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Effect of different weed management options on weed flora, rice grain yield and economics in dry direct-seeded rice

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ABSTRACT

The shift in the method of rice establishment from traditional manual transplanting of seedlings to direct seeding has occurred in many Asian countries including India. Weeds are the most important biotic constraint in dry direct-seeded rice (dry-DSR) production. Field experiments were carried out during 2015-16 and 2016-17 at Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal, and Puducherry UT, India to study the effect of different weed management options on the diverse weed flora, rice grain yield and economics in dry-DSR under unpuddled condition. The grassy weeds dominated the weed flora, with 86.12% relative density of *Echinochloa colona* (L). Link. The sequential application of pendimethalin and bispyribac-sodium herbicides (1000 *fb* 25 g/ha) with a manual weeding in 40 days after sowing (DAS) reduced total weed density (14.4 /m^2) and biomass (37 g/m^2), resulted in better rice growth (plant height and tillers/m^2), yield parameters (panicle weight and 1000 grain weight) and higher rice grain yield (3.86 t/ha). Negative linear relationship was observed between rice grain yield and total weed biomass at 80 DAS. Uncontrolled weeds caused 68.3% dry-DSR yield loss. Pre-emergence pendimethalin 1.0 kg/ha application integrated with manual weeding with or without bispyribac-sodium application and manual weeding thrice recorded higher B: C ratio in deltaic coastal ecosystem of Karaikal, Puducherry UT.

INTRODUCTION

Rice is the most important food crop of India and provides food for half of the world population. Insufficient water availability, early maturing modern crop varieties, inexpensive and cost-efficient herbicides along with enhanced labour costs, labour shortage during peak planting season (Chauhan 2012), and declining profitability of rice production have encouraged many rice farmers in South-East Asian countries including India to shift from transplanting to direct-seeding (Rao *et al.* 2017a).

Direct-seeded rice (DSR) production system is subject to greater weed pressure than conventional rice transplanting systems, in which weeds are suppressed by flooding and transplanted rice seedlings have a "head start" over germinating weed seedlings (Moody 1983, Rao *et al.* 2007). Direct-seeding is practiced in two major ways, *viz.* wet-seeding and dry-seeding (Rao *et al.* 2017b). In wet-seeded rice, pre-germinated seeds are broadcasted onto the puddled soil. However, in dry direct-seeding of rice (dry-DSR), non pre-germinated seeds are sown onto dry-ploughed, unpuddled dry or moist soil. The major constraint for higher productivity in dry-DSR is weeds. Failure to manage the weeds result in 50 to 90% rice yield loss (Rao *et al.* 2007, Chauhan and Jhonson 2011). Generally farmers resort to single application of either pre or post-emergence herbicides which fail to manage the diverse spectrum of weeds in dry-DSR. The work is limited with regard to sequential/tank-mix application of herbicides or mechanical weeding in dry-DSR of the deltaic coastal ecosystem of Karaikal, Puducherry UT. Hence, a two year field experiment was conducted to evaluate the efficacy of varying weed management options to manage the weeds in dry-DSR at Karaikal, Puducherry UT, India.

MATERIALS AND METHODS

A field study was conducted for two years (September 2015 to January 2016 and September 2016 to January 2017) at research farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry (11° 56' N latitude, 79° 53' E longitude, 4 m above mean level), India. The climate is sub-tropical, with an annual average rainfall of 1200 mm (75-80% of which is received due to North-East monsoon from October to December) with minimum temperature (23-28°C) in January and maximum temperature (33-38°C) in June. The soil at the experimental site was sandy clay loam in texture, near neutral in reaction (pH: 6.94), low in available nitrogen (119 kg/ha) and high in available phosphorus (24 kg/ha) and potassium (366 kg/ha).

The experiment in both years was arranged in randomized complete block design with three replications. Ten treatments were included to evaluate different weed management options in DSR, *viz*. bispyribac-sodium 25 g/ha at 20 DAS, pendimethalin *fb* bispyribac-sodium (1000 *fb* 25 g/ha) at 3 *fb* 20 DAS, oxadiargyl *fb* bispyribac-sodium (100 *fb* 25 g/ha) at 3 *fb* 20 DAS, pyrazosulfuron *fb* bispyribac-sodium (20 *fb* 25 g/ha) at 3 *fb* 20 DAS, pendimethalin *fb* bispyribac-sodium (1000 *fb* 25 g/ha) *fb* manual weeding at 3 *fb* 20 *fb* 40 DAS, pendimethalin (1000 g/ha) *fb* manual weeding at 3 *fb* 40 DAS, bispyribac-sodium + (chlorimuron + metsulfuron) 20 + 4 g/ha at 20 DAS, mechanical weeding thrice at 20,40 and 60 DAS, manual weeding thrice at 20,40 and 60 DAS and unweeded control.

Rice (cultivar '*ADT 46*' with duration of 135 days) was dry-seeded in the first week of September and harvested during the second week of January. Disc harrow was used twice to cultivate and wooden board was used to level the experimental field, respectively. Manual seeding was done with seed rate of 75 kg/ha at 25 cm inter - row spacing. The size of the experimental plots was 5 x 4 m. The field was surface irrigated immediately after the sowing with the water available in the farm ponds, in order to have enough moisture at pre-emergence herbicide application. Herbicides were applied using a knapsack sprayer fitted with a flat fan nozzle with water as a carrier at 500 L/ha for pre-emergence spray and 375 L/ha for post-emergence spray. Mechanical weeding was carried out in the experimental plots using the manually operated garden and weeder at 20 and 40 DAS and rice cono weeder at 60 DAS in the experimental plots due to the rainfall received from the North-East monsoon. Phosphorus (50 kg/ha) and potassium (50 kg/ha) were applied basal. The nitrogen (150 kg/ha) was applied at three equal splits starting from 20 DAS. Recommended rates of chlorpyriphos insecticide was used to manage insects and no major disease was observed during both the years of the experimentation. Pre-emergence and post-emergence herbicides were used as per the treatment. Weed density at 80 DAS was recorded using two quadrats (0.5 x 0.5 m) placed randomly in each plots. The composition of the weed flora in the unweeded control treatment was observed from composite weed samples using the quadrats and the relative density (RD) was computed using standard formula. Weeds were cut at ground level during weed observation at 80 DAS, washed with running water, sun dried, oven dried at 70°C for 48 h, and then weighed to record weed biomass. Rice grain yield was measured from the net plot leaving the border rows and expressed in t/ha at 14% moisture content.

Square root transformation ($\sqrt{x+0.5}$) was performed for the data on weed density and biomass before analyses. Unless indicated otherwise, differences were considered significant only at $p< 0.05$. The relationships between grain yield and weed biomass at 80 DAS were assessed using linear regression analysis. Experimental data were subjected to statistical scrutiny as per the procedures given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Weed floristic composition

Experimental field infested with diverse weed flora comprised of grasses sedge and broad-leaved-weeds. Analyses of the relative density revealed that *Echinochloa colona* was the major weed species (86.12%) in the experimental field which was followed by *F. miliaceae* (7.93%) and *L. chinensis* (3.28%). Previous studies revealed that DSR favors the growth of *E. colona* (Chauhan and Jhonson 2011), *L. chinensis* (Singh *et al*. 2005) and *Fimbristylis miliacea* (Azmi and Mashhor 1995). Rao *et al*. (2007) indicated that adaptation of *Echinochloa* species under the conditions of DSR is possibly due to the germination variability of their seeds and establishment in response to imposed water regime.

Weed density

E. colona density (4.3 and 9.8/m^2) has significantly reduced due to sequential application of pendimethalin *fb* bispyribac-sodium application integrated with manual weeding and the density reduction was found to be 97.9 and 95.3% compared to the unweeded control (**Table 1**). Lower density of *E. colona* was noticed under other sequential (pendimethalin *fb* bispyribac-sodium and pyrazosulfuron *fb* bispyribac-sodium) herbicide applications also. Persistence nature of pendimethalin herbicide is due to its half life period of 10.5 to 44 days depending upon soil temperature and moisture (Ramirez and Plaza 2015), which has potential to control grasses and in particular, *E. colona*. Khaliq and Matloob (2012) reported that pre-emergence pendimethalin application effectively controlled the density of jungle rice. Escape of *E. colona* population in the intra-row space during the operation of mechanical weeder led to its poor control and resulted in higher density of *E. colona* population (155.8/m^2) compared to the rest of the treatments.

The density of *Leptochloa chinensis* was significantly higher with the application of bispyribac-sodium alone (20.7/m^2). But, tank mix application of bispyribac –sodium +(chlorimuron + metsulfuron) improved the control of *L. chinensis* (10.7 /m^2). All other weed management treatments found to be effective in managing this weed compared to unweeded control. An earlier study revealed that bispyribac-sodium was ineffective against *L. chinensis* (Mahajan and Chauhan, 2013). *F. miliaceae* population was significantly lower with treatments received the single or sequential application of herbicides involving bispyribac-sodium. The number of *F. miliaceae* was higher with mechanical weeding thrice, unweeded control (19.3/m^2 each) and manual weeding twice (7.2/m^2) compared to rest of the treatments. Begum *et al.* (2008) indicated that ALS inhibitor bispyripac-sodium gave good control of *F. miliaceae* population in rice. The relative density of broadleaved weed population was less than 3% of the total weed flora and they were not significantly influenced by any of the weed management treatments. Further, the total weed density also followed the similar trend of *E. colona* (**Table 1**).

Weed biomass and weed control efficiency

The weed biomass was significantly influenced by weed management treatments except the broad-leaved weeds (BLW). Weed biomass ranged from 2.0- 158.0 g/m^2 in grasses, 0.1-6.0 g/m^2 in sedge, 0.1 – 3.8 g/m^2 in BLW and 3.7- 166.5 g/m^2 in total weed biomass. Sequential application of pendimethalin *fb* bispyribac-sodium herbicides integrated with manual weeding effectively reduced the grass and total biomass (2.0 and 3.7 g/m^2, respectively) whereas sequential application of oxadiargyl *fb* bispyribac-sodium and tank mix application of bispyribac-sodium + (chlorimuron + metsulfuron) recorded lower sedge and BLW biomass (0.1 g/m^2, respectively). Earlier studies also revealed that sequential application of pre- and post-emergence or tank mix herbicides is more effective against diverse weed flora (Singh *et al.* 2010, Choudhary and Dixit 2018). Total weed biomass was higher with unweeded control and mechanical weeding thrice (166.5 and 109.9 g/m^2). Cherati *et al.* (2011) reported that employing manually operated mechanical weeders for weed management resulted in higher weed biomass in rice crop.

Weed control efficiencies influenced due to weed biomass recorded in various treatments (**Table 2**). Higher weed control efficiency (97.7%) was recorded with sequential application of pendimethalin *fb* bispyribac-sodium herbicides integrated with manual weeding, which was followed by the manual weeding thrice (94.4%). However, plots treated with pre-emergence pendimethalin with or without bispyribac-sodium were comparable to each other (88-94%) but lower weed control efficiency was observed with mechanical weeding using weeders (34%). Singh *et al.* (2010) opined that herbicide combination widens the spectrum of weed control. The results of current study are also in agreement with earlier findings of better weed suppression with proper use of both pre- and post-herbicides in DSR (Chauhan 2012).

Rice growth, yield and economics

The rice plant height and tillers/m^2 were significantly ($p<0.05$) influenced by weed management treatments (**Table 3**). The sequential herbicide application of pendimethalin and bispyribac-sodium integrated with manual weeding and manual

Table 1. Effect of varying weed management treatments on weed density at 80 DAS in dry direct- seeded rice (mean data of two years)

Treatment	Weed density (no./m^2)								
	E. colona	*L. chinensis*	*F. meliaceae*	*L. perennis*	*B. capensis*	*S. indicus*	*E. alba*	*M. quadrifolia*	Total weeds
Bispyribac-sodium	5.50(28.8)	4.91(20.7)	1.91(2.0)	2.32(3.7)	2.12(3.0)	2.01(4.5)	0.50(0.0)	1.52(2.0)	8.5(64.7)
Pendimethalin *fb* bispyribac-sodium	4.14(13.7)	1.65(2.0)	1.58(3.5)	1.85(1.8)	0.74(0.2)	1.65(2.0)	0.97(0.7)	1.65(2.0)	5.5(25.9)
Oxadiargyl *fb* bispyribac-sodium	4.84(19.8)	0.50(0.0)	1.08(1.0)	2.42(5.7)	0.97(0.7)	2.16(4.7)	1.50(1.7)	1.17(1.3)	6.4(34.9)
Pyrazosulfuron *fb* bispyribac-sodium	4.45(17.5)	0.50(0.0)	1.08(1.0)	1.55(1.7)	0.74(0.2)	2.26(6.0)	1.17(1.3)	0.74(0.2)	5.5(27.9)
Pendimethalin *fb* bispyribac-sodium *fb* manual weeding	2.51(4.3)	0.97(0.7)	1.69(2.2)	1.91(2.0)	1.21(1.5)	1.97(3.7)	0.50(0.0)	0.50(0.0)	4.2(14.4)
Pendimethalin *fb* manual weeding	3.63(9.8)	0.50(0.0)	1.85(3.0)	2.27(5.0)	1.57(1.8)	1.91(2.0)	1.74(2.3)	0.97(0.7)	5.4(24.6)
Bispyribac-sodium + (chlorimuron + metsulfuron)	6.37(35.2)	3.57(10.7)	1.21(0.8)	1.36(1.2)	0.83(0.3)	1.93(2.2)	1.32(2.0)	0.97(0.3)	7.7(52.7)
Mechanical weeding thrice	13.0(155.8)	1.17(1.3)	4.78(19.3)	1.17(1.3)	0.50(0.0)	1.17(1.3)	2.17(5.0)	0.50(0.0)	14.0(184.0)
Manual weeding thrice	4.48(16.7)	1.17(1.3)	3.01(7.2)	0.50(0.0)	2.07(5.5)	2.22(4.7)	2.02(2.8)	0.50(0.0)	6.6(38.2)
Unweeded control	15.0(210.0)	2.70(8.0)	4.47(19.3)	1.41(1.3)	1.08(1.0)	1.78(2.5)	1.44(1.3)	0.83(0.3)	16.0(243.7)
LSD (p=0.05)	2.07	1.91	2.33	NS	NS	NS	NS	NS	2.27

LSD, least significant difference, DAS- Days after sowing; Figures in parentheses were original values weeding thrice resulted in taller rice plants with more tillers (114.8 and 108.9 cm; 464.6 and 408.2 tillers/ m^2). Closure of canopy might have occurred due to better competitive ability and nutrient use-efficiency in weeds managed environment. The shorter rice plants with lesser number tillers were recorded in unweeded control (88.4 cm and 251.5 tillers). Azmi and Mashhor (1995) indicated that plant height of rice was significantly reduced when weeds were allowed to compete.

Grain yield of rice was significantly ($p<0.05$) influenced by weed management treatments during 2015-16 and 2016-17 (**Table 3**). During both the years, the highest grain yield was observed with sequential application of pre- and post-emergence application of pendimethalin and bispyribac-sodium herbicides integrated with manual weeding (3.84 and 3.88 t/ha) and the lowest in the unweeded control (1.12 and 1.33 t/ha). Average of two years data indicated that rice grain yield obtained from the plots treated with sequential/tank-mix application of herbicides or manual weeded thrice ranged from 2.86 to 3.86 t/ha and three mechanical weeding and unweeded plots ranged from 1.23 to 2.09 t/ha. Grain yield was statistically comparable with manual weeding thrice (3.61t/ha) and application of pre-emergence pendimethalin integrated with manual weeding once (3.56 t/ha). The response for the panicle weight and 1000 grain weight was similar to that observed for grain yield (**Table 3**). Poor filling of grains and less panicle weight under unweeded control may be due to the vigorous crop-weed competition for growth factors like nutrient, space, light and carbon dioxide (Tindall *et al.* 2005). Rice grain yield and total dry weight at 80 DAS showed negative linear relationship with co-efficient of determination of 0.949 (**Figure 1**). Current study clearly indicated that weed interference contributed to the negative influence on the growth and yield attributes of the crop, which cumulatively reduced the grain yield of dry-DSR. Uncontrolled weeds resulted in 68.3% yield reduction in dry-DSR. Earlier, rice yield loss to the tune of 86.3 was recorded in DSR at Karaikal, Puducherry UT (Saravanane *et al.* 2016).

Table 2. Effect of varying weed management treatments on weed biomass and weed control efficiency at 80 DAS in dry direct-seeded rice (mean data of two years)

Treatment	Weed biomass (g/m^2)				Weed control efficiency(%)
	Grasses	Sedges	BLW	Total	
Bispyribac-sodium	9.04 (77.6)	1.22 (0.9)	2.26(3.1)	11.52 (81.6)	51.0
Pendimethalin *fb* bispyribac- sodium	4.75 (18.4)	1.03 (0.8)	1.21 (0.7)	4.93 (19.9)	88.0
Oxadiargyl *fb* bispyribac- sodium	7.90 (58.7)	0.57 (0.1)	1.73 (1.8)	8.02 (60.6)	63.7
Pyrazosulfuron *fb* bispyribac- sodium	6.35 (45.7)	1.07 (0.5)	1.05(0.9)	6.56 (47.1)	71.7
Pendimethalin *fb* bispyribac- sodium *fb* manual weeding	1.63 (2.0)	0.94 (0.2)	1.70 (1.5)	2.41 (3.7)	97.7
Pendimethalin *fb* manual weeding	2.55 (4.7)	1.68 (1.4)	2.43 (3.8)	3.61 (9.9)	94.0
Bispyribac-sodium + (chlorimuron + metsulfuron)	7.19 (48.0)	0.95 (0.3)	0.70 (0.1)	7.21 (48.4)	71.1
Mechanical weeding thrice	10.78 (106.4)	1.50 (2.3)	1.53 (1.2)	10.96 (109.9)	34.0
Manual weeding thrice	2.84 (7.0)	1.18 (0.8)	1.64 (1.5)	3.26 (9.3)	94.4
Unweeded control	12.99 (158.0)	2.80 (6.0)	2.02 (2.5)	13.30 (166.5)	-
LSD (p=0.05)	3.79	1.18	0.92	3.67	

LSD, least significant difference, DAS- Days after sowing; the figures in parentheses were original values; BLW = Broad-leaved weeds

Table 3. Effect of varying weed management treatments on growth, yield and economics in dry direct-seeded rice (mean data of two years)

Treatment	Plant height (cm)	Tillers $/m^2$	Panicle weight (g)	1000-seed weight (g)	Grain yield (t/ha)			Weed index	GR (x 10^3/ ha)	NR (x 10^3/ ha)	B: C ratio		
					2015 -16	2016 -17	Mean				2015 -16	2016 -17	Mean
Bispyribac-sodium	105.2	398.4	2.01	24.05	2.60	2.60	2.60	32.6	52.60	27.28	0.96	1.18	1.07
Pendimethalin *fb* bispyribac- sodium	111.0	402.4	2.40	23.44	2.86	3.50	3.18	17.7	63.67	36.72	1.02	1.66	1.34
Oxadiargyl *fb* bispyribac- sodium	110.9	386.4	2.21	23.47	3.20	2.82	3.01	22.2	59.08	32.63	1.28	1.20	1.24
Pyrazosulfuron *fb* bispyribac- sodium	113.0	387.8	2.33	23.39	3.04	2.76	2.90	24.9	58.91	32.89	1.25	1.27	1.26
Pendimethalin *fb* bispyribac- sodium *fb* manual weeding	114.8	464.6	2.86	24.46	3.84	3.88	3.86	-	77.52	47.78	1.45	1.75	1.60
Pendimethalin *fb* manual weeding	111.1	405.5	2.60	24.43	3.67	3.45	3.56	07.8	71.32	43.74	1.51	1.65	1.58
Bispyribac-sodium + (chlorimuron + metsulfuron)	104.5	382.9	2.12	24.03	2.80	2.48	2.64	31.6	52.99	27.15	1.03	1.07	1.05
Mechanical weeding thrice	98.8	307.4	2.07	23.96	1.85	2.33	2.09	46.0	41.95	16.80	0.37	0.93	0.65
Manual weeding thrice	108.9	408.2	2.68	24.61	3.53	3.69	3.61	06.7	72.63	42.43	1.21	1.59	1.40
Unweeded control	88.4	251.5	1.57	22.92	1.12	1.33	1.23	68.3	24.29	1.14	-0.08	0.16	0.04
LSD (p=0.05)	7.36	69.9	0.40	0.91	0.77	0.72	0.40	-	-	-	-	-	-

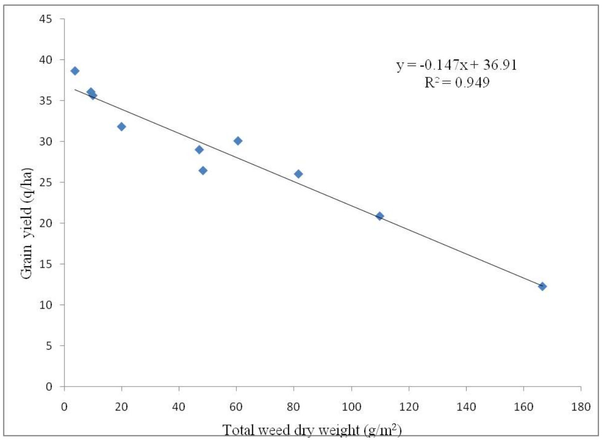

Figure 1. The relationship between grain yield and total weed biomass at 80 DAS

Pre-emergence pendimethalin 1.0 kg/ha application integrated with manual weeding with or without bispyribac-sodium application recorded higher benefit- cost ratio, which ranged between 1.45 to 1.51 and 1.65 to 1.75 during 2015-16 and 2016-17, respectively. Average of two years data indicated that manual weeding thrice (1.40) was also the other best option compared to other treatments (**Table 3**). These results are in conformity with earlier observations that herbicides used in combination with manual weeding were most economical (Rao and Ladha 2014, Saravanane *et al.* 2016).

It was concluded that farmers can opt for pre-emergence pendimethalin 1.0 kg/ha application integrated with manual weeding with or without bispyribac-sodium application in labour scarcity areas or manual weeding thrice at 20, 40 and 60 DAS in labour sufficient areas to effectively manage the diverse weed flora, enhance rice yield with better benefit- cost ratio in dry-DSR of the deltaic coastal ecosystem of Karaikal, Puducherry UT.

REFERENCES

Azmi M and Mashhor M. 1995. Weed succession from transplanting to direct-seeding method in Kemubu rice area, Malaysia. *Journal of Bioscience* **6**(2): 143–154.

Begum M, Juraimi AS, Amartalingum SR, Omar S and Man AB. 2009. Effect of *Fimbristylis miliacea* competition with MR220 rice in relation to different nitrogen levels and weed density. *International Journal of Agriculture and Biology* **11**: 183–187.

Chauhan BS and Johnson DE. 2011. Growth response of direct seeded rice to oxadiazon and bispyribac-sodium in aerobic and saturated soils. *Weed Science* **59**(1): 119–122.

Chauhan BS. 2012. Weed ecology and weed management strategies for direct-seeded rice in Asia. *Weed Technology* **26**: 1–13.

Cherati FE, Bahrami H and Asakereh A. 2011. Evaluation of traditional, mechanical and chemical weed control methods in rice fields. *Australian Journal of Crop Science* **5**(8): 1007–1013.

Choudhary VK and Dixit A. 2018. Herbicide weed management effect on dynamics, crop growth and yield in direct-seeded rice. *Indian Journal of Weed Science* **50**(1): 6–12.

Khalik A and Matloob A. 2012. Germination and growth response of rice and weeds to herbicides under aerobic conditions. *International Journal of Agriculture and Biology* **14**: 775–780.

Mahajan G and Chauhan BS. 2013. The role of cultivars in managing weeds in dry-seeded rice production systems. *Crop Protection* **49**: 52–57.

Moody K. 1983. The status of weed control in Asia. *FAO Plant Protection Bulletin* **30**: 119–120.

Panse VG and Sukhatame PU 1967. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Ramirez JG and Plaza G. 2015. Effect of post-emergence herbicide applications on rice crop weed communities in Tolima, Colombia. *Planta Daninha* **33**(3): 499–508.

Rao AN and Ladha JK. 2014. Economic weed management approaches for rice in Asia. pp. 500–509. In: *Proceedings of 24th Asian-Pacific Weed Science Society Conference*, October 22-25, 2013, Bandung, Indonesia.

Rao AN, Jhonson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 153–255.

Rao AN, Wani SP, Ahmed S, Ali HH and Marambe B. 2017a. An overview of weeds and weed management in rice of south asia. pp. 247–281. In: *Weed management in Rice in the Asian-Pacific Region* (Eds. Rao AN and Matsumoto H). APWSS; The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India.

Rao AN, Wani SP, Ramesha MS and Ladha JK. 2017b. Rice Production Systems. pp. 185–205, In: *Rice Production Worldwide*. (Eds. Chauhan BS, Jabran K and Mahajan G), Springer International Publishing AG 2017 185. DOI 10.1007/978-3-319-47516-5_8.

Saravanane P, Mala S and Chellamuthu V. 2016. Integrated weed management in aerobic rice. *Indian Journal of Weed Science* **48**(2): 152–154.

Singh VP, Singh G, Singh RK, Singh SP, Kumar A, Dhayani VC, Kumar M and Sharma G. 2005. Effect of herbicides alone and in combination on direct seeded rice. *Indian Journal of Weed Science* **37**(3&4): 197–201.

Singh RG, Singh S, Singh V and Gupta RK. 2010. Efficacy of azimsulfuron applied alone and tank mixed with metsulfuron + chlorimuron (almix) in dry direct-seeded rice. *Indian Journal of Weed Science* **42**: 168–172.

Tindall KV, Williams BJ, Stout MJ, Geaghan JP, Leonard BR and Webster EP. 2005. Yield components and quality of rice in response to graminaceous weed, weed density and rice stink bug population. *Crop Protection* **24**: 991–998.

Indian Journal of Weed Science **52**(2): 107–115, 2020

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Long-term weed management effect on weed dynamics, weed shift and productivity of direct-seeded rice-chickpea cropping system

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ABSTRACT

A long-term experiment was conducted on Inceptisol at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during 2010 to 2015 in direct-seeded rice (DSR)-chickpea cropping system to study the effect of continuous and rotational use of weed management practices on weed shift and productivity. No remarkable weed shift was visualized due to continuous or rotational application of combination of herbicides or manual weeding or its integration. However, appearance of *Celosia argentea* in unweeded plot was noticed in sixth year of DSR mainly due to its aggressive growth habit and non-submergence of rice field during *Kharif* 2015. The appearance of *Celosia argentea* suppressed the *Alternanthera triandra*. The *Celosia argentea* produced 8430 seeds/plant as against 1564 seeds/plant by *Alternanthera triandra.* Significantly higher seed yield of rice was registered under two hand weedings followed by oxadiargyl 80 g/ha *fb* bispyribac 25 g/ha. Seed yield of chickpea was higher under conventional tillage and continuous application of pendimethalin 1000 g/ha. Studies on weed seed bank suggested that although, there was no effect of different weed management treatments on seed bank up to 15 cm soil depth neither in DSR nor in chickpea at initial stage, but in unweeded control plot, there was perceptible variation in number of weed seeds of different annual weed species. The dominant weeds species were *Celosia argentea* (37.7%), *Echinochloa colona* (19.6%), *Ischaemum rugosum* (14.7%) and *Cyperus iria* (9.8%) over initially dominant species of *Alternanthera triandra.*

INTRODUCTION

Rice-chickpea is one of the important cropping systems in India including Chhattisgarh. Rice is major *Kharif* crop occupies an area of around 3.67 million hectare (mha) while during *Rabi* season, chickpea is an important pulse crop in Chhattisgarh, covering an area of 0.40 mha with an annual production of 0.43 metric tons. In recent years, due to severe water and labour scarcity, farmers are changing their rice establishment method from transplanting to direct-seeding (Walia *et al*. 2012), therefore, there has been a continuous shift from transplanted rice to direct-seeded rice (DSR) cultivation in several countries of South-East Asia (Pandey and Velasco 2002). The Chhattisgarh state traditionally has an area of nearly 70% under direct-seeding. The DSR has several advantages over puddle transplanted rice like easier planting, timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirement, better soil physical condition for next crop and low production cost with more profit (Kumar and Ladha 2011). The additional benefits of DSR would be water conservation, soil temperature moderation and built up of soil organic carbon status due to residue retention at the surface (Singh *et al.* 2014). However, heavy weed infestation is one of the major constraints in DSR cultivation causing severe yield losses (Rao *et al*. 2007). Yield losses due to weeds varied from 40-100% in direct-seeded rice (Choubey *et al*. 2001). The chickpea is also a poor competitor of weeds because of slow growth rate and limited leaf development during early stage of crop growth and lack of proper weed management which resulted in yield loss of 40-87% (Chaudhary *et al*. 2005). Although, tillage and herbicides are used for weed control, but the degree of control achieved may vary widely depending on weed species present, soil type, climatic conditions, tillage methods *etc*. Thus, herbicide use becomes more important in rice-chickpea cropping system because weeds and rice seedling emerge simultaneously in DSR and starts crop weed competition (Raj *et al.* 2013). Herbicides offer most effective, economical and practical way to weed management and are considered an alternative supplement to hand weeding. Considering the weed flora and its density, combination of different herbicide molecules may work better than over-dosing of a single recommended herbicide. Continuous use of the same herbicide year after year may also lead to problem of shift in weed flora. Weed population dynamics depends on weed management practices of both crops of cropping system along with tillage practices in chickpea crop. With this background, the present study was conducted to explore the long-term use of herbicides either continuously or in rotation in comparison with manual weeding in DSR and chickpea along with different tillage practices in succeeding crop on weed dynamics, weed shift and productivity of rice-chickpea cropping system.

MATERIALS AND METHODS

Experiment was initiated in *Kharif* 2010 on Inceptisols type of soil at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh and continued from rainy seasons of 2010 to 2015 in DSR as first crop and chickpea as second crop in rice-chickpea cropping system under mid land ecosystem. During *Kharif*, five treatments comprised of oxadiargyl 80 g/ha at 3 days after sowing (DAS) *fb* bispyribac Na 25 g/ha 25 DAS, fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha 20 DAS; pyrazosulfuron 25 g/ha at 3 DAS *fb* hand weeding at 35 DAS, hand weeding twice at 20 and 35 DAS and unweeded control were assigned in a randomized block design with three replications. Of these five treatments, three plots, *viz*. oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha, hand weeding twice and un-weeded control remained fix continuously for five years on same piece of land, whereas, fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha and pyrazosulfuron 25 g/ha *fb* hand weeding were rotated with each other in every two years. In case of follow-up crop of chickpea, each plot of *Kharif* rice was divided into two treatments, one with conventional tillage and another with zero tillage which again sub-divided into three sub-sub plots consisting weed management practices; namely farmers' practice (hand weeding and interculture at 20 DAS), pendimethalin 1.0 kg/ha as pre-emergence (PE) and unweeded control in split-split plot design replicated thrice. The soil was sandy-loam with low organic carbon and available nitrogen but medium in phosphorus and high in potassium with neutral soil reaction. Medium duration rice cultivar '*MTU 1010*' and chickpea cultivar '*JG-130*' were taken as test crop. The sowing of rice at 80 kg/ha was done with the help of seed cum fertilizer drill in third week of June during all the five years at a spacing of 20 cm row to row with recommended dose of fertilizer *i.e.* 100:50:30 kg/ha of N:P:K. The crop did not suffer with any kind of incidence like drought, insect, disease *etc*. during its entire growth period, however, during 2015 *Kharif*, there was no submergence as rain water was not available throughout the crop period and the survival was only on the basis of irrigation water.

Sowing of chickpea crop was done in the third week of November every year with a seed rate of 75 kg/ha and row spacing of 30 cm with the help of seed cum fertilizer drill in conventional tillage, whereas, it was sown with zero-till seed cum fertilizer drill in zero tillage plots. The recommended fertilizer dose of 20:50:30 kg/ha N:P:K was applied to chickpea as basal. The observations, *viz*. weed flora, weed density, weed biomass and their effect on yield of rice and chickpea and economic viability of different treatments were analyzed as per the standard procedure. All other agronomic practices were kept normal and uniform for all the treatments of the experiment. Effect of continuous use of herbicides and herbicide-tillage combination on weed shift in rice and chickpea was recorded in the initial and final year. The herbicides were applied by using knapsack sprayer with 375 liters of spray volume per hectare as per treatment. The species and category wise weed density and dry weight was recorded using quadrate of 50 × 50 cm in all the seasons. Weed seed bank studies were conducted to see the changes in weed flora over initial status. Soil samples from a depth of 0-15 cm were collected treatment wise from 3 random spots in each treatment after the harvest of rice and chickpea in the initial year 2010-11 and concluding year 2015. The soil samples weighing 500 g were put in small pots followed by a regular watering to facilitate early emergence of weeds. Species wise weed emergence was recorded at 30 DAS.

RESULTS AND DISCUSSION

Weed flora

Rice: Major weed flora observed in the experimental field of rice during rainy seasons of 2010 to 2015 were *Echinochloa colona, Ischeamum rugosum* among grasses; *Alternanthera triandra, Cyanotis axillaris* among broad-leaved and *Cyperus iria* among sedges. Other weeds present in lower density were *Commelina benghalensis, Croton bonplandianus, Spilanthus acmella, Ludwigia parviflora.* In the initial years, *Alternanthera triandra* was the dominant weed but became gradually insignificant later.

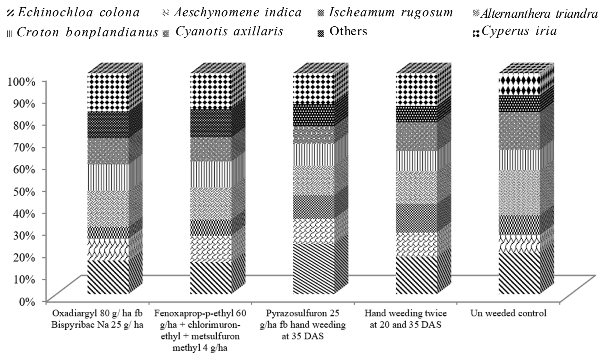

Figure 1. Relative weed density in the initial year, *Kharif* 2010 under direct seeded rice

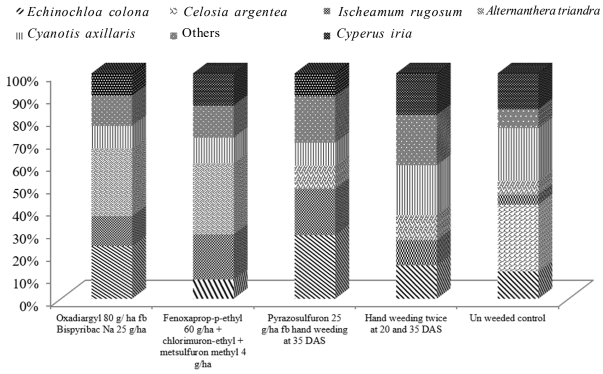

Figure 2. Relative weed density in the concluding sixth year, *Kharif* 2015 under direct seeded rice

Chickpea: Major weed flora observed in the chickpea field during winter seasons of 2010-11 to 2014-2015 was *Medicago denticulata* and *Chenopodium album*. Other weeds in lower density were *Anagalis arvensis, Melilotus alba, Echinochloa colona, Cyperus iria.* Sekhon and Singh (1993) has also reported the similar weed flora as problematic weeds in pulses.

Weed density and dry weight

Rice: The data of weed densities in rice recorded at 60 DAS in the initial year (**Figure 1** and **2**) revealed that density of grassy weed mainly *Echinochloa colona* was higher with pyrazosulfuron 25 g/h *fb* one hand weeding at 35 DAS due to the fact that pyrazosulfuron is more effective on broad-leaves than grasses. The density of broad-leaves and sedge was slightly more under oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha 25 DAS in the first year. However, in the concluding year *i.e.* sixth, there was shift in weed flora except for *E. colona* which remained unchanged and was found higher under pyrazosulfuron 25 g/ha *fb* one hand weeding. Density of *I. rugosum* was also found higher under this treatment. The relative density of *A. triandra* was recorded to be the highest under fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha at 20 DAS. It was mainly due to the lesser effect of chlorimuron-ethyl + metsulfuron-methyl 4 g/ha against *A. triandra*. The remarkable change in weed densities was noted under untreated control plot where density of *A. triandra* reduced drastically from 20.5% in the initial year to 5.6% in the sixth year. This was mainly due to suppressive effect of *C. argentea,* which emerged as the most dominating weed species at the sixth year and contributed the share of 27.5%. Another weed density increased over initial year was *C. axillaris,* which contributed for 28.9% in the control plot.

Significantly lower weed dry matter was recorded at 60 DAS under all the treatments over un-weeded control plot in all the years (**Table 1**). Among different weed management treatments, significantly lower weed dry matter was registered under two hand weeding at 20 and 35 DAS in all the years, which was closely followed by oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS. Weed dry matter was also found significantly low under rotational treatments than unweeded control.

Chickpea: There was no change in weed species either due to weed management practices or tillage practices. *M. denticulata* and *C. album* were the most dominant weeds. Out of these two, *M. denticulata* proved to be more serious weed of chickpea and contributed for 70.7 and 78.5%, respectively in the initial and concluding year under conventional tillage whereas it was to the tune of 60.6 and 80.3% in zero tillage for the same period. The relative density of *M. denticulata* was 76.5 and 80% in the initial and concluding year under unweeded control (**Figure 3 and 4**).

