicides and other weed control treatments on weed biomass (g/m^2) observed on different days after sowing (DAS) in blackgram during summer 2016 and *Kharif* 2016

Treatment	20 DAS		45 DAS		65 DAS		At Harvest	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
Sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE	2.95(7.7)	3.40(10.5)	2.64(5.97)	3.08(9.1	2.60(5.7)	2.53(5.4)	2.67(6.1)	2.96(7.7)
Sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE	2.92(7.5)	3.52(11.4)	2.66(4.70)	3.03(8.2)	2.08(3.3)	2.25(4.1)	2.14(3.6)	2.30(4.3)
Sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE	2.79(6.8)	3.42(10.7)	2.62(4.25)	2.98(7.9)	2.06(3.2)	2.19(3.8)	2.00(3.0)	2.20(3.8)
Sodium acifluorfen 165 g/ha PoE	2.59(5.7)	3.29(9.8)	2.28(4.20)	2.80(6.8)	1.92(2.7)	2.07(3.3)	1.78(2.2)	2.14(3.6)
Clodinafop-propargyl 80 g /ha PoE	2.79(6.8)	3.23(9.5)	3.44(10.9)	3.68(12.6)	3.59(11.8)	3.73(12.9)	3.92(14.3)	4.68(21.0)
Propaquizafop 100 g/ha PoE	2.71(6.4)	3.19(9.2)	2.70(6.3)	3.39(10.5)	2.70(6.3)	3.20(9.3)	2.84(7.1)	3.30(9.9)
Hand weeding twice 20 and 45 DAS	2.64(6.0)	3.45(10.9)	2.79(6.9)	3.66(12.4)	2.86(7.2)	3.45(10.9)	2.98(7.9)	4.26(17.2)
Weedy check	2.79(6.8)	3.36(10.3)	2.48(3.9)	2.72(6.4)	2.23(4.0)	2.01(3.05)	2.09(6.0)	2.33(4.4)
Sodium acifluorfen + clodinafop-propargyl 330+160 g/ha PoE	2.67(6.1)	3.29(9.8)	4.02(15.2)	4.34(17.8)	4.47(19.0)	4.94(23.4)	5.42(28.4)	6.36(39.4)
LSD (p=0.05)	NS	0.16	0.35	0.40	0.32	0.19	0.32	0.20
Minimum	2.59	3.19	2.28	2.72	1.92	2.01	1.78	2.14
Maximum	2.95	3.52	4.02	4.34	4.47	4.94	5.42	6.36
Mean	2.76	3.35	2.85	3.30	2.72	2.93	2.87	3.39
SD	0.12	0.11	0.54	0.52	0.94	1.00	1.33	1.50

Data averaged over three replications; Data analyzed using transformation= Square root of (x+1); Data within parentheses are original values

Herbicide efficiency index

The herbicide efficiency index (HEI) would indicate about the potential of the herbicide for killing the weeds in the field (Krishnamurthy *et al.* 1975). Maximum herbicide efficiency index was observed with sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE (5.92%), followed by its application rate of 123.75 + 60 g/ha and 165 + 80 g/ha (4.38 and 3.94%) (**Table 3**). Higher herbicide efficiency index was observed due to the broad spectrum of weed control by the PoE herbicides in blackgram which have resulted in a significantly lower weed biomass in those treatments.

Weed index

The weed index is an index which is indicative of the weed's competition effect on the grain yield. The weedy check treatment was found to attain a significantly higher weed index of 58.41%. The weed index ranged from 10.90 to 58.41% with mean of 31.10% during summer 2016, while it ranged from 5.3 to 56.50% with mean of 27.0% during *Kharif* 2016. Lower weed index was found with sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha (8.59%) PoE, followed by its application of 165 + 80 g/ha 123.75 + 60 g/ha (15.34 and 35.63%, respectively) (**Table 3**). The lower weed index was due to satisfactory control of all the weeds resulting in a significant reduction in the crop and weed competition. This has also enabled the crop to efficiently utilize all the available resources like light, nutrients, moisture and space (Gupta by *et al.* 2013).