Table 1. Weed dry weight at 60 DAS of direct-seeded rice as influenced by long term weed management practices under rice-chickpea cropping system

Treatment	Weed dry weight (g/m^2)						
	2010	2011	2012	2013	2014	2015	Mean
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	6.79(45.6)	6.70(44.4)	3.78(13.8)	4.69(21.7)	6.08(26.5)	4.33(18.2)	5.37(28.4)
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha	6.53(42.1)	7.33(53.2)	6.55(42.4)	6.15(37.6)	6.64(43.9)	5.40(28.7)	6.47(41.3)
Pyrazosulfuron 25 g/ha *fb* HW at 35 DAS	6.44(41.0)	9.19(83.9)	4.56(20.3)	5.27(27.5)	6.42(40.9)	5.09(25.4)	6.35(39.8)
Hand weeding (HW) twice at 20 and 35 DAS	6.50(41.8)	5.57(30.5)	4.24(17.5)	4.25(17.7)	4.70(21.7)	4.09(16.2)	4.97(24.2)
Unweeded control	11.86(140.2)	12.61(158.6)	9.27(85.5)	9.74(94.6)	11.80(139.1)	15.44(237.9)	11.96(142.6)
LSD (p=0.05)	0.36	0.52	0.40	0.22	0.65	0.78	-

*Data in parentheses is original and transform by ($\sqrt{x+0.5}$)

The treatments of weed management applied during *Kharif* to DSR had no significant impact on weed dry matter in *Rabi* at 60 DAS, though, there was slightly higher dry matter of weeds was recorded under unweeded control plot of *Kharif* season than other practices (**Table 2**). However, there was significant impact in previous two years *i.e.* 4th and 5th year. The impact of previous season treatments on weed dry matter was seen in 4th and 5th year where weed dry matter was significantly lower under permanent plots of two hand weeding treatment and this was closely followed by oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS than un-weeded control. Tillage also had no significant impact on weed dry matter at 60 DAS in chickpea except during 2014-15. Though, there was slightly higher weed dry matter obtained under conventional than zero tillage during entire period of expermentation. Among weed management treatments, significantly higher weed dry matter was recorded under un-weeded control plot. However, in the initial two years, significantly lower weed dry matter was recorded under farmers' practice than others, but in the later part, higher density was seen in the entire experiment and significantly lower weed dry matter was registered under pre-emergence application of pendimethalin 1.0 kg/ha had better control of wide spectrum of weeds in chickpea.

Weed seed bank

Rice: The annual weed species emerged during *Kharif* were *E. colona, I. rugosum, A. indica* among grasses; *A. triandra, C. bonplandianus, C. argentea* among broad-leaved and *C. iria* among sedges. *E. colona* and *A. triandra* dominated the flora to the tune of 27.9 and 24.4%, respectively, at the start of experiment in 2010 (**Table 3**). The status of weed seed bank up to a soil depth of 15 cm studied at concluding year (**Table 3**) during *Kharif* (sixth year in case of direct-seeded rice) revealed that continuous or rotational application of combination of herbicides

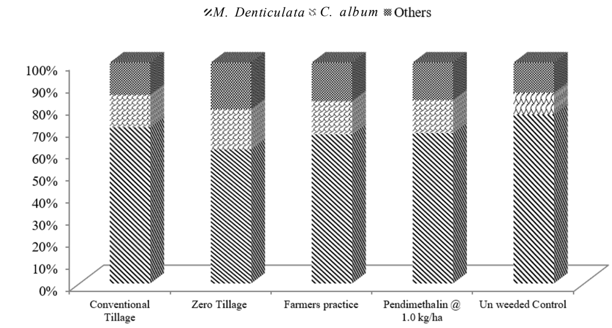

Figure 3. Relative weed density during 1st year of *Rabi* 2010-11 under rice-chickpea cropping system

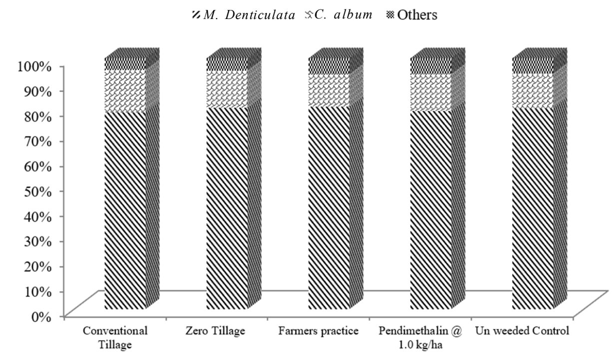

Figure 4. Relative weed density during fifth year of *Rabi* 2014-15 under rice-chickpea cropping system

Table 2. Weed dry weight at 60 DAS of chickpea influenced by long term weed management practices under rice-chickpea cropping system

Treatment	Weed dry weight (g/m^2)					
	2010-11	2011-12	2012-13	2013-14	2014-15	Mean
Weed management (Kharif)						
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	2.55 (6.0)	3.98(15.4)	4.02(15.7	7.96(62.8)	4.01(15.6)	4.86(23.1)
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha	2.63(6.4)	4.09(16.2)	4.26(17.6)	7.96(62.9)	4.91(23.6)	5.08(25.3)
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	2.74(7.0)	4.02(15.6)	4.13(16.5)	7.96(62.8)	4.67(21.3)	5.02(24.7)
Hand weeding twice at 20 and 35 DAS	2.82(7.4)	3.73(13.4)	3.37(10.9)	7.47(55.3)	4.35(18.4)	4.65(21.1)
Unweeded control	2.67(6.6)	4.60(20.7)	4.61(20.7)	8.35(69.1)	4.35(29.9)	5.47(29.4)
LSD (p=0.05)	NS	NS	NS	5.99	0.32	-
Tillage						
Conventional	2.69(6.8)	3.99(15.5)	4.30(18.0)	8.55(72.6)	4.99(24.4)	5.28(27.4)
Zero	2.68(6.7)	4.12(16.5)	4.16(16.8)	7.10(49.9)	4.43(19.1)	4.72(21.8)
LSD (p=0.05)	NS	NS	NS	NS	0.28	-
Weed management (Rabi)						
Farmers practice	2.15(4.1)	3.86(14.4)	3.85(14.4)	8.01(63.7)	4.54(20.1)	4.88(23.3)
Pendimethalin 1.0 kg/ha	2.49(5.7)	3.03(8.7)	3.47(11.5)	6.18(37.7)	4.22(17.3)	4.08(16.2)
Unweeded Control	3.28(10.3)	4.84(22.9)	4.88(23.3)	9.32(86.4)	5.32(27.8)	5.89(34.1)
LSD (p=0.05)	0.65	0.51	0.47	0.95	0.31	-

*Data in parentheses is original and transform by $(\sqrt{x+0.5})$^0.5

or integration of herbicide and one hand weeding or purely two hand weedings did not show remarkable variation in weed seed bank of different annual weed species like *E. colona, I. rugosum* (among grasses), *A. triandra* (among broad-leaved) and *C. iria* (among sedges). However, in unweeded control plot, there was remarkable variation in number of weed seeds of different annual weed species. The dominant weeds species were *Celosia argentea* (37.7%), *E. colona* (19.6 %), *I. rugosum* (14.7%), *C. iria* (9.8 %), whereas, initially dominant species *A. triandra* registered its presence by a reduced tune of 1.6% only. This indicated that intra-weed competition in long term which causes the the appearance or disappearance of particular weed species.

Chickpea: During *Rabi* season, annual weeds like *M. denticulata* and *C. album* were the dominant weed species. *M. denticulata* alone contributed 41.5% of the total share of seed bank, of which 25.7% shared by conventional tillage and 15.8% seed bank was shared by conservation tillage. Share of *C. album* was next in order. Weed seeds of other weeds like *A. arvensis, M. alba, E. colona, C. iria* also emerged in meager number (**Table 4**).

During concluding years' *i.e. Rabi* 2014 -15 from a soil depth of 15 cm revealed that there was no change in weed flora either due to long-term application of pendimetalin as PE, or farmers' practice or no weeding in control plot as well as conventional/zero tillage in chickpea sown after direct-seeded rice (**Table 5**). The dominant annual dicotyledonous weeds observed during *Rabi* were *M. denticulata* and *C. album* along with seeds of some other weed species but in a very meager number and irregular appearance. However, the number of seeds of different weed species varied remarkably due to tillage as well as un-weeded conditions. It is obvious that tillage systems disturb the vertical distribution of

Table 3. Weed seed bank in initial year 2010 and sixth year 2015 *Kharif* at 0-15 cm in long term weed management practices under rice-chickpea cropping system

Treatment	*E. colona*	*A. indica*	*I. rugosum*	*A. triandra*	*C. bonplandianus*	*C. argentea*	*C. rotundus*	Others	Total
Weed seed bank (initial) year 2010									
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	3.2(10)	1.6(2)	1.9(3)	2.9(8)	2.1(4)	1.9(3)	1.9(3)	1.9(3)	6.04(36)
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha	2.9(8)	1.2(1)	2.1(4)	3.1(9)	1.9(3)	1.2(1)	1.9(3)	1.9(3)	5.70(32)
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	3.1(9)	1.2(1)	1.9(3)	2.7(7)	1.6(2)	1.6(2)	2.1(4)	1.6(2)	5.52(30)
Hand weeding twice at 20 and 35 DAS	3.2(10)	1.2(1)	2.1(4)	2.9(8)	1.9(3)	1.9(3)	1.9(3)	1.6(2)	5.87(34)
Unweeded control	3.2(10)	1.2(1)	2.1(4)	3.1(9)	1.6(2)	1.6(2)	2.1(4)	1.6(2)	6.04(36)
Weed seed bank (at last) year 2015									
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	2.1(4)	-	1.6(2)	1.9(3)	-	-	1.6(2)	1.9(3)	3.8(14)
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha	1.9(3)	-	2.6(6)	2.9(8)	-	-	1.9(3)	2.6(6)	5.2(26)
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	3.1(9)	-	2.7(7)	1.9(3)	-	-	1.6(2)	2.1(4)	5.1(25)
Hand weeding twice at 20 and 35 DAS	1.9(3)	-	2.4(5)	1.9(3)	-	-	1.2(1)	1.6(2)	3.8(14)
Unweeded control	4.1(16)	-	3.1(9)	1.2(1)	-	4.2(17)	2.6(6)	3.2(10)	7.7(59)

Table 4. Weed seed bank (0-15 cm) at harvest of chickpea in 2010-11 under long term weed management practice under rice-chickpea cropping system

Treatment main plot (*Kharif*)	Sub-plot (*Rabi*)	*Medicago denticulata*		*Chenopodium album*		*Cyperus iria*		Others	
		CT	ZT	CT	ZT	CT	ZT	CT	ZT
Oxadiargyl 80 g/ha *fb*	Framer's practice	3.94(15)	2.74(7)	1.58(2)	-	-	1.58(2)	-	1.22(1)
bispyribac-Na 25 g/ha	Pendimethalin 1.0 kg/ha	3.54(12)	2.35(5)	1.22(1)	-	1.58(2)	-	-	1.22(1)
	weed check	5.79(33)	3.08(9)	1.87(3)	1.58(2)	1.58(2)	1.58(2)	1.58(2)	1.22(1)
Fenoxaprop-p-ethyl 60 g/ha +	Framer's practice	2.55(6)	2.35(5)	-	-	-	-	1.87(3)	1.87(3)
chlorimuron-ethyl +	Pendimethalin 1.0 kg/ha	2.35(5)	1.87(3)	1.58(2)	1.58(2)	-	-	-	-
metsulfuron-methyl 4 g/ha	Weed check	5.52(30)	2.92(8)	2.35(5)	1.58(2)	1.87(3)	-	-	2.12(4)
Pyrazosulfuron 25 g/ha *fb*	Framer's practice	2.55(6)	2.55(6)	1.58(2)	1.22(1)	1.58(2)	-	-	-
hand weeding at 35 DAS	Pendimethalin 1.0 kg/ha	2.12(4)	2.35(5)	1.22(1)	-	1.58(2)	1.87(3)	-	-
	Weed check	3.94(15)	2.92(8)	1.87(3)	-	2.12(4)	1.87(3)	1.22(1)	-
Hand weeding twice at 20	Framer's practice	3.94(15)	2.55(6)	1.58(2)	1.58(2)	-	-	-	-
and 35 DAS	Pendimethalin 1.0 kg/ha	3.39(11)	1.87(3)	-	-	-	1.22(1)	1.22(1)	-
	Weed check	5.34(28)	12.0	1.58(2)	1.22(1)	1.58(2)	1.22(1)	1.22(1)	-
Unweeded control	Framer's practice	3.67(13)	1.87(3)	1.58(2)	1.87(3)	1.58(2)	-	1.58(2)	1.58(2)
	Pendimethalin 1.0 kg/ha	3.24(10)	1.87(3)	-	-	-	-	1.58(2)	1.22(1)
	Weed check	5.79(33)	2.74(7)	1.58(2)	1.87(3)	2.12(4)	-	1.87(3)	1.58(2)
Total		15.38(236)	12.0(144)	5.34(28)	4.06(16)	4.85(23)	3.54(12)	3.67(13)	3.94(15)

CT- Conventional tillage, ZT - Zero tillage

Table 5. Weed seed bank (0-15 cm) at harvest of chickpea in 2014-15 under long term weed management practice under rice-chickpea cropping system

Treatment Main plot (*Kharif*)	Sub-plot (*Rabi*)	*M. denticulata* CT	*M. denticulata* ZT	*C. album* CT	*C. album* ZT	Others CT	Others ZT
Oxadiargyl 80 g/ha *fb*	Framer's practice	2.92(8)	2.35(5)	1.22(1)	1.22(1)	1.22(1)	1.22(1)
bispyribac-Na 25 g/ha	Pendimethalin 1.0 kg/ha	2.35(5)	1.58(2)	1.22(1)	-	1.22(1)	-
	Weed check	6.04(36)	5.43(29)	1.58(2)	1.58(2)	1.87(3)	1.22(1)
Fenoxaprop-p-ethyl 60 g/ha	Framer's practice	3.08(9)	2.35(5)	1.22(1)	-	1.58(2)	1.22(1)
+ chlorimuron-ethyl +	Pendimethalin 1.0 kg/ha	2.55(6)	1.58(2)	1.22(1)	1.22(1)	1.22(1)	-
metsulfuron- methyl 4 g/ha	Weed check	6.04(36)	5.43(30)	1.87(3)	1.58(2)	1.58(2)	1.22(1)
Pyrazosulfuron 25 g/ha *fb*	Framer's practice	3.24(10)	2.74(7)	1.22(1)	1.22(1)	1.58(2)	-
hand weeding at 35 DAS	Pendimethalin 1.0 kg/ha	2.35(5)	1.87(3)	1.22(1)	1.22(1)	1.22(1)	-
	Weed check	5.52(30)	5.52(30)	2.12(4)	1.58(2)	1.58(2)	1.22(1)
Hand weeding twice at 20	Framer's practice	3.39(11)	3.08(9)	1.58(2)	-	1.22(1)	1.22(1)
and 35 DAS	Pendimethalin 1.0 kg/ha	2.55(6)	2.12(4)	1.58(2)	-	1.22(1)	1.22(1)
	Weed check	5.96(35)	5.15(26)	2.12(4)	1.87(3)	1.87(3)	1.87(3)
Unweeded control	Framer's practice	4.06(16)	3.39(11)	1.22(1)	1.87(3)	1.87(3)	1.58(2)
	Pendimethalin 1.0 kg/ha	2.92(8)	2.35(5)	1.87(3)	1.22(1)	1.58(2)	1.58(2)
	Weed check	7.97(63)	7.04(49)	2.55(6)	1.87(3)	2.12(4)	1.58(2)
Total		17.13(293)	14.75(217)	5.96(35)	4.53(20)	5.43(29)	4.06(16)

CT- Conventional tillage, ZT - Zero tillage

weed seeds in the soil in different ways. Size and composition of seed bank as well as above ground weed flora reflect past and present weed, crop and soil management. Similarly in the present investigation, the number of weed seeds was more under conventional tillage than zero tillage system, due to vertical soil disturbance. Tillage practices also alter distribution of weed seeds vertically within the soil profile (Buhler, 1995). The number of weed seed emergence of weed species, *M. denticulata* and *C. album* was 26 and 42% higher under conventional tillage than zero tillage. The studies of Buhler (1995) and Buhler *et al.* (1996) also reported changes in weeds due to tillage practices The number of weed emergence was considerably high under un-weeded plots than plots where pendimethalin as PE, or farmers' practice was adopted continuously for weed management irrespective to tillage system, which suggests that weed management practices are quite effective in controlling weeds in chickpea.

Weed shift

Rice: At the beginning of the study in 2010-11, the major weed flora observed in the beginning was *E.colona* and *I. rugosum* (among grasses), *A. triandra, C. axillaris, C. benghalensis, C. bonplandianus* and *C. argentea* (among broad-leaved) and *C. iria* (as sedge). Continuous and rotational use of cultural, chemical as well as integrated weed management practices in rice for six years lowered the density of all the weed species. There was no major or noticeable weed shift or change in weed flora due to continuous use of combination of pre- and post-emergence application of herbicide oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha 25 DAS and cultural practice of hand weeding twice at 20 and 35 DAS. Similarly, there was no remarkable weed shift due to rotational application of combination of fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha 20 DAS and integration of PE pyrazosulfuron 25 g/ha at 3 DAS *fb* hand weeding at 35 DAS, with each other in every two years. But in untreated control plot, densities of *A. triandra* and *E. colona* progressed with each year might be due to aggressive nature of both of these weeds as well as ability to tolerate continuous submergence. However, *C. benghalensis* and *C. bonplandianus* got disappeared mainly due to intra-weed competition, whereas density of *C. argentea* remained at lower level up to fifth year. However, in sixth year of experimentation, *C. argentea* abruptly emerged as one of the most dominant weed and did not allow *A.triandra* to grow at all. Similarly, it suppressed the density of *E. colona* considerably. This might be due to favourable environments for *C. argentea* in *Kharif* 2015 in terms of lesser rains, longer dry spells, nil submergence in the entire season as well as sufficiency of seed bank. Thus, *A.triandra* got disappeared due to aggressive appearance of *Celosia argentea* in the concluding year. The comparative biology of *A. triandra* and *C. argentea* is given in **Table 6** for better understanding of reasons behind appearance or disappearance of any particular weed species. Tillage practices also alter distribution of weed seeds vertically within the soil profile (Buhler, 1995). Application of herbicide

Table 6. Comparative biology of *Alternanthera triandra* and *Celosia argentea, Kharif* 2015

Characters \ Weed species	*A. triandra*	*C. argentea*
Height, cms	89	165
Branches/plant	11	4
Fruits/plant	527	15
Total no. of seeds/plant	1564	8430
Weight of 1000 seeds, g	0.33	0.43

was found effective to reduce weed seed numbers. It is obvious from the **Table 6** that height and number of seeds per plant in *C. argentea* were 46 and 81.4% higher over *A. triandra,* respectively, which proved the aggression of *C. argentea* against *A. triandra* in the favourable environments like *Kharif* 2015.

Chickpea: No remarkable effect of weed management and tillage practices on weed shift was found. *M. denticulata* was observed to the most dominant weed during winter followed by *C. album*. The manual and chemical weed management in chickpea did not make any change in the weed flora. However, there was manifold increase in density of both the above weeds in last two years. Other weeds in lower densities were *A. arvensis, M. alba, E. colona* and *C. iria***.**

Crop yield

Rice: In general, hand weeding twice at 20 and 35 DAS proved to be significantly superior over control but was at par with most of the other treatments. However, herbicide combinations or integration with one hand weeding applied either in continuation for six years or rotation between fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron- methyl 4 g/ ha and pyrazosulfuron 25 g/ha *fb* one hand weeding at 35 DAS every two years, the grain yield was significantly higher under the continuous application of oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ ha 25 DAS but this was statistically at par with other herbicide combinations (**Table 7**). The effectiveness of bispyribac-Na as a PoE herbicide for DSR is also reported by Mahajan *et al.* (2009), Khaliq *et al.* (2011) and Choudhary and Dixit (2018). The initial broad- spectrum weed control by oxadiargyl and later on by bispyribac-Na provided a weed free environment continuously for a period of nearly 60-70 days and even more resulted in rice yield similar to that of two hand weeding. The yield of rice was at par to two hand weedings and other herbicide combination treatment applied in rotation of two years. This indicates that the continuous or rotational use of same herbicide combinations did not affect the rice yields adversely as compared to manual weeding. Higher seed yield under above treatments was due to the proper utilization of moisture, nutrients light and space by the rice crop in the absence of weed competition**.**

Chickpea: The effect of previously applied weed management treatments to direct-seeded rice during *Kharif* season had no significant effect on seed yield of chickpea in *Rabi* (**Table 8**). However, marginally higher chickpea yield obtained under the treatment of oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac- Na 25 g/ha at 25 DAS as oxadiargyl has the potential to check some of the *Rabi* season weeds especially *M. denticulata* and *C. album* upto some extent. Therefore, weed population was low in this treatment. However, tillage had no significant impact on chickpea seed yield and there was no significant yield difference between conventional and zero tillage. Seed yield was marginally higher under conventional than zero tillage. More mobilization of photosynthates to grain under conventional tillage as a result of higher harvest index might have also led to slight increase of yield over zero tillage (Singh *et al.* 2011). Among different weed management treatments, significantly higher seed yield was obtained under pendimethalin 1.0 kg/ha than unweeded check and this was closely followed by farmers' practice. On an average of five years, increase of 11.85% seed yield under pendimethalin 1.0 kg/ha was estimated over farmers' practice. Higher seed yield under above treatments might be due to the proper utilization of moisture, nutrients light and space by the chickpea crop in the absence of weed competition. Similar findings have been reported by Singh and Mukherjee (2009).

Table 7. Grain yield and B:C ratio of rice as influenced by long-term weed management practices under rice-chickpea cropping system

Treatment	Grain yield(t/ha)							B:C ratio					
	2010	2011	2012	2013	2014	2015	Mean	2011	2012	2013	2014	2015	Mean
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	3.53	4.21	4.64	4.82	4.53	5.08	4.47	2.21	2.54	2.52	2.37	2.65	2.46
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha	3.90	4.11	4.19	4.07	4.23	4.83	4.22	2.33	2.46	2.28	2.37	2.65	2.42
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	4.22	3.87	4.22	4.45	4.25	4.83	4.31	1.97	2.23	2.24	2.14	2.37	2.19
Hand weeding twice at 20 and 35 DAS	4.15	4.56	4.34	5.02	4.59	4.92	4.60	2.06	1.97	2.28	2.09	2.08	2.10
Unweeded control	0.52	0.41	1.44	0.46	0.10	0.38	0.55	-0.24	-0.90	-0.29	-0.06	-0.35	-0.37
LSD (p=0.05)	0.42	0.60	0.40	0.22	0.37	1.18	-						

Table 8. Seed yield and B:C ratio of chickpea as influenced by long-term weed management practices under rice-chickpea cropping system

Treatment	Seed yield (t/ha)						B:C ratio					
	2010-11	2011-12	2012-13	2013-14	2014-15	Mean	2010-11	2011-12	2012-13	2013-14	2014-15	Mean
Weed management (Kharif)												
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	1.09	1.22	1.24	0.84	0.99	1.08	1.60	2.33	2.03	1.38	1.78	1.82
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron methyl 4 g/ha	1.16	1.15	1.16	0.83	0.95	1.05	1.70	2.20	1.90	1.36	1.72	1.78
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	1.13	1.14	1.12	0.83	0.96	1.04	1.66	2.18	1.83	1.36	1.73	1.75
Hand weeding twice at 20 and 35 DAS	1.19	1.20	1.18	0.87	0.98	1.08	1.75	2.30	1.93	1.43	1.76	1.83
Unweeded control	1.08	1.02	1.04	0.76	0.89	0.96	1.60	1.95	1.70	1.25	1.60	1.62
LSD (p=0.05)	0.08	NS	NS	NS	NS	-						
Tillage												
Conventional	1.17	1.20	1.22	0.84	0.94	1.07	1.72	2.30	2.00	1.38	1.69	1.82
Zero	1.08	1.10	1.11	0.81	0.97	1.01	2.13	2.80	2.27	1.65	2.16	2.20
LSD (p=0.05)	NS	NS	NS	NS	0.02	-						
Weed management (Rabi)												
Farmers practice	1.28	1.22	1.39	0.91	1.17	1.19	1.60	1.97	1.88	1.24	1.77	1.69
Pendimethalin 1.0 kg/ha	1.38	1.47	1.48	1.14	1.30	1.35	1.84	2.55	2.31	1.78	2.24	2.14
Unweeded control	0.70	0.61	0.62	0.34	0.38	0.53	1.03	1.14	1.01	-0.65	-0.63	0.38
LSD (p=0.05)	0.08	0.13	0.12	0.11	0.08	-						

Table 9. Rice equivalent yield of chickpea as influenced by long term-weed management practices under rice-chickpea cropping system

Treatment	Rice equivalent yield of chickpea (t/ha)					
	2010-11	2011-12	2012-13	2013-14	2014-15	Mean
Weed management (Kharif)						
Oxadiargyl 80 g/ha *fb* bispyribac-Na 25 g/ha	2.12	3.02	2.86	1.85	2.15	2.40
Fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron methyl 4 g/ha	2.25	2.85	2.68	1.82	2.06	2.33
Pyrazosulfuron 25 g/ha *fb* hand weeding at 35 DAS	2.20	2.82	2.58	1.82	2.09	2.30
Hand weeding twice at 20 and 35 DAS	2.31	2.97	2.72	1.91	2.13	2.41
Unweeded control	2.10	2.53	2.40	1.67	1.93	2.13
Tillage						
Conventional	2.27	2.97	2.81	1.85	2.04	2.39
Zero	2.11	2.72	2.56	1.78	2.11	2.26
Weed management (Rabi)						
Farmers practice	2.49	3.02	3.21	2.00	2.54	2.65
Pendimethalin 1.0 kg/ha	2.68	3.64	3.41	2.51	2.83	3.01
Unweeded control	1.36	1.49	1.43	0.75	0.83	0.12

Rice yield equivalence

The highest rice yield equivalence was recorded under the continuous application of two hand weeding at 20 and 35 DAS in direct-seeded rice during *Kharif* which was closely followed by the treatments of oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS. This was due to higher chickpea yields in these plots. The average of five years of rice yield equivalence was marginally high under conventional tillage than zero tillage dut to higher chickpea yields. The pre-emergence application of pendimethalin 1.0 kg/ha produced higher rice yield equivalence over farmers' practice and unweeded control, respectively due to better weed control by pendimethalin in chickpea during *Rabi* season (**Table 9**).

Economics

Rice: Treatment having oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS and fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha were more profitable than hand weeding and other treatments due to higher yield with low cost of cultivation. Maximum B: C ratio was obtained for above treatments contuously for six years, which proved the efficacy and economics of the above herbicide combinations for weed management in direct-seeded rice (**Table 7**). Use of herbicides is an efficient and cost-effective method for weed control in DSR while manual weeding could be adopted where cheap labour is available (Mahajan *et al.* 2009).

Chickpea: Economics in terms of B: C was higher under the treatments of hand weeding twice at 20 and 35 DAS and oxadiargyl 80 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS applied to direct seeded rice during *Kharif* seasons, respectively (**Table 8**). However, B: C ratio calculted for other treatments was also very close to each other. The zero tillage proved to be more economical than conventioanl tillage with an obvious reason of low cost involved in tillage operations in zero tillage system. Among the weed management practices, the highest B: C ratio was obtained under the treatment of pre-emergence application of pendimethalin 1.0 kg/ha and was followed by farmers' practice. The average B: C ratio was higher by 21% over the B: C ratio of farmers practice.

Conclusion

It was concluded that the continuous or rotational use of herbicides, manual weeding or their integration as well as cropping system has no effect on weed shift and crop performance. However, there exists a direct relationship between weed shift and submergence especially during *Kharif*. Different herbicides although have depressive impact on weeds in long run but under natural condition as in unweeded control there is a possibility of replacing one or more species by another dominant one in intra-weed competition.

REFERENCES

Buhler DD. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean in the central USA. *Crop Science* **35**: 1247–1258.

Buhler DD, Gunsolus JL and Ralston DF. 1996. Integrated weed management techniques to reduce herbicide inputs in soybean. *Agronomy Journal* **84**: 973–978.

Chaudhary BM, Patel JJ and Delvadia DR. 2005. Effect of weed management practices and seed rates on weeds and yield of chickpea. *Indian Journal of Weed Science* **37**(3&4): 271–272.

Choubey NK, Kohle SS and Tripathi RS. 2001. Relative performance of cyhalofop-butyl for weed control in direct seeded rice. *Indian Journal of Weed Science* **33**(3&4): 132–135.

Choudhary VK and Dixit A. 2018. Herbicidal weed management on weed dynamics, crop growth and yield in direct seeded rice. *Indian Journal of Weed Science* 50(1): 6–12.

Derksen DA, Lafond GP, Thomas, AG, Loeppky HA and Swanton CJ. 1993. Impact of agronomic practices on weed communities: Tillage systems. *Weed Science* **41**: 409–417.

Khaliq A, Matloob A, Shafique HM, Farooq M and Wahid A. 2011. Evaluating sequential application of pre- and post-emergence herbicides in dry seeded finer rice. *Pakistan Journal Weed Science Research* **17**: 111–123.

Kumar V and Ladha JK. 2011. Direct seeded rice: Recent development and future research needs. *Advances in Agronomy* **111**: 297–413.

Kuperman RG and Margaret MC. 1997. Soil heavy metal concentration microbial biomass and enzyme activity in a contaminated grassland ecosystem. *Soil Biology and Bio-chemistry* **29**: 179–190.

Mahajan G. Chauhan BS and Johnson DE. 2009. Weed management in aerobic rice in north western Indo-Gangetic Plains. *Journal of Crop Improvement* **23**(4): 366–382.

Pandey S and Velasco LE. 2002. Economics of direct seeding on Asia: patterns of adoption and research priorities, pp.171-181.In*: Direct Seeding: Research Strategies and Opportunities*. (Eds. Pandey S, Mortimer M, Wade L, Tuong TP, Lopes K, Hardy B), International Rice Research Institute, Los Banos, Philippines.

Raj SK, Jose N, Mathew R and Leenakumary S. 2013. Chemical management of non-grassy weeds in direct-seeded rice. *Indian Journal of Weed Science* **45**(3): 159–162.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**:153–255.

Sekhon HS and Singh G. 1993. Effect of chemical, mechanical and cultural manipulation on weed growth and grain yield of various pulse crops, integrated weed management for sustainable agriculture. pp. 18–20. In: *Proceedings of Indian Society of Weed Science International Symposium,* Hisar, India.

Singh R, Pal R, Singh T, Singh AP, Yadav S and Singh J. 2014. Management of weeds in direct-seeded rice by bispyribac-sodium. *Indian Journal of Weed Science* **46**(2): 126–128.

Singh VK, Dixit V, Singh R and Barthwal A. 2011. Efficacy of mechanical, cultural and chemical methods on weed suppression and yield of lentil. *Indian Journal of Weed Science* **43**(3&4): 192-194.

Walia US, Walia SS, Sidhu AS and Nayyar S. 2012. Bioefficacy of pre-emergence and post-emergence herbicides in direct-seeded rice in Central Punjab. *India Journal of Weed Science* **44**(1): 30–33.

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Herbicide combinations effect on weeds and yield of wheat in North-Eastern plain

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ABSTRACT

A field experiment was conducted at District Seed Farm (AB Block), Kalyani under Bidhan Chandra Krishi Vishwavidyalaya during winter season of 2016-17 and 2017-18 in upland situation to evaluate the effect of various herbicides and it's combinations against different weed species and yield of wheat under new alluvial zone. The experiment was carried out in a randomized block design with eleven treatments in three replications. Total weed density at 30 days after spray, was recorded minimum with halauxifen-methyl-ester + florasulam + carfentrazone 10.21 + 20 g/ha and it was at par with the metsulfuron + carfentrazone 4 + 20 g/ha and considerably better than all other control measures except weed free situation. At 30 days after spray, least total weed biomass was observed with the 2,4-D E + carfentrazone 400 + 20 g/ha and showed parity with the halauxifen + florasulam + carfentrazone 10.21 + 20 g/ha, metsulfuron + carfentrazone 4 + 20 g/ha and halauxifen-methyl ester + florasulam 12.76 g/ha and statistically better than all other treatments except weed free situation. Amongst various herbicidal treatments, total weed density at 60 days after spray, lowest with halauxifen-methyl-ester + florasulam 12.76 g/ha and was at par with most of the treatments except 2,4-D Na 500 g/ha, 2,4-D Na + carfentrazone 400 + 20 g/ha and weedy check. This treatment also registered low weed biomass. The soil microbial population was significantly affected by weed control measures at 60 days after sowing.Higher grain yield of wheat was observed in weed free (4.80 t/ha) and was at par with metsulfuron + carfentrazone 4 + 20 g/ha (4.56 t/ha), halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha (4.44 t/ha) and 2,4-D E + carfentrazone 400 + 20 g/ha (4.40 t/ha) and significantly better than other treatments. Total nutrient uptake by crop was highest in weed free and was at par with metsulfuron + carfentrazone 4 + 20 g/ha and significantly better to other treatments. From the study. It was concluded that use of metsulfuron + carfentrazone 4 + 20 g/ha resulted in maximum wheat yield followed by halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha.

INTRODUCTION

North eastern plain zone is not a traditional wheat (*Triticum aestivum* L.) growing area in India. However, at present, this crop became a staple food crop next to rice and its consumption is gradually increasing because of change in food habit and economic prosperity. In spite of a wide range of adoptability, little attention has been paid towards wheat production and maximization of yield potential of this crop in this state (West Bengal, Bihar, Jharkhand *etc*.) and its share to national production is less than 1%. Productivity of 2.8 t/ha is also far below the national average of 3.14 t/ha (Mukherjee 2018). The productivity of wheat in this zone is very low due to the continuous adoption of cereal-cereal (rice-wheat) cropping system, poor weed management, poor soil health and imbalance fertilizer use. Wheat is infested with diverse type of weed flora, as it is grown under diverse agro-climatic conditions, different cropping sequence, tillage and irrigation regimes (Meena *et al*. 2019). Weed infestation is one of the major biotic constraints in wheat production and weeds reduce wheat yield up to 60% if not controlled at the critical stages of crop (Yadav *et al.* 2019). Chemical weed control is a preferred practice due to unavailability of labour and high labour costs (Mukherjee *et al*. 2011). Also there is lesser feasibility of mechanical or manual weeding in wheat. Hence chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding (Mukherjee *et al*. 2011). The effect of herbicide application on soil health (microbial environment) is a great concern as it may affect the microbial growth (Kumar *et al.* 2014). Keeping all these in view, the present investigation was carried out to find out herbicidal effect on soil health and yield of wheat under new alluvial zone of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted at District Seed Farm (AB Block), Kalyani under Bidhan Chandra Krishi Viswavidyalaya during winter season of 2016-17 and 2017-18 in upland situation. The farm is situated at approximately 22° 56′ N latitude and 88° 32′ E longitude with an average altitude of 9.75 m above mean sea level (MSL). The soil of the experimental field was loamy in texture and almost neutral in reaction having pH 7.2, organic carbon 0.44%, available nitrogen 241.6 kg, available phosphorus 22.9 kg and available potassium 251.6 kg/ha. The aim of this research is to assess paradigm (new ready-mix broad-leaf weeds herbicide) combinations with other herbicides with different mode of action on both broad and narrow leaf weeds affecting wheat crops under new alluvial zone.

The experiment was carried out in a randomized block design, replicated thrice with eleven treatment namely halauxifen methyl-ester + florasulam 40.85 WG + surfactant polyglycol 26-2 N (12.76 + 750 ml/ha), metsulfuron + surfactant (4 + 625 ml/ha), carfentrazone (20 g/ha), 2,4-D Na (500 g/ha), 2,4-D E (500 g/ha), metsulfuron + carfentrazone + surfactant (4.0 g + 20 g + 625 ml/ha), 2,4-D Na + carfentrazone (400 + 20 g/ha), 2,4-D E + carfentrazone (400 + 20 g/ha), halauxifen-methyl + florasulam + carfentrazone + surfactant (10.21 + 20 g + 750 ml/ha), weedy check and weed free. Wheat cultivar "*HD 2967*" was used for this experiment. The sowing of crop was done on 7th November, 2016 and 12th November, 2017 with recommended seed rate of 100 kg/ha using 150 kg N, 60 kg P and 40 kg K/ha. All herbicides were applied 28 days after sowing (DAS) with the help of knapsack sprayer fitted with flat fan nozzle at spray volume of 500 l/ha. Weed density and biomass were recorded at 30 and 60 days after spray (DASP) by placing a quadrate of 50 x 50 cm randomly at two spots in each plot. Data on weed density and biomass were subjected to square root transformation before statistical analysis. The experimental data were analysed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusions were drawn at 5% probability level (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Weed density

At 30 days after spray (DASP), post-emergence application of halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha recorded the lowest density of *Eleusine indica* and was statistically better to other treatments (**Table 1**). Halauxifen-methyl is considered to mimic to plant growth hormone auxin, resulting in the disruption of growth processes in susceptible plants. Cellular effects include alterations in cell wall elasticity and gene expression. Additionally, non- productive tissue growth is induced, resulting in epinasty and phloem disruption, preventing the movement of photosynthates and causing death in days to weeks. Rest of the treatments are followed to these treatments. The results corroborate the findings of Mahmoud *et al*. (2016). Amongst broad-leaf weeds, minimum density of *Chenopodium album* and *Melilotus alba* was with the 2,4-D E + carfentrazone 400 + 20 g/ha and was at par with the halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha for control of *Melilotus* species and significantly better to other treatments. This corroborate with the finding of Siveran *et al.* (2020). The density of *Vicia hirsuta* was completely checked with the halauxifen + florasulam + carfentrazone 10.21 + 20 g/ha, metsulfuron + carfentrazone 4 + 20 g/ha and halauxifen-methyl ester + florasulam 12.76 g/ha and was at par with the weed free situation. *Rumex spinosus* density was completely checked by 2,4-D E 500 g/ha and was at par with the weed free situation. The use of 2,4-D E + carfentrazone 400 + 20 g/ha and 2,4-D Na 500 g/ha produced less broad-leaf weed density and statistically better to other treatments except weed free situation. Similarly, effectiveness of carfentrazone and 2,4-D against various broad-leaf weeds has already been reported by Balyan and Malik (2000). Carfentrazone 20 g/ha was effective against *Cyperus difformis* and was at par with metsulfuron 4 g/ha and statistically superior to all the treatments except weed free situation.

At 60 days after spray, halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha recorded lowest density of *Eleusine indica* and was statistically at par with 2,4-D E + carfentrazone 400 + 20 g/ha, 2,4-D Na + carfentrazone 400 + 20 g/ha and carfentrazone 20 g/ha and significantly better to other herbicidal control measures (**Table 2**). Effect of halauxifen-methyl ester + florasulam on grassy weed was also reported by Mahmoud *et al.* (2016). Minimum density of *Chenopodium album* was observed with carfentrazone 20 g/ha and was at par only with metsulfuron + carfentrazone 4 + 20 g/ha and statistically better than all other treatments either in alone or mixed application of herbicides. The density of *Melilotus alba* was lowest with the halauxifen-methyl ester + florasulam 12.76 g/ha and was significantly better than all other herbicidal treatments (**Table 2**). Lowest density of *Vicia hirsuta* was observed with halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha and was at par with 2,4-D Na 500 g/ha and halauxifen methyl-ester + florasulam 12.76 g/ha. and notably better than other. Significantly lower density of *Rumex spinosus* was observed with halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha and was at par with the metsulfuron 4 g/ha. This corroborate with the earlier finding of Yadav *et al.* (2019).