Weed control efficiency

The weed control efficiency at harvest stage ranged from 46.86 to 93.2% with mean of 68.40% in summer 2016 and from 48.18 to 91.0% with mean of 69.10% in *Kharif* 2016 (**Table 3**). Among different herbicides, a significantly higher weed control efficiency at the harvest stage was observed with sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha (89.88%), followed by its application at 165 + 80 g/ha and 123.25 + 60 g/ha (88.27 and 79.43%, respectively). The higher weed control efficiency was associated with a minimum weed density and biomass at the subsequent stages due to the herbicide efficacy for a longer period (Jagadesh *et al.* 2019 and Marimuthu *et al.* 2016). The combined application of sodium acifluorfen and clodinafop-propargyl was found to be beneficial and has controlled both the grassy and broad-leaved weeds resulted in a higher weed control efficiency as observed by Jha *et al.* (2014).

Effect of treatments on seed and haulm yield

The seed yield ranged from 616 to 1320 kg/ha with mean of 1021 kg/ha during summer 2016, while it ranged from 705 to 1519 kg/ha with mean of 1176 kg/ha during *Kharif* 2016. The haulm yield ranged from 928 to 2265 kg/ha with mean of 1637 kg/ha during summer 2016, while it ranged from 1148 to 2440 kg/ha with mean of 1860 kg/ha during *Kharif* 2016 (**Table 4**).

The blackgram seed yield (1412 kg/ha) and haulm yield (2171 kg/ha) were significantly higher with sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha and was at par with the hand weeding at 20 and 45 DAS (1543 kg/ha and 2353 kg/ha, respectively). A significantly higher seed yield attained in these treatments was due to an efficient control of all categories of weeds, reduced weed index, higher weed control index and higher

Table 3. Effect of treatments on weed index and weed control efficiency at harvest of blackgram during summer 2016 and *Kharif* 2016

Treatment	Weed index (%)			Weed control efficiency (%) at harvest			Herbicide efficiency index (%)
	Summer	*Kharif*	Pooled	Summer	*Kharif*	Pooled	Pooled
Sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE	36.73	34.53	35.63	78.5	80.35	79.425	4.38
Sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE	19.51	11.16	15.34	87.47	89.07	88.27	3.94
Sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE	11.88	5.3	8.59	89.51	90.24	89.88	5.92
Sodium acifluorfen + clodinafop-propargyl 330 + 160 g/ha PoE	10.90	9.90	11.00	93.20	91.0	92.1	-
Sodium acifluorfen 165 g/ha	49.97	42.39	46.18	46.86	48.18	46.86	0.44
Clodinafop-propargyl 80 g/ha PoE	45.1	39.03	42.07	74.9	75.03	74.90	0.95
Propaquizafop (100 g/ha) PoE	47.33	44.2	45.77	56.44	64.38	56.44	0.73
Hand weeding twice 20 and 45 DAS	0	0	0	88.74	83.74	88.74	-
Weedy check	58.41	56.50	57.45	0	0	0	-
Minimum	10.90	5.30	8.59	46.86	48.18	46.86	0.44
Maximum	58.41	56.50	57.45	93.20	91.00	92.10	5.92
Mean	31.1	27.0	29.1	68.4	69.1	68.5	2.73
SD	19.0	17.4	18.1	21.4	18.5	19.2	2.31

herbicide efficiency in controlling the weeds to a great extent confirming the findings made by Hemraj *et al*. (2009) in cluster bean and Nishant and Tigga (2018) in blackgram.

Effect of on economics

The cost of cultivation ranged from ₹ 21500/ha to ₹ 31500/ha with mean of ₹ 23988/ha while the gross returns has ranged from ₹ 24400/ha to ₹ 61720/ha with mean of ₹ 43107/ha (**Table 5**). The net returns ranged from ₹ 2900/ha to ₹ 32542/ha with mean of ₹ 19119/ha while the benefit-cost ratio has ranged from 1.13 to 2.36 with mean of 1.78 Minimum cost of cultivation, gross, net return and benefit-cost ratio were recorded with weedy check, while maximum cost of cultivation and gross return was observed with hand weeding twice 20 and 45 DAS. The maximum net returns and benefit-cost ratio was attained by sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE.