Weed biomass

Weed biomass was significantly influenced by various treatments at 30 and 60 DASP (**Table 3** and **4**). Lowest weed biomass of *Eleusine indica* was observed in weed free and was at par with the the halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha metsulfuron + carfentrazone 4 + 20 g/ha, carfentrazone 20 g/ha, halauxifen-methyl ester + florasulam 12.76 g/ha and metsulfuron 4 g/ha at 30 and 60 DASP (**Table 3**). The lowest weed biomass of *Cynodon dactylon* occurred with carfentrazone 20 g/ha and was significantly superior to all other treatments except weed free situation. The lowest biomass of *Chenopodium album* and *Melilotus alba* was observed with 2,4-D E + carfentrazone 400 + 20 g/ha and was at par with weed free situation and statistically superior to all other weed control measures except halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha for *Melilotus alba.* Dry biomass of *Vicia hirsuta* was lowest in weed free at 30 DASP, and was at par with all other treatments except carfentrazone 20 g/ha and 2,4-D E 500 g/ha. However at 60 DASP, biomass of *Vicia hirsuta* was least with halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha and was at par with halauxifen-methyl ester + florasulam 12.76 g/ha, 2,4-D Na 500 g/ha and metsulfuron + carfentrazone 4 + 20 g/ha and significantly better than all other herbicidal treatments. Significantly lower biomass of *Rumex spinosus* was observed with 2,4-D E 500 g/ha and was at par with the weed free at 30 DASP. Moreover at 60 DASP, low biomass of *Rumex*

Table 1. The density (no./m^2) of major weed species at 30 days after herbicides spray (no./m^2) as affected by weed control treatments (pooled data of two years)

Treatment	Grasses		Broad-leaf weeds					Sedges	
	Eleusine indica	*Cynodon dactylon*	*Chenopodium album*	*Melilotus alba*	*Vicia hirsuta*	*Rumex spinosus*	Other minor BLW	*Cyperus difformis*	*Cyperus iria*
Halauxifen-methyl + florasulam (12.76 g/ha)	1.22 (1.00)	2.42 (5.36)	2.03 (6.33)	1.81 (2.78)	0.71 (0.00)	2.19 (4.33)	4.22 (17.36)	2.71 (6.96)	1.68 (2.33)
Metsulfuron (4 g/ha)	2.63 (6.42)	1.91 (3.13)	4.26 (12.33)	2.86 (7.66)	1.36 (1.36)	1.66 (2.27)	2.78 (7.23)	2.19 (4.33)	2.61 (6.35)
Carfentrazone (20 g/ha)	1.69 (2.36)	1.43 (1.56)	2.12 (4.00)	3.03 (8.66)	2.04 (3.65)	1.41 (5.33)	3.45 (11.44)	1.95 (3.33)	2.90 (7.91)
2,4-D Na (500 g/ha)	2.90 (7.89)	2.04 (3.65)	3.49 (11.66)	2.86 (7.66)	1.08 (0.66)	1.76 (2.61)	2.04 (3.65)	3.02 (8.66)	3.02 (8.63)
2,4-D E (500 g/ha)	3.03 (8.69)	3.61 (12.54)	3.34 (10.66)	2.48 (5.66)	1.26 (1.08)	0.71 (0.00)	2.59 (6.21)	2.59 (10.00)	3.10 (9.11)
Metsulfuron + carfentrazone (4 + 20 g/ha)	1.31 (1.21)	2.12 (4.02)	1.68 (2.33)	1.54 (1.87)	0.71 (0.00)	2.10 (3.91)	2.57 (6.15)	2.27 (4.66)	2.52 (5.89)
2,4-D Na + carfentrazone (400 + 20 g/ha)	1.62 (2.12)	2.47 (5.62)	3.49 (11.66)	1.68 (2.33)	1.51 (1.78)	2.27 (4.66)	2.04 (3.65)	3.09 (9.06)	3.24 (10.00)
2,4-D E + carfentrazone (400 + 20 g/ha)	2.04 (3.65)	2.16 (4.18)	1.22 (1.00)	1.08 (0.67)	1.10 (0.71)	1.26 (1.07)	2.65 (6.55)	2.72 (6.91)	2.48 (5.69)
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	0.89 (0.30)	2.03 (3.65)	2.18 (4.25)	1.22 (1.00)	0.71 (0.00)	1.65 (2.22)	3.43 (11.33)	2.04 (3.65)	1.43 (1.56)
Weedy check	3.61 (12.6)	4.26 (17.65)	3.98 (15.36)	3.28 (10.23)	2.40 (5.24)	3.98 (15.36)	5.08 (25.36)	3.27 (10.23)	3.61 (12.56)
Weed free	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)
LSD (p=0.05)	0.23	0.35	0.32	0.19	0.30	0.22	0.32	0.26	0.30

Data analyzed after square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are original values

Table 2. The density (no. /m²) of major weed species at 60 days after herbicides spray as affected by weed control treatments (pooled data of two years)

Treatment	Grasses		Broad-leaf weeds					Sedges	
	Eleusine indica	*Cynodon dactylon*	*Chenopodium album*	*Melilotus alba*	*Vicia hirsuta*	*Rumex spinosus*	Other minor BLW	*Cyperus difformis*	*Cyperus iria*
Halauxifen-methyl + florasulam (12.76 g/ha)	1.98 (3.44)	3.29 (10.36)	3.58 (12.33)	2.37 (5.11)	1.98 (3.44)	3.33 (10.64)	5.56 (30.51)	3.35 (10.76)	3.71 (13.33)
Metsulfuron (4 g/ha)	3.24 (10.00)	3.55 (12.11)	4.10 (16.33)	3.21 (9.78)	2.38 (5.16)	2.74 (7.01)	5.26 (27.23)	3.39 (11.00)	3.13 (9.35)
Carfentrazone (20 g/ha)	3.04 (8.77)	2.24 (4.56)	2.55 (6.00)	4.18 (17.00)	2.92 (8.05)	3.67 (13.00)	5.14 (25.98)	2.81 (7.43)	4.30 (18.00)
2,4-D Na (500 g/ha)	3.39 (10.98)	4.48 (19.65)	5.02 (24.69)	3.75 (13.54)	1.87 (3.00)	3.67 (12.98)	6.64 (43.65)	4.73 (21.89)	5.19 (26.44)
2,4-D E (500 g/ha)	3.88 (14.58)	4.47 (19.54)	4.08 (16.11)	3.17 (9.56)	2.95 (8.18)	3.14 (9.36)	4.74 (22.01)	4.18 (17.00)	4.73 (21.88)
Metsulfuron + carfentrazone (4 + 20 g/ha)	3.32 (10.55)	3.56 (12.19)	3.61 (12.53)	4.42 (19.07)	2.44 (5.44)	3.72 (13.36)	4.31 (18.15)	4.45 (19.33)	3.39 (11.00)
2,4-D Na + carfentrazone (400 + 20 g/ha)	2.92 (8.03)	3.62 (12.61)	4.68 (21.36)	4.18 (17.00)	3.14 (9.33)	3.48 (11.66)	5.84 (33.65)	4.36 (18.55)	4.10 (16.31)
2,4-D E + carfentrazone (400 + 20 g/ha)	2.77 (7.15)	3.41 (11.18)	3.14 (9.36)	4.02 (15.69)	3.72 (13.36)	3.97 (15.33)	5.36 (28.31)	4.29 (17.92)	3.25 (10.09)
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	2.61 (6.30)	3.48 (11.65)	3.88 (14.55)	4.40 (18.87)	1.68 (2.33)	2.54 (5.95)	4.88 (23.33)	4.01 (15.65)	4.22 (17.33)
Weedy check	5.35 (28.16)	6.41 (40.65)	5.39 (35.11)	4.44 (19.25)	5.48 (29.56)	6.46 (41.33)	7.40 (54.36)	5.66 (31.54)	4.84 (22.96)
Weed free	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)
LSD (p=0.05)	0.53	0.48	0.60	0.57	0.43	0.58	0.61	0.55	0.59

DASP – Days after spray; Data analyzed after square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are original values

Table 3. The weed biomass (g/m²) of major weeds at 30 days after herbicides spray as affected by weed control treatments (pooled data of two years)

Treatment	Grassy weeds		Broad-leaf weeds					Sedges	
	Eleusine indica	*Cynodon dactylon*	*Chenopodium album*	*Melilotus alba*	*Vicia hirsuta*	*Rumex spinosus*	Other minor BLW	*Cyperus difformis*	*Cyperus iria*
Halauxifen-methyl + florasulam (12.76 g/ha)	0.72 (0.02)	1.54 (1.89)	1.44 (1.56)	1.17 (0.88)	0.71 (0.00)	1.42 (1.53)	2.03 (3.65)	1.35 (1.33)	1.01 (0.53)
Metsulfuron (4 g/ha)	0.91 (0.32)	1.17 (0.87)	2.12 (3.98)	1.35 (1.32)	0.94 (0.39)	1.26 (1.10)	1.68 (2.33)	1.46 (1.65)	1.56 (1.95)
Carfentrazone (20 g/ha)	0.75 (0.06)	0.85 (0.23)	1.18 (0.89)	1.62 (2.11)	1.31 (1.22)	1.42 (1.53)	2.11 (3.98)	1.07 (0.65)	1.58 (2.01)
2,4-D Na (500 g/ha)	1.28 (1.13)	1.23 (1.02)	1.78 (2.66)	1.47 (1.66)	0.74 (0.05)	1.18 (0.91)	1.21 (0.98)	1.68 (2.33)	1.61 (2.11)
2,4-D E (500 g/ha)	1.31 (1.19)	1.77 (2.65)	2.15 (4.11)	1.41 (1.48)	1.08 (0.66)	0.71 (0.00)	1.57 (1.98)	1.90 (3.11)	1.87 (3.01)
Metsulfuron + carfentrazone (4 + 20 g/ha)	0.90 (0.31)	1.21 (0.98)	1.17 (0.87)	1.03 (0.56)	0.71 (0.00)	1.22 (0.99)	1.62 (2.13)	1.21 (0.98)	1.52 (1.81)
2,4-D Na + carfentrazone (400 + 20 g/ha)	1.01 (0.53)	1.35 (1.33)	2.01 (3.56)	1.17 (0.88)	0.75 (0.06)	1.20 (0.96)	1.23 (1.02)	1.69 (2.36)	1.74 (2.54)
2,4-D E + carfentrazone (400 + 20 g/ha)	1.21 (0.97)	1.31 (1.22)	0.77 (0.09)	0.77 (0.09)	0.77 (0.09)	0.92 (0.36)	1.68 (2.33)	1.38 (1.41)	1.60 (2.09)
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	0.74 (0.05)	1.19 (0.93)	1.22 (0.98)	0.93 (0.36)	0.71 (0.00)	1.09 (0.69)	2.27 (4.66)	1.22 (1.00)	0.87 (0.26)
Weedy check	1.85 (2.93)	1.92 (3.22)	2.04 (3.66)	2.05 (3.69)	1.54 (1.88)	2.18 (4.22)	2.86 (7.69)	1.86 (2.98)	1.82 (2.81)
Weed free	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)
LSD (p=0.05)	0.25	0.22	0.24	0.28	0.23	0.19	0.31	0.32	0.29

Data analyzed after square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are original values.

spinosus was observed with metsulfuron + carfentrazone 4 + 20 g/ha and was statistically similar with all other chemical treatments except carfentrazone 20 g/ha and 2,4-D E + carfentrazone 400 + 20 g/ha. *Cyperus difformis* biomass was least found free, however at 60 DASP, least biomass found with carfentrazone 20 g/ha and was at par with the metsulfuron 4 g/ha and halauxifen-methyl ester + florasulam 12.76 g/ha and significantly better to other treatments. *Cyperus iria* biomass was lowest in the weed free and was at par with halauxifen + florasulam + carfentrazone 10.21 + 20 g/ha.

At 30 and 60 DASP, lowest total weed density was observed registered with halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha and it was at par with the metsulfuron + carfentrazone 4 + 20 g/ha and considerably better to all other control measures except weed free situation (**Table 5**). At 30 DAS, least total weed biomass was observed with

Table 4. The weed biomass (g /m²) of major weed at 60 days after herbicides spray as affected by weed control treatments (pooled data of two years)

Treatment	Grassy weeds		Broad-leaf weeds					Sedges	
	Eleusine indica	*Cynodon dactylon*	*Cheno-podium album*	*Melilotus alba*	*Vicia hirsuta*	*Rumex spinosus*	Other minor BLW	*Cyperus difformis*	*Cyperus iria*
Halauxifen-methyl + florasulam (12.76 g/ha)	1.56 (1.92)	2.93 (8.09)	3.32 (10.51)	2.12 (3.98)	1.77 (2.63)	2.72 (6.92)	4.70 (21.60)	2.93 (8.13)	3.57 (12.25)
Metsulfuron (4 g/ha)	2.13 (4.02)	2.37 (5.11)	3.26 (10.16)	2.77 (7.20)	2.97 (8.33)	2.69 (6.77)	4.22 (17.36)	2.74 (7.05)	3.15 (9.45)
Carfentrazone (20 g/ha)	1.96 (3.36)	2.04 (3.66)	3.11 (9.19)	3.61 (12.54)	3.40 11.05)	3.94 (15.02)	4.63 (20.98)	2.37 (5.15)	3.55 (12.12)
2,4-D Na (500 g/ha)	2.05 (3.69)	3.52 (11.92)	4.01 (15.61)	3.19 (9.66)	1.47 (1.65)	3.32 (10.52)	5.44 (29.11)	3.75 (13.61)	3.67 (12.98)
2,4-D E (500 g/ha)	2.33 (4.95)	3.55 (12.11)	3.19 (9.66)	1.41 (1.48)	2.04 (3.65)	2.59 (6.23)	3.47 (11.54)	3.60 (12.51)	4.69 (21.51)
Metsulfuron + carfentrazone (4 + 20 g/ha)	2.00 (3.52)	3.02 (8.66)	2.89 (7.87)	2.89 (7.83)	1.69 (2.36)	2.48 (5.68)	3.38 (10.93)	3.62 (12.65)	3.36 (10.81)
2,4-D Na + carfentrazone (400 + 20 g/ha)	2.04 (3.66)	3.47 (11.54)	3.59 (12.36)	3.58 (12.33)	2.56 (6.06)	2.90 (7.96)	4.42 (19.11)	3.85 (14.36)	3.41 (11.03)
2,4-D E + carfentrazone (400 + 20 g/ha)	1.84 (2.88)	2.69 (6.78)	2.62 (6.34)	3.01 (8.55)	3.41 (11.11)	3.55 (12.11)	3.28 (10.31)	3.27 (10.21)	3.69 (13.14)
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	1.31 (1.21)	2.82 (7.44)	3.10 (9.08)	4.08 (16.11)	1.57 (1.98)	2.80 (7.36)	3.94 (15.06)	2.93 (8.12)	3.27 (10.26)
Weedy check	4.75 (22.11)	6.66 (43.89)	5.75 (32.56)	4.96 (24.11)	4.48 19.55)	3.08 (8.99)	6.66 (43.98)	4.76 (22.18)	4.51 (19.81)
Weed free	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)
LSD (p=0.05)	0.48	0.70	0.78	0.64	0.51	0.66	0.79	0.62	0.64

Data analyzed after square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are original values

Table 5. The total weed density, biomass, WCE and nutrient uptake by weeds as affected by weed control treatments (pooled data of two years)

Treatment	Weed density (at 30 DASP) (no./m²)	Weed density (at 60 DASP) (no./m²)	Weed biomass (at 30 DASP) (g/m²)	Weed biomass (at 60 DASP) (g/m²)	WCE (at 30 DASP) (%)	WCE (at 60 DASP) (%)	Nutrient uptake by weeds (kg/ha)			Total uptake by weeds (kg/ha)
							N	P	K	
Halauxifen-methyl + florasulam (12.76 g/ha)	6.85(46.4)	10.02(99.9)	3.45(11.4)	8.87(78.1)	65.58	66.78	6.14	1.67	6.02	13.83
Metsulfuron (4 g/ha)	7.18(51.1)	10.41(108.0)	3.80(13.9)	8.71(75.4)	57.95	67.90	6.90	1.93	6.21	15.04
Carfentrazone (20 g/ha)	6.98(48.2)	10.45(108.8)	3.63(12.7)	9.67(93.1)	61.66	60.47	8.84	3.56	8.98	21.38
2,4-D Na (500 g/ha)	7.45(55.1)	13.32(176.8)	3.64(12.7)	10.50(108.7)	61.45	53.74	9.94	5.04	10.78	25.76
2,4-D E (500 g/ha)	8.03(63.9)	11.78(138.2)	4.32(18.2)	9.17(83.6)	45.01	64.42	8.02	3.11	8.42	19.55
Metsulfuron + carfentrazone (4 + 20 g/ha)	5.53(30.0)	11.05(121.6)	3.02(8.6)	7.75(59.5)	73.91	74.69	2.81	0.81	2.36	5.88
2,4-D Na + carfentrazone (400 + 20 g/ha)	7.17(50.9)	12.21(148.5)	3.71(13.2)	9.95(98.4)	59.97	58.14	5.12	1.43	5.62	12.17
2,4-D E + carfentrazone (400 + 20 g/ha)	5.56(30.4)	11.35(128.4)	3.02(8.6)	9.05(81.4)	73.85	65.36	3.98	1.13	4.98	10.09
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	5.33(28.0)	10.79(116.0)	3.07(8.9)	8.78(76.6)	73.00	67.41	3.11	0.95	3.06	6.96
Weedy check	11.18(124.5)	17.42(302.9)	5.79(33.1)	15.30(235.1)	-	-	19.31	4.01	13.36	36.68
Weed free	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	100	100	0.00	0.00	0.00	0.00
LSD (p=0.05)	1.11	2.03	0.52	0.83	-	-	1.52	0.29	1.61	3.54

DASP – Days after spray; Data analyzed after square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are original values

2,4-D E + carfentrazone 400 + 20 g/ha and was at par with halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha, metsulfuron + carfentrazone 4 + 20 g/ha and halauxifen-methyl ester + florasulam 12.76 g/ha. The total weed biomass at 60 DASP was least with metsulfuron + carfentrazone 4 + 20 g/ha and was significantly superior to all other treatments except weed free situation. The weed control efficiency (WCE) was highest at 30 and 60 DASP with metsulfuron + carfentrazone 4 + 20 g/ha and was followed by 2,4-D E + carfentrazone 400 + 20 g/ha at 30 DASP, and metsulfuron 4 g/ha at 60 DASP. Nutrients uptake by weeds was minimum with the metsulfuron + carfentrazone 4 + 20 g/ha and was at par with the halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha and 2,4-D E + carfentrazone 400 + 20 g/ha and notably better to other treatments.

Soil microbial population

The soil microbial population was significantly affected by various weed control measures at different stages (**Table 6**). However, after the crop harvest, there was no toxic effect on microbial population due to degradation of herbicides by micro-organism which resulted in improved microbial population. Among different weed control practices, weed free recorded maximum microbial population as reported by Kumar *et al.* (2014) and Singh *et al.* (2015).

Yield

The growth parameter was significantly affected by weed control treatments (**Table 7**), The results were in consistent with the findings of Singh *et al.* (2003) and Mukherjee (2012). Higher grain

Table 6. The soil microbial population as affected by weed control treatments (pooled data of two years)

Treatment	Bacteria (CFU x 10^7/ g soil)			Fungi (CFU x 10^3 / g soil)			Actinomycetes (CFU x 10^4 / g soil)		
	Initial	60 DAS	Harvest	Initial	60 DAS	Harvest	Initial	60 DAS	Harvest
Halauxifen-methyl + florasulam (12.76g/ha)	6.21	8.33	12.32	3.15	4.77	7.32	8.98	5.23	10.26
Metsulfuron (4 g/ha)	6.87	4.95	13.36	3.64	5.65	8.36	8.33	5.36	12.33
Carfentrazone (20 g/ha)	6.11	4.68	13.14	4.16	3.37	8.32	9.17	6.32	9.22
2,4-D Na (500 g/ha)	6.93	7.34	15.32	3.98	6.87	7.36	9.25	5.11	11.98
2,4-D E (500 g/ha)	6.11	3.38	10.23	3.43	3.11	11.32	9.17	4.36	9.87
Metsulfuron + carfentrazone (4 + 20 g/ha)	6.13	11.92	16.32	4.46	7.27	8.69	8.94	5.69	9.63
2,4-D Na + carfentrazone (400 + 20 g/ha)	6.91	10.46	14.25	4.99	6.73	9.65	8.25	3.65	15.46
2,4-D E + carfentrazone (400 + 20 g/ha)	6.12	6.04	18.34	4.73	3.69	9.14	9.18	4.11	8.56
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	6.66	5.45	12.44	4.33	5.11	8.58	8.95	4.02	10.02
Weedy check	6.65	8.36	15.36	4.25	3.66	7.59	9.05	8.31	8.96
Weed free	6.07	10.32	18.36	4.32	4.66	10.23	8.72	9.89	13.54
LSD (p=0.05)	NS	1.96	1.03	NS	1.73	0.98	NS	0.74	2.11

DAS – Days after crop sowing NS – Non-significant

Table 7. The growth parameters, yield attributes and yield of wheat crop as affected by weed control treatments (pooled data of two years)

Treatment	Plant height (at 60 DAS)	LAI (at 60 DAS)	ET (no./ m^2)	DMA (g/m^2) (at 90 DAS)	Grain/ spike (no.)	Test weight (g)	Grain yield (t/ha)			Straw yield (t/ha)			Harvest index (%)	Nutrient uptake by crop (kg/ha)			Total uptake by crop (kg/ha)
							2017	2018	Pooled	2017	2018	Pooled		N	P	K	
Halauxifen-methyl + florasulam (12.76 g/ha)	94.6	3.19	313.5	498.1	34.24	38.22	3.85	4.31	4.08	5.24	7.52	6.38	39.0	550.1	13.0	46.1	109.2
Metsulfuron (4 g/ha)	94.4	3.15	286.6	418.2	34.83	37.89	4.20	3.83	4.02	7.06	7.56	7.31	35.4	448.9	12.6	43.2	104.7
Carfentrazone (20 g/ha)	100.1	3.09	275.5	314.1	31.01	38.19	3.09	3.72	3.40	5.64	6.68	6.16	35.6	637.1	10.3	35.8	83.3
2,4-D Na (500 g/ha)	98.4	3.13	276.3	316.5	36.75	37.61	3.08	3.45	3.27	5.81	7.05	6.43	33.7	633.3	10.0	33.1	76.5
2,4-D E (500 g/ha)	92.7	2.49	303.5	404.7	31.41	37.04	3.48	3.60	3.54	4.87	6.53	5.70	38.3	540.2	11.2	38.5	89.9
Metsulfuron + carfentrazone (4 + 20 g/ha)	99.1	3.41	307.0	516.7	37.11	40.31	3.99	5.12	4.56	6.70	7.72	7.21	38.7	772.2	17.3	60.2	149.8
2,4-D Na + carfentrazone (400 + 20 g/ha)	74.4	3.01	301.5	318.3	29.12	38.91	3.95	4.26	4.11	6.35	6.18	6.26	39.6	559.2	14.3	51.3	124.8
2,4-D E + carfentrazone (400 + 20 g/ha)	86.1	2.52	297.5	309.1	30.63	39.14	3.92	4.86	4.39	6.01	5.90	5.96	42.4	765.0	16.1	55.3	136.4
Halauxifen-methyl + florasulam + carfentrazone (10.21 + 20 g/ha)	98.2	3.11	274.4	487.2	33.65	38.55	4.95	3.87	4.41	6.69	6.98	6.84	38.2	767.6	17.1	58.3	142.9
Weedy check	90.0	2.05	225.9	235.1	17.23	36.61	1.87	1.36	1.61	3.05	2.23	2.64	37.9	519.6	9.1	25.4	53.1
Weed free	101.3	3.45	334.5	534.3	34.55	40.00	5.23	436	4.80	7.21	6.82	7.01	40.6	779.1	18.3	63.2	160.7
LSD (p=0.05)		0.43	11.13	33.6	3.41	1.35	0.54	0.60	0.64	0.67	0.80	0.70	2.3	6.4	1.6	6.1	16.3

DAS – Days after crop sowing; ET- Effective tillers; DMA - Dry matter accumulation yield of wheat was observed in weed free (4.80 t/ha) and was at par with metsulfuron + carfentrazone 4 + 20 g/ha (4.56 t/ha), halauxifen + florasulam + carfentrazone 10.21 + 20 g/ha. (4.44 t/ha), 2,4-D E + carfentrazone 400 + 20 g/ha (4.40 t/ha), confirming the findings of Kumar *et al*. (2014). Highest harvest index was registered with 2,4-D E + carfentrazone 400 + 20 g/ha and was at par with the weed free situation. Further observation revealed that, nutrient uptake by crop, was significantly influenced by various weed management practices (**Table 7**). Highest NPK uptake by wheat crop was registered with weed free and was at par with metsulfuron + carfentrazone 4 + 20 g/ha and halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha. Total nutrient uptake by crop was highest registered with the weed free situation and was at par only with the metsulfuron + carfentrazone 4 + 20 g/ha. This might be due to inhibition of the enzyme acetolactate synthase (ALS) from metsulfuron, which acts as the catalyst in the first step of the biosynthesis of essential amino acids (valine, leucine and isoleucine). Better expression of yield attributes due to reduced weed infestation through these treatments might have helped the crop plants to accumulate more dry matter through greater nutrient uptake that might have provided more quantity of photosynthates to developing sink in crop plants produced more yield (Meena *et al*. 2019).

From the study, it may be concluded that use of metsulfuron + carfentrazone 4 + 20 g/ha and halauxifen-methyl ester + florasulam + carfentrazone 10.21 + 20 g/ha results in maximum wheat yield.

REFERENCES

Balyan RS and Malik RK. 2000. New herbicides for jungali palak (*Rumex retroflexus* L.). *Indian Journal of Weed Science* **32**: 86–88.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research* John Willey and Sons, New York.

Kumar R, Jaidev, Singh RS, Singh SS and Tripathi SK. 2014. Effect of soil enzymes and beneficial soil micro-organism as influence by weed management practices under rice-wheat cropping system. *New Agriculture* **25**(1): 79–81.

Mahmoud S M, Soliman FS and Elsheik M. 2016.Combination of Halauxifen-methyl + florasulam with other grassy herbicides against complex weed flora in wheat. *Journal of Plant Protection and Pathology Mansoura University* **7**(5): 315–320.

Meena V, Kaushik MK, Dotaniya ML, Meena BP and Das H. 2019. Bio-efficacy of ready-mix herbicides on weeds and productivity in late-sown wheat. *Indian Journal of Weed Science* **51**(4): 344–351.

Mukherjee D. 2012. Resource conservation through indigenous farming system in hills of West Bengal. *Journal of Crop and Weed* **8**(1): 160–164.

Mukherjee D. 2018. Impact of improved technology for enhancing wheat productivity in West Bengal. *Journal of Experimental Biology and Agricultural Sciences* **6**(1): 258-263.

Mukherjee PK, Bhattacharya PM and Chowdhury AK.2011. Weed control in wheat (*Triticum aestivum* L.) under terai-agroecological region of West Bengal. *Journal of Wheat Research* **3**(2): 30–34.

Singh P, Sarathambal C, Kewat ML and Singh VP. 2015. Conservation tillage and weed management effect on soil microflora of soybean-wheat cropping system. *Indian Journal of Weed Science* **47**(4): 366–370.

Singh RP, Mukherjee D, Singh RK and Sinha AK. 2003. Bio-efficacy of herbicide in late sown wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **48**(3): 196–198.

Sivran AC, Choudhary J and Sarita. 2020. Efficacy of herbicides on broad-leaved weed and yield of wheat (*Triticum aestivum* L.). *International Journal of Chemical Studies* **8**(2): 180–184.

Yadav HL, Gupta AK, Kumar S and Gupta S. 2019. Comparative efficacy of herbicides applied in wheat and their residual effect on the succeeding crops. *International Journal of Current Microbiology and Applied Sciences* **8**(4): 1866–1874.

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Endozoochorous dissemination of *Rumex dentatus* and its impact on wheat productivity

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ABSTRACT

The effectiveness of endozoochory and germination success of the weeds after passage through the animal gut are the important traits for dissemination and invasion of weeds. With this view, experiments were conducted during the *Rabi* season of 2017-18 and 2018-19 at ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar Campus with the objective to assess the effect of endozoochorous dissemination of weed (*Rumex dentatus*) on late sown wheat productivity (Variety *HD 3059*) while using cattle shed water for irrigation. The results revealed that late harvesting of the berseem led to the development of *R. dentatus* up to seeding stage. Berseem green fodder contaminated with seeds of *R. dentatus* was fed to the cattle and buffaloes. Application of carfentrazone at 25 days after sowing (DAS) reduced the population of existing broad-leaved weeds, however, use of cattle shed water for irrigation increased the population of *R. dentatus* from 35 DAS up to 17% at 50 DAS, 134% at 65 DAS and 186% at 80 DAS. Whereas, the adjacent plot irrigated with normal ground water, recorded the declining trend of *R. dentatus* population from 35 DAS *i.e.* up to 15, 32 and 50% reduction at 50, 65 and 80 DAS, respectively. Large infestation of *R. dentatus* due to use of cattle shed water contaminated with seeds of *R. dentatus* reduced wheat productivity up to 44% (2.14 t/ha) as compared to the grain yield 3.82 t/ha obtained from the plot irrigated with normal ground water. During second year, the entire field was irrigated with normal ground water and similarly carfentrazone was used at 25 DAS. These measures reduced the population of *R. dentatus* and weed showed declining trend up to 30, 71 and 79% reduction at 50, 65 and 80 DAS from 35 DAS. These results confirmed that *R. dentatus* has the endozoochorous mechanism of its dissemination and use of cattle shed water for irrigation may not be recommended if the berseem fodder is infested with seeds of *R. dentatus*.

INTRODUCTION

Since many weeds cannot rely only on soil seed bank, germination success through the endozoochorous seed dispersal has significant role on their survival and persistent nature into several ecosystems. The effectiveness of endozoochory as well as germination success of weeds after passage through animal gut is dependent on amount of seeds ingested, animal type and livestock digestive system (Fazelian *et al.* 2014). This can happen either deliberately due to high palatability or accidentally when an herbivore consumes seeds along with palatable leaves (Pakeman *et al.* 2002). Germination of weeds may be enhanced by the softening of the seed coats during the digestive process, however, destruction of seeds and inhibition of germination can also occur (Ramos *et al.* 2006). Deposition of seeds with faecal material may provide nutrients that promote seedling establishment; however, seed germination and seedling establishment could also be inhibited due to the toxicity and hydrophobic nature of dung (Ramos *et al.* 2006). There is a close relationship between endozoochorous dissemination of weeds and weed infestation in crops when dung and cattle shed water for irrigation are used to provide nutrients to the crop plants. Very scanty information is available on this aspect. Therefore, present study has been conducted to study the effect of endozoochorous dissemination of weed (*R. dentatus*) on late sown wheat productivity while using cattle shed water for irrigation. Fazelian *et al.* (2014) reported that *R. ponticus* and *R. crispus* germination percentage in cattle dung was higher than sheep and goat treatments. Among the species, germination of *Rumex ponticus* was higher than that of *R. crispus*. The seeds of plant species *Salvia officinalis*, *Conium maculatum*, *Cynara scolymus*, *Silybum marianum* and *Plantago lanceolata*, were germinated well in cattle dung treatment.

MATERIALS AND METHODS

The field experiments were conducted during the *Rabi* season of 2017-18 and 2018-19 at ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar Campus, Bareilly, UP, India with the objective to assess the effect of endozoochorous dissemination of weed (*R. dentatus*) on late-sown wheat productivity (Variety *HD 3059*) while using cattle shed water for irrigation. The experiment was comprised by irrigation with cattle shed water and normal ground water in 6,000 m^2 land area each grown with late-sown wheat. Wheat at the seed rate of 120 kg/ha was sown on December 26 and January 4 during 2017 and 2019, respectively with the help of ferti-seed-drill. The fertilizer dose of NPK (120-60-30 kg/ha) was applied in the form of chemical fertilizer having NPK ratio of 12:32:16 as basal through ferti-seed-drill and remaining 98 kg of N/ha was applied as urea in two equal split at crown root initiation (CRI) stage of wheat and 35 days after sowing (DAS). Irrigation was given at CRI stage, jointing stage, heading stage, booting stage and grain filling stage. The herbicide carfentrazone-ethyl was applied at 25 DAS at the rate of 25 g/ha using spray volume of 600 L water/ha with knap-sack sprayer having flood-jet nozzle.

Appraisal of weed flora have been made by following standard procedure for weed survey as followed by All India Coordinated Research Project on Weed Management (ICAR), by plotting one meter square quadrats in randomized manner. The weed flora have been surveyed at different stages of wheat crop. Absolute and relative values of density, frequency and basal area and ultimately importance value index have been determined to screen out the dominance spectrum of the species. The calculations have been used to determine absolute density, relative density, absolute frequency, relative frequency, important value and summed dominance ration of the weeds appeared in wheat crop (Raju 1997) and the data have been expressed in the form of absolute density and absolute frequency in order to highlight population and distribution of the weeds.

RESULTS AND DISCUSSION

Weed flora in wheat crop

In general, dominance of dicot weeds (77.3%) was observed during the experimental period. Major weeds observed in the experimental field were *R. dentatus, Solanum nigrum* and *Amaranthus viridis* among dicot weeds and *Phalaris minor* (14.8%) in monocot weeds.

Weed flora in fodder crops

Weed flora in fodder crops revealed that *Trianthema monogyna* and *T. portulacastrum* were widely distributed during summer and rainy seasons. The weed *Celosia argentea* preferred the growing condition of fodder sorghum, whereas *Coccinia grandis* was associated with fodder maize and sorghum. Among the other weeds, grasses were widely distributed, whereas the sedges were appeared in patches. Three major broad-leaved weeds *Coronopus didymus, R. dentatus* and *Cichorium intybus* appeared during 1st, 2nd, 3rd and 4th cutting of berseem, respectively. The results also revealed that late harvesting of the berseem led to the development of *R. dentatus* up to the seeding stage (**Figure 1**). Berseem along with *R. dentatus* was harvested and provided to the cattle as green fodder. On an average *R. dentatus* produced 1,364 seeds/plant.

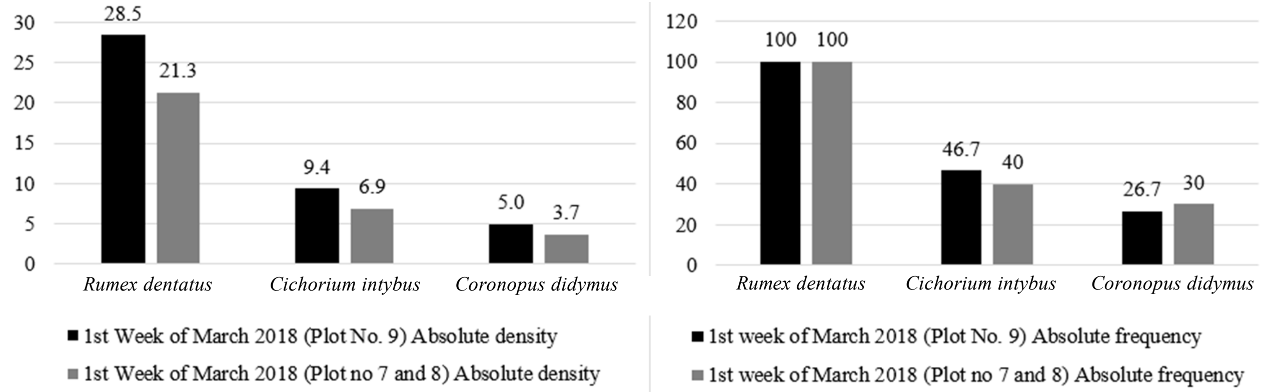

Figure 1. Absolute density (no./m^2) and absolute frequency (%) of different weeds in berseem

Infestation of *Rumex dentatus* in wheat

In wheat, application of carfentrazone at 25 DAS reduced the population (no./m^2) of *R. dentatus, Amaranthus viridis* and *Solanum nigrum* up to 63%, 70% and 64%, respectively at 35 DAS from 20 DAS. Use of cattle shed water for irrigation increased the population of *R. dentatus* from 35 DAS up to 17% at 50 DAS, 134% at 65 DAS and 186% at 80 DAS (**Figure 2a** and **3a**). Whereas the adjacent plot irrigated with normal ground water recorded the declining trend of *R. dentatus* population from 35 DAS *i.e.* up to 15%, 32% and 50% at 50 DAS, 65 DAS and 80 DAS, respectively (**Figure 2b** and **3b**).These results are in harmony with the findings of Fazelian *et al.* (2014). During the 2nd year, entire field was irrigated with normal ground water and similarly carfentrazone was used at 25 DAS. Application of herbicide reduced the population of *R. dentatus* up to 73% at 35 DAS from 20 DAS. Results revealed that population of *R dentatus* showed declining trend up to 30, 71 and 79% reduction at 50, 65 and 80 DAS from 35 DAS (**Figure 2c** and **3c**). Control of *R. dentatus* led to the spread of *Solanum nigrum* at the terminal phase of wheat crop.

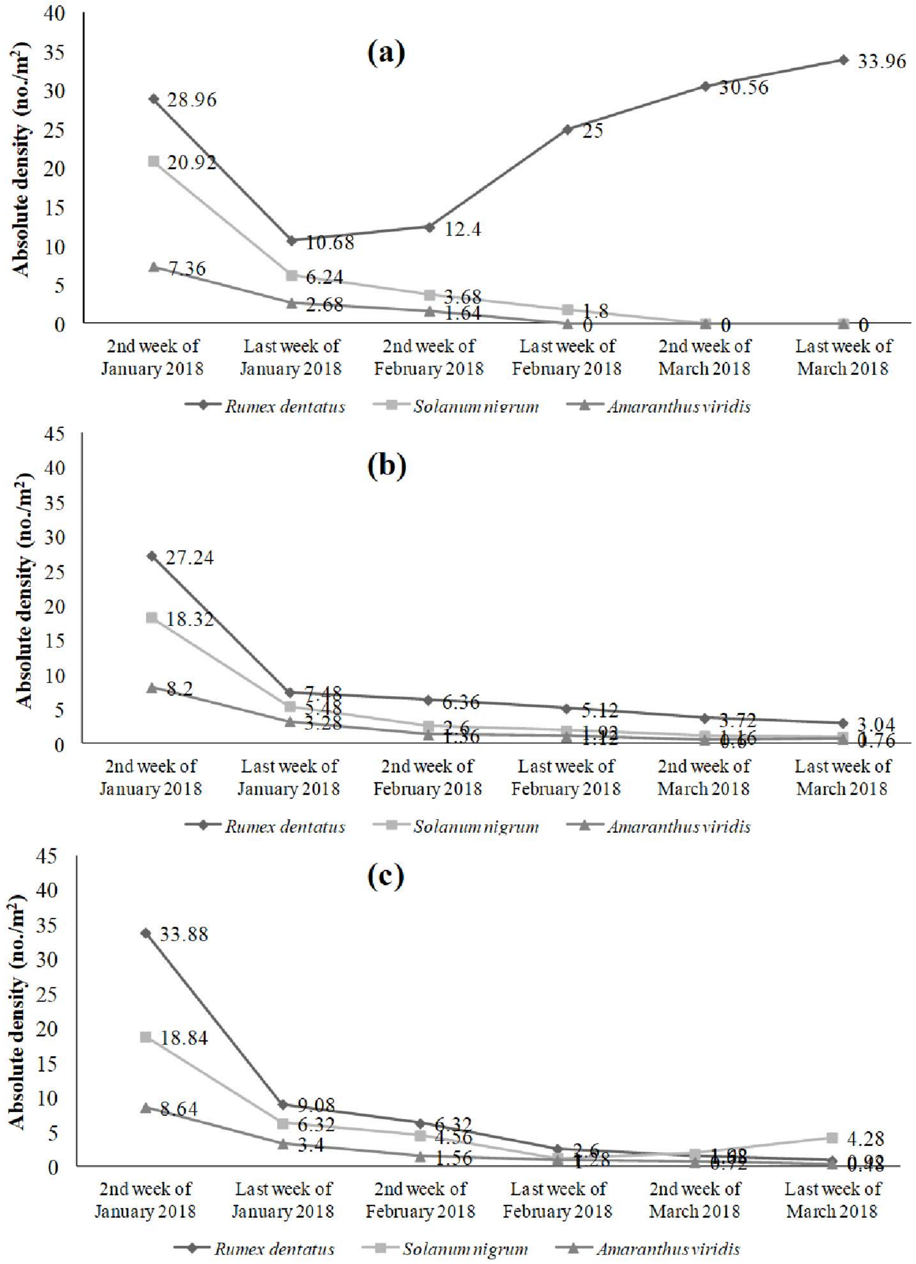

Figure 2. Absolute density (no./m^2) of weeds in wheat irrigated with cattle shed water in 1st year (a), with normal ground water in 1st year(b) and with normal ground water in 2nd year (c)

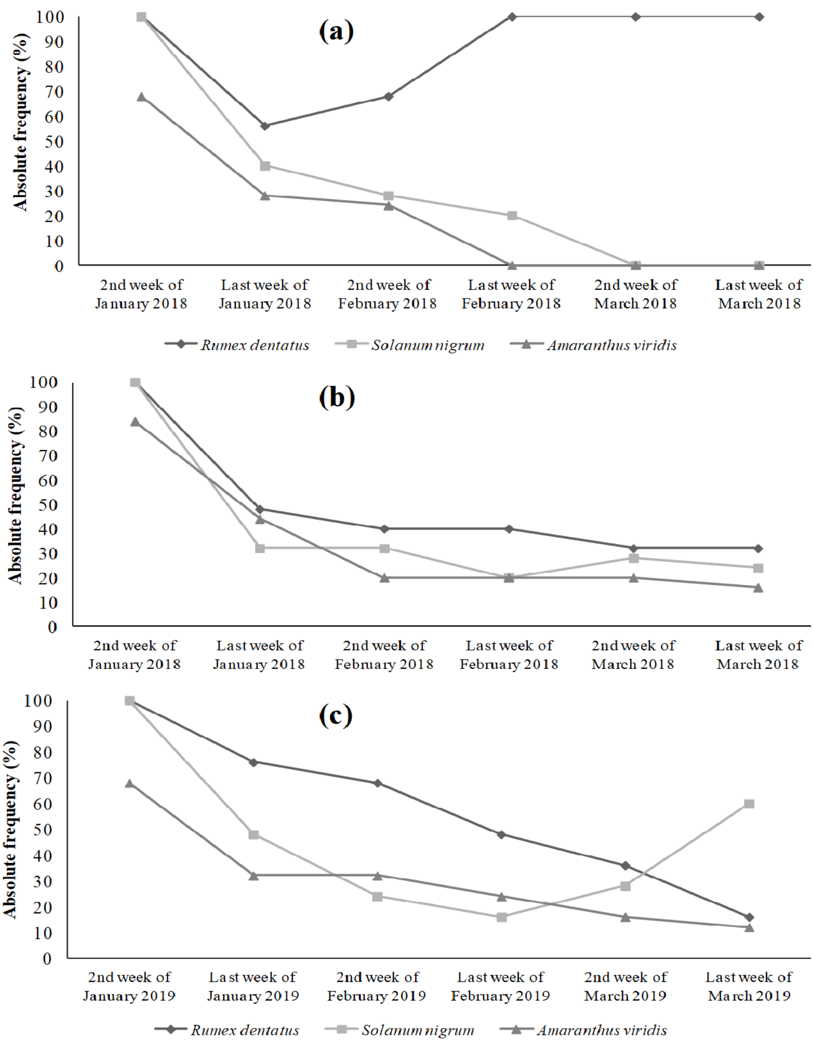

Figure 3. Absolute frequency (%) of weeds in wheat irrigated with cattle shed water in 1st year (a), with normal ground water in 1st year(b) and with normal ground water in 2nd year (c)

Effect on grain yield of wheat

Massive infestation of *R. dentatus* due to use of cattle shed water for irrigation contaminated with seeds of *R. dentatus* reduced the wheat productivity up to 44% (2.14 t/ha), whereas the plot irrigated with normal water registered the grain yield of 3.82 t/ha. During 2nd year wheat productivity was recorded to the tune of 3.92 t/ha. As the wheat (Variety *HD 3059)* was grown for seed production at KVK farm of ICAR-IVRI and also curtailed seed bank contribution of *R. dentatus*, 45 man days with the total cost of ₹ 14,500 for the area of 6000 m^2 irrigated with cattle shed water was invested for uprooting *R. dentatus* during 80 to 90 DAS in 1st year of experimentation. In 2nd year no such investment was required as combination of carfentrazone-ethyl and irrigation with normal ground water reduced infestation of *R. dentatus.*

It was concluded that *R. Dentatus* has the potential to disseminate through endozoochory mechanism and use of cattle shed water for irrigation may not be recommended if the berseem fodder is infested with seeds of *R. dentatus.*

REFERENCES

Fazelian S, Kohyani PT and Shirmardi HA. 2014. Endozoochorous seed dispersal of plant species in semi-steppe rangelands. *International Journal of Advanced Biological and Biomedical Research* **2 (2)**: 473–486

Pakeman RJ, Digneffe Gand Small JL. 2002. Ecological correlates of endozoochory by herbivores. *Functional Ecology* **16**: 296–304.

Raju RA. 1997. *Field Manual for Weed Ecology and Herbicide Research*. Agrotech Publishing Academy, Udaipur, 78 p.

Ramos E, Robles B and Castro J. 2006. Efficiency of endozoochorous seed dispersal in six dry-fruited species (Cistaceae): from seed ingestion to early seedling establishment. *Plant Ecolology* **185**: 97–106.

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Tillage and weed management effect on productivity of wheat in North-West Rajasthan

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ABSTRACT

A field experiment was carried out at SKRAU, Bikaner, Rajasthan, during *Rabi* seasons of 2016-17 and 2017-18 to investigate the effect of tillage and weed management practices on productivity of wheat (*Triticum aestivum*) in North-West Rajasthan. Amongst the tillage treatments, adoption of stale seedbed (SSB) using glyphosate at 2.0 kg/ha resulted in higher dry matter at harvest, effective tillers (101.77 per m.r.l.) and grain yield (4.06 t/ha), and significantly lowered the density and dry matter of weeds. Among various weed management treatments, metsulfuron 4.0 g/ha + one hand weeding (HW) at 45 DAS significantly lowered the density and dry matter of all the broad-leaf weeds, but not effective against *Cyperus rotundus* and *Cynodon dactylon*. Being at par with weed free check and also 2,4-D E + one HW, it was significantly superior to all other treatments and resulted 4.40 t/ha grain yield of wheat.

INTRODUCTION

Wheat is an important winter season cereal crops of North-West India not only in terms of providing calories but also in terms of versatile adoption under wide range of agro climatic conditions. In India, wheat is grown in 30 million ha area with total production of 107 mt and an average productivity of 3400 kg/ha (IASRI 2019). Its success largely depends on adaptability to environmental conditions and agronomic practices. Weeds substantially reduce the productivity and production of wheat. It competes with crops for water, soil, nutrients, light, and space and thus reduces crop yields (Das 2008). Stale seedbed technique involves rains or irrigation applied to invoke germination of weeds and then the soil preparation of a seedbed or application of non-selective pre-seeding herbicide to kill the germinated weeds, a weeks before the actual planting of the crop, thus depleting the seed bank in the surface layer of soil and reducing subsequent emergence of weeds. Looking to the scenario of stale seedbed technique with tillage and herbicides and its impact on weeds, and productivity of wheat, there is a need to test this current practice in wheat. Deep tillage may also bury the weed seed deeper in the soil layer and minimize the weed seed bank in upper layer of soil. Supplementing these mentioned practices, herbicides play an important role for weed control in close spaced crops like wheat, where manual or mechanical weeding is difficult (Yaduraju and Das 2002). Also the mimicry weeds are arduous to be weeded out by hand weeding or other mechanical methods. Only chemical weed control is most suitable option to overcome this problem; and in this backdrop the present study was undertaken.

MATERIALS AND METHODS

A field experiment was conducted in wheat at College of Agriculture, Bikaner (28.01^{0}N latitude and 73.22^{0}E longitude at an altitude of 234.7 M above mean sea level). The soil was loamy sand, low in organic carbon (0.08%) and available N (78 kg/ha) and medium in available phosphorus (22 kg P/ha) and available K (210 kg/ha) with pH 8.3. The experiment was laid down in strip-plot design with four replications. The treatments comprising of 28 combinations having four tillage methods, *viz.* stale seedbed (SSB) using shallow tillage, SSB using glyphosate 2.0 kg/ha, deep tillage) and conventional tillage as main plots; and seven weed management practices, *viz.* weedy check, weed free, one hand weeding (1 HW) at 30 DAS, 2,4-D at 0.5 kg/ha 30 DAS, metsulfuron at 4.0 g/ha 30 DAS, 2,4-D at 0.5 kg/ha 30 DAS + 1 HW 45 DAS and metsulfuron 4.0 g/ha + 1 HW 45 DAS as sub-plots. Wheat cultivar '*Raj- 3077*' was sown using seed rate of 100 kg/ha with a row spacing of 22.5 cm on 25 November and 28 November during 2016-17 and 2017-18, respectively. The crop was supplied with (100 kg N, 60 kg P and 40 K kg/ha). In stale seedbed (SSB) technique, after seedbed preparation or without it, the field was irrigated and left unsown to allow weeds to germinate and then these were killed by spraying of glyphosate 2.0 kg/ha or by carrying out shallow tillage prior to the sowing. Whereas in deep tillage, disc plough and in conventional tillage one harrow along with cultivator was used. Metsulfuron (4 g/ha) and 2,4-D ester (0.5 kg/ha) were applied as post-emergence with 500 liters of water with the help of knapsack sprayer, fitted with flat-fan nozzle. Weed density was recorded (at 30, 60 DAS and crop maturity) from 0.25 m^2 by placing a quadrate of 0.5 × 0.5 m randomly at three places in each plot. The weeds were dried in an oven till a constant weight was observed and then transformed into g/m^2 by using the appropriate formula. The data on total weed count and weed dry matter were subjected to square root transformation to normalize their distribution (Gomez and Gomez 1984). In order to test the significance of variance in experiments, the data obtained for various treatment effects were pooled and statistically analysed as per procedure described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever, the "F" test was found significant at 5 per cent level of significance.

RESULTS AND DISCUSSION

Tillage

Stale seedbed (SSB) using glyphosate at 2.0 kg/ha significantly decreased the density and dry matter of *Chenopodium album, Rumex dentatus, Cyperus rotundus* and *Cynodon dactylon* at 30, 60 DAS and crop maturity followed by SSB using shallow tillage and it was significantly superior to deep and conventional tillage (**Table 1** and **2**). It might be due to the removal of most of germinated sprout seeds, which were active in upper top soil layer, as compared to deep and conventional tillage. The perennial weeds *i.e. C. rotundus* and *C. dactylon* were difficult to control because of their re-germination capacity but with the adoption of stale seed bed technique particularly using glyphosate at 2.0 kg/ha, these were significantly controlled. This might be due to fact that glyphosate destroys reserve food material in its rhizome by its systemic action (Safdar *et al.* 2011).

Table 1. Effect of tillage and weed management on weed density (no./m^2) in wheat on pooled basis

Treatment	*Chenopodium album*			*Rumex dentatus*			*Cyperus rotundus*			*Cynodon dactylon*
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS
Tillage										
SSB using shallow tillage	3.21 (10.9)	1.65 (3.1)	1.99 (4.1)	2.76 (8.0)	1.63 (2.9)	1.87 (3.5)	1.99 (3.8)	1.80 (3.7)	2.01 (4.3)	2.01 (3.8)
SSB using glyphosate at 2.0 kg/ha	2.91 (8.9)	1.54 (2.5)	1.85 (3.4)	2.54 (6.5)	1.54 (2.5)	1.83 (3.3)	1.67 (2.5)	1.50 (2.3)	1.60 (2.3)	1.42 (1.6)
Deep tillage	3.79 (15.5)	1.87 (4.3)	2.08 (4.6)	3.21 (11.0)	1.76 (3.5)	2.01 (4.2)	2.99 (9.5)	1.85 (4.1)	1.94 (3.9)	2.38 (5.7)
Conventional tillage	4.00 (17.4)	1.94 (4.7)	2.19 (5.2)	4.00 (17.4)	1.88 (4.3)	2.11 (4.7)	3.19 (10.9)	1.96 (4.7)	2.08 (4.6)	2.57 (6.7)
LSD(p=0.05)	0.10	0.04	0.07	0.11	0.06	0.07	0.08	0.04	0.04	0.08
Weed management										
2,4-D at 0.5 kg/ha 30 DAS	4.07 (16.4)	2.32 (5.1)	2.51 (5.9)	3.51 (12.4)	2.57 (6.2)	2.47 (5.7)	2.81 (8.1)	2.80 (7.5)	2.66 (6.8)	2.34 (5.3)
Metsulfuron at 4.0 g/ha 30 DAS	3.88 (14.9)	2.18 (4.4)	2.18 (4.3)	3.53 (12.5)	2.15 (4.2)	2.02 (3.6)	2.74 (7.6)	2.76 (7.3)	2.63 (6.6)	2.34 (5.3)
2,4-D at 0.5 kg/ha 30 DAS + 1 HW at 45 DAS	3.99 (15.8)	0.71 (0.0)	1.55 (1.9)	3.44 (11.7)	0.71 (0.0)	1.54 (1.9)	2.74 (7.6)	0.71 (0.0)	1.38 (1.4)	2.32 (5.1)
Metsulfuron at 4.0 g/ha 30 DAS + 1 HW at 45 DAS	3.86 (14.7)	0.71 (0.0)	1.43 (1.6)	3.55 (11.7)	0.71 (0.0)	1.47 (1.7)	2.78 (7.9)	0.71 (0.0)	1.45 (1.7)	2.33 (5.2)
One hand weeding (HW) at 30 DAS	3.96 (15.6)	2.16 (4.2)	2.42 (5.4)	3.62 (13.2)	2.05 (3.7)	2.36 (5.1)	2.73 (7.6)	1.93 (3.4)	1.82 (2.9)	2.29 (5.0)
Weed free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy check	3.88 (15.0)	3.47 (11.8)	3.40 (11.3)	3.54 (12.7)	3.01 (8.8)	3.11 (9.3)	2.73 (7.6)	2.83 (7.7)	2.70 (7.0)	2.31 (5.2)
LSD (p=0.05)	0.16	0.10	0.11	0.15	0.06	0.10	0.13	0.09	0.10	0.10

SSB- Stale Seedbed technique, DAS- Days after sowing

Stale seedbed using glyphosate 2.0 kg/ha accumulated maximum dry matter of wheat over all other treatments at 90 DAS and crop maturity **(Table 3)**. This might be due to adequate weed control by reducing the broad-leaved as well as perennial weeds. These results are in agreement with the findings of Khatun *et al*. (2016). Data showed that spike length, grain/spike and test weight of wheat was not influenced due to crop establishment methods. SSB using glyphosate 2.0 kg/ha recorded significantly higher effective tillers, grain and biological yield than deep and conventional tillage but remained at par with SSB using shallow tillage. The increase of grain yield due to adoption of SSB using glyphosate at 2.0 kg/ha was to the tune of 9.9 and 7.7 per cent than deep and conventional tillage, respectively. This might be due to significant improvement in dry matter accumulation and higher number of effective tillers that could be due to less competition by weeds to wheat. These results are in agreement with the findings of Kumar *et al*. (2003) and Khatun *et al*. (2016).

Weed management

At crop maturity, significantly the lowest density and dry matter of weeds was found in metsulfuron at 4.0 g/ha + 1 HW followed by 2,4-D at 0.5 kg/ha + 1 HW and metsulfuron 4.0 g/ha. Dry matter of *R. dentatus* and *C. album* at harvest was decreased by metsulfuron at 4.0 g/ha + 1 HW over weedy check to the tune of 98.8 and 99.1%, respectively **(Table 1** and **2)**. Regeneration of *R. dentatus* was noticed in 2,4-D at 0.5 kg/ha applied plots and thus increased the dry matter of the weed as compared to metsulfuron treated plots. These findings were in conformity with those reported by Singh and Ali (2004) and Pisal *et al.* (2013). The extent of weed control achieved with these herbicides, *i.e.* metsulfuron-methyl and 2,4-D seems to be due to their phytotoxic action on weeds. Metsulfuron-methyl is generally absorbed by leaves and translocated to growing points of the plant where it stops cell division and inhibiting the photosynthesis resulting into yellowing of plants. 2,4-D herbicide kills the target weed by mimicking the plant growth hormone auxin (indole acetic acid), and when administered at effective doses, causes uncontrolled and disorganized plant growth that leads to plant death (Tu *et al*. 2001).

Application of metsulfuron 4.0 g/ha + one hand hoeing significantly increased the grain, straw and biological yield over 1 HW 30 DAS and 2,4-D at 0.5 kg/ha, but was statistically at par with 2,4-D at 0.5 kg/ha + 1 HW as well as weed free check **(Table 3)**. Increase in grain yield due to applied weed control

Table 2. Effect of tillage and weed management on weed dry matter (g/m^2) in wheat on pooled basis

Treatment	*Chenopodium album*			*Rumex dentatus*			*Cyperus rotundus*			*Cynodon dactylon*		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Tillage												
SSB using shallow tillage	1.45	3.36	7.08	2.02	3.20	8.60	1.51	2.66	2.51	1.53	3.25	7.27
	(1.7)	(22.0)	(94.0)	(3.9)	(21.1)	(131.4)	(1.9)	(9.9)	(8.3)	(2.0)	(12.2)	(89.5)
SSB using glyphosate at 2.0 kg/ha	1.37	3.03	6.48	1.84	2.85	8.19	1.24	2.10	2.01	1.07	2.47	6.03
	(1.5)	(17.3)	(78.9)	(3.1)	(15.5)	(122.3)	(1.1)	(5.7)	(4.8)	(0.7)	(6.5)	(59.2)
Deep tillage	1.62	3.84	7.62	2.28	3.55	9.50	1.74	2.88	2.71	1.61	3.32	7.99
	(2.3)	(20.5)	(108.5)	(5.2)	(25.8)	(156.6)	(2.7)	(11.7)	(9.7)	(2.2)	(12.8)	(106.6)
Conventional tillage	1.70	4.05	8.22	2.72	3.84	9.88	1.82	2.89	2.81	1.69	3.57	8.65
	(2.5)	(32.2)	(122.5)	(7.6)	(32.1)	(169.5)	(3.0)	(11.8)	(10.6)	(2.5)	(14.9)	(126.8)
LSD (p=0.05)	0.03	0.14	0.25	0.06	0.17	0.15	0.04	0.09	0.06	0.03	0.09	0.32
Weed management												
2,4-D at 0.5 kg/ha 30 DAS	1.67	4.04	11.31	2.41	6.47	14.51	1.73	4.53	4.14	1.60	4.54	14.05
	(2.3)	(16.2)	(129)	(5.5)	(42.7)	(212.9)	(2.5)	(20.4)	(17.0)	(2.2)	(20.7)	(202.4)
Metsulfuron at 4.0 g/ha 30 DAS	1.66	2.98	4.99	2.46	3.03	7.27	1.71	4.48	4.13	1.60	4.50	13.91
	(2.3)	(8.6)	(25.2)	(5.7)	(8.8)	(53.8)	(2.5)	(19.9)	(16.9)	(2.2)	(20.3)	(196.8)
2,4-D at 0.5 kg/ha 30 DAS + 1 HW at	1.67	0.71	2.47	2.44	0.71	2.98	1.72	0.71	0.89	1.60	2.50	1.49
45 DAS	(2.3)	(0.0)	(5.7)	(5.6)	(0.0)	(8.5)	(2.5)	(0.0)	(0.3)	(2.1)	(5.8)	(1.8)
Metsulfuron at 4.0 g/ha 30 DAS + 1	1.68	0.71	2.17	2.50	0.71	2.75	1.72	0.71	0.94	1.61	2.35	1.42
HW at 45 DAS	(2.3)	(0.0)	(4.3)	(6.0)	(0.0)	(7.2)	(2.6)	(0.0)	(0.4)	(2.2)	(5.0)	(1.6)
One hand weeding (HW) at 30 DAS	1.69	4.47	8.12	2.49	1.45	10.24	1.72	2.75	2.61	1.59	2.92	5.71
	(2.4)	(19.9)	(66.4)	(5.9)	(1.6)	(107.6)	(2.5)	(7.5)	(6.7)	(2.1)	(8.2)	(32.8)
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Weedy check	1.67	11.37	21.70	2.51	10.47	24.83	1.72	4.56	4.17	1.61	4.57	15.09
	(2.3)	(131.9)	(476.5)	(6.0)	(112.3)	(623.8)	(2.5)	(20.7)	(17.2)	(2.2)	(21.0)	(233.4)
LSD (p=0.05)	0.04	0.26	0.24	0.08	0.24	0.17	0.04	0.10	0.08	0.04	0.16	0.33

SSB- Stale Seedbed Technique, DAS- Days after sowing

Table 3. Effect of tillage and weed management on growth, net return and B:C on pooled basis

Treatment	Plant height	Dry matter (g) 60 DAS	90 DAS	At harvest	Effective tillers (mrl)	Spike length (cm)	Grain /spike	Test weight (g)	Net return (x10³ ₹/ha)	BC ratio
Tillage										
SSB using shallow tillage	37.9	60.9	108.4	148.9	98.2	6.16	35.13	41.11	32.17	1.89
SSB using glyphosate at 2.0 kg/ha	37.8	61.4	114.5	153.1	101.8	6.20	35.68	41.41	36.41	2.03
Deep tillage	37.6	60.1	102.9	144.6	93.6	6.13	33.54	41.11	30.59	1.87
Conventional tillage	37.2	59.6	100.4	140.8	91.4	6.10	33.73	40.63	29.24	1.83
LSD (p=0.05)	NS	NS	3.4	2.4	3.6	NS	NS	NS	1.47	
Weed management										
2,4-D at 0.5 kg/ha 30 DAS	37.4	57.4	104.2	145.5	89.0	6.12	31.91	40.53	25.43	1.73
Metsulfuron at 4.0 g/ha 30 DAS	37.9	61.1	109.2	152.6	100.7	6.20	35.00	41.16	37.44	2.10
2,4-D at 0.5 kg/ha 30 DAS + 1 HW at 45 DAS	37.9	63.2	113.3	156.7	104.2	6.23	36.94	41.38	39.57	2.11
Metsulfuron at 4.0 g/ha 30 DAS + 1 HW at 45 DAS	37.8	63.4	114.9	158.0	105.7	6.26	38.53	40.84	43.03	2.27
One hand weeding (HW) at 30 DAS	37.4	61.5	113.1	151.8	98.2	6.05	32.28	40.91	33.74	1.96
Weed free	37.8	66.2	121.3	161.7	107.4	6.29	39.81	41.78	40.29	2.03
Weedy check	37.2	50.7	69.7	101.5	68.5	5.90	27.16	40.84	5.23	1.16
LSD (p=0.05)	NS	2.3	3.9	5.1	6.5	0.10	3.04	NS	2.06	

SSB:-Stale Seedbed technique, MRL: - Meter row length, DAS- Days after sowing

Table 4. Effect of tillage and weed management on yields and harvest index of wheat during both the years

Treatment	Grain yield (t/ha) 2016-17	2017-18	Pooled	Straw yield (t/ha) 2016-17	2017-18	Pooled	Biological yield (t/ha) 2016-17	2017-18	Pooled	Harvest index (%) 2016-17	2017-18	Pooled
Tillage												
SSB using shallow tillage	3.11	2.83	2.97	4.07	3.75	3.91	7.17	6.57	6.87	43.45	43.17	43.31
SSB using glyphosate at 2.0 kg/ha	3.27	2.99	3.13	4.18	3.94	4.06	7.45	6.93	7.19	43.96	43.34	43.65
Deep tillage	3.01	2.75	2.88	3.75	3.71	3.73	6.76	6.46	6.61	44.73	42.60	43.67
Conventional tillage	2.92	2.70	2.81	3.69	3.55	3.62	6.61	6.25	6.43	43.96	43.30	43.63
LSD (p=0.05)	0.21	0.19	0.13	0.23	0.26	0.16	0.40	0.23	0.21	NS	NS	NS
Weed management												
2,4-D at 0.5 kg/ha 30 DAS	2.79	2.50	2.64	3.50	3.27	3.39	6.29	5.77	6.03	44.43	43.30	43.87
MSM at 4.0 g/ha 30 DAS	3.29	3.08	3.19	4.18	3.87	4.02	7.47	6.94	7.21	44.16	44.48	44.32
2,4-D at 0.5 kg/ha 30 DAS+ 1 HW at 45 DAS	3.44	3.16	3.30	4.35	4.29	4.32	7.79	7.45	7.62	44.33	42.50	43.42
MSM at 4.0 g/ha 30 DAS+ 1 HW at 45 DAS	3.48	3.23	3.35	4.48	4.33	4.40	7.95	7.56	7.76	43.72	42.91	43.31
One hand weeding (HW) at 30 DAS	3.07	2.87	2.97	4.03	3.87	3.95	7.10	6.74	6.92	43.16	42.64	42.90
Weed free	3.68	3.29	3.49	4.65	4.54	4.60	8.33	7.83	8.08	44.38	42.10	43.24
Weedy check	1.78	1.57	1.68	2.26	2.01	2.14	4.04	3.59	3.81	44.00	43.78	43.89
LSD(p=0.05)	0.21	0.13	0.12	0.39	0.37	0.26	0.49	0.42	0.31	NS	NS	NS

*SSB-Stale Seedbed Technique, DAS- Days after sowing, MSM- Metsulfuron

measures like metsulfuron 4.0 g/ha + 1 HW, 2,4-D at 0.5 kg/ha + 1 HW and metsulfuron 4.0 g/ha alone was to the extent of 102, 99 and 92% than the weedy check. These results were in close conformity with the finding of Das (2008) and Singh *et al.* (2018). The lowest value of yield attributes and yield in weedy check might be due to severe competition by weeds for resources, which made the crop plant incompetent to take up more moisture and nutrients, consequently growth was adversely affected. Poor growth and less uptake of nutrients in weedy check might be due to less photosynthates, then less assimilates to numerous metabolic sink and ultimately poor development of yield components.

Economics

Maximum net returns were recorded under SSB using glyphosate 2.0 kg/ha than deep and conventional tillage (**Table 4**). These results were in corroborate the findings of Kumar *et al.* (2018). Application of metsulfuron 4.0 g/ha + one hand hoeing recorded significantly higher net return over all the weed control treatments. This might be due to lower cost to control of weed. (Jat *et al.* 2003) based on present investigation, it was concluded that SSB (with glyphosate or shallow tillage) and post-emergence application of either metsulfuron 4.0 g/ha + 1 HW, 2,4-D 0.5 kg/ha + 1 HW provided effective weed control and consequently higher productivity but only metsulfuron 4.0 g/ha + 1 HW could increase yield similar to weed free check.

REFERENCES

Das TK. 2008. *Weed Science: Basics and Application*. Jain Brothers Pub, New Delhi, 1st Ed. 655p.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research* (2nd Edition). A Wiley-Inter-science Publication, John Wiley and Sons, New York.

IASRI.2019. *Agricultural Research Data Book* 2019. ICAR-IASRI, New Delhi. 337p.

Jat RS, Nepalia V and Jat RL. 2003. Effect of weed control and sowing methods on production potential of wheat. *Indian Journal of Agronomy* **48**(3): 192–195.

Khatun MJ, Begum M and Hossain MM. 2016. Effect of tillage method and weeding regime on soil weed seed bank status and yield performance of wheat. *Progressive Agriculture* **27**: 9–19.

Kumar D, Angiras NN and Rana SS. 2003. Influence of seed bed manipulations and herbicides on leaf area index and growth rate of wheat and associated weeds. *Himachal Journal of Agricultural Research* **29**(1&2): 1–10.

Kumar M, Ghorai AK, Nandy U, Mitra S and Kundu DK. 2018. Effect of stale seed bed and subsequent application of herbicides on weeds and productivity of jute fibre. *Journal of Agriculture Search* **5**(1): 8–12.

Panse VG and Sukhatme PV. 1985. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi.

Pisal RR, Gopinath K and Pandey AK. 2013. Evaluation of sulfosulfuron and metribuzin for weed control in irrigated wheat. *Indian Journal of Agronomy* **51**(31): 135–138.

Safdar ME, Asif M, Ali A, Aziz A, Yasin M, Aziz M, Afzal M and Ali A. 2011. Comparative efficacy of different weed management strategies in wheat. *Chilean Journal of Agricultural Research* **71**(2): 195–204.

Singh A, Jain KK and Upadhyaya SD. 2018. Effect of weed control methods on weeds and wheat under *Eucalyptus tereticornis* based agroforestry system. *International Journal Current Microbial and Applied Sciences* **7**(8): 2856–2867.

Singh P and Ali M. 2004. Efficacy of metsulfuron-methyl on weeds in wheat and its residual effects on succeeding soybean crop grown on vertisol of Rajasthan. *Indian Journal of Weed Science* **36**(1-2): 34–37.

Tu M, Hurd C, Robison R and Randall JM. 2001. *Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas*, The Nature Conservancy.

Yaduraju NT and Das TK. 2002. Bio-efficacy of metsulfuron methyl and 2,4-D on Canada thistle. *Indian Journal of Weed Science* **34**(3&4): 110–111.

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Tillage and weed control effect on weeds and wheat productivity

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Zero-till

ABSTRACT

A 3-year study was conducted to assess the impact of tillage and weed control practices on weed flora and wheat productivity. Experiments were conducted during *Rabi* season of 2012-13 to 2014-15 at GBPUA&T, Pantnagar, with clay-loam soil. There were five crop establishment methods, *viz.* Transplanted rice (conventional tillage) (TPR)– wheat (conventional tillage) (CTW) (TPR-CTW), Transplanted rice (conventional tillage)– wheat (zero tillage)- *Sesbania* green manuring (S) (TPR-ZTW-S), Direct-seeded rice (conventional tillage)- wheat (conventional tillage)- *Sesbania* incorporation (S) (DSR-CTW-S), Direct-seeded rice (zero tillage)- wheat (zero tillage)- *Sesbania* brown manuring (S) (ZTR-ZTW-S) and Direct-seeded rice (zero tillage) + residue retention- wheat (zero tillage) + residue retention- *Sesbania* brown manuring (S) (ZTR + R-ZTW+R-ZTS) and three weed control methods [(weedy check, recommended herbicide (Recommended ready-mix herbicide clodinafop 15% + MSM 1% (60 + 4 g/ha) and integrated weed management *i.e.,* clodinafop 15% + MSM 1% 60 + 4 g/ha *fb* manual weeding at 45 days after seeding (DAS)]. Continuous zero-till cropping system along with residue retention and brown manuring of *Sesbania* has resulted in the lowest total weed biomass at 60 DAS and greatly reduced the density of *Phalaris minor, Medicago denticulata, Polygonum plebeium* and *Coronopus didymus.* However, density of *C. didymus, Rumex acetosella* and *Vicia sativa* was reduced under conventionally tilled wheat. Ready mix application of clodinafop 15% + MSM 1% supplemented with one hand weeding at 45 DAS greatly reduced the density and biomass of weeds. The maximum wheat grain (4.5 t/ha) and straw (6.3 t/ha) yields was achieved under zero-tilled wheat with rice residue retention and *Sesbania* as brown manure. The integration of clodinafop 15% + MSM 1% with 1 HW at 45 DAS resulted in an increase in grain and straw yields by 45.5% and 30.8%, respectively, over weedy check. It may inferred that in wheat cultivation conventional tillage could be replaced with zero-tillage along with residue retention by growing of *Sesbania* and the application of 2,4-D at 30 days stage to attain sustainability of rice-wheat cropping system.

INTRODUCTION

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system is the most important cropping system of the Indo-Gangetic plains (IGP) in India (Singh *et al.* 2014). India is the second largest consumer as well as producer of wheat in the world, with production of 99.70 million tonnes (Anonymous 2018). The traditional method of wheat establishment involves excessive tillage which is time and energy consuming (Tripathi *et al.* 2002). The sowing of wheat after harvest of transplanted rice is generally delayed due to intensive tillage operation for seed bed preparation under conventional system. This results in reduced yield due to reduced crop duration, equivalent to an extent of 1.0-1.5% yield loss/hectare/day (Gathala *et al.* 2011). Under such condition, conservation agriculture (CA) practices like direct-seeding, zero tillage along with retention of residues have several advantages, *viz.* advance sowing, conserve the energy, more moisture availability for wheat seed germination by reducing turn-around time and also reduced number of weeds due to lesser turning of soil. Weeds are one of the major constraints in wheat production (Sharma and Singh 2010). Weeds reduce the crop yield, deteriorate quality, and reduce market value of grains. Weed causes yield reduction in wheat from 50-80% (Chhokar and Malik 2002, Jain *et al.* 2007). Sowing wheat under ZT further saves fuel costs (Chauhan and Johnson 2009) and energy (Erenstein and Laxmi 2008). Many researchers observed that with the adoption of ZT, there is shift in weed species (Rao *et al.* 2007 and Shahzad *et al.* 2016) which need to be controlled by appropriate methods. Farooq *et al.* (2011) suggested to include integrated weed management as a component of CA. The current three year field study was conducted to evaluate the impact of different tillage and weed control practices on weed growth and wheat productivity.

MATERIALS AND METHODS

A field experiment was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, Uttarakhand, India, during 2012-15. Pantnagar falls in the *'Tarai'* zone (a lowland region that has outer hills of Himalayas), adjoining the foothills of 'Shivalik' range of the Himalayas and situated at 29°N latitude and 79.32°E longitude having an altitude of 243.8 meter above the mean sea level. The climate falls under sub-humid, sub-tropical climatic zone. Summer is being warm and humid. The mean annual rainfall is about 1400 mm, of which 80 to 90 per cent is received during *Kharif* season (June to September). Frost generally occurs towards the end of December and may continue till the end of January. Winters are very cold and extend from November to March. The daily average minimum temperature in the coldest month varies from 1.0-9.0°C and during summer, the maximum temperature varies from 30-43°C. The soil had a clay loam texture and classified under order mollisols (Deshpande *et al.* 1971), with slightly alkaline reaction (pH 7.7) and moderately fertile, being low in organic carbon (0.41%) and available nitrogen (168.2 kg/ha) and medium in available phosphorus (14.8 kg/ha) and potassium (194.6 kg/ha). The field experiment was laid out in a strip plot design, sub-plot size of 3.6 x 10 m with five tillage establishment methods in vertical strip and three weed control treatments in horizontal strip, replicated thrice (**Table 1)**.

Field was prepared mechanically according to the treatments. Before sowing of rice, *Sesbania*, with seed rate of 40 kg/ha, was sown with seed drill and incorporated in the field as green manure with puddling under conventional transplanted rice and incorporated into the soil with the help of harrow in direct-seeded rice, while in zero-till rice, the *Sesbania* was knocked out by the application of 2,4-D at 45 DAS and considered as brown manure. During *Rabi* season, the same experimental plots after rice harvesting were prepared mechanically with the help of small harrow and power tiller for conventional sown wheat; while in case of zero tillage, directly the seeds were sown with zero-till-ferti seed drill, without any disturbance of the permanent layout of the experiment. Sowing of wheat variety '*UP 2572*' was done between second and third week of November, each year after rice harvest, with seed rate of 100 kg/ha, manually by opening furrow at 22.5 cm apart with the help of furrow opener in case of conventional plots while in zero tillage, seed and fertilizer was placed directly with the help of zero-till-ferti seed drill.

A dose of 150 kg N, 60 kg P and 40 kg K per hectare was applied through urea (46% N) and NPK mixture (12:32:16% of nitrogen, phosphorus and potassium). Half of nitrogen, full dose of phosphorus and potassium was applied as basal while remaining nitrogen was applied in two splits at the time of tillering and heading stage. After sowing of the crop, residue of the previous crop (rice residue in wheat and wheat residue in rice) was left in experimental plots according to the treatments. Harvesting was done manually with sickle from the net plot (10 m^2), when more than 90 per cent of grains in the panicle were fully ripe and free from greenish tint. The produce of individual plot was threshed by Pullman thresher. Grain yields were reported at 14% moisture content.