Effect on succeeding finger millet crop

The germination percentage of succeeding finger millet was not affected by acifluorfen + clodinafop-propargyl 165 + 80 g/ha and 330 + 160 g/ha PoE and up to 30 days stage of the finger millet crop, yellowing, stunting, wilting and deformities *i.e.*, epinasty, hyponasty and necrosis *etc*. were not noticed (**Table 6**). This was in accordance with Sathya Priya and Chinnusamy (2020).

Conclusion

It can be concluded from this study that post-emergence application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC 206.25 + 100 g/ha at 22 DAS results in efficient control of both the grassy and broad-leaved weeds in blackgram with significant improvement in the growth, yield and economics of blackgram crop and it was non phyto-toxic to the succeeding finger millet crop.

Table 4. Effect of treatments on seed yield and haulm yield of blackgram during summer 2016 and *Kharif* 2016

Treatment	Seed yield (kg/ha)			Haulm yield (kg/ha)		
	Summer	*Kharif*	Mean	Summer	*Kharif*	Mean
Sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE	937	1050	994	1587	1784	1686
Sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE	1192	1425	1309	1808	2095	1952
Sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE	1305	1519	1412	2088	2253	2171
Sodium acifluorfen + clodinafop-propargyl 330 + 160 g/ha PoE	1320	1485	1402	2080	2420	2250
Sodium acifluorfen 165 g/ha	741	924	833	1407	1615	1511
Clodinafop-propargyl 80 g/ha PoE	813	978	896	1308	1523	1416
Propaquizafop (100 g/ha) PoE	780	895	838	1263	1458	1361
Hand weeding twice 20 and 45 DAS	1481	1604	1543	2265	2440	2353
Weedy check	616	705	661	928	1148	1038
SEM	59.38	68.53	46.53	65.32	69.04	62.34
LSD (p=0.05)	178.01	205.59	139.59	195.3	200.22	187.02
Minimum	616	705	66	928	1148	1038
Maximum	1320	1519	1543	2265	2440	2353
Mean	1021	1176	1099	1637	1860	1749
SD	320	317	317	451	457	454

Table 5. Cost of cultivation, gross and net returns and benefit-cost ratio of different treatments in blackgram

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit-cost ratio
Sodium acifluorfen + clodinafop-propargyl 123.75 + 60 g/ha PoE	22963	45200	22237	1.97
Sodium acifluorfen + clodinafop-propargyl 165 + 80 g/ha PoE	23450	41400	17950	1.77
Sodium acifluorfen + clodinafop-propargyl 206.25 + 100 g/ha PoE	23938	56480	32542	2.36
Sodium acifluorfen + clodinafop-propargyl 330 + 160 g/ha PoE	24590	56080	31490	2.28
Sodium acifluorfen 165 g/ha	22738	33320	10582	1.47
Clodinafop-propargyl 80 g/ha PoE	22560	35840	13280	1.59
Propaquizafop (100 g/ha) PoE	22650	33520	10870	1.48
Hand weeding twice 20 and 45 DAS	31500	61720	30220	1.96
Weedy check	21500	24400	2900	1.13
Minimum	21500	24400	2900	1.13
Maximum	31500	61720	32542	2.36
Mean	23988	43107	19119	1.78
SD	2952	12705	10640	0.40

Table 6. Residual effect of Sodium acifluorfen + clodinafop-propargyl on succeeding finger millet crop

Treatment	Germination (%)	Yellowing			Stunting			Wilting			Deformities**		
		7 DAS	15 DAS	30 DAS	7 DAS	15 DAS	30 DAS	7 DAS	15 DAS	30 DAS	7 DAS	15 DAS	30 DAS
Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha)	93.0	0	0	0	0	0	0	0	0	0	0	0	0
Sodium acifluorfen + clodinafop-propargyl (330 + 160 g/ha)	90.0	0	0	0	0	0	0	0	0	0	0	0	0
Weedy check (untreated)	94.0	0	0	0	0	0	0	0	0	0	0	0	0

*Mean of three replications, ** Deformities consists epinasty, hyponasty and necrosis, NS=Non significant, DAS: Days After Sowing

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