Weed samples were collected at 60 DAS by placing a quadrate (0.5 x 0.5 m) from the area marked for observation in each plot. Species wise weed counts were recorded and grouped into grasses, sedges and broad-leaved weeds (BLW) and expressed as no./m^2. Weeds enclosed in a quadrate were removed at ground level and separated as grasses, sedges and broad-leaved weeds. After sun drying, the samples were kept in hot air oven at 60 ± 10°C till constant dry weight is obtained. The total weed biomass was obtained by adding the weight of all the weed groups and expressed as g/m^2. All the data obtained during the course of investigation were subjected to statistical analysis by using CPCS-1 programme, designed and developed by Punjab Agriculture University, Ludhiana, (Cheema and Singh 1991) for determining the statistical difference between the treatments and to draw conclusions. The data on weed density and their biomass were subjected to square root transformation $(\sqrt{x+1})$ to reduce heterogeneity of variance. The original values were given in the parentheses. The analyzed data are presented in tables.

RESULTS AND DISCUSSION

Weed density

Dominant weed species in weedy check were *Phalaris minor* (44.0%) among grassy, *Medicago denticulata* (30.3%), *Polygonum plebeium* (9.5%), *Coronopus didymus* (2.1%), *Rumex acetosella* (1.4%), *Melilotus alba* (5.5%), *Chenopodium album* (6.3%) and *Vicia sativa* (0.9%) among BLW at 60 days after seeding (DAS) (**Figure 1**). Majority of weeds in the wheat field under rice-wheat cropping system were *Phalaris minor*, *Avena ludoviciana*, *Cyperus rotundus*, *Coronopus didymus*, *Chenopodium album*, *Anagallis arvensis*, *Convolvulus arvensis*, *Melilotus indica*, *Melilotus alba, Medicago denticulate, Rumex* spp. and *Vicia sativa* (Usman *et al.* 2010[a,b,] Kumar *et al.* 2012, Kumar *et al.* 2013 and Shyam *et al.* 2014). Singh *et al.* 2015[a,b] revealed the dominance of *Phalaris minor* (40.7%) as a grassy weed and *Chenopodium album* (13.3%), *Coronopus didymus* (10.4%), *Melilotus indica* (9.4%), *Rumex* spp. (4.8%) and *Fumaria parviflora* (3.8%),as major broad-leaved weeds infesting experimental area of wheat.

Among grassy weeds, significantly the lowest density was recorded under zero-till wheat with or without residue retention along with the *Sesbania* grown as brown manure. CT favoured *Phalaris minor* (Chhokar *et al.* 2007, 2009, Usman *et al.* 2010a, Shyam *et al.* 2014 and Punia *et al.* 2016). Clodinafop 15% + MSM 1% (60+4 g/ha) supplemented with one hand weeding achieved the least density of *P. minor* (**Table 1**). Zero-till wheat with and without residue retention along with the *Sesbania* as brown manure recorded the lowest density with integration of IWM practices (**Table 2**). Chhokar *et al.* (2007) at Karnal, Haryana reported that if zero tillage is practiced with residue retention then weed infestation will be lesser. The ready-mix doses of clodinafop + metsulfuron (UPH-206) at 35 DAS in wheat at 60 + 4 g/ha provided good control of dominant grassy weeds, *viz. Phalaris minor* and broad-leaf weeds like *Chenopodium album*, *Melilotus indica*, *Rumex* spp.and *Coronopus didymus* over unweeded check (Chopra and Chopra 2010, Singh *et al.* 2012 and Chopra *et al.* 2015).

Figure 1. Dominant weed species in weedy check at 60 DAS

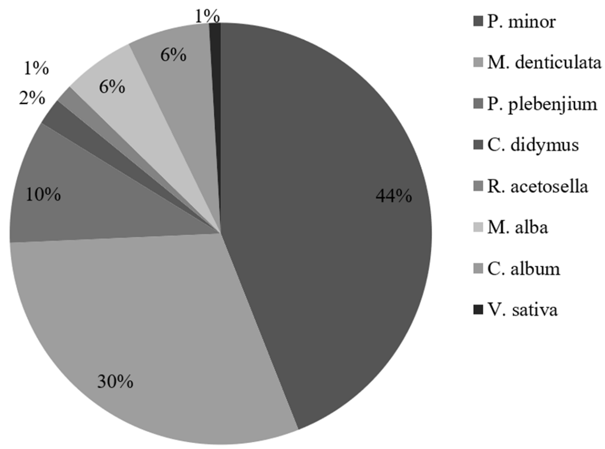

Table 1. Effect of establishment methods and weed management on weed density and total weed biomass of wheat in rice-wheat cropping system at 60 DAS (pooled data of 3 years)

Treatment	Weed density (no./m^2)									Total weed biomass (g/m^2) 60 DAS
	Grassy weeds	Broad-leaved weeds							Total BLWs	
	P. minor	*M. denticulata*	*P. plebeium*	*C. didymus*	*R. acetosella*	*M. alba*	*C. album*	*V. sativa*		
Establishment system										
TPR (CT)- wheat (CT)	8.0(101.3)	2.7(11.3)	1.8(4.0)	1.2(0.7)	1.2(0.9)	2.1(5.0)	2.3(8.2)	1.2(0.6)	4.1(29.9)	5.6(58.2)
TPR (CT)- wheat (ZT)- *Sesbania* (ZT)	5.0(32.2)	3.1(15.6)	1.8(5.6)	1.8(4.5)	1.2(0.6)	1.6(2.5)	1.4(1.3)	1.1(0.3)	4.1(30.0)	4.8(36.1)
DSR (CT)- wheat (CT)- *Sesbania* (ZT)	6.4(49.2)	4.3(32.6)	3.0(14.2)	1.3(1.0)	1.1(0.4)	2.1(6.2)	2.5(8.9)	1.1(0.2)	5.5(61.0)	5.2(43.5)
DSR (ZT)- wheat (ZT)- *Sesbania* (ZT)	4.0(26.7)	4.5(54.4)	2.6(12.0)	1.5(1.9)	1.7(2.4)	1.9(4.9)	1.9(4.3)	1.1(0.4)	5.7(79.7)	4.7(36.3)
DSR (ZT)+R- wheat (ZT)+R- *Sesbania* (ZT)	3.5(15.9)	2.4(12.6)	1.6(4.0)	1.2(0.9)	1.4(1.6)	1.8(4.0)	1.7(3.7)	1.6(1.9)	3.5(28.7)	3.5(20.3)
LSD (p=0.05)	1.1	1.0	0.6	0.3	0.3	NS	0.4	0.2	0.9	0.9
Weed management										
Clodinafop 15% + MSM 1% at 60+4 g/ha)	4.2(20.1)	1.8(3.1)	1.3(1.1)	1.0(0.2)	1.0(0.1)	1.1(0.4)	1.2(0.7)	1.0(0.0)	2.0(4.9)	3.2(13.1)
IWM (herbicide *fb* one HW)	2.7(9.5)	1.0(0.1)	1.0(0.1)	1.1(0.3)	1.0(0.1)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.1(0.5)	1.3(1.1)
Weedy check	9.3(105.5)	7.3(72.6)	4.2(22.7)	2.1(5.0)	1.9(3.4)	3.6(13.2)	3.6(15.1)	1.6(2.1)	10.6(132.1)	9.7(102.4)
LSD (p=0.05)	0.8	2.1	1.1	0.4	0.1	0.2	0.6	0.3	2.4	1.2

Vertical strip- TPR- CTW: Transplanted rice (conventional tillage) (TPR) – wheat (conventional tillage) (CTW); TPR- ZTW- S: Transplanted rice (conventional tillage)- wheat (zero tillage)- *Sesbania* green manuring(S); DSR- CTW- S: Direct-seeded rice (conventional tillage)- wheat (conventional tillage)- *Sesbania* incorporation(S); ZTR- ZTW- S: Direct-seeded rice (zero tillage)- wheat (zero tillage)- *Sesbania* brown manuring(S); ZTR+ R- ZTW+ R- ZTS: Direct-seeded rice (zero tillage) + residue retention- wheat (zero tillage) + residue retention- *Sesbania* brown manuring(S): Horizontal Strip- Recommended ready-mix herbicide (clodinafop 15% + MSM 1% 60+4 g/ha); IWM; Integrated weed management (clodinafop 15% + MSM 1% 60+4 g/ha *fb* manual weeding at 45 DAS)

Significantly the lowest population of *M. denticulata* and *P. plebeium* was recorded under ZT wheat with rice residue retention and *Sesbania* as brown manuring. Higher density of *C. didymus* was observed under ZT wheat with *Sesbania* as green manure which was significantly superior to other establishment methods. Whereas, significantly higher density of *R. acetosella* was observed under ZT wheat with *Sesbania* as brown manure. Significantly the lowest density of *C. album* was recorded under ZT wheat with *Sesbania* incorporated as green manure. Similar was reported by Chhokar *et al.* (2007) that *Phalaris minor* was dominant under the conventional tillage system and *Medicago denticulata* and *Coronopus didymus* was dominant under zero tillage system in wheat. All the establishment methods of wheat recorded significantly low weed density being at par with each other, except ZT wheat with residue retention of rice and brown manuring of *Sesbania*. The minimum density of all BLWs was achieved under IWM (clodinafop 15% + MSM 1% (60+4 g/ha) supplemented with one hand weeding at 45 DAS followed by alone application of ready-mix herbicide except *C. didymus* which have least density under sole herbicidal application at par with IWM approach and both the treatments reduced the population over weedy check (**Table 1**). Continuous ZT with effective weed management using recommended herbicide + one hand weeding was more remunerative (Mishra and Singh 2012).

The lowest density of all BLWs was achieved under zero-till wheat with rice residue retention followed by *Sesbania* as brown manuring under zero-till rice. IWM achieved the least density of BLWs being at par with herbicidal application (**Table 1**). The surface retention of rice residue of more than 4 t/ha in combination with no-till system reduced the weed abundance in wheat (Chhokar *et al.* 2014). Effective control of broad-leaved weeds with high yield attributes was found by application of clodinafop-propargyl + metsulfuron-methyl 400 g/ha (Tiwari *et al.* 2015). Conventional wheat with *Sesbania* incorporated as green manure recorded the lowest density with integration of IWM practices. Along with zero-till wheat with as well as without retention of rice residue with *Sesbania* as brown manuring with IWM and sole application of herbicide (**Table 3**). Chhokar *et al.* (2007) at Karnal, Haryana reported that if zero tillage is practiced with residue retention then weed infestation will be lesser. Continuous ZT with effective weed management using recommended herbicide + one hand weeding was more remunerative (Mishra and Singh 2012).

Table 2. Interaction effect of establishment methods and weed management on total grassy weeds of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60+4 g/ha)	5.2	3.7	5.9	2.9	3.1	4.2
IWM (herbicide *fb* one hand weeding)	2.8	3.3	3.3	2.1	2.2	2.7
Weedy check	16.1	8.1	10.1	7.1	5.1	9.3
Mean	8.0	5.0	6.4	4.0	3.5	
LSD(p=0.05)			1.6			

Table 3. Interaction effect of establishment methods and weed management on total BLWs of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60 + 4 g/ha)	2.2	1.9	2.8	2.2	1.0	2.0
IWM (herbicide *fb* one hand weeding)	1.1	1.5	1.0	1.0	1.1	1.1
Weedy check	8.9	8.8	12.8	13.8	8.5	10.6
Mean	4.1	4.1	5.5	5.7	3.5	
LSD(p=0.05)			1.2			

Table 4. Interaction effect of establishment methods and weed management on total biomass of weeds of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60+4 g/ha)	3.3	3.4	4.3	3.3	1.9	3.2
IWM (herbicide *fb* one hand weeding)	1.2	1.5	1.5	1.2	1.3	1.8
Weedy check	12.2	9.6	9.8	9.6	7.5	9.7
Mean	5.6	4.8	5.2	4.7	3.5	
LSD(p=0.05)			1.5			

Table 5. Effect of establishment methods and weed management on yield and yield attributes of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	Spikes (no./m^2)	Grains/ spikes	1000-grain weight (g)	Grain yield (t/ha)				Straw yield (t/ha)
				2012-13	2013-14	2014-15	Pooled	
Establishment system								
TPR (CT)- wheat (CT)	247.3	45.0	44.0	4.3	4.2	4.2	4.2	6.1
TPR (CT)- wheat (ZT)- *Sesbania* (ZT)	277.2	43.3	43.7	4.2	4.1	4.2	4.2	6.2
DSR (CT)- wheat (CT)- *Sesbania* (ZT)	282.9	42.2	43.5	4.2	4.0	3.9	4.0	6.2
DSR (ZT)- wheat (ZT)- *Sesbania* (ZT)	275.0	45.4	43.9	3.9	3.9	4.1	4.0	5.7
DSR (ZT)+R- wheat (ZT)+R- *Sesbania* (ZT)	258.9	42.7	45.2	4.2	4.7	4.7	4.5	6.3
LSD (p=0.05)	NS	NS	NS	0.24	0.35	0.34	NS	NS
Weed management								
Clodinafop 15 % + MSM 1% at 60+4 g/ha)	280.5	45.4	44.4	4.3	4.5	4.6	4.5	6.3
IWM (herbicide *fb* one hand weeding)	307.8	43.6	44.6	4.8	4.8	4.9	4.8	6.8
Weedy check	216.5	42.1	43.2	3.4	3.2	3.3	3.3	5.2
LSD(p=0.05)	33.5	NS	NS	0.31	0.40	0.43	0.3	0.4

Significantly lowest biomass was recorded under zero-till wheat with residue retention of rice along with *Sesbania* as brown manure. IWM achieved the least biomass of weeds (**Table 1**). Lowest weed biomass was achieved under zero-till wheat without residue retention with *Sesbania* as brown manure in combination with IWM (**Table 4)**. Zero-till wheat exhibited significantly lower weed dry weight per unit area than conventional method of wheat sowing (Shyam *et al.* 2014).

Effect on yield

Among different establishment system, the highest number of spike/m^2 (282.9), grains/spike (45.4) and 1000-grain weight (45.2 g) was achieved in conventional wheat after direct-seeded rice *fb Sesbania* incorporation, zero-till rice and wheat with *Sesbania* as brown manure and both zero-till rice and wheat with residue retention *fb Sesbania* as brown manure, respectively. Ram *et al.* (2010) reported higher yields of wheat under ZT with residue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains/spike and 1000-grain weight than no-residue application under ZT practices, as well as CT practices. Higher wheat grain (4.5 t/ha) and straw (6.3 t/ha) yields were recorded under zero-till rice and wheat with residue retention of rice along with brown manuring of *Sesbania*. An increase in number of spikes/m^2 (307.8), 1000-grain weight (43.6 g), grain (4.8 t/ha) and straw (6.8 t/ha) yields of wheat was recorded under IWM (clodinafop 15% + MSM 1% 60 + 4 g/ha *fb* one hand weeding) compared to weedy check (**Table 5**). The conservational tillage (no-till) for wheat generally resulted in yields that were better than or equal to yields obtained with conventional tillage (Punia *et al.* 2016). Integration of zero tillage + *Sesbania* + previous crop residue in rice -zero tillage + rice residue in wheat -zero tillage + residue in green gram along with weed control by bispyribac-sodium in rice and tank-mix of clodinafop and sulfosulfuron in wheat effectively controlled the weeds and enhanced the system productivity in rice-wheat-green gram cropping (Sapre *et al.* 2015). The ready-mix doses of clodinafop + metsulfuron at 35 DAS in wheat at 60 + 4 g/ha attained the grain yields similar to weed free check (Yadav *et al.* 2009, Kumar *et al.* 2012), about 18.5% higher than the sole application of herbicides (Chopra and Chopra 2010).

Conclusion

Continuous ZT with IWM (clodinafop 15% + MSM 1% 60+4 g/ha *fb* one hand weeding) resulted in highest yield by reducing the weed density and biomass of weeds.

REFERENCES

Anonymous . 2018. Ministry of Agriculture & Farmers Welfare. Department of Agriculture, Cooperation & Farmers Welfare. Directorate of Economics & Statistics. New Delhi. India. 77 p.

Chauhan BS and Johnson DE. 2009. Influence of tillage systems on weed seedling emergence pattern in rainfed rice. *Soil and Tillage Research* **106**: 15–21.

Cheema HS and Singh B. 1991. *Software Statistical Package CPCS-1*. Department of Statistics, PAU, Ludhiana

Chhokar RS and Malik RK. 2002. Isoproturon resistant *Phalaris minor* and its response to alternate herbicides. *Weed Technology* **16**: 116–123.

Chhokar RS, Sharma RK, Gill SC, Singh RK and Sharma I. 2014. Influence of tillage and residue management practices on weeds in rice-wheat cropping systems. pp. 14–15. In: *Proceedings of World Congress on Conservation Agriculture*. June 22-25, 2014.

Chhokar RS, Sharma RK, Jat GR, Pundir AK and Gathala MK. 2007. Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing system. *Crop Protection* **26**: 1689–1696.

Chhokar RS, Singh S, Sharma RK and Singh M. 2009. Influence of straw management on *Phalaris minor* control. *Indian Journal of Weed Science* **41**: 150–156.

Chopra NK and Chopra N. 2010. Evaluation of tillage system and herbicides on wheat (*Triticum aestivum*) performance under rice (*O. sativa*)-wheat (*T. aestivum*) cropping system. *Indian Journal of Agronomy* **55**(4): 304–307.

Chopra NK, Chopra N and Choudhary D. 2015. Bioefficacy of sole and tank-mix of pinoxaden and clodinafop with carfentrazone and metsulfuron for control of complex weed flora in wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **60**(1): 104–108.

Deshpande SB, Fehrenbacher JB and Beavers AH. 1971. Mollisols of *Tarai* region of Uttar Pradesh, Northern India. 1. Morphology and Minerology. *Geoderma* **6**: 179–193.

Erenstein O and Laxmi V. 2008. Zero tillage impacts in India's rice-wheat systems: A review. *Soil & Tillage Research* **100**: 1–14.

Farooq M, Siddique HM, Rehman HK, Aziz T and Lee Donge-Jin Wahid A. 2011.Rice direct-seeding: experiences, challenges and opportunities. *Soil and Tillage Research* **111**: 87–98.

Gangwar KS, Singh KK, Sharma SK and Tomar OK. 2006. Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo-Gangetic Plains. *Soil and Tillage Research* **88**: 242–252.

Garnett T, Appleby MC, Balmford A, Bateman J, Benton TG, Bloomer P, Burlingame B, Dawkins M, Dolan L, Fraser D, Herrero M, Hoffmann I, Smith P, Thornton PK, Toulmin C, Vermeulen SJ and Godfray HCJ. 2013. Sustainable intensification in agriculture: premises and policies. *Agricultural Sciences* **341**: 333–334.

Gathala MK, Ladha JK, Kumar V, Saharawat YS, Kumar V, Sharma PK, Sharma S and Pathak H. 2011. Tillage and crop establishment affects sustainability of South Asian rice-wheat system. *Agronomy Journal* **103**: 961–971.

Jain N, Mishra JS, Kewat ML and Jain V. 2007. Effect of tillage and herbicides on grain yield and nutrient uptake by wheat and weeds. *Indian Journal of Agronomy* **52**: 131–134.

Kumar S, Singh R, Shyam R and Singh VK. 2012. Weed dynamics, nutrient removal and yield of wheat as influenced by weed management practices under valley conditions of Uttarakhand. *Indian Journal of Weed Science* **44**(2): 110–114.

Kumar V, Singh S, Chhokar RS, Malik RK, Brainard DC and Ladha JK. 2013. Weed management strategies to reduce herbicide use in zero-till rice-wheat cropping systems of the indo-gangetic plains. *Weed Technology* **27**(1): 241–254.

Mishra JS and Singh VP. 2012. Tillage and weed control effects on productivity of a dry seeded rice-wheat system on a Vertisol in Central India. *Soil & Tillage Research* **123**: 11–20.

Punia SS, Singh S, Yadav A, Yadav DB and Malik RK. 2016. Long-term impact of crop establishment methods on weed dynamics, water use and productivity in rice-wheat cropping system. *Indian Journal of Weed Science* **48**(2): 158–163.

Ram H, Kaler DS, Singh Y and Kumar K. 2010. Productivity of maize (*Zea mays*) wheat (*Triticum aestivum*) system under different tillage and crop establishment practices. *Indian Journal of Agronomy* **55**(3): 185–190.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 153–255.

Sapre N, Kewat ML, Sharma AR, Singh VP and Jha G. 2015. Effect of tillage and weed management on weed dynamics and system productivity of rice-wheat-green gram cropping system. pp. 351–352. In: *25th Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during October 13-16, 2015.

Shahzad M, Farooq M and Hussain M. 2016. Weed spectrum in different wheat-based cropping systems under conservation and conventional tillage practices in Punjab, Pakistan. *Soil Tillage Research* **163**:71–79.

Sharma SN and Singh RK. 2010. Weed management in rice wheat cropping system under conservation tillage. *Indian Journal of Weed Science* **42**(1&2): 23–29.

Shyam R, Singh R and Singh VK. 2014. Effect of tillage and weed management practices on weed dynamics, weed seed bank and grain yield of wheat in rice-wheat system. *Indian Journal of Weed Science* **46**(4): 322–325.

Singh R, Shyam R, Singh VK, Kumar J, Yadav SS and Rathi SK. 2012. Evaluation of bio-efficacy of clodinafop-propargyl + metsulfuron-methyl against weeds in wheat. *Indian Journal of Weed Science* **44**(2): 81–83.

Singh R, Singh AP, Chaturvedi S, Rekha, Pal R and Pal J. 2015[a]. Control of complex weed flora in wheat by metribuzin + clodinafop application. *Indian Journal of Weed Science* **47**(1): 21–24.

Singh R, Singh AP, Chaturvedi S, Rekha, Pal R and Pal J. 2015[b]. Metribuzin +clodinafop-propargyl effects on complex weed flora in wheat and its residual effect on succeeding crop. *Indian Journal of Weed Science* **47**(4): 362–365.

Singh SS, Singh AK and Sundaram PK. 2014. Agrotechnological options for upscaling agricultural productivity in eastern indo gangetic plains under impending climate change situations: A Review. *Journal of Agricultural Search* **1**(2): 55–65.

Tiwari A, Verma BK, Dev J and Kumar R. 2015. Bioefficacy of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat. *Indian Journal of Weed Science* **47**(4): 422–424.

Tripathi J, Bhandari D, Justice S, Shakya NK, Kharel TP and Shisodia R. 2002. Resource conservation technologies for wheat production in rice-wheat system. Vol. 1, pp. 157-165. In: *Proceedings of Wheat Research Papers presented at 25th National Winter Crops Workshop.*

Usman K, Khalil SK and Khan MA. 2010a. Impact of tillage and herbicides on weed density and some physiological traits of wheat under rice-wheat cropping system. *Sarhad Journal of Agriculture* **26**(4): 475–487.

Usman K, Khalil SK, Khan AZ, Khalil IH, Khan MA and Amanullah. 2010b.Tillage and herbicides impact on weed control and wheat yield under rice-wheat cropping system in North western Pakistan. *Soil and Tillage Research* **110**: 101–107.

Yadav DB, Yadav A, Punia SS, Malik RS and Balyan RS. 2009. Efficacy of ready-mix combination of clodinafop-propargyl and metsulfuron-methyl against complex weed flora in wheat. *Haryana Journal of Agronomy* **25**(1&2): 9–12.

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Control of mixed weed flora with different herbicides in barley

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ABSTRACT

A field experiment was conducted during 2014-15 and 2015-16 to study the efficacy of herbicides for control of diverse weeds in barley. Herbicides were sprayed alone or in combinations. The highest grain yield (5.54-6.07 t/ha) was recorded in weed-free treatment which was at par with isoproturon 750 g/ha + 2,4-D 500 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha. Uncontrolled weed competition caused an average 8-54% yield reductions compared to weed-free treatment. The magnitude of net returns and the benefit-cost ratio was higher with the applications of isoproturon 750 g/ha + 2,4-D (Na salt) 500 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha, isoproturon 750 g/ha + metsulfuron 4 g/ha and pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and in weed-free.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is cultivated mainly for green forage and malt production. It is grown worldwide, ranging from sub-Arctic to subtropical climates, including developing countries of Central Asia, which contributes about 32 million ha of land under barley cultivation (Grando and Mcpherson 2005). In India, barley is cultivated over 0.59 million ha land with an average production of 1.51 million tons (Anonymous 2016). However, barley production is severely constrained in India due to cultivation on poor soils, low input usage and higher weed infestations. The infestations of grass and broad-leaf weeds can reduce barley yields by 6-79% (Watson *et al.* 2006, Scursoni and Satorre 2005) depending on weed densities and duration of weed competition. Weeds also caused a reduction in protein content and grain size leading to loss of valuable malting premiums (Gerhards *et al.* 2005).

In barley, very limited herbicides have been evaluated and recommended. Among herbicides, 2,4-D is widely used in barley to control broad-leaf weeds. However, the major concern with the over-dependence on single herbicide is buildup of herbicide-resistant weeds and shift in weed flora. Bhullar *et al.* (2013) reported that extensive use of 2,4-D in barley has increased the abundance of some of the broad-leaf weeds like *Rumex spinosus* and *Malva.* Therefore, herbicides having a different mode of actions in various combinations, are mainly needed as one of the strategies for integrated weed management in barley. Herbicides such as metsulfuron-methyl and carfentrazone-ethyl have shown excellent efficacy in the control of broad-leaf weeds in wheat and barley (Howatt 2005, Tiwari *et al.* 2005, Zand *et al.* 2010). Moreover, these herbicides have a different mode of action and hence, their rotational use with 2,4-D can be done to reduce the selection pressure for the evolution of herbicide-resistant weeds. Keeping these facts in view, an experiment was planned to study the efficacy of alternative herbicides either alone or in combination, for weed control in barley to minimize the yield and quality losses.

MATERIALS AND METHODS

Studies were conducted at the Punjab Agricultural University, Ludhiana (38°56′ N, 75° 52′ E longitude, 247 metres ASL) India during 2014-15 and 2015-16. The experiment was laid out in RCBD with four replications and eleven treatments *viz.* pinoxaden 0.030 kg/ha, pinoxaden 0.040 kg/ha, pinoxaden 0.050 kg/ha, pinoxaden 0.040 kg/ha + metsulfuron 0.004 kg/ha, pinoxaden 0.040 kg/ha followed by metsulfuron 0.004 kg/ha, pinoxaden 0.040 kg/ha + carfentrazone 0.020 kg/ha, isoproturon 1 kg/ha, isoproturon 0.75 kg/ha + 2,4-D (Na salt) 0.5 kg/ha, isoproturon 0.75 kg/ha + metsulfuron 0.004 kg/ha, weedy check and weed-free. Malt barley (variety *'DWRUB 52'*) was sown in the first week of

November as per standard agronomic practices in a plot size of 10 m^2. All the post-emergence herbicides were applied at 40 days after sowing (DAS) at maximum tillering stage. Weed density and dry matter data were recorded at 60 days after sowing (DAS), 90 DAS, and at the harvest. Collected samples were first sun-dried and then dried in an oven at 60±2^{0}C for 4-5 days till constant dry weight was achieved. Weed control efficiency (WCE) and weed index (WI) were calculated as per standard methods. For measurement of chlorophyll index, a middle portion of the leaf was exposed to *atLEAF* chlorophyll meter (Wilmington, USA). The number of effective tillers was recorded at harvest time. The number of grains per ear were recorded from manually threshed five ears. Crop biomass yield of a net plot was weighted after harvesting at physiological maturity and expressed in tons per hectare. Grain yield was calculated by threshing of total plot biomass and presented in tons per hectare. Economics of different treatments was worked out by taking the prevailing market prices of inputs and produce under consideration. Analysis of variance is calculated using Proc GLM (SAS software 9.1, SAS institute Ltd, USA). The differences between means were compared with Fisher's least significant difference test (LSD) at the 0.05 probability level.

RESULTS AND DISCUSSION

Effect on weeds

Various weed species such as *Phalaris minor, Chenopodium album, Malva neglecta,* and *Anagallis arvensis,* etc. were found in a barley crop. Maximum weed count was found in weedy check at 60 days after sowing (DAS) and 90 DAS, which was statistically higher than weed-free treatment (**Table 1**). The lowest weed count (63.6, 57.3/m^2) in 2014-15 was recorded in isoproturon 750 g/ha + 2,4-D 500 g/ha and it was statistically at par with isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + metsulfuron 4 g/ha, pinoxaden 50 g/ha and isoproturon 1000 g/ha. During 2015-16, the lowest weed density was recorded in pinoxaden 40 g/ha + metsulfuron 4 g/ha which was significantly lower than weedy check and other herbicide treatments at 60 DAS. Pinoxaden 40 g/ha + metsulfuron 4 g/ha was statistically similar to isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha. Weed dry matter recorded at the 90 DAS and at harvest revealed that the weedy check had the highest weed dry matter **(Table 1**). The lowest weed dry matter was recorded in isoproturon 750 g/ha + 2,4-D 500 g/ha in 2014-15 and in pinoxaden 40 g/ha + carfentrazone 20 g/ha in 2015-16 at 90 DAS and at harvest. In 2014-15, dry matter recorded in isoproturon 750 g/ha + 2,4-D 500 g/ha was statistically similar to isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + metsulfuron 4 g/ha and pinoxaden 40 g/ha at both the time of observation. However, in 2015-16, the lowest weed dry matter recorded in pinoxaden 40 g/ha + carfentrazone 20 g/ha at 90 DAS and at harvest which was statistically similar to isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + metsulfuron 4 g/ha. The herbicides like isoproturon 750 g/ha + 2,4-D 500 g/ha, isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + metsulfuron 4 g/ha, pinoxaden 50 g/ha and isoproturon 1000 g/ha were effective in reducing weed density and dry matter due to better weed control. The herbicide

Table 1. Effect of various weed control treatments on weed density, weed dry matter and weed control efficiency in barley

Treatment	Total weed density (no./m^2)				Weed dry matter (g/m^2)				WCE (%)	
	60 DAS		90 DAS		(90 DAS)		At harvest			
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Pinoxaden 30 g/ha	9.3(88)	8.8(78)	8.9(81)	8.1(65)	7.6(57)	5.5(31)	13.8(189)	10.5(111)	29.6	53.4
Pinoxaden 40 g/ha	9.5(90)	8.4(71)	8.8(77)	7.7(59)	7.1(50)	5.4(29)	12.9(164)	10.2(104)	42.9	56.6
Pinoxaden 50 g/ha	8.6(74)	8.1(65)	8.2(67)	7.4(54)	6.2(38)	5.2(26)	11.0(124)	9.6(91)	61.6	61.8
Pinoxaden 40 g/ha + metsulfuron 4 g/ha	8.3(70)	6.5(42)	8.0(65)	6.7(45)	6.0(36)	3.8(15)	10.9(119)	6.7(44)	55.0	81.9
Pinoxaden 40 g/ha *fb* metsulfuron 4 g/ha	8.3(68)	7.8(61)	7.9(62)	7.1(50)	5.7(33)	4.8(23)	10.5(110)	9.0(80)	59.9	66.3
Pinoxaden 40 g/ha + carfentrazone 20 g/ha	9.9(98)	7.3(54)	9.5(91)	5.9(35)	5.5(33)	3.6(12)	10.0(108)	6.7(44)	47.2	81.4
Isoproturon 1000 g/ha	8.8(77)	9.3(86)	8.3(69)	8.5(71)	7.0(49)	5.6(33)	12.7(162)	10.6(121)	48.4	50.1
Isoproturon 750 g/ha + 2,4-D 500 g/ha	8.0(64)	8.5(72)	7.6(57)	7.8(60)	5.4(29)	5.4(30)	9.7(96)	10.3(107)	70.5	54.9
Isoproturon 750 g/ha + metsulfuron 4 g/ha	8.3(69)	7.7(60)	7.9(63)	7.1(50)	6.4(42)	4.7(22)	11.7(139)	9.0(81)	57.9	65.7
Weedy check	11.9(142)	10.1(103)	11.5(131)	9.3(86)	9.2(84)	8.0(64)	16.8(281)	15.5(240)	-	-
Weed free	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1(0)	1(0)	1(0)	1.0(0)	100.0	100.0
LSD (p=0.05)	1.02	0.2	1.1	1.2	1.5	1.2	2.82	2.41	14.1	22.7

The data were square root transformed and values in the parentheses are original values combinations performed better than individual herbicides, which was due to complex weed flora in the experimental fields. Ram and Singh (2009) also reported that isoproturon 1000 g + metsulfuron 4 g/ha, isoproturon 1000 g/ha, isoproturon 1000 g + carfentrazone 20 g/ha and isoproturon 1000 g + 2,4-D 500 g/ha were effective in controlling the mixed weed flora. The herbicide combinations are more effective to control complex weed flora (Bhullar *et al.* 2013, Tiwari *et al.* 2005, Howatt 2005, Zand *et al.* 2010).

Among the herbicide treatments, the highest WCE (70.5%) was recorded in isoproturon 750 g/ha + 2,4-D 500 g/ha during 2014-15 which was similar to isoproturon 750 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha + metsulfuron 4 g/ha and pinoxaden 50 g/ha. In 2016-17 pinoxaden 40 g/ha + metsulfuron 4 g/ha recorded the highest WCE (81.9%) which was at par to isoproturon 750 g/ha + metsulfuron 4 g/ha, in pinoxaden 40 g/ha + carfentrazone 20 g/ha and in pinoxaden 50 g/ha. Lower WI and higher WCE recorded in isoproturon 750 g/ha + 2,4-D 500 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha was due to better weed management achieved in these treatments. Bhullar *et al.* (2013) reported that the application of carfentrazone-ethyl or metsulfuron-methyl was effective in reducing density and biomass of broad-leaf weeds.

Effect on crop growth and yield

Among herbicide treatments, isoproturon 750 g/ha + 2,4-D 500 g/ha had lower WI, which was 16.3% less than the weedy check. During the second year, WI of 6.4% was recorded in pinoxaden 40 g/ha + carfentrazone 20 g/ha, which was 43.7% less than weedy check (**Table 2**). Chlorophyll index ranged from 52.2-57.1 in 2014-15 and 53.9-64.1 in 2015-16. Weedy check and isoproturon 1000 g/ha recorded a significant reduction in chlorophyll index. Weedy check reduced chlorophyll index by about 7.53-16.4%, depicting less nutrient in this plot. Weedy check, isoproturon 1000 g/ha, pinoxaden 40 g/ha + metsulfuron 4 g/ha reduced chlorophyll index in barley leaves which was due to their toxic effect on the leaves which was recovered later on. There may be other physiological processes like nutrient and water absorption, light interception, carbon fixation, and root architecture, which might be hampered by crop weed interference.

A significant decline of 9.5-12.4% was observed in the number of effective tillers per square metre in weedy check conditions as compared to weed-free (p=0.05, **Table 2**). The highest number of effective tillers in weed-free treatment was at par with pinoxaden 50 g/ha, pinoxaden 40 g/ha, followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha. In addition to the above, a combination of isoproturon 750 g/ha + 2,4-D 500 g/ha in 2014-15, and isoproturon 750 g/ha + metsulfuron 4 g/ha in 2015-16 also resulted in effective tillers similar to weed free treatment. In 2015-16, the number of effective tillers recorded in isoproturon 1000 g/ha were similar to the weedy check. The reduction of 9.6-12.4% effective tillers in weedy check indicated that weeds stole the nutrient, water, space, and light. The herbicide treatments of pinoxaden 50 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha, isoproturon 750 g/ha + 2,4-D

Table 2. Effect of weed control treatments on weed index (WI), chlorophyll index, yield attribute, biomass yield and grain yield of barley

Treatment	WI (%)		Chlorophyll index		Effective tillers (/m^2)		Grains /Ear[1]		Biomass yield (t/ha)		Grain yield (t/ha)	
	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16
Pinoxaden 30 g/ha	25.7(19.0)	32.2(29.1)	55.9	57.3	381.7	362.7	29.8	19.1	12.17	11.25	4.90	3.88
Pinoxaden 40 g/ha	23.0(16.7)	27.5(24.7)	56.2	60.6	378.0	364.0	30.8	22.0	12.17	11.83	5.03	4.08
Pinoxaden 50 g/ha	21.6(14.7)	28.9(24.0)	55.5	56.3	387.0	367.7	30.1	20.4	12.67	10.63	5.15	4.17
Pinoxaden 40 g/ha + metsulfuron 4 g/ha	32.5(29.1)	24.4(18.1)	56.7	55.2	375.7	354.7	26.1	22.3	10.67	12.75	4.28	4.50
Pinoxaden 40 g/ha *fb* metsulfuron 4 g/ha	12.2(06.8)	18.1(10.7)	54.7	57.9	389.3	373.0	34.0	23.5	13.67	14.00	5.63	4.92
Pinoxaden 40 g/ha + carfentrazone 20 g/ha	13.6(08.6)	6.4(02.9)	55.3	59.6	388.3	381.3	32.3	25.7	13.17	15.33	5.52	5.50
Isoproturon 1000 g/ha	29.0(24.3)	27.9(23.3)	52.2	54.2	377.3	345.7	27.9	21.7	11.50	11.83	4.57	4.19
Isoproturon 750 g/ha + 2,4-D 500 g/ha	9.6(04.0)	26.4(27.2)	55.0	59.5	395.7	357.3	33.0	20.2	14.00	11.50	5.82	5.17
Isoproturon 750 g/ha + metsulfuron 4 g/ha	23.5(16.7)	20.6(15.0)	53.9	56.2	380.3	366.7	30.8	22.9	12.17	10.83	5.05	4.67
Weedy check	25.9(19.3)	50.1(58.8)	52.8	53.9	365.0	336.0	31.8	13.8	13.00	11.79	4.90	2.25
Weed free	0.8(0.0)	0.8(0.0)	57.1	64.1	403.7	383.7	34.3	24.7	14.00	13.54	6.0	5.54
LSD (p=0.05)	11.3	18.2	4.1	8.3	17.5	16.0	4.6	5.6	1.41	2.78	0.7	0.7

Weed index data were square root transformed and values in the parentheses are original values

500 g/ha and isoproturon 750 g/ha + metsulfuron 4 g/ha in 2014-15 were able to improve the effective tillers comparable to weed free treatment. It might be due to effective control of weeds by reducing the weed density and dry matter and improving the WCE, which provided more space and growth factors to the crop. Chhokar *et al.* (2008) and Ram and Singh (2009) also reported a similar finding.

Number of grains per ear head in pinoxaden 40 g/ha + metsulfuron 4 g/ha and isoproturon 1000 g/ha during 2014-15 were 23.9 - 44.1% less than the weed-free treatment. In 2015-16, pinoxaden 40 g/ha + carfentrazone 20 g/ha recorded the highest value for grains per earhead, which was significantly higher than weedy check but statistically at par to all the herbicide treatments. Weedy check reduced the crop biomass by 7.14% in 2014-15 and 12.9% in 2015-16. The highest biomass was recorded in weed-free during 2014-15 and in pinoxaden 40 g/ha + carfentrazone 20 g/ha during 2015-16. The biomass yield recorded in pinoxaden 50 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha was similar to weed-free treatment during 2014-15. In 2015-16, pinoxaden 40 g/ha + carfentrazone 20 g/ha recorded similar biomass as recorded in pinoxaden 40 g/ha + metsulfuron 4 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and weed-free treatment. Magnitude of expansion in the biomass yield recorded in pinoxaden 50 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha and pinoxaden 40 g/ha + metsulfuron 4 g/ha was similar to weed-free treatment. It was due to less weed density, weed dry matter, WI, and higher yield attributes in these treatments.

Weed-free treatment recorded 6.07 t and 5.54 t/ha grain yield in consecutive years, which was 23.9 and 146.2% higher than the weedy check. All the herbicidal treatments improved the grain yield significantly as compared to weedy check during 2015-16. Still, only isoproturon 750 g/ha + 2,4-D 500 g/ha, and pinoxaden 40 g/ha, followed by metsulfuron 4 g/ha could improve the grain yield significantly than the weedy check. The herbicides treatments like isoproturon 750 g/ha + 2,4-D 500 g/ha, pinoxaden 40 g/ha, followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha recorded grain yield similar to weed-free treatment. The herbicide combinations like isoproturon 750 g/ha + 2,4-D 500 g/ha and pinoxaden 40 g/ha followed by metsulfuron 4 g/ha, pinoxaden 40 g/ha + carfentrazone 20 g/ha recorded similar grain yield as recorded in weed-free due to elimination of weeds which provided sufficient space, moisture, nutrient and light to the crop, which in turn, improved the effective tillers, grains per earhead, and 1000-grain weight, and ultimately the grain yield. Metsulfuron-methyl and carfentrazone-ethyl effectively controlled the broad-leaf weeds in wheat and barley (Howatt 2005, Tiwari *et al.* 2005, Zand *et al.* 2010) as these herbicides have a different mode of action so these can be used as alternative herbicides with 2,4-D to control resistant weeds. Ram and Singh (2009) while working on barley crop also reported that isoproturon 1000 g + metsulfuron 4 g/ha, isoproturon 1000 g/ha, isoproturon 1000 g + carfentrazone 20 g/ha and isoproturon 1000 g + 2,4-D 500 g/ha herbicides enhanced the crop yield by controlling the mixed weed flora. Bhullar *et al.* (2013) reported that the application of carfentrazone-ethyl or metsulfuron-methyl effectively controlled the broad-leaf weeds and enhanced the grain yield of barley.

Economics

Pooled partial budget analysis indicated that the highest gross returns were found in the weed-free treatment (**Table 3**) which was statistically at par with pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha, but significantly higher than other treatments. The net returns and B:C ratio in isoproturon 750 g/ha + 2,4-D 500 g/ha were the highest, and statistically similar to pinoxaden 40 g/ha, followed by metsulfuron 4 g/ha, isoproturon 750 g/ha + metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha and weed-free treatment. Chhokar *et al.* (2008) concluded that pinoxaden 30-35 g/ha is highly effective against grass weeds like *Phalaris minor*, *Avena ludoviciana*, and *Polypogon monspeliensis* under North Indian conditions. Higher net returns with isoproturon 750 g/ha + 2,4-D 500 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha and isoproturon 750 g/ha + metsulfuron 4 g/ha was due to better weed management and higher gross income.

Therefore, it was concluded that isoproturon 750 g/ha + 2,4-D (Na salt) 500 g/ha, pinoxaden 40 g/ha followed by metsulfuron 4 g/ha and pinoxaden 40 g/ha + carfentrazone 20 g/ha and isoproturon 750 g/ha + metsulfuron 4 g/ha can be used for weed control in barley.

Table 3. Pooled partial budget analysis of barley as influenced by different weed management practices

Treatment	Cost of cultivation ($\times10^3$ ₹/ha)	Gross returns ($\times10^3$ ₹/ha)	Net returns ($\times10^3$ ₹/ha)	Benefit: cost ratio
Pinoxaden 30 g/ha	36.80	95.70	58.90	1.60
Pinoxaden 40 g/ha	37.25	99.30	62.05	1.67
Pinoxaden 50 g/ha	37.85	101.60	63.75	1.68
Pinoxaden 40 g/ha + metsulfuron 4 g/ha	37.90	96.15	58.25	1.54
Pinoxaden 40 g/ha followed by metsulfuron 4 g/ha	37.90	115.15	77.25	2.04
Pinoxaden 40 g/ha + carfentrazone 20 g/ha	37.70	120.55	82.85	2.20
Isoproturon 1000 g/ha	36.20	95.70	59.50	1.64
Isoproturon 750 g/ha + 2,4-D 500 g/ha	36.45	120.00	83.55	2.29
Isoproturon 750 g/ha + metsulfuron 4 g/ha	36.45	106.20	69.75	1.91
Weedy check	35.35	77.30	41.95	1.19
Weed free	43.95	126.80	82.85	1.89
LSD (p=0.05)	-	15.20	15.20	0.40

REFERENCES

Anonymous. 2016. *Progress Report of All India Coordinated Wheat and Barley Improvement Project 2015-16.* ICAR-Indian Institute of Wheat and Barley Research, Karnal, India.

Bhullar MS, Kaur S, Kaur T, Singh T, Singh M and Jhala AJ. 2013. Control of broad-leaf weeds with post-emergence herbicides in four barley (*Hordeum* spp.) cultivars. *Crop Protection* **43**: 216–222.

Chhokar, RS, Sharma RK and Verma RPS. 2008. Pinoxaden for controlling grass weeds in wheat and barley. *Indian Journal of Weed Science* **40**: 41–46.

Gerhards R, Dicke D and Oebel H. 2005. Testing and analyzing decision rules for site specific weed control in malt barley (*Hordeum vulgare* L.) using a geographic information system. *Zeitschriftfur Pflanzenkrankheiten und Pflanzenschutz*. **112**: 447–456.

Grando S and Mcpherson HG. 2005. Food Barley: Importance, Uses and Local Knowledge. p.156. In: *International Workshop on Food Barley Improvement*, 14–17 January 2002, Hammamet, Tunisia. ICARDA, Aleppo, Syria.

Howatt KA. 2005. Carfentrazone-ethyl injury to wheat (*Triticum aestivum*) is minimized by some ALS-inhibiting herbicides. *Weed Technology* **19**: 777–783.

Ram H and Singh A. 2009. Studies on efficacy of tank mix herbicides for the control of weeds in irrigated barley (*Hordeum vulgare* L.). *Indian Journal Weed Science.* **41**: 167–171.

Scursoni JA and Satorre EH. 2005. Barley (*Hordeum vulgare*) and wild oat (*Avena fatua*) competition is affected by crop and weed density. *Weed Technology* **19**: 790–795.

Tiwari SN, Tewari AN and Tripathi AK. 2005. Effect of herbicidal weed management on wheat (*Triticum aestivum*) productivity and weed growth. *Indian Journal of Agricultural Sciences* **75**: 569–571.

Watson PR, Derksen DA and VanAcker RC. 2006. The ability of 29 barley cultivars to compete and withstand competition. *Weed Science* **54**: 783–792.

Zand E, Baghestani MA, Alikhani MA, Soufizadeh S, Khayami MM, Azar RP, Sabeti P, Jamali M, Bagherani N, Forouzesh S. 2010. Chemical control of weeds in wheat (*Triticum aestivum* L.) in Iran. *Crop Protection* **29**: 1223–1231.

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Efficacy of pre- and post-emergence herbicides in maize

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ABSTRACT

A field investigation was carried out at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during three consecutive *Kharif* seasons (2016-2018) to study the relative efficacy of herbicides on weed control in maize. Results revealed that, among the herbicidal treatments, atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE at 20 DAS produced less weed count and weed dry matter than rest of the herbicides. Among the herbicidal treatments, maximum growth and yield attributes were recorded with treatment of atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha which was at par with atrazine 0.5 kg/ha *fb* 2,4-D sodium salt 0.5 kg/ha. Yield reduction varied from 12.49% to 54.17% in the herbicide applied plots as compared to weed free treatment. Atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS (4.33 t/ha) and atrazine 1.0 kg/ha PE (3.89 t/ha) proved as effective as weed free treatment (4.91 t/ha) and recorded significantly higher grain yield with net monitory returns of ₹ 47832/ha and B:C ratio of 3.22.

INTRODUCTION

Maize (*Zea mays* L.) being one of the most important cereals, has attained the status of commercial crop. In India, it is cultivated over an area of 8.9 million hectares with a production of about 23 million tones and productivity of 2.58 t/ha (Anonymous 2016). However, in Maharashtra it occupies an area of about 0.9 million hectare with a production of 2.06 million tones and productivity of 2.90 t/ha. (Anonymous 2016). Rainy season maize suffers from severe weed competition depending upon the intensity, nature, stages and duration of weed infestation and yield losses varied from 28-100 per cent (Patel *et al.* 2006). A wide spaced crop suffers from heavy weed infestation due to slow initial growth particularly during *Kharif* season. Weed depletes 30-40% of applied nutrients from the soil. They interfere with efficiency of fertilizer utilization by crops plants because a sizeable portion of the fertilizer added to the soil is used by weed. The quantities of growth factors used by weeds are thus unavailable to the crop. Some of the grassy and broad-leaf weeds found in maize field are *Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Cyanotis oxillaris, Denebra arabica, Tridax procumbens, Lagasca mollis, Euphorbia hirta, Euphorbia geniculata, Parthenium hysterophorus, Digera arvensis, Phyllanthus niruri, Celosia argentina* and *Acalyfa indica.* These are among the deadly weeds of the world which infest the maize field and thus, increase the cost of production as hand weeding is not effective against these weeds.

Management of weeds is considered to be an important factor for achieving higher productivity. Rout *et al.* (1996) revealed that weeds cause enormous damage upto 30 to 50% in maize crop. Uncontrolled weed growth may reduce maize yield as much as 90% (Ratta *et al.* 1991). Weeds also pose severe problems for crop husbandry and infest fallow land, reduce soil fertility and moisture conditions and develop a potential threat to the succeeding crops (Khan *et al.* 2003). Chemical weed management by using pre- and post-emergence herbicides can lead to the efficient and cost-effective control of weeds during critical period of crop weed competition, which may not be possible in manual or mechanical weeding due to its high cost of cultivation (Triveni *et al.* 2017). The present investigation was therefore, done with an objective to study the efficacy of pre and post-emergence herbicides and its effect on weed flora, growth and yield of maize.

MATERIALS AND METHODS

The present field experiment was conducted during three consecutive *Kharif* season (2016-2018) at the research farm AICRP-Weed Management, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) in a randomized block design with three replication having twelve different treatments of weed management. namely weed free , weedy check, 2,4-D sodium salt 0.80 kg/ha PoE 30 DAS, 2,4-D sodium salt 1.20 kg/ha PoE 30 DAS, atrazine 1.0 kg/ha PE, atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS, pendimethalin 1.0 kg/ha PE, atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE, 2,4-D sodium salt 0.5 kg PoE 30 DAS, topramezone 0.0252 kg/ha PoE 20 DAS, halosulfuron-methyl 0.05 kg/ha PoE 20 DAS and metribuzin 0.35 kg/ha PE.

The soil of the experimental field was black and clayey in texture and slightly alkaline in reaction, low in nitrogen, medium in phosphorous and fairly rich in potash. The maize variety '*Maharaja*' was sown at the spacing of 60x30 cm on 23rd June, 25th June and 22nd June during the year 2016, 2017 and 2018, respectively with recommended dose of fertilizer 120:60:30 NPK kg/ha. The application of herbicide was done as per the treatments with manually operated knapsack sprayer attached with a flood jet nozzle. After calibrating the sprayer, water volume used was 700 liter. per ha for PE and 500 liter per ha. for PoE spray. The observations on weed density and weed biomass were taken at 15 days-interval upto harvest from four randomly selected spots from net plot area by using a quadrate of 50 x 50 cm. Then, weeds were grouped as monocot and dicot species. Weed control efficiency (WCE) was calculated by using standard formula suggested by Maity and Mukherjee (2011). Phytotoxicity symptoms due to herbicides on crop were recorded by using a visual score scale of 0-10. Visual assessment of herbicide toxicity on crop was monitored 10 days after application of herbicide in respective treatments. Data on various crop growth and yield attributing characters were statistically analysed as per the standard procedure.

RESULTS AND DISCUSSION

Weed flora

Both broad- and narrow-leaved weeds were observed but dominance of broad-leaved weeds was more in entire field. In general dominance of dicot weeds (67.9%) was recorded during the experimental period. The major weed flora during *Kharif* season in maize crop in the selected area composed of *Xanthium strumarium, Celosia argentea, Tridax procumbens, Phyllanthus niruri, Portulaca oleracae, Lagasca mollis, Euphorbia geniculata, Euphorbia hirta*, *Abutilon indicum*, *Abelmoschus moschatus, Boerhavia diffusa*, C*alotropis gigantea*, *Ageratum conyzoides*, *Bidens pilosa*, *Mimosa pudica*, *Alternanthera triandra, Parthenium hysterophorus, Digera arvensis, Cynodon dactylon, Cyperus rotundus, Amaranthis viridis, Dinebra arabica, Panicum* spp*., Commelina benghalensis, Ischaemum pilosum*, *Digitaria sanguinalis, Dinebra retroflexa, Poa annua, Cyanotis axillaris etc.*

Effect on weeds

Weed control treatments significantly reduced the weed population and weed biomass when compared with unweeded control (**Table 1**). The sequential application of atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS produced less weed count and weed dry matter than rest of the herbicides tested during the study, but it was at par with atrazine 1.0 kg/ha PE. Similar trend of results was also noticed in individual years. This might be due to the herbicidal application alone (higher dose) and in combination which were effective in timely reducing total weed population. Similar results were reported by Gantoli *et al.* (2013), Madhavi *et al.* (2014) and Singh *et al.* (2015).

The sequential application of pre- and post-emergence herbicides was found superior to only post-emergence herbicide applications. The highest weed control efficiency (76.11%) was found with atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS followed by atrazine 1.0 kg/ha PE (71.08%) and atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE. This showed that all the pre-emergence herbicides used in this experiment were compatible, which increased their efficiency over post-emergence herbicide application without any phytotoxic effects causing adversity. Weed index as showed that there was least yield reduction (12.49%) with atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS followed by atrazine 1.0 kg/ha PE (22.88%) and atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE (22.97%). Whereas yield reduction varied from 12.49% to 54.17% in the herbicide applied plots as compared to weed free treatment. The weed index was lower in all the treatments as compared to weedy check. Similar trend of weed control efficiency and weed index were recorded during 2016-17 to 2018-19. This result corroborate with finding of Patel *et al.* (2006), Shantveerayya and Agasimani (2011) and Gantoli *et al.* (2013).

Effect on crop

Maximum cob weight (135.53g) at harvest was found in weed free which was at par with atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS and atrazine 1.0 kg/ha PE. Grain weight per cob was found maximum (86.06 g) and was recorded in weed free treatment followed by atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS and atrazine 1.0 kg/ha PE. Significantly higher test weight was found in weed free over rest of the treatments. The lowest yield attributes values were recorded in weedy check. (**Table 2**). The similar type of result with chemical and mechanical measures of weed control were also reported by Walia *et al*. (2007) and Triveni *et al*. (2017).

Different weed control treatments registered significant increase in grain yield of maize compared to unweeded control. Unweeded control registered the lowest average grain yield, whereas the treatments atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS (4.33 t/ha) and atrazine 1.0 kg/ha PE (3.89 t/ha) proved as effective as weed free treatment (4.91 t/ha) and recorded significantly higher grain yield over rest of the treatments. It may be due to better control of weeds initially by pre-emergence spray and after that late emerging weeds were controlled by post-emergence herbicides. The higher yield in these treatments might be due to more availability of nutrients and moisture as there was less competition between weeds and crop. Similar results were also found by Shantveerayya and Agasimani, (2012), Sharma (2007) and Walia *et al*. (2009). The overall yield levels of maize were low during the study due to less rainfall received at grain filling stage of maize.

Table 1. Weed count, weed dry matter, weed control efficiency and weed index as influenced by different weed control treatments (pooled of three years)

Treatment	Weed density (no./m^2)				Weed dry matter (g/m^2)				Weed control efficiency (%)	Weed index (%)
	2016	2017	2018	Pooled	2016	2017	2018	Pooled		
2,4-D sodium salt 0.80 kg/ha PoE 30 DAS	8.41 (70.3)	8.34 (69.2)	8.74 (76.5)	8.51 (72.0)	7.98 (63.3)	7.91 (62.2)	7.30 (53.3)	7.73 (59.6)	61.20	27.10
2,4-D sodium salt 1.20 kg/ha PoE 30 DAS	8.02 (64.0)	7.95 (62.9)	8.00 (64.0)	7.99 (63.6)	7.83 (60.9)	7.76 (59.8)	7.49 (56.1)	7.69 (58.9)	61.62	26.00
Atrazine 1.0 kg/ha PE	6.54 (42.3)	6.45 (41.2)	6.24 (38.9)	6.41 (40.8)	7.00 (48.6)	6.92 (47.5)	6.11 (37.3)	6.68 (44.5)	71.08	22.88
Atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS	5.81 (33.3)	5.71 (32.2)	6.01 (36.1)	5.84 (33.9)	6.21 (38.2)	6.12 (37.1)	5.91 (35.0)	6.08 (36.7)	76.11	12.49
Pendimethalin 1.0 kg/ha PE	7.79 (60.7)	7.72 (59.5)	7.63 (58.2)	7.71 (59.5)	8.04 (64.2)	7.97 (63.1)	7.78 (60.5)	7.93 (62.6)	59.23	23.54
Atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE	6.81 (46.0)	6.72 (44.9)	6.98 (48.8)	6.84 (46.5)	7.90 (61.9)	7.83 (60.8)	7.95 (63.3)	7.90 (62.0)	67.64	22.97
2,4-D sodium salt 0.5 g PoE 30 DAS	7.08 (49.7)	7.00 (48.5)	7.23 (53.7)	7.14 (50.7)	7.40 (54.2)	7.32 (53.1)	7.15 (51.1)	7.29 (34.7)	65.64	26.25
Topramezone 0.0252 kg/ha PoE 20 DAS	6.86 (46.7)	6.78 (45.5)	7.10 (50.4)	6.91 (47.5)	7.22 (51.7)	7.14 (50.6)	6.84 (46.8)	7.07 (49.7)	59.62	23.36
Halosulfuron-methyl 0.05 kg/ha PoE 20 DAS	7.64 (58.0)	7.56 (56.9)	7.80 (60.8)	7.57 (58.6)	7.96 (62.8)	7.89 (61.7)	7.78 (60.5)	7.88 (61.7)	59.83	24.80
Metribuzin 0.35 kg/ha PE	7.36 (53.7)	7.28 (52.5)	7.57 (57.2)	7.50 (54.5)	7.45 (55.1)	7.38 (54.0)	7.96 (63.3)	7.60 (57.5)	62.56	23.18
Weed free	3.12 (9.3)	2.93 (8.1)	2.91 (8.5)	2.99 (8.6)	2.44 (5.5)	2.20 (4.3)	2.73 (7.4)	2.46 (5.8)	96.35	0.00
Weedy check	12.77 (162.7)	12.73 (161.5)	12.98 (168.0)	12.83 (164.1)	12.42 (153.9)	12.38 (152.8)	12.38 (152.7)	12.39 (153.1)	0.00	54.17
LSD (p=0.05)	0.68	0.60	0.52	0.59	0.49	0.53	0.58	0.45		

Figures in parentheses are original values

Table 2. Yield attributes and grain yield as influenced by weed control treatments (pooled of three years)

Treatment	Cob weight at harvest (g)	Grain weight/ cob (g)	Test wt. (100-seed) (g)	Grain yield (t/ha)			
				2016	2017	2018	Pooled
2,4-D sodium salt 0.80 kg/ha PoE 30 DAS	105.49	58.94	24.69	3.57	3.52	3.71	3.60
2,4-D sodium salt 1.20 kg/ha PoE 30 DAS	115.71	70.41	24.75	3.63	3.58	3.77	3.66
Atrazine 1.0 kg/ha PE	131.62	83.88	25.55	3.77	3.73	4.16	3.89
Atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS	132.18	84.10	26.15	4.27	4.24	4.47	4.33
Pendimethalin 1.0 kg/ha PE	113.62	71.98	25.30	3.74	3.69	3.91	3.78
Atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE	126.98	78.43	25.53	3.77	3.73	3.87	3.79
2,4-D sodium salt 0.5 g PoE 30 DAS	113.56	69.62	24.82	3.61	3.56	3.77	3.65
Topramezone 0.0252 kg/ha PoE 20 DAS	128.88	81.10	25.45	3.76	3.72	3.94	3.81
Halosulfuron-methyl 0.05 kg/ha PoE 20 DAS	112.73	70.87	25.18	3.67	3.63	3.84	3.71
Metribuzin 0.35 kg/ha PE	125.37	77.78	25.38	3.77	3.73	3.92	3.80
Weed free	135.53	86.06	26.55	4.90	4.86	4.99	4.91
Weedy check	97.03	50.56	24.27	2.24	2.21	2.37	2.27
LSD (p=0.05)	8.69	9.16	1.12	0.46	0.48	0.51	0.45

Table 3. Gross monetary returns, net monetary returns and B:C as influenced by weed control treatments (pooled of 3 years)

Treatment	GMR (x10^3 ₹/ha)				NMR (x10^3 ₹/ha)				B:C ratio			
	2016	2017	2018	Pooled	2016	2017	2018	Pooled	2016	2017	2018	Pooled
2,4-D sodium salt 0.80 kg/ha PoE 30 DAS	57.78	56.58	49.47	54.61	37.42	36.82	25.69	33.31	2.84	2.86	2.08	2.59
2,4-D sodium salt 1.20 kg/ha PoE 30 DAS	58.70	57.49	55.39	57.19	38.16	37.56	35.22	36.98	2.86	2.88	2.75	2.83
Atrazine 1.0 kg/ha PE	60.92	59.72	72.33	64.32	40.17	39.57	47.66	42.47	2.94	2.96	2.93	2.94
Atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS	68.21	67.00	72.94	69.38	47.07	46.46	49.97	0.00	3.23	3.26	3.18	3.22
Pendimethalin 1.0 kg/ha PE	59.82	58.62	57.29	58.58	38.28	37.68	33.62	36.53	2.78	2.80	2.42	2.67
Atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE	60.54	59.33	65.01	61.63	39.39	38.79	43.02	40.40	2.86	2.89	2.96	2.90
2,4-D sodium salt 0.5 g PoE 30 DAS	58.30	57.10	55.02	56.81	36.12	35.52	33.45	35.03	2.63	2.65	2.55	2.61
Topramezone 0.0252 kg/ha PoE 20 DAS	60.66	59.46	66.59	62.24	38.45	37.85	41.24	39.18	2.73	2.75	2.63	2.70
Halosulfuron-methyl 0.05 kg/ha PoE 20 DAS	59.47	58.26	56.55	58.09	35.46	34.85	28.64	32.98	2.48	2.49	2.03	2.33
Metribuzin 0.35 kg/ha PE	60.83	59.63	69.45	63.30	39.92	39.32	44.98	41.41	2.91	2.94	2.84	2.89
Weed free	76.98	75.78	76.72	76.50	50.91	48.40	50.85	50.06	2.95	2.77	2.97	2.90
Weedy check	38.77	37.57	35.33	37.22	19.30	18.70	15.86	17.95	1.99	1.99	1.81	1.93

GMR - Gross monetary returns, NMR - Net monetary returns

Economics

Based on an average B:C ratio atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS (3.22) was closely followed by atrazine 1.0 kg/ha PE (2.94) while atrazine 0.5 kg + pendimethalin 0.5 kg/ha PE and 2,4-D sodium salt 1.20 kg/ha PoE 30 DAS recorded more or less identical values (**Table 3**). This might be owing to good seed yield obtained under these treatments because of better management of weeds. The gross monetary return (GMR), net monetary returns (NMR) and B:C ratio was the lowest in weedy check due to more weed density and lesser yield. The highest pooled GMR of ₹ 69381/ha, NMR of ₹ 47832/ha and B:C ratio (3.22) was registered in treatments of atrazine 0.5 kg/ha *fb* tembotrione 0.120 kg/ha PoE 20 DAS closely followed by atrazine 1.0 kg /ha PE. The differences in B:C ratio is due to the cost of herbicides and productivity of the crop. Similar results were obtained by Shantveerayya and Agasimani (2011), Swetha *et al.* (2015) and Gupta *et al.* (2018). Though the weed free treatment resulted in highest seed yield (4.91 kg/ha) owing to 97.42% weed control efficiency but due to higher expenditure incurred on engaging more labours, it could not found as profitable as herbicidal treatments.

REFERENCES

Anonymous. 2016. *Agriculture Stastistics at a Glance*, Department of Agriculture and Cooperation, Government of India.

Gantoli G, Ayala VR and Gerhards R. 2013. Determination of the critical period for weed control in corn. *Weed Technology* **27**: 63–71.

Gupta SK, Mishra GC and Purushottam. 2018. Efficacy of pre and post-emergence herbicide on weed control in *Kharif* maize (*Zea mays L.*). *International Journal of Chemical Studies* **6**(1): 1126–1129.

Khan, BM, N Khan, & Khan IA. 2003. Efficacy of different herbicides on the yield and yield components of maize. *Asian Network for Scientific Information* **3**(2): 300–304.

Madhavi M, Ramprakash T, Srinivas A and Yakadri M. 2014. Topramezone (33.6% SC) + atrazine (50%) WP tank mix efficacy on maize. p 23. In: *Proceedings of Biennial conference on "Emerging Challenge in Weed Management"* Organized by *Indian Society of Weed Science* 15-17, February.

Maity SK, and Mukherjee PK. 2011. Effect of brown manuring on grain yield and nutrient use efficiency in dry direct seeded kharif rice. *Indian Journal of Weed Science* **43**: 61–66.

Patel VJ, Upadhyay PN and Patel BD. 2006. Residual effect of herbicide applied as alone and mixture to kharif maize on succeeding *Rabi* oat and mustard. *Indian Journal of Weed Science* **38**(3&4): 258–262.

Ratta A, Vanderlip RL, Higgins RA and Feyerherm AM. 1991. Suitability of corn growth models for incorporation of weed and insect stresses. *Agronomy Journal* **83**: 757–765

Rout D and Satapathy MR. 1996. Chemical weed control in rainfed maize. *Indian Journal of Agronomy* **41**(1):51–53.

Shantveerayya H. and Agasimani CA. 2011. Effect of herbicides on weed control and productivity of maize (*Zea mays* L.). *Karnataka Journal of Agriculture Science* **25**(1): 137–139.

Sharma. 2007. Growth and development studies in maize as affected by integrated weed management under rainfed condition. *Indian Journal of Agronomy* **52**(4) 321–324.

Singh AK, Parihar CM, Jat SL and Sharma S. 2015. Weed management strategies in maize *(Zea mays)*: Effect on weed dynamics, productivity and economics of the maize-wheat (*Triticum aestivum)* cropping system in Indo-Gangetic Plains. *Indian Journal of Agricultural Sciences* **85**(1): 87–92.

Swetha K. 2015. *Weed Management with New Generation Herbicides in Kharif Maize (Zea mays L.).* M.S. (Ag.) Thesis. *Professor Jayashankar Telangana State Agricultural University*, Hyderabad, India.

Triveni U, Patro SK and Bharathalakshmi M. 2017. Effect of different pre and post emergence herbicides on weed control, productivity and economics of maize. *Indian Journal of Weed Science* **49**(3): 231–235.

Walia U, Singh SS and Sing B. 2009. Integrated control of hardy weed in maize (*Zea mays* L.), *Indian Journal of Weed Science* **39**(1&2): 17–20.

Walia U, Singh SS and Singh B. 2007. Integrated control of hardy weeds in maize (*Zea mays L.). Indian Journal of Weed Science* **39**(1/2): 17–20.

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Weed management effect in blackgram under acidic soils of Manipur

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WCE

ABSTRACT

A field experiment on effect of different weed management practices in blackgram under acidic soils of Manipur was conducted at C.A.U. research farm, Andro, Imphal East of Central Agricultural University, Manipur during *Kharif* season 2013, 2014 and 2015. It was laid out in randomized block design with nine different weed management treatments, *viz.* pre-emergence application of pendimethalin 1.0 kg/ha, pendimethalin + imazethapyr 1.0 kg/ha, pendimethalin 1.0 kg/ha + quizalofop-ethyl 75 g as post-emergence application, pendimethalin + imazethapyr 1.0 kg/ha + quizalofop-ethyl 75 g as post-emergence application, pendimethalin 1.0 kg/ha + imazethapyr 55 g/ha, pendimethalin 1.0 kg/ha + hand weeding at 30 DAS, pendimethalin + imazethapyr 1.0 kg/ha + hand weeding at 30 DAS and twice hand weeding at 20 and 40 DAS. Pendimethalin1.0 kg/ha with hand weeding twice at 20 and 40 DAS recorded significant reduction in weed density, weed biomass and weed control efficiency followed by pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha, + hand weeding at 25 DAS. Significantly higher number of pods per plant, seed and stover yield and growth attributes like plant height and number of branches per plant were recorded under twice hand weeding followed by integrated treatment of pendimethalin + imazethapyr 1.0 kg/ha + hand weeding.

INTRODUCTION

Grain legumes are inseparable ingredients of vegetarian diet, and one of the cheapest weapons for combating the malnutrition problem by supplying dietary protein to the people. India, contributes 27.65% to the global grain legume production and holds 35.2% of the world's pulse acreage (Kundu *et al.* 2009). Surprisingly, about 80% of the area under pulses is currently grown in rainfed land of the country. Blackgram [*Vigna mungo* (L.) Hepper] is one of the important grain legumes grown throughout the country during both in summer and rainy seasons. It fits well in various multiple and intercropping systems due to its rapid growth, shorter duration and nitrogen fixing capacity. The crop can be grown on all types of soils ranging from sandy loam to heavy clay except the alkaline and saline soil. Blackgram contributes about 13% of total area in pulses and 10% of their total production in our country. This crop was cultivated on an area of about 5.44 million hectares (*Kharif* + *Rabi*) and recorded a production of 3.56 million tonnes at a productivity level of 655 kg/ha during 2017 (Anonymous 2018). It is extensively grown in the states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Uttar Pradesh. In Manipur, it is grown during *Kharif* season on an area of 1300 ha with a production of 1072 tonnes with a productivity of 825 kg/ha, which is above the national average (Shashidhar and Samuel 2017).

Blackgram is susceptible to weed competition (Balyan *et al.* 2016) with yield reduction of 42-51% (Malliswari *et al.* 2008, Begum and Rao 2006). Thus, weed management has become imperative to sustain productivity of this crop (Kumar *et al.* 2018). Higher weed density is seen mainly in the rainy season due to ample presence of moisture in the soil and limited field work days (Ramamoorthy *et al.* 2004). The most intensive period for weed competition is around 3 and 6 weeks after sowing which needs control measures for achieving yield targets (Asaduzzaman *et al.* 2010).Weeds can be checked by adopting various methods like eco-physical, biological, chemical and recently through combining direct and indirect approach *i.e.* integrated weed management.

Increasing in labour cost and constraints in availability on time, manual weed control is less economical practice for most of the agricultural crops (Kumar *et al.* 2016), which make us to explore the possibility of herbicidal weed control in blackgram. Chemical measures though become cost-effective; their efficiencies are greatly reduced during *Kharif* due to uncertain rainfall. Application of selective herbicides may control certain species or group of weeds but may not be effective on other weed species. In such situation, while one group of weeds is effectively eliminated, other group takes over and offers severe competition to the crop. High dose of herbicides may leave residue in the soil to injure the subsequent crops and also create the pollution (Pahwa and Prakash 1996).

Very few farmers follow chemical weed control in pulses like blackgram. Pendimethalin, a pre-emergence herbicide is used 0.75 to 1.0 kg/ha to control initial flush of weeds in most of pulses including blackgram. This alone is not sufficient to control the diverse weed flora of the blackgram. Singh *et al.* (2014) discussed the need of post-emergence herbicide to control the second flush of weeds in pulses and to reduce human labour. Kumar (2010) stressed the importance of identifying the broad spectrum effective group of pre- and post-emergence herbicides to be identified to sustain the productivity of the blackgram. Thus, keeping these points in view, an experiment was conducted with the objective of evaluating the relative efficacy of different weed control practices in blackgram in high rainfall areas like Manipur.

MATERIALS AND METHODS

A field investigation was conducted during wet seasons of 2013, 2014 and 2015 at Central Agricultural University Farm, Andro, Imphal East, Manipur, India (latitude of 24° 45' 89'' N, longitude 94° 03' 46'' E with an altitude of 875 m above MSL) to identify the best combination of herbicide and management practices to increase the efficacy of weed control in blackgram under sub-tropical conditions of Manipur. The soils of experimental site was clay loam in texture having acidic pH of 5.2, bulk density 1.39 g/cc and with a high organic carbon content (0.98%). The soil was medium in nitrogen (293.87 kg/ha), low in phosphorus (20.42 kg/ha) and medium in potassium (315.85 kg/ha) contents at the time of initiation of the experiment. The climate of the area is subtropical, received annual average rainfall of 1549 mm and means maximum and mini-mum temperature is were 29.2°C and 21.5°C, respectively.

The experiment comprising of nine treatments was laid out in randomized complete block design. Treatments comprised of pre-emergence application of pendimethalin 1.0 kg/ha, pendimethalin + imazethapyr 1.0 kg/ha, pendimethalin 1.0 kg/ha + quizalofop-ethyl 75 g/ha as post-emergence application, pendimethalin + imazethapyr 1.0 kg/ha + quizalofop-ethyl 75 g/ha as post-emergence application, pendimethalin 1.0 kg/ha + imazethapyr 55 g/ha, pendimethalin 1.0 kg/ha + hand weeding at 30 DAS, pendimethalin + imazethapyr 1.0 kg/ha + and weeding at 30 DAS and twice hand weeding at 20 and 40 DAS. The blackgram variety '*IPU-94-1*' (*Uttara*) having duration of 70-80 days was sown with 30 cm spacing using seed rate of 20 kg/ha. Fertilizer dose of 40:20:20 kg as, NPK per ha using urea (43 kg/ha), single super phosphate (250 kg/ha) and murite of potash (33 kg/ha) was incorporated into the soil well before sowing. A knapsack sprayer fitted with flat-fan nozzle was used to apply the pre-emergence herbicides on the first day after sowing (DAS) and post-emergence herbicides at 20 DAS with a spray volume of 600 l/ha as per the treatments. Suitable plant protection chemicals were sprayed in all the plots to check the incidence of pests and diseases. In the plots ear marked for hand weeding, the operation was done at 20 and 40 days after sowing as per the treatments.

Weed population was recorded by using 0.25 m^2 (side 0.5 m) iron square quadrate at 20 and 40 DAS in all the treatments by random sampling in each plot. Weeds were dried under the sun and then in an oven at 70^0C for 72 h, weighed and converted into g/m^2. The data was analysed after subjecting the original data to transformation using square root of ($\sqrt{x+0.5}$). Weed control efficiency (WCE) was calculated as per formula suggested by Patil and Patil (1983).

Five random plants were selected from each plot at 30 DAS to record observations on nodulation and plant growth and yield parameters, *viz.* plant height (cm), no. of branches per plant at maturity, no. of pods per plant, number of seeds per pod, test weight (g), seed and stover yield (kg/ha) were recorded at harvest.

Statistical analysis of the data was done as per the Fisher's analysis of variance technique for the experimental designs and treatment means were compared using least significant difference test at 5% probability level using t-test and calculating LSD values. The economics of treatments was computed on the basis of prevailing market prices of inputs and outputs (₹ 4500/- per quintal of blackgram as per minimum support price) under each treatment. Analysis of variance was performed on all the collected data. Pooling was made over the years as similar trend was noticed during both the years (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Weed studies

The common weeds in the experimental site were *Cyperus rotundus, Cyperus iria* among sedges and *Echinochloa colona*, *Echinochloa crus-galli, Cynodon dactylon*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Setaria glauca*, *Eleusine india* among grasses and *Commelina benghalensis*, *Ageratum conyzoides*, *Euphorbia hirta*, *Amaranthus spinosus, Phyllanthus niruri and Trianthema monogyna*, *Ipomoea pestigridis*, *etc*. were the commonly seen broad-leaved weeds in the experimental site. The weed intensity was in the order of sedges>grasses> broad-leaved weeds during all the years of cropping seasons.

The critical period of weed infestation in blackgram is 4-7 weeks after sowing. Weed infestation during this period reduces productivity of the crop. It is apparent from the results that all the treatments significantly reduced the density and dry weight of weeds at all the growth stages of crop in comparison to un-weeded control that was observed to be the most severely infested by weeds. The highest weed density of 122.6 per m^2 was noted in weedy check plot at 30 DAS that increased to 172.8 at 45 DAS (**Table 1**).

Significantly lower weed intensity and weed dry weight which reflected the best control of weeds was recorded with pre-emergence application of pendimethalin + imazethapyr plus hand weeding at 20 DAS (43.3/m^2 and 32.0 g/m^2). This could be ascribed to the competition of weeds for moisture, nutrients, space and shadiness and short life cycle of weeds resulting in extermination of the some species. Among the herbicide applications, the pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha (48.4 g/m^2 and 37.2 g/m^2) was effective reducing the weed population at 30 DAS, which was at par with pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + hand weeding at 30 DAS (43.3 and 32 g/m^2) at 30 DAS. The pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha (66.0 g/m^2 and 48.2 g/m^2), the combination of the pre-emergence application of pendimethalin+ imazethapyr 1.0 kg/ha + post-emergence application of quizalofop-ethyl 100 g/ha at 20 DAS (66.5 g/m^2 and 44.5 g/m^2) and pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + imazethapyr 55 g/ha as PoE at 20 DAS (67.4 g/m^2 and 55.6 g/m^2) did not differ significantly with respect to weed density but differed significantly with respect to weed dry weight at 45 DAS. The combination of pre-emergence pendimethalin + hand weeding at 30 DAS (70.3 g/m^2 and 60 g/m^2) and pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + hand weeding at 30 DAS (57.3g/m^2 and 44 g/m^2) differed significantly even at 45 DAS. This indicated that effectiveness of herbicide pendimethalin + imazethapyr was very effective in controlling weeds. Similar trend was recorded with weed control efficiency at 30 and 45 DAS (**Table 1**). The increase in density and dry weight of weeds in different treatments was attributed to uninterrupted growth of weeds with greater competitive ability than crop that was utmost suppressed due to profuse growth of weeds.

Efficacy of the herbicidal treatments that were subsequently followed by HW at 30 DAS was better in weed control than sole application of these herbicides (**Table 1**). Pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + HW at 30 DAS was found effective than application of pendimethalin 1.0 kg/ha + HW at 30 DAS. It was equally effective with HW twice and pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha. The superiority of these treatments could mainly be ascribed to the fact that application of herbicide alone inhibited the germination and emergence of weeds during initial growth stage of crop only but at later stages, these herbicides dissipated and deactivated in the soil and next flush of weeds appeared in such plots. The hand weeding done at 30 DAS effectively controlled the subsequent flush of weeds and thus kept the field weed free for a longer duration. Accelerated growth of crop due to looseness of soil and aeration in root zone incurred due to hand weeding could be assigned as another reason of lower density and dry matter of weeds obtained under these treatments.

By removing two initial flushes of weeds, two HW at 20 and 40 DAS reduced the weed growth effectively during most of the growth phases of crop. On the other hand, inhibition of germination and growth of weeds following application of different herbicides might have reduced the weed growth through arresting different metabolic activities and HW done at 30 DAS controlled the second flush of weeds efficiently. These seem to be the most spectacular reason of accumulating lesser dry weight of weeds and consequently higher weed control efficiencies.

The variation in crop-weed competition under different treatments is associated with variation in weed dry production and the corresponding nutrient depletion by weeds that were eventually reflected in weed completion indices. Results indicated that the pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + HW at 30 DAS treatment recorded the lowest weed competition index of 0.92 per cent, only as against in the maximum of 55.3% observed under weedy check. Samant and Mishra (2014) in groundnut reported the post-emergence application of quizalofop-ethyl at 20 DAS followed HW for effective control of grassy weeds, and Vyas and Jain (2003) reported higher weed control efficiency, seed yield with application of imazethapyr over quizalofop-p-ethyl in soybean crop. Similarly, pendimethalin + imazethapyr 1.0 kg/ha as pre-emergence application and pendimethalin+ imazethapyr 1.0 kg/ha + quizalofop-ethyl at 20 DAS were found to be the next best treatments that represented the significantly lower weed intensity and weed dry weight by increasing the weed control efficiency. The treatments with hand weeding components registered higher weed competition indices which incurred higher cost for hand weeding leading the treatments to be less remunerative.

The increased dry matter accumulation of weeds corresponding to reduction in grain yield seemed to be responsible for variation in weed competition indices among different treatments.

Growth and yield of blackgram

On the basis of mean data of three (3) years, two HW at 20 and 40 DAS recorded the highest (820 kg/ha) grain yield in *Kharif* seasons, which was followed by pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + HW 30 DAS (812 kg/ha) (**Table 2**). This provided effective control of weeds and high grain yield of blackgram (Rathi *et al.* 2004). The two HW done on 20 and 40 DAS provided as high grain yield as the weed free treatment (Chand *et al.* 2004, Singh 2011). Several reports on application of pendimethalin 1.0-2.0 kg, pendimethalin 1.0 kg/ha + HW 25 DAS and fluchloralin 0.5-1.5 kg/ha have been reported to provide better grain yield of summer blackgram (Bhandari *et al.* 2004). Similar outcomes have also been reported by Vaishya *et al.* (2003), Gupta 2014 and Jhakar *et al.* 2015. The yield attributing characters like number of pods per plant, number of seeds per pod recorded similar trend as that of seed and stover yield which helped in increasing the yield of these treatments as compared to two HW 20 and 40 DAS, the uncontrolled weeds caused, on an average, 38% reduction in grain yield.

Net returns and B:C ratio were the highest with the application of pendimethalin + imazethapyr 1.0 kg/ha as pre-emergence spray + post-emergence

Table 1. Influence of different herbicides and weed management practices on growth and weed intensity, dry weight and weed control efficiency of blackgram during 2013-2015 (mean of 3 years)

Treatment	Plant height (cm)	No. of branches	No. of pods/ plant	No. of seeds/ pod	Weed intensity (no./m^2)		Weed dry weight (g/m^2)		Weed control efficiency (%)	
					30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Pendimethalin 1.0 kg/ha as PE	27.4	4.20	17.8	4.10	8.6 (74.1)	9.3 (87.5)	7.7 (50.9)	8.1 (65.2)	44.59	57.81
Pendimethalin + imazethapyr 1.0 kg/ha as PE	30.4	4.72	20.9	4.19	7.0 (48.4)	8.1 (66.0)	6.1 (37.2)	7.0 (48.2)	65.44	69.23
Pendimethalin 1.0 kg/ha as PE+ quizalofop-ethyl 100 g/ha as PoE at 20 DAS	29.5	4.44	20.0	3.96	8.0 (63.4)	8.0 (63.9)	7.0 (48.6)	7.5 (55.6)	54.98	64.16
Pendimethalin + imazethapyr 1.0 kg/ha as PE + quizalofop-ethyl 100 g/ha as PoE at 20 DAS	30.9	4.60	21.6	4.19	7.2 (52.7)	8.1 (66.5)	6.3 (39.6)	6.7 (44.5)	63.26	71.56
Pendimethalin 1.0 kg/ha as PE + imazethapyr 55 g/ha as PoE at 20 DAS	29.4	4.51	20.9	3.82	8.6 (74.3)	8.2 (67.4)	7.7 (60.2)	7.5 (55.6)	44.86	63.89
Pendimethalin 1.0 kg/ha as PE+ manual weeding at 30 DAS	29.9	4.40	18.8	4.05	8.3 (68.5)	8.4 (70.3)	7.6 (57.4)	7.9 (63.0)	46.69	60.03
Pendimethalin+ imazethapyr1.0 kg/ha as PE + manual weeding at 30 DAS	32.2	5.20	23.2	4.18	6.6 (43.3)	7.6 (57.3)	5.7 (32.0)	6.6 (44.0)	70.19	72.00
Two manual weeding at 20 and 40 DAS	33.6	5.83	24.7	4.12	4.7 (21.9)	5.3 (28.3)	4.4 (19.5)	4.7 (21.5)	81.90	86.03
Weedy check	23.2	3.50	11.2	3.63	11.1 (122.6)	13.1 (172.8)	10.4 (108.8)	12.5 (157.0)	0.00	0.00
LSD (p=0.05)	2.2	0.31	1.9	0.36	0.41	0.50	0.45	0.45	6.42	4.54

* Data in parentheses are original values; PE – Pre-emergent application; PoE – Post-emergent application

Table 2. Influence of different herbicides and weed management practices on yield economics and weed index of black gram during 2013-2015

Treatment	Seed yield (kg/ha)				Stover yield (t/ha)				Gross returns (x10³ ₹/ha)	Net returns (x10³ ₹/ha)	B:C ratio	Weed index (%)
	2013	2014	2015	Pooled	2013	2014	2015	Pooled				
Pendimethalin 1.0 kg/ha as PE	511	664	668	614	1.18	1.59	1.78	1.52	27.65	6.89	1.33	22.12
Pendimethalin+ imazethapyr 1.0 kg/ha as PE	524	689	753	655	1.31	1.67	1.86	1.61	29.50	8.45	1.40	17.49
Pendimethalin 1.0 kg/ha as PE+ quizalofop-ethyl 100 g/ha as PoE at 20 DAS	522	654	753	643	1.26	1.61	1.80	1.56	28.94	8.93	1.45	19.35
Pendimethalin+ imazethapyr 1.0 kg/ha as PE + quizalofop-ethyl 100 g/ha as PoE at 20 DAS	538	692	839	690	1.30	1.64	1.83	1.59	31.04	12.49	1.67	14.30
Pendimethalin 1.0 kg/ha as PE+ imazethapyr 55 g/ha as PoE at 20 DAS	513	691	827	677	1.24	1.60	1.79	1.54	30.48	7.54	1.33	18.16
Pendimethalin 1.0 kg/ha as PE+ manual weeding at 30 DAS	509	695	963	722	1.22	1.66	1.85	1.58	32.51	3.40	1.12	13.00
Pendimethalin+ imazethapyr1.0 kg/ha as PE + manual weeding at 30 DAS	576	779	1080	812	1.32	1.72	1.91	1.65	36.52	8.55	1.31	0.91
Two manual weeding at 20 and 40 DAS	580	791	1090	820	1.37	1.77	2.07	1.74	36.91	6.49	1.21	0.00
Weedy check	251	355	328	311	1.08	1.43	1.62	1.38	14.01	-5.06	0.73	55.28
LSD (p=0.05)	31.4	39.8	79.9	51.8	0.06	0.07	0.07	0.06	-	-	-	5.64

Note: The data on economics is mean of three years; PE – Pre-emergent application; PoE – Post-emergent application

spray of quizalofop-ethyl 100 g/ha at 20 DAS (₹ 12489/ha and 1.67, respectively) followed by pre-emergence spray of pendimethalin 1.0 kg/ha + quizalofop-ethyl 100 g/ha as post-emergence spray at 20 DAS (₹ 8927 and 1.45) and pendimethalin + imazethapyr 1.0 kg/ha as pre-emergence spray + HW at 20 DAS (₹ 8554 and 1.31). Weedy check though involved the lowest cost of cultivation yet it provided the lowest net returns (Singh 2011) (**Table 2**).

It is reflected from results that different weed control treatments evaluated for their efficacy in present investigations differed significantly in their effect on plant height, branches per plant in blackgram (**Table 1**). The variation in treatments and their effect on growth attributes has been found to be directly associated with almost similar variation in weed control. All the treatments significantly enhanced the growth parameters of crop at most of the stages over weedy check plots. The maximum plant height and number of branches per plant were recorded with the treatment with hand weeding at 20 and 40 DAS at harvest (33.6 and 5.83 cm). This treatment was at par with pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + HW at 30 DAS (32.3 cm and 5.2) at harvest stages. However, the plant height did not differ significantly among rest of the treatments except weedy check. Further, the number of branches did not differed significantly among rest of the treatments except the pre-emergence application of pendimethalin 1.0 kg/ha and weedy check (4.2 and 3.5).

Conclusion

Pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha + HW at 30 DAS was found the most effective with regard to grain yield (812 kg/ha), net returns (₹ 8454/ha) and B:C ratio (1.31). Two hand weeding done at 20 and 40 DAS also produced grain yield of 820 kg/ha with net returns of ₹ 6491/ha and thus proved equally effective and remunerative weed management treatment in blackgram.

REFERENCES

Anonymous. 2018, *Pulses Revolution from Food to Mutritional Security*, Crops Division, Government of India, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare, Krishi Bhavan, New Delhi. 110 001.

Asaduzzaman M, Sultana S, Roy TS and Masu M. 2010. Weeding and plant spacing effects on the growth and yield of blackgram. *Bangaldesh Research Publications Journal* **3**(1): 62–68.

Balyan JK, Choudhary RS, Kumpawat BS and Choudhary Roshan. 2016. Weed management in blackgram under rainfed conditions, *Indian Journal of Weed Science* **48**(2): 173–177.

Begum G and Rao AS. 2006. Efficacy of herbicides on weeds and relay crop of blackgram. *Indian Journal of Weed Science* **38**(1&2): 145–147.

Bhandari V, Singh B, Randhawa JS and Singh J. 2004. Relative efficacy and economics of integrated weed management in blackgram under semi-humid climate of Punjab. *Indian Journal of Weed Science* **36**: 276–277.

Bhowmick Malay K and Gupta Supravo. 2005. Herbicidal-cum-integrated approach to weed management in blackgram, *Journal of Crop and Weed* **2**(1): 75–77.

Chand R, Singh NP and Singh VK. 2004. Effect of weed control treatments on weeds and grain yield of late sown blackgram (*Vigna mungo* L.) during *Kharif* season. *Indian Journal of Weed Science* **36**: 127–128.

Chaudhry A, Ozair Bashir, Malik A and Bashir M. 1981. Critical period of weed–crop competition in blackgram and mungbean, *Pakistan Journal of Agriculture. Research* **10**(4): 341–345.

Dixit JP, Singh Harvendra and Bhadauria SKS. 2012. Quizalofop-ethyl: an effective post emergence herbicide to control grassy weeds of groundnut, *Annals of Plant and Soil Research* **14**(1): 22–24.

Gill GS and Kumar V. 1969. Weed index- a new method for reporting weed control trials. *Indian Journal of Agronomy* **14**: 96–98.

Gomez A and Gomez A. 1984. Statistical Procedure for Agricultural Research. 2nd Ed. New York: John Willey and Sons.

Gupta Vikas, Singh Mahender, Kumar Anil, Sharma BC and Kher Deepak. 2014. Effect of different weed management practices in blackgram (*Vigna mungo* L. hepper) under sub-tropical rainfed conditions of Jammu, India, *Legume Research* **37**(4): 424–429.

Jakhar Prahlad, Yadav SS and Choudhary Rakesh. 2015. Response of weed management practices on the Productivity of blackgram (*Vigna mungo* L. Hepper), *Jounal Applied and Natural Sci*ences **7**(1): 348–352.

Kumar N. 2010. Imazethapyr: A potential post-emergence herbicide for *Kharif* pulses. *Pulses Newsletter* **21**(3): 5.

Kumar Narendra, Hazra KK and Nadarajan N. 2016, Efficacy of post- emergence application of imazethapyr in summer mungbean (*Vigna radiata* L.), *Legume Research* **39**(1): 96–100.

Kumar Narendra, Hazra KK, Nath CP, Praharaj CS and Singh U. 2018. Grain legumes for resource conservation and agricultural sustainability in South Asia, (Eds: Meena RS, Anup Das, Gulab Singh Yadav and Ratanlal), Grain legumes for soil health and sustainable management, Springer Nature Singapore, https://doi.org/10.1007/978-981-13-0253-4_3

Kundu R, Bera PS and Brahmachari K. 2009. Effect of different weed management practices in summer mungbean [*Vigna radiata* L.] under new alluvial zone of West Bengal, *Journal of Crop and Weed* **5**(2): 117–121.

Malliswari ET, Reddy MT, Sagar KG and Chandrika V. 2008. Effect of irrigation and weed management practices on weed control and yield of blackgram. *Indian Journal of Weed Science* **40**(1&2): 85–86.

Pahwa SK and Prakash J. 1996. Studies on the effect of herbicide on the growth, nodulation and symbiotic natural N fixation in mungbean (*Vigna radiata* L. Wilczeck). *Indian Journal of Weed Science* **28**: 160–163.

Patil VC and Patil SV. 1983. Studies on weed control in bamboo. *Indian Journal of Weed Science* **15**: 83–86

Ramamoorthy K, Lourduraj AC, Thiyagarajan TM, Prem Sekhar M and Steware BA. 2004. Weeds and weed control in dryland agriculture a review, *Agriculture. Re*views **25**(2): 79–99.

Rathi JPS, Tewari AN and Kumar M. 2004. Integrated weed management in blackgram (*Vigna mungo* L.). *Indian Journal of Weed Science* **36**: 218–220.

Samant TK and Mishra KN. 2014. Efficacy of post-emergence herbicide quizalofop ethyl for controlling grassy weeds in groundnut *Indian Journal of Agricultural Research* **48**(6) 488-492.

Shashidhar KS and Samuel Jeberson. 2017. Effect of different weed management practices on productivity of blackgram, *CAU Research Newsletter* **8**(2): 4–5.

Singh Guriqbal. 2011. Weed Management in Summer and *Kharif* Season Blackgram [*Vigna mungo* (L.) Hepper], *Indian Journal of Weed Science* **43**(1&2): 77–80.

Singh RP, Verma SK, Singh RK and Idnani LK. 2014. Influence of sowing dates and weeds management on weed growth and nutrients depletion by weeds and uptake by chickpea (*Cicer arietinum*) under rainfed condition. *Indian Journal of Agricultural Sciences.* **84** (4): 468–472.

Vaishya RD, Srivastava BK and Singh G. 2003. Integrated weed management in summer blackgram. *Indian Journal Pulses Research* **16**: 161–162.

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Intercrops and weed management effect on productivity and competition indices of cotton

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Productivity

ABSTRACT

Field experiments were conducted during summer 2016 and winter 2016-17 at Agricultural College and Research Institute, Madurai to study the allelopathic effect of different intercrops and tree leaf extracts in managing weeds and increasing productivity of cotton. The cotton + sorghum intercropping system registered lower weed density at 20, 40 and at 60 days after seeding (DAS) during both the seasons. Among the weed management practices, lower weed density was recorded with pre-emergence application of pendimethalin at 1.0 kg/ha at 20 DAS and with hand weeding twice at 20 and 40 DAS at 40 and 60 DAS during studied periods. The highest cotton equivalent yield (389, 419 kg/ha), land equivalent ratio (1.52, 1.54), monetary equivalent ratio (1.18, 1.17) and system productivity (2.13, 2.39 t/ha) were recorded in cotton + sunflower intercropping system with hand weeding twice at 20 and 40 DAS during both the years. Among the combined applications of intercropping system and tree leaf extracts, cotton + sunflower (1:1) + pre-emergence application of *Mangifera indica* leaf extract at 30% + hand weeding at 40 DAS registered the maximum cotton equivalent yield (349, 374 kg/ha), land equivalent ratio (1.31, 1.34), monetary equivalent ratio (1.0, 1.02) and system productivity (1.81, 2.07 t/ha) during summer 2016 and winter 2016-17, respectively.

INTRODUCTION

Cotton (*Gossypium hirsutum*) is one of the major commercial crop in India. Cotton is known for the fibre and oil from seed, which plays a prominent role in the national and international economy. The early slow growth and adoption of wider spacing favours the weeds to grow luxuriously in cotton fields. Weeds remove about 30-50% of applied fertilizer, 20-40% moisture (Jayakumar *et al.* 2008) and reduce seed cotton yield by 13-41% (Iqbal and Cheema 2008). Weeds, besides removing moisture and nutrients, harbour insects and diseases. Poor crop stand due to weed competition has been found to lower production by 30-90% depending upon weed pressure (Singh 2014). Manual weed management practices are laborious and expensive. In spite of herbicides being effective in increasing yield, indiscriminate use of herbicides has resulted in serious ecological implications such as development of herbicide resistance weeds and shift in weed population (Jabran *et al.* 2010). Recently, research attention has been focused to find out alternative strategies for chemical weed control in several crops (Muhammad *et al.* 2014). Reduction in herbicide use is one of major goals of modern agriculture and there is much emphasis in search for alternative weed management strategies that are cheap, safe and sustainable (Hozayn *et al.* 2011). Allelopathy is considered as an effective, economical and environment friendly weed management approach (Iqbal and Cheema 2009).Weed density and biomass may substantially be reduced through intercropping (Poggio 2005). Singh *et al.* (2003) indicated that growing companion plants, which are selectively allelopathic to weeds, may provide a cost effective alternative to the use of synthetic chemicals. The slow initial growth coupled with indeterminate growth habit favours the growing of intercrops in cotton without affecting it's yield (Javid and Anjum 2006). Intercropping has unique capacity to raise the unit profitability without disturbing the cotton ecosystem (Harisudan *et al.* 2009). Hence, the present study was carried out to study the efficacy of intercrops and plant leaf extracts in managing weeds and increase the productivity of cotton.

MATERIALS AND METHODS

Field experiments were conducted at Agricultural College and Research Institute, Madurai during summer 2016 and winter 2016-17. Twenty four treatment combinations comprised of four intercropping as main plots, I_1- cotton + sorghum (1:1), I_2 - cotton + sunflower (1:1), I_3 - cotton + sesame (1:1), I_4- sole cotton, and six weed management practices as sub plots, W_1 - *Prosopis juliflora* leaf extract 30% pre-emergence application (PE) + one hand weeding on 40 days after seeding (DAS), W_2 - *Annona squamosa* leaf extract 30% PE + one hand weeding on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one hand weeding on 40 DAS, W_4 - pendimethalin 1.0 kg/ha PE + one hand weeding on 40 DAS, W_5 - two hand weeding at 20 and 40 DAS, W_6 - control (no weeding or spray). The experiments were laid out in a split plot design with three replications. Healthy and viable seeds of cotton variety '*SVPR 4*' were sown as base crop at the rate of 15 kg/ha. Main cotton crop was sown with row to row spacing of 75 cm and plant to plant spacing of 30 cm, on the same day intercrops were sown in between two rows of cotton crop following 1:1 ratio for main and intercrops. Pre-emergence (PE) application of pendimethalin at 1.0 kg/ha was done at 3 DAS. The plant to plant spacing adopted for intercrop was 30 cm. Leaves of *Prosopis juliflora, Annona squamosa* and *Mangifera indica* at vegetative stage were collected and washed gently with tap water for a few seconds to remove contaminants like dust etc. The fresh leaves of above species were cut into small species, soaked in alcohol and water 1:1 proportion and kept for overnight. After 12 hours, soaked leaves were ground with the help of mixer grinder. From the paste, the leaf extract of each botanical species was prepared by filtration which represented 100% stock solution (Sripunitha 2009). From the stock solution, 30% concentration was prepared and sprayed on 3 DAS by using knapsack sprayer as per the treatment schedule.

Land equivalent ratio (LER)

Land equivalent ratio is the relative land areas under sole crop required to produce the same yield as obtained under a mixed or inter cropping system at the same level of management. It was calculated by the formula suggested by Willey (1979).

$$\text{LER} = \frac{\text{Ya}}{\text{Sa}} + \frac{\text{Yb}}{\text{Sb}}$$

Where,

Ya and Yb = Yield of individual crop 'a' and 'b', respectively in mixture

Sa and Sb = Yields of individual crop 'a' and 'b', respectively in pure stand

Cotton equivalent yield (CEY) and system productivity (kg/ha)

It was calculated by the formula suggested by Willey (1979)

$$\text{CEY} = \frac{\text{Yield of intercrop x Price of intercrop}}{\text{Price of cotton}}$$

System productivity = (CEY + Yield of cotton)

$$\text{In terms of money} = \frac{\text{System productivity (₹/ha)}}{\text{Agricultural year (365 days)}}$$

Competition index (CI)

It is a measure to find out the yield of various crops when grown together as well as separately. It indicates the yield per plant of different crops in mixture and their respective pure stand on a unit area basis. If the yield of any crop, grown together is less than its respective yield in pure stand then it is harmful association but on increased yield means positive benefit (Donald 1963).

$$\text{CI} = \frac{(\text{Yaa} - \text{Yab}) \times (\text{Ybb} - \text{Yba})}{\text{Yaa} \times \text{Yab}}$$

Where,

Yaa = Yield in pure stand of crop 'a'

Ybb = Yield in pure stand of crop 'b'

Yab = Mixture yield of crop 'a' grown with 'b'

Yba = Mixture yield of crop 'b' grown with 'a'

Monetary equivalent ratio (MER)

Monetary Equivalent Ratio (MER) is defined as the sum of the ratios of intercrop monetary returns to the highest sole crop monetary return from the entire land area occupied by all intercrops per unit time (Adetiloye and Adekunle 1989). Mathematically MER can be expressed as

$$\text{MER} = (\text{ra} + \text{rb} + \text{rc}) / \text{Ra}$$

Where,

ra, rb, rc is the monetary returns from intercrops

'Ra' is the highest sole crop monetary return

RESULTS AND DISCUSSION

Total weed density

Among the intercropping system, the cotton + sorghum intercropping system registered lower weed density (**Table 1** and **2**) and biomass (**Table 3** and **4**) during both the seasons and it was at par with cotton + sesame intercropping system. Sole cotton registered higher weed density during both the years. Among the weed management practices, pendimethalin at 1.0 kg/ha PE significantly reduced the weed density and biomass at 20 DAS during the both the years. This was followed by *Mangifera indica* leaf extract at 30% PE. At 40 and 60 DAS, hand weeding twice at 20 and 40 DAS recorded lower weed density and biomass. It was followed by pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS. The maximum weed density was recorded under control during both the seasons.

The interaction effect was significant between intercropping system and weed management practices at 20, 40 and at 60 DAS. The combination of cotton + sorghum intercropping system with pendimethalin at 1.0 kg/ha PE was more efficient in reducing the total weed density and biomass at 20 DAS during Summer 2016 and Winter 2016-17 and it was on par with intercropping of cotton + sesame intercropping system with pendimethalin at 1.0 kg/ha PE. At 40 and 60 DAS, cotton intercropped with sorghum + hand weeding at 20 and 40 DAS registered the lowest weed density and biomass during both the years. This was comparable with intercropping of cotton + sesame intercropping system and hand weeding at 20 and 40 DAS and

Table 1. Effect of intercropping system and weed management practices on total weed density (no./m²) in cotton during summer 2016

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	5.67 (31.7)	5.82 (33.3)	5.76 (32.7)	6.39 (40.3)	5.91 (34.5)	7.24 (52.0)	8.24 (67.3)	7.56 (56.7)	9.23 (84.7)	8.07 (65.2)	5.12 (25.7)	5.52 (30.0)	5.46 (29.3)	6.34 (39.7)	5.61 (31.2)
W_2	5.93 (34.7)	6.10 (36.7)	6.07 (36.3)	6.77 (45.3)	6.22 (38.2)	8.32 (68.7)	8.65 (74.3)	8.46 (71.0)	9.77 (95.0)	8.80 (77.2)	5.76 (32.7)	5.90 (34.3)	5.84 (33.7)	6.77 (45.3)	6.07 (36.5)
W_3	4.74 (22.0)	5.08 (25.3)	4.92 (23.7)	5.37 (28.3)	5.03 (24.8)	6.23 (38.3)	6.89 (47.0)	6.54 (42.3)	7.06 (49.3)	6.68 (44.2)	4.74 (22.0)	4.88 (23.3)	4.78 (22.3)	5.18 (26.3)	4.90 (23.5)
W_4	3.67 (13.0)	4.53 (20.0)	4.06 (16.0)	4.67 (21.3)	4.23 (17.6)	5.31 (27.7)	5.85 (33.7)	5.64 (31.3)	6.07 (36.3)	5.72 (32.2)	4.02 (15.7)	4.26 (17.7)	4.26 (17.7)	4.41 (19.0)	4.24 (17.5)
W_5	7.34 (53.3)	7.63 (57.7)	7.38 (54.0)	9.50 (89.7)	7.96 (63.7)	4.26 (17.7)	4.85 (23.0)	4.78 (22.3)	5.11 (25.7)	4.75 (22.2)	3.14 (9.3)	3.39 (11.0)	3.39 (11.0)	3.72 (13.3)	3.41 (11.2)
W_6	7.82 (60.7)	8.28 (68.0)	8.05 (64.3)	9.70 (93.7)	8.46 (71.7)	10.22 (104.0)	11.34 (128.0)	10.95 (119.3)	12.72 (161.3)	11.31 (128.2)	10.78 (115.7)	11.68 (136.0)	11.37 (128.7)	14.13 (199.3)	11.99 (144.9)
Mean	5.86 (35.9)	6.24 (40.2)	6.04 (37.8)	7.07 (53.1)		6.93 (51.4)	7.64 (62.2)	7.32 (57.2)	8.33 (75.4)		10.78 (36.8)	11.68 (42.1)	11.37 (40.4)	14.13 (57.1)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.26	0.26	0.54	0.52		0.40	0.34	0.74	0.69		0.35	0.51	1.00	1.03	

Table 2. Effect of intercropping system and weed management practices on total weed density (no./m⁻²) in cotton during winter 2016-17

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	4.74 (22.0)	4.92 (23.7)	4.78 (22.3)	6.10 (36.7)	5.14 (26.2)	6.67 (44.0)	7.38 (54.0)	6.94 (47.7)	8.09 (65.0)	7.27 (52.7)	4.78 (22.3)	4.95 (24.0)	4.85 (23.0)	5.79 (33.0)	5.09 (25.6)
W_2	5.46 (29.3)	5.58 (30.7)	5.52 (30.0)	6.36 (40.0)	5.73 (32.5)	7.47 (55.3)	7.97 (63.0)	7.67 (58.3)	8.26 (67.7)	7.84 (61.1)	5.28 (27.3)	5.52 (30.0)	5.37 (28.3)	6.07 (36.3)	5.56 (30.5)
W_3	3.94 (15.0)	4.49 (19.7)	4.49 (19.7)	4.67 (21.3)	4.40 (18.9)	5.87 (34.0)	6.10 (36.7)	6.07 (36.3)	6.39 (40.3)	6.11 (36.8)	4.18 (17.0)	4.49 (19.7)	4.42 (19.0)	4.56 (20.3)	4.41 (19.0)
W_4	3.14 (9.3)	3.34 (10.7)	3.29 (10.3)	3.54 (12.0)	3.33 (10.6)	4.67 (21.3)	5.43 (29.0)	4.88 (23.3)	5.61 (31.0)	5.15 (26.2)	3.39 (11.0)	4.14 (16.7)	3.63 (12.7)	4.18 (17.0)	3.84 (14.3)
W_5	6.79 (45.7)	6.96 (48.0)	6.89 (47.0)	8.42 (70.3)	7.27 (52.7)	3.67 (13.0)	4.10 (16.3)	3.76 (13.7)	4.45 (19.3)	4.00 (15.6)	2.48 (5.7)	3.03 (8.7)	2.80 (7.3)	3.14 (9.3)	2.86 (7.7)
W_6	7.08 (49.7)	7.27 (52.3)	7.11 (50.0)	8.80 (77.0)	7.57 (57.2)	8.92 (79.0)	10.09 (101.3)	9.41 (88.0)	10.99 (120.3)	9.85 (97.2)	10.48 (109.3)	11.17 (124.3)	10.82 (116.7)	12.08 (145.3)	11.14 (125.9)
Mean	5.19 (28.5)	5.43 (30.8)	5.35 (29.9)	6.32 (42.9)		6.21 (41.1)	6.85 (50.1)	6.46 (44.5)	7.30 (57.3)		5.10 (32.1)	5.55 (37.2)	5.32 (34.5)	5.97 (44.9)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.23	0.23	0.48	0.46		0.26	0.24	0.51	0.48		0.22	0.22	0.47	0.45	

Figures in the parenthesis are original values. Others are ($\sqrt{x+0.5}$).

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

intercropping of cotton + sunflower intercropping system and hand weeding at 20 and 40 DAS during the years crop growth. The reduction in total weed density and biomass were more pronounced in cotton + sorghum intercropping system. Intercropping of sorghum, sunflower and sesame in cotton recorded lower weed density than sole cotton. The total weed density was reduced (32.4, 31.8 and 35.6% at 20, 40 and at 60 DAS, respectively during summer 2016 and 33.6, 28.2 and 26.3% at 20, 40 and at 60 DAS, respectively during winter 2016-17) in cotton when intercropped with sorghum than sole cotton during both years of experimentation. Cotton intercropped with sorghum reduced the total weed biomass (21.1, 21.8 and 23.1% at 20, 40 and at 60 DAS, respectively during summer 2016 and 30.3, 22.4 and 21.2% at 20, 40 and at 60 DAS, respectively during winter 2016-17) during the both years. The reduction of weed density and biomass in intercropping might be due to establishment of intercrops on land surface which quickly smothered the weeds and prevented germination. Low weed density and biomass may also be reflective of the allelopathic impacts of sorghum and sunflower which were released by volatilization and root exudation. This fact is supported by Weston and Duke (2003) who reported

Table 3. Effect of intercropping system and weed management practices on total weed biomass (kg/ha) in cotton during summer 2016

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	11.89	12.32	12.01	13.88	12.53	16.30	17.26	16.71	20.38	17.66	11.32	11.75	11.47	13.48	12.01
	(140.8)	(151.2)	(143.8)	(192.1)	(157.0)	(265.2)	(297.4)	(278.8)	(414.8)	(314.0)	(127.6)	(137.6)	(131.0)	(181.3)	(144.4)
W_2	12.82	13.36	13.07	14.43	13.42	17.59	19.76	18.79	21.05	19.30	11.78	12.86	12.19	13.84	12.67
	(163.9)	(178.0)	(170.4)	(207.8)	(180.0)	(308.9)	(390.1)	(352.4)	(442.4)	(373.4)	(138.3)	(164.9)	(148.1)	(191.1)	(160.6)
W_3	10.29	11.44	10.74	11.62	11.02	14.79	15.17	14.90	15.92	15.20	9.65	10.69	10.43	10.91	10.42
	(105.3)	(130.4)	(114.8)	(134.5)	(121.2)	(218.3)	(229.6)	(221.5)	(252.9)	(230.6)	(92.6)	(113.7)	(108.2)	(118.6)	(108.3)
W_4	8.22	8.74	8.41	9.71	8.77	13.78	13.93	13.85	14.00	13.89	7.31	7.97	7.71	8.87	7.97
	(67.1)	(75.9)	(70.3)	(93.8)	(76.8)	(189.4)	(193.5)	(191.3)	(195.6)	(192.4)	(53.0)	(63.0)	(58.9)	(78.1)	(63.2)
W_5	14.23	14.61	14.39	15.82	14.76	11.57	12.21	11.95	12.52	12.06	6.31	6.72	6.53	6.92	6.62
	(201.9)	(213.0)	(206.6)	(249.9)	(217.8)	(133.4)	(148.6)	(142.2)	(156.2)	(145.1)	(39.3)	(44.7)	(42.2)	(47.4)	(43.4)
W_6	14.79	15.16	14.95	16.13	15.26	21.29	22.37	21.70	23.30	22.17	23.16	24.41	23.66	25.82	24.26
	(218.2)	(229.2)	(223.1)	(259.6)	(232.5)	(452.8)	(499.9)	(470.2)	(542.4)	(491.3)	(536.1)	(595.3)	(559.1)	(666.1)	(589.1)
Mean	12.04	12.61	12.26	13.60		15.89	16.78	16.32	17.86		11.59	12.40	12.00	13.31	
	(149.5)	(162.9)	(154.8)	(189.6)		(261.3)	(293.2)	(276.1)	(334.0)		(164.5)	(186.5)	(174.6)	(213.8)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.28	0.21	0.48	0.42		0.70	0.69	1.44	1.38		0.47	0.37	0.82	0.74	

Table 4. Effect of intercropping system and weed management practices on total weeds biomass (kg/ha) in cotton during winter 2016-17

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	11.16	11.46	11.26	12.79	11.67	15.62	16.70	15.79	18.92	16.76	10.25	11.11	10.61	11.57	10.89
	(124.0)	(130.9)	(126.3)	(163.2)	(136.1)	(243.6)	(278.3)	(248.9)	(357.5)	(282.1)	(104.6)	(122.9)	(112.0)	(133.3)	(118.2)
W_2	11.69	12.56	12.00	13.08	12.33	16.98	18.21	17.38	19.66	18.06	11.28	11.45	11.35	12.44	11.63
	(136.1)	(157.2)	(143.5)	(170.6)	(151.8)	(287.9)	(333.1)	(301.4)	(385.9)	(326.6)	(126.7)	(130.5)	(128.4)	(154.2)	(134.9)
W_3	9.61	10.76	10.31	12.50	10.80	13.43	14.72	13.14	15.31	14.15	8.37	9.04	8.48	9.99	8.97
	(91.9)	(115.2)	(105.7)	(155.7)	(117.1)	(179.9)	(216.2)	(172.1)	(233.9)	(200.5)	(69.6)	(81.2)	(71.4)	(99.4)	(80.4)
W_4	7.42	8.22	7.62	10.33	8.40	12.37	12.55	12.48	13.06	12.62	6.49	7.20	6.99	7.84	7.13
	(54.5)	(67.1)	(47.6)	(106.3)	(71.4)	(152.5)	(157.1)	(155.3)	(170.1)	(158.7)	(41.6)	(51.3)	(48.4)	(60.9)	(50.5)
W_5	12.64	12.99	12.74	15.44	13.45	10.36	11.68	10.49	11.95	11.12	4.95	5.48	5.16	5.64	5.31
	(159.3)	(168.3)	(161.9)	(237.8)	(181.8)	(106.9)	(135.9)	(109.6)	(142.3)	(123.7)	(24.0)	(29.5)	(26.1)	(31.3)	(30.4)
W_6	13.63	14.76	14.11	15.62	14.53	20.27	21.41	20.67	22.13	21.12	22.37	24.24	23.50	24.91	27.73
	(185.4)	(217.4)	(198.6)	(243.5)	(211.2)	(410.0)	(457.9)	(426.7)	(489.4)	(446.1)	(499.7)	(587.3)	(551.8)	(619.9)	(564.7)
Mean	11.03	11.79	11.34	13.29		14.84	15.88	14.99	16.84		10.62	11.42	11.02	12.07	
	(125.2)	(142.7)	(132.3)	(179.5)		(230.2)	(262.7)	(235.7)	(296.5)		(144.4)	(167.1)	(156.3)	(183.2)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.44	0.37	0.81	0.75		0.48	0.39	0.85	0.78		0.42	0.27	0.66	0.55	

Figures in the parenthesis are original values. Others are ($\sqrt{x+0.5}$).

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

that suppression of weeds might be due to allelopathic compounds released through root exudation of intercrops. Sorghum and sunflower are reported to have high allelopathic potential, containing several allelochemicals such as sorgoleone, glycosides, terpenoids, flavonoids, alkaloids and phenolics (Iqbal and Cheema 2008). If intercrops are more effective than sole crops in usurping resources from weeds or suppressing weed growth through allelopathy, less weed growth may be obtained (Oliveira *et al*. 2011, Poggio 2005 and Iqbal 2007). Among the weed management practices, in the early stages of the crop growth (20 DAS), total weed density and biomass were reduced greatly by the PE application of pendimethalin at 1.0 kg/ha. This might be due to the fact that initial flush of weeds could not emerge due to effect of pendimethalin. These results were in accordance with that of Chaudhary *et al*. (2011) who observed an effective weed control with PE application of pendimethalin. But at later stages of crop growth (40 and 60 DAS), total weed density and bio mass of grass, sedge and BLW weed density were reduced by hand weeding twice at 20 and 40 DAS. This was due to the early emerging weeds were controlled by first hand weeding and late emerging weeds were removed by second hand weeding with better removal of underground root portions.

Cotton equivalent yield (CEY) and land equivalent ratio (LER)

Crop equivalent yield and land equivalent ratio is an important index assessing the performance of different crops under a set of given circumstances (**Table 5**). Among the treatments, intercropping of cotton + sunflower with hand weeding twice at 20 and 40 DAS produced the maximum cotton equivalent yield and land equivalent ratio during both the years, which was followed by intercropping of cotton + sunflower with PE application of pendimethalin at 1.0 kg/ha + hand weeding at 40 DAS. This may be attributed to better performance and yields of both the component crops under intercropping system. This was accordance with findings of Gajendra *et al.* (2017) and Abdel-Galil and Abdel-Ghany (2014). The lowest CEY and LER was registered with intercropping of cotton + sesame with control and lowest LER was recorded with intercropping of cotton + sorghum with control.

Relative yield total (RYT) and competition index (CI)

Relative yield total and competitive index was considerably influenced by the intercropping system and weed management practices (**Table 6**). Cotton + sesame intercropping system with hand weeding twice at 20 and 40 DAS recorded the highest relative yield total and the lowest value of competitive index during summer 2016 and Winter 2016-17. This was followed by cotton + sesame with PE application of pendimethalin at 1.0 kg/ha + hand weeding at 40 DAS. Abdel-Galil and Abdel-Ghany (2014) reported that groundnut + sesame (3:1) intercropping system recorded higher relative yield of groundnut. Efficiency of productivity in intercropping might be increased by minimizing the interspecific competition between the component populations for growth limiting factors (Dhima *et al.* 2007). The lowest RYT and highest competition index was registered with intercropping of cotton + sorghum with control.

System productivity (t/ha), system productivity (₹/ha/day) and monetary equivalent ratio (MER)

Among the treatments, intercropping of cotton + sunflower with hand weeding twice at 20 and 40

Table 5. Effect of intercropping system and weed management practices on cotton equivalent yield (kg/ha) and land equivalent ratio (LER) in cotton during summer 2016 and winter 2016-17

Treatment	CEY										LER									
	2016					2016-17					2016					2016-17				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	260	320	253	-	278	269	340	290	-	300	0.70	1.26	1.11	-	1.02	0.70	1.21	1.11	-	1.11
W_2	252	303	232	-	262	264	320	273	-	286	0.66	1.12	1.03	-	0.94	0.67	1.14	1.03	-	1.03
W_3	265	349	263	-	292	276	374	292	-	314	0.78	1.31	1.16	-	1.08	0.77	1.34	1.17	-	1.17
W_4	272	372	299	-	314	281	396	324	-	334	0.90	1.48	1.31	-	1.23	0.90	1.49	1.33	-	1.33
W_5	280	389	317	-	329	287	419	338	-	348	0.94	1.52	1.36	-	1.27	0.91	1.54	1.37	-	1.37
W_6	126	128	106	-	120	137	137	121	-	132	0.39	0.44	0.42	-	0.42	0.42	0.48	0.46	-	0.46
Mean	243	310	245	-		252	331	273	-		0.73	1.19	1.07	-		0.73	1.20	1.08	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	27	26	39	35		35	31	41	38		0.08	0.08	0.15	0.14		0.08	0.07	0.16	0.15	

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

Table 6. Effect of intercropping system and weed management practices on relative yield total and competition index of cotton

Treatment	Relative yield total (RYT)										Competition index (CI)									
	2016					2016-17					2016					2016-17				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	0.33	0.64	0.66	-	0.54	0.34	0.62	0.66	-	0.54	1.77	0.12	0.07	-	0.65	1.59	0.15	0.07	-	0.60
W_2	0.32	0.57	0.61	-	0.50	0.32	0.58	0.60	-	0.50	2.01	0.22	0.10	-	0.78	1.81	0.19	0.10	-	0.70
W_3	0.37	0.66	0.69	-	0.57	0.37	0.69	0.70	-	0.59	1.27	0.10	0.05	-	0.47	1.23	0.08	0.05	-	0.45
W_4	0.41	0.75	0.78	-	0.65	0.42	0.77	0.79	-	0.66	0.81	0.02	0.01	-	0.28	0.74	0.02	0.01	-	0.26
W_5	0.43	0.77	0.80	-	0.67	0.42	0.79	0.82	-	0.68	0.71	0.01	0.01	-	0.24	0.71	0.01	0.00	-	0.24
W_6	0.18	0.22	0.24	-	0.21	0.20	0.24	0.27	-	0.24	4.55	2.03	0.88	-	2.49	3.59	1.60	0.69	-	1.96
Mean	0.34	0.60	0.63	-		0.35	0.62	0.64	-		1.85	0.42	0.19	-		1.61	0.34	0.15	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.02	0.02	0.06	0.06		0.03	0.02	0.08	0.07		0.10	0.09	0.18	0.17		0.12	0.10	0.20	0.18	

Table 7. Effect of intercropping system and weed management practices on system productivity and monetary equivalent ratio of cotton during summer 2016

Treatment	System productivity (t/ha)					System productivity in terms of money (₹/ha/day)					Monetary equivalent ratio (MER)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	1.00	1.76	1.70	-	1.48	123	217	210	179	182	0.55	0.98	0.95	-	0.83
W_2	0.94	1.55	1.58	-	1.36	116	191	195	175	169	0.52	0.86	0.88	-	0.75
W_3	1.15	1.81	1.77	-	1.57	141	223	218	199	195	0.64	1.00	0.98	-	0.87
W_4	1.35	2.07	2.00	-	1.81	166	255	247	213	220	0.75	1.15	1.11	-	1.00
W_5	1.41	2.13	2.08	-	1.87	174	262	256	222	229	0.78	1.18	1.16	-	1.04
W_6	0.57	0.60	0.63	-	0.60	70	74	77	69	73	0.32	0.33	0.35	-	0.33
Mean	1.07	1.65	1.63	-		132	204	201	176		0.59	0.92	0.91	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.07	0.10	0.18	0.18		6	9	19	21		0.03	0.04	0.07	0.07	

Table 8. Effect of intercropping system and weed management practices on system productivity and monetary equivalent ratio of cotton based intercropping system during winter 2016-17

Treatment	System productivity (t/ha)					System productivity In terms of money (₹/ha/day)					Monetary equivalent ratio (MER)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	1.12	1.85	1.88	-	1.61	138	228	231	204	200	0.55	0.91	0.92	-	0.79
W_2	1.05	1.75	1.73	-	1.51	130	215	213	186	186	0.52	0.86	0.85	-	0.74
W_3	1.25	2.07	2.00	-	1.77	154	255	246	224	220	0.61	1.02	0.98	-	0.87
W_4	1.51	2.32	2.27	-	2.03	186	287	280	241	249	0.74	1.14	1.12	-	1.00
W_5	1.52	2.39	2.33	-	2.08	188	294	288	251	255	0.75	1.17	1.15	-	1.02
W_6	0.70	0.73	0.78	-	0.73	86	90	96	85	89	0.34	0.36	0.38	-	0.36
Mean	1.19	1.85	1.83	-		147	228	226	199		0.59	0.91	0.90	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.07	0.11	0.18	0.19		8	12	23	24		0.03	0.04	0.08	0.09	

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

DAS (I_2 W_5) recorded the highest system productivity and monetary equivalent ratio which was followed by intercropping of cotton + sesame intercropping system with hand weeding twice at 20 and 40 DAS (**Table 7** and **8**). Hence, it may be inferred that the higher CEY of intercropping system was mainly due to an additional yield of intercrops as a bonus in intercropping system and also higher yield of cotton coupled with higher market price of components crops under the same intercropping system. The results were in close conformity with Gajendra *et al.* (2017). Aasim *et al.* (2008) also revealed that positive monetary index obtained from intercropping of cotton with cowpea and sorghum. The lowest system productivity and monetary equivalent ratio was registered with intercropping of cotton + sorghum with control.

It may be concluded that cotton + sunflower intercropping system with pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS or cotton + sesame intercropping system with pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS may be suggested for better in weed control, higher yield and economic returns. Alternatively, cotton + sunflower or cotton + sesame intercropping system with *Mangifera indica* leaf extract at 30% PE + hand weeding at 40 DAS were also found to be effective in reducing the weed density and biomass and enhanced the productivity of cotton and economic returns.

REFERENCES

Aasim M, Ejaz MU and Karim A. 2008. Yield and competition indices of intercropping cotton (*Gossypium hirsutum* L.) using different planting patterns. *Journal of Agricultural Sciences* **14**: 326–333.

Abdel-Galil, AM and Abdel-Ghany REA. 2014. Effect of groundnut – sesame intercropping and nitrogen fertilizer on yield, yield components and infection of root – rot and wilt diseases. *International Journal of Plant & Soil Science* **3**(6): 623–643.

Adetiloye PO and Adekunle AA. 1989. Concept of monetary equivalent ratio and its usefulness in the evaluation of intercropping advantages. *Tropical Agriculture* **66**: 337–341.

Chaudhary SU, Iqbal J, Hussain M and Wajid A. 2011. Economical weed control in lentils crop. *Journal of* Animal *and* Plant *Sciences* **21**(4): 734–737.

Dhima KV, Lithourgidis AS, Vasilakoglou IB and Dordas CA. 2007. Competition indices of common vetch and cereal intercrops in two seedling ratio. *Field Crops Research* 100: 249–256.

Donald CM. 1963. Competition among crop and pasture plants. *Advances in Agronomy* **15**: 1–118.

Gajendra Singh, Pushkar Choudhary, Dharmraj Saini and Bhanwar Lal Jat. 2017. Effects of legume intercrops on growth, yield and economics of hybrid American cotton under controlled condition. Global *Journal* of *Bio-Science and Bio Technology* **6**(1): 61–82.

Harisudan C, Senthivel S, Arulmozhiselvan K, Vaidyanathan R and Manivannan V. 2009. Blackgram as intercrop in cotton – A Review. *Agricultural Reviews* **30**(3): 219–223.

Hozayn M, Lateef EMA, Sharar FF and Monem AAA. 2011. Potential uses of sorghum and sunflower residues for weed control and to improve lentil yields. *Allelopathy Journal* **27**(1): 15–22.

Iqbal J and Cheema ZA. 2008. Purple nutsedge (*Cyperus rotundus* L.) management in cotton with combined application of sorgaab and S - metolachlor. *Pakistan Journal of Botany* **40**(6): 2383–2391.

Iqbal J and Cheema ZA. 2009. Response of purple nutsedge (*Cyperus rotundus* L.) to crop extracts prepared in various solvents. *Allelopathy Journal* **23**(2): 450–452.

Iqbal J. 2007. *Management of Purple Nutsedge in Cotton Through Allelopathy, Intercropping and Crop Water Extracts Combined with Reduced Herbicide Rates*. PhD Dissertation, University of Agriculture, Faisalabad, Pakistan.

Jabran K, Cheema ZA, Farooq M and Hussain M. 2010. Lower doses of pendimethalin mixed with allelopathic crop water extracts for weed management in canola (*Brassica napus*). *International Journal* of *Agriculture* and *Biology* **12**: 335–340.

Javaid A and Anjum T. 2006. Control of *Parthenium hysterophorus* (L.) by aqueous extracts of allelopathic grasses. *Pakistan Journal of Botany* **38**(1): 139–145.

Jayakumar M, Ponnuswamy K and Amanullah MM. 2008. Effect of sources of nitrogen and intercropping on weed control, growth and yield of cotton. *Research Journal* of *Agriculture* and *Biological Sciences* **4**(2): 154–158.

Muhammad Nawaz Kandhro, Shamsuddin Tunio, Inayatullah Rajpar and Qamaruddin Chachar. 2014. Allelopathic impact of sorghum and sunflower intercropping on weed management and yield enhancement in cotton. *Sarhad Journal of Agriculture* **30**(3): 311–318.

Oliveira AM, Silva PSL, Albuquerque CC, Azevedo CMSB, Cardoso MJ and Oliveira OF. 2011. Weed control in corn via intercropping with gliricidia sown by broadcasting. *Planta Daninha* **29** (3): 535–543.

Poggio SL. 2005.Structure of weed communities occurring in monoculture and intercropping of pea and barley. *Agriculture*, *Ecosystems and Environment* **109**(1-2): 48–58.

Singh HP, Batish DR and Kohli RK. 2003. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. *Critical Reviews in Plant Science* **22**: 239–311.

Singh S. 2014. Sustainable weed management in cotton. *Haryana Journal of Agronomy* **30**(1): 1–14.

Sripunitha A. 2009. Herbal hydration-dehydration treatments for Improving Vigour, Viability and Productivity in Tomato (*Lycopersicon esculentum*. Mill) cv. *'PKM1'*. M.Sc., Thesis, Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu.

Weston A and Duke SO. 2003. Weed and crop allelopathy. *Critical Reviews in Plant Science* **22**: 367–389.

Willey RW. 1979. Intercropping - its importance and research needs. Intercrop Competition and yield advantage. *Field Crops Abstract* **32**: 1–10.

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Efficacy of herbicides on weed control, rhizospheric micro-organisms, soil properties and leaf qualities in tea plantation

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ABSTRACT

Field trials were conducted in Tarai region of Jalpaiguri, West Bengal, India (26°88′ N latitude; 88°32′ E longitude, and 122 m above mean sea level) under natural weed infestations in tea garden during 2017 and 2018 to evaluate the efficacy of herbicides on weed flora, non-target soil organisms, leaf quality and productivity of tea (var. *TV-23*). The pattern of nutrient uptake and soil physico-chemicals properties were also itemized. The treatments were comprised of three doses of glufosinate ammonium 13.5% SL (0.27, 0.34, 0.45 kg/ha), glyphosate 41% SL (1.23 kg/ha), paraquat dichloride 24% SL (0.60 kg/ha) and weedy check within a randomized complete block design, replicated four times. The results revealed that glufosinate ammonium at 0.45 kg/ha was the most efficient against grassy and broad-leaf weeds with higher weed control efficiency (> 90%) and total green leaf yield (3.0 t/ha and 2.96 t/ha). Herbicides did not show any phytotoxicity symptoms on the matured tea plants throughout the observation period. An initial detrimental effect on rhizospheric micro-flora (total bacteria, fungi, and actinomycetes) was imposed by residual toxicity of herbicides but at later stage, no harmful effects were observed. Maximum nutrients uptake and soil available nutrients were determined under the higher dose of glufosinate ammonium. Tea leaf quality did not significantly influence by weed management practices. Based on overall performance, the glufosinate ammonium 0.45 kg/ha may be considered as the best substitute for others post-emergent herbicide against the complex weed floras in tea garden.

INTRODUCTION

India adorned as the second-largest tea producer and consumer in the world by producing more than 1000 million kg of industrial tea from an area of 579.35 thousand hectares (Tea Board of India 2017). The annual turnover of 8 million USD (Bandana *et al.* 2015) from the tea industry not only contributes to the Indian economy but also in employment generation. Amongst the tea producing states, West Bengal acquires second position with the production of 329.7 million kilograms annually, contributes 26% of the national production (Tea Board of India 2017).

Tea, being a perennial crop, remains productive for several decades. So, the long term cultivation of tea in the same location affects the soil quality, specifically the nutrient content is exhausted (Dang 2002). A proficient and integrated agricultural practice including dexterous weed management practices can improve tea production. The competition for nutrients, sunshine, moisture and other resources with weeds reduce tea leaves yield from 12 to 21% (Ilango *et al.* 2010), if weed control practices are not imposed in critical weed infestation period. Weeds meddle with routine operations in the tea garden and act as an anchorage for some insect and disease pest (Wilson 2005). They also impede branching, frame development in young tea and trim down the plucking efficiency (Kumar *et al.* 2017). So, weeding is an important practice for sustainable tea crop production.

Various weed management approaches are advocated for tea plantations. Taking up of preventive measures are advantageous as it minimize the weed seed bank in the soil, which alleviates the present and future population of weed (Banerjee *et al.* 2019). Presently, the involvement of higher cost and manpower crisis at the peak period, mechanical weed control practice becomes unsatisfactory and has been largely replaced by chemical weed control by using herbicides (Biswas *et al.* 2019, Kundu *et al.* 2020a). The mode of action of herbicides performs through the disruption of essential plant physiological processes namely photosynthesis, mitosis and the biosynthesis of pigments and essential amino acids (Kundu *et al.* 2020b). Further, it demands less time, less labour and causing less potential of injuring tea roots and the stem collar (Mirghasemi *et al.* 2012).

Glufosinate ammonium is a broad-spectrum post-emergence herbicide that can be used as a substitute for the glyphosate and others post-emergent non-selective herbicides. It is chemically known as 2-amino-4-hydroxymethyl phosphinoyl butanoic acid having the ability to control annual and perennial weeds non-selectively in both crop and fallow lands when applied as post-emergence (Reddy 2003). To kill the targeted weed species completely, thorough spray coverage of glufosinate is essential, as the permeability of the herbicide through underground rhizomes and stolons is limited (Everman *et al.* 2009). It acts as a glutamine synthetase inhibitor which converts glutamate and ammonia to glutamine (Reddy *et al.* 2011). The inhibition of glutamine synthesis also disrupts the nitrogen assimilation in the plant body, directly and indirectly, slows down the photosynthesis rate by inhibiting the electron flow. The stagnation of ammonia reduces the cell membrane pH which uncouples photo-phosphorylation (Senseman 2007). However, leaf chlorosis within 3-5 DAA (days after application) followed by necrosis within 1-2 weeks is the most common symptom observed in glufosinate treated plot.

Keeping the aforesaid points in view, the present experiment was conducted to optimize the dose of glufosinate ammonium 13.5% SL against the diversified weed flora to enhance the productivity of tea without hampering the tea leaf quality.

MATERIALS AND METHODS

The field experiment was conducted at Tarai region of Jalpaiguri (26° 88′ N latitude; 88° 32′ E longitude), West Bengal in two consecutive seasons of 2017 (September-December) and 2018 (July-October) in a pre-established tea garden. The soil of the experimental site was loamy in texture having slightly acidic pH (5.37) and rich in available major three nutrients (213.88 kg N, 16.01 kg P and 222.14 kg K/ha). The soil color was blackish grey mainly due to presence of high organic matter and poor in bases. The experimental site was situated in a warm and temperate climate. The temperature reached the maximum (34.5^{0}C) in June and it starts dropping from the middle of October and recorded a minimum (11.8^{0}C) in January. Rainfall started during May and very erratic up to October (average annual rainfall 3000 mm). The relative humidity gradually decreased from July to December, accounting 98% and 75% as maximum and minimum values. The field trial was laid out in a randomized complete block design in a tea (var. *TV-23*) garden consisting of seven treatments including three different doses of glufosinate ammonium (13.5% SL) i.e. 0.27, 0.34 and 0.45 kg/ha along with glyphosate 41% SL 1.2 kg/ha and paraquat dichloride 24% SL 0.6 kg/ha and one weedy check as a control plot with four replications. The herbicides were applied in the month of September and August during two seasons, respectively at the active vegetative growth stage (4-6 leaf) of weeds by using knapsack sprayer with a flood jet nozzle WFN 0.040 in a spray volume of 500 L/ha. Bio-efficacy evaluation was recorded at 40 days after application (DAA) according to the numbers and total dry weight of the major weed flora by placing a quadrate of 0.5 × 0.5 m randomly in each plot.

Reduction in weed number (%), reduction in dry weight (%), and herbicide efficiency index (HEI) were worked out by using the following:

Reduction in weed number (%) =

$$\frac{WD_c - WD_t}{WD_c} \times 100$$

Where WD_c and WD_t indicate the weed density (no./m^2) in the control plot and in the treated plot, respectively.

Reduction in weed dry weight (%) =

$$\frac{WDM_c - WDM_t}{WDM_c} \times 100$$

Where WDM_c and WDM_t indicate the weed dry matter weight (g/m^2) in the control plot and in the treated plot, respectively.

Herbicide Efficiency Index (HEI) =

$$HEI = \frac{Y_t - Y_c}{Y_t} \times \frac{WDM_c}{WDM_t}$$

Where Y_t is the crop yield from the treated plot; Y_c is the crop yield from the control plot. Weed control efficiency was calculated based on the data recorded 40 DAA as per the formula is given below:

$$WCE = \frac{X - Y}{X} \times 100$$

Where, X indicates the value of the dry weight of weeds in the unweeded plot.

Y indicates the value of the dry weight of weeds in the treated plot.

The soil was collected at initial, 3, 7, 15, 30 and 45 DAA (days after application) with an auger (5 cm diameter) from the mid-points between tea rows in five locations per plot from a depth of 15 cm and bulked, having almost 200–250 g fresh weight. The colony-forming units (CFU) of fungi, bacteria, and actinomycetes were enumerated in Czapek's Dox medium, nutrient agar, and actinomycetes isolation agar (Hi-media), respectively. Then the serial dilution technique and agar/pour plate methods were followed by using a 1 mL soil solution for plating (Alexander 1978). The microbes were incubated at 30°C after serial dilution and spreading of the soil solution on the respective plates. The populations of bacteria per plate were scored within 3 days, whereas the populations of fungi and actinomycetes were observed after an incubation period of 5–7 days (Das *et al.* 2010; Mondal *et al.* 2018).

Green tea leaf and weed samples from each treatment were collected, oven dried, and ground for analyzing total recoveries of N, P and K at harvest, as per standard methods. At harvest, soil samples were collected from each plot at 0-15 cm depth and analyzed for different physico-chemical properties of post-harvest soil following standard procedures. Bio-chemical properties of tea leaf, namely per cent content of moisture, water extract, alkalinity of water, total ash, water soluble ash, soluble ash, acid insoluble ash and crude fiber in tea leaf were estimated following standard methods given in FSSAI Manual (2015).Total antioxidant activity (% DPPH reduction/mg fresh wt) and total polyphenol content (µg/ml) were determined following the protocols suggested by Armoskaite *et al.* (2011).

The weed density and dry weight were analyzed after subjecting the original data to the square root transformation ($\sqrt{x+0.5}$). The STAR Software version 2.0.1 of International Rice Research Institute, Philippines, 2013 was used for analyzing recorded data on selected parameters. The treatment means were separated using the least significant difference (LSD) at the 5% level of significance.

RESULTS AND DISCUSSION

Weed population and biomass

The experimental plots were mostly infested by broad-leaf weeds (BLWs) followed by grassy weeds. Densities and biomass of weeds were significantly (P=0.05) higher in weedy check **(Table 1** and **2)**. In contrast, among tested herbicides, glufosinate ammonium (GA) 13.5% SL 0.45 kg/ha was found to be the most effective against *Borreria articularis*, *Ageratum houstonianum* as well as other BLWs during 2017, while *Commelina benghalensis* was effectively suppressed with the application of glyphosate 41% SL 1.23 kg/ha; being statistically at par with glufosinate ammonium 13.5% SL 0.34 kg/ha **(Table 1)**. The total grassy weed population was significantly (P=0.05) declined where the treatment plot received the highest dose of glufosinate ammonium (0.45 kg/ha) and this treatment was also proved its superiority for suppressing *Panicum repens* at 40 DAA **(Table 1)**. Other grassy weed species, namely *Sporobolus indicus* and *Digitaria setigera* were efficiently controlled by spraying of glufosinate ammonium (0.34 kg/ha); being statistically at par with its highest dose (0.45 kg/ha) during 2017. It was also revealed that among the tested herbicides, the reduction of total grassy and BLWs density over control was lowest (84.2%, and 73.0%, respectively) with the application of glufosinate ammonium 0.27 kg/ha and the extent of reduction was continuously increased with its higher doses, accounting 91% reduction with glufosinate ammonium 0.45 kg/ha over unweeded control plot. More than 80% weed control with chemical herbicide alone or mixture over control was also confirmed by other investigators (Mirghasemi *et al.* 2012). Among the chemical weed management practices, the lower dry biomass of BLWs was accumulated for both the years with post-emergence application of glufosinate ammonium 0.45 kg/ha; being statistically at par with the result observed from glyphosate treated plot **(Table 2)**. Similar types of results were observed for grassy weeds also during both the years of study. Furthermore, weed dry weight was mostly suppressed (~ 93%) by the herbicide glufosinate ammonium with its higher dose **(Table 3)**. These results also confirmed by Banerjee *et al.* (2018) who found maximum effectiveness of glufosinate ammonium 625 g/ha against versatile weed flora in terms of weed density and dry matter accumulation at different time interval.

Weed control efficiency and herbicide efficiency index

Weed control efficiency (WCE) varied from 74 to 94% and 76 to 97% in grassy and BLWs, respectively during 2017 **(Table 3)**. These results were almost alike for 2018. The application of glufosinate ammonium 0.45 kg/ha showed WCE, accounting 93.6 and 96.6% for BLWs and grassy weeds, respectively in 2017. Experimental plot receiving glyphosate 1.23 kg/ha also exhibited satisfactory WCE in grassy weeds (> 95%) for both of the years **(Table 3)**. The herbicide efficiency index

Table 1. Effects of different weed control treatments on grassy weed population (no./m^2) in tea cultivation at 40 DAA

Treatment	*Sporobulus indicus*		*Digitaria setigera*		*Panicum repens*		Others		Total		Reduction (%) of TWD over control*	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Glufosinate ammonium (0.27 kg/ha)	1.74 (1.83)	1.78 (1.84)	2.37 (2.05)	2.42 (2.07)	1.39 (1.69)	1.42 (1.70)	2.25 (2.01)	2.29 (2.02)	7.75 (3.29)	7.91 (3.32)	73.49	73.00
Glufosinate ammonium (0.34 kg/ha)	0.58 (1.27)	0.59 (1.28)	0.52 (1.23)	0.53 (1.24)	1.05 (1.53)	1.07 (1.54)	1.57 (1.76)	1.62 (1.78)	3.72 (2.44)	3.80 (2.46)	87.27	87.03
Glufosinate ammonium (0.45 kg/ha)	0.93 (1.48)	0.95 (1.49)	0.72 (1.36)	0.73 (1.37)	0.70 (1.35)	0.71 (1.35)	1.35 (1.67)	1.38 (1.68)	3.70 (2.43)	3.77 (2.45)	87.34	87.13
Glyphosate (1.23 kg/ha)	1.97 (1.91)	2.00 (1.92)	1.54 (1.75)	1.58 (1.77)	0.82 (1.41)	0.83 (1.42)	0.45 (1.18)	0.46 (1.19)	4.78 (2.70)	4.87 (2.72)	83.65	83.38
Paraquat dichloride (0.6 kg/ha)	1.05 (1.53)	1.07 (1.54)	2.06 (1.95)	2.10 (1.96)	4.64 (2.66)	4.73 (2.69)	1.23 (1.62)	1.27 (1.63)	8.98 (3.51)	9.17 (3.54)	69.28	68.70
Untreated control	6.72 (3.10)	6.86 (3.13)	10.92 (3.81)	10.62 (3.77)	7.42 (3.23)	7.57 (3.26)	4.17 (2.55)	4.25 (2.57)	29.23 (5.92)	29.30 (5.92)	0.00	0.00
LSD (p=0.05)	0.46	0.72	0.42	0.42	0.36	0.86	0.42	0.51	0.63	0.63	0.16	0.53

Original figures in parentheses were subjected to square-root transformation ($\sqrt{x+0.5}$) before statistical analysis; DAA, Days after application; LSD, Least significant difference; *Reduction (%) of total weed density (TWD) over control was calculated based on original (non-transformed) data.

Table 2. Effects of different weed control treatments on broad leaf weed population (no./m^2) in tea cultivation at 40 DAA

Treatment	*Borreria articularis*		*Ageratum houstonianum*		*Commelina benghalensis*		Others		Total		Reduction (%) of TWD over control*	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Glufosinate ammonium (0.27 kg/ha)	2.90 (2.21)	2.77 (2.18)	1.96 (1.91)	1.87 (1.88)	2.44 (2.07)	2.32 (2.03)	3.94 (2.49)	3.77 (2.45)	11.23 (3.86)	10.73 (3.79)	74.19	84.25
Glufosinate ammonium (0.34 kg/ha)	1.05 (1.53)	0.56 (1.26)	0.83 (1.42)	1.68 (1.80)	1.50 (1.74)	2.21 (2.00)	1.23 (1.62)	3.34 (2.34)	4.61 (2.66)	6.71 (3.10)	89.40	90.15
Glufosinate ammonium (0.45 kg/ha)	0.58 (1.27)	0.56 (1.26)	0.62 (1.30)	0.59 (1.28)	2.32 (2.03)	0.77 (1.39)	1.02 (1.52)	3.12 (2.28)	4.54 (2.64)	6.13 (2.99)	89.57	91.00
Glyphosate (1.23 kg/ha)	0.58 (1.27)	0.58 (1.27)	1.75 (1.83)	0.63 (1.30)	0.82 (1.41)	2.24 (2.01)	1.46 (1.72)	3.37 (2.35)	4.61 (2.66)	6.83 (3.12)	89.40	89.97
Paraquat dichloride (0.6 kg/ha)	4.75 (2.69)	4.53 (2.64)	3.40 (2.35)	3.25 (2.31)	3.48 (2.38)	3.32 (2.33)	2.59 (2.12)	11.18 (3.85)	14.23 (4.28)	22.29 (5.23)	67.29	67.28
Untreated control	9.62 (3.61)	9.19 (3.54)	18.14 (4.77)	17.32 (4.67)	7.31 (3.21)	6.98 (3.15)	8.45 (3.42)	34.64 (6.40)	43.51 (7.11)	68.12 (8.76)	0.00	0.00
LSD (p=0.05)	0.52	0.67	0.43	0.82	0.48	0.65	0.61	0.78	0.93	1.5	0.27	0.86

Original figures in parentheses were subjected to square-root transformation ($\sqrt{x+0.5}$) before statistical analysis; DAA, Days after application; LSD, Least significant difference; * Reduction (%) of total weed density (TWD) over control was calculated based on original (non-transformed) data.

(HEI) indicates the weed-killing potential of herbicidal treatment and its phytotoxicity on the crop (Mishra *et al.* 2016). In this study, each year glufosinate ammonium with its highest dose proved its superiority over other herbicides each year. In contrast, paraquat dichloride 0.60 kg/ha exhibited least weed killing potential, as seen in HEI values for 2017 and 2018 **(Table 3)**.

Green leaf yield

The data on green leaf yield **(Table 4)** revealed that all the treatments recorded significantly (P=0.05) higher green leaf yield over weedy check. Among the different herbicidal applications, the plot treated with glufosinate ammonium 0.45 kg/ha yielded maximum green leaf during August to October, which had ultimately been reflected in total yield of green tea leaf production (3 t/ha) in 2017. During 2018, the maximum yield (2.96 t/ha) was obtained with glufosinate ammonium 0.45 kg/ha while the untreated weedy check resulted in poor yield (2.48 t/ha). Kumar et al. (2017) established that the maximum green leaf yield of tea (1.17 t/ha) was obtained from the treatment received the higher dose of post-emergence herbicides followed by lower doses. The efficiency of glufosinate ammonium with its utmost

Table 3. Effects of different weed control treatments on the total dry weight of weeds, weed biomass reduction, WCE and HEI in tea cultivation at 40 DAA

Treatment	Total weed dry weight (g/m^2)				Reduction of TWB (%) over control				WCE (%)				HEI	
	BLW		Grassy weeds		BLW		Grassy weeds		BLW		Grassy weeds		2017	2018
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018		
Glufosinate ammonium (0.27 kg/ha)	6.36	5.78	3.59	2.89	82.67	81.64	83.33	85.64	81.70	83.69	83.20	85.64	0.60	0.50
Glufosinate ammonium (0.34 kg/ha)	2.87	2.60	1.54	2.45	92.18	91.74	92.85	87.83	91.74	91.84	92.80	87.83	2.38	1.88
Glufosinate ammonium (0.45 kg/ha)	2.43	1.97	0.72	0.68	93.38	93.74	96.66	96.62	93.51	93.59	96.63	96.62	3.70	2.96
Glyphosate (1.23 kg/ha)	2.66	2.32	0.92	0.70	92.75	92.63	95.73	96.52	93.21	93.45	95.70	96.52	2.75	1.48
Paraquat dichloride (0.6 kg/ha)	9.43	10.57	5.23	4.89	74.31	66.43	75.71	75.71	72.87	73.69	75.53	75.71	0.14	0.11
Untreated control	36.70	31.49	21.53	20.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD (p=0.05)	1.82	2.53	0.97	1.14	0.67	0.35	0.87	0.51	-	-	-	-	-	-

WCE, Weed control efficiency; HEI, Herbicide efficiency index; BLW, Broad leaf weed; TWB, Total weed biomass

Table 4. Effects of different weed control treatments on green tea leaf yield and post-harvest soil nutrient status in tea cultivation

Treatment	Tea leaf yield (t/ha)								Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2017				2018									
	Aug.	Sept.	Oct.	Total	Sept.	Oct.	Nov.	Total	2017	2018	2017	2018	2017	2018
Glufosinate ammonium (0.27 kg/ha)	0.94	0.97	0.76	2.67	1.00	0.97	0.75	2.72	245.3	218.7	19.3	19.0	253.7	254.3
Glufosinate ammonium (0.34 kg/ha)	1.09	1.00	0.84	2.93	1.08	0.99	0.83	2.90	249.6	228.5	20.4	20.9	263.8	261.3
Glufosinate ammonium (0.45 kg/ha)	1.11	1.01	0.88	3.00	1.09	1.00	0.87	2.96	252.1	234.8	22.0	22.5	266.6	265.5
Glyphosate (1.23 kg/ha)	1.20	0.97	0.72	2.89	1.08	0.96	0.70	2.73	250.5	228.4	22.8	21.6	259.1	263.0
Paraquat dichloride (0.6 kg/ha)	0.98	0.83	0.68	2.49	0.96	0.91	0.68	2.56	247.6	220.8	21.2	20.2	256.8	257.1
Untreated control	0.99	0.75	0.67	2.40	0.97	0.86	0.66	2.49	207.6	203.5	17.2	19.0	225.1	234.3
LSD (p=0.05)	0.06	0.06	0.07	0.08	0.08	0.07	0.06	0.07	6.34	6.3	3.45	3.7	6.34	6.8

dose to control the broad spectrum weed flora also reported by Banerjee *et al.* (2018). They revealed that maximum dose of glufosinate ammonium yielded 3.60 t/ha tea green leaf. These results were in tune with the findings of Ghosh *et al.* (2005) and Patra *et al.* (2016).

A strong correlation (R^2= 0.92 and 0.88 in 2017 and 2018, respectively) was found between herbicide efficiency index and tea leaf yield **(Figure 1)**. These results highlighted the poor competitive ability of crops with weeds and the need to control them effectively by suitable herbicides having good killing potential during whole growing season. Chauhan and Opena (2013) also found similar correlation between yields and weed biomass at harvest.

Effect on soil micro-organism

Different weed management treatments significantly (p=0.05) influence the microbial populations at different tea growing phases. All the herbicidal treatments showed an initial depression in the colony count having concomitant effect on growth of soil micro flora (total bacteria, fungi, and actinomycetes). Microbes were least affected where the plots remained free from herbicides (*i.e.* weedy check). The bacterial population sharply declined from 39.43 (initial) to 21.90 CFU × 10^4/g of soil (at 7 DAA) by the residual effect of glufosinate ammonium 0.45 kg/ha after the ending of second seasons, closely followed by glyphosate 1.23 kg/ha **(Figure 2a)**. Thereafter, the bacterial population increased continuously until 60 DAA because of the rapid degradation of herbicides by soil microorganisms. However, the fungi population was counted lower at 7 DAA with the treatment glyphosate 1.23 kg/ha **(Figure 2b)**. Total actinomycetes populations at the end of growing season exhibited the similar trends to that of bacterial populations **(Figure 2c)**. These results were in tune with the findings of Das *et al.* (2010) who reported that the optimum dose of herbicides generally have no longer phototoxic effects on the total rhizospheric bacterial population in the soil. This might be due to the fact that microorganisms have the potentiality to degrade the herbicide molecule and utilize them as a source of biogenic elements that helps their physiological processes (Bera and Ghosh 2013). However, before degradation, the toxicity of herbicides on

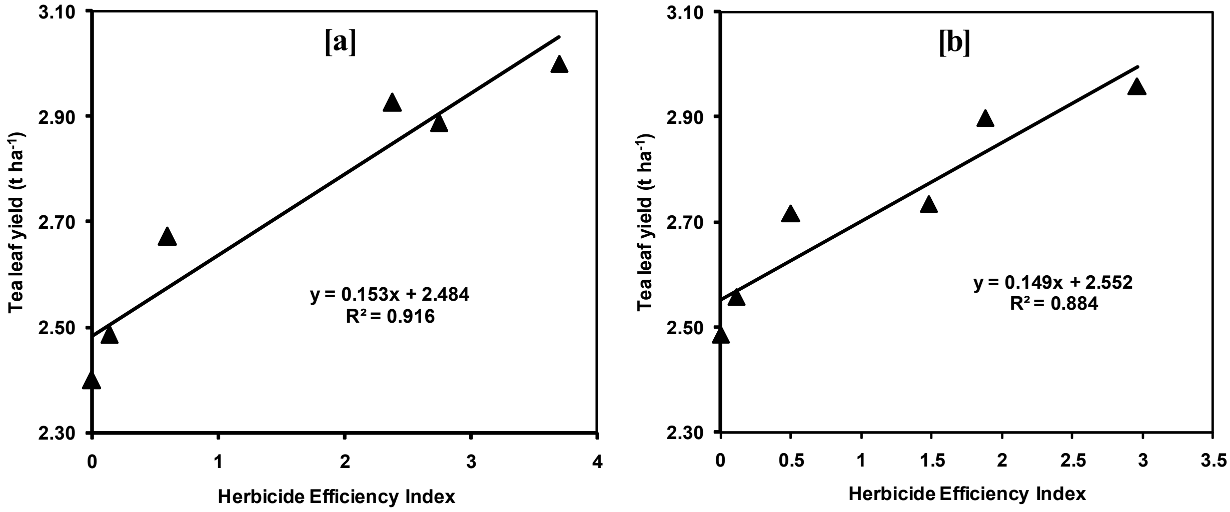

Figure 1. Relationship between herbicide efficiency index (HEI) and tea leaf yield during 2017 [a] and 2018 [b]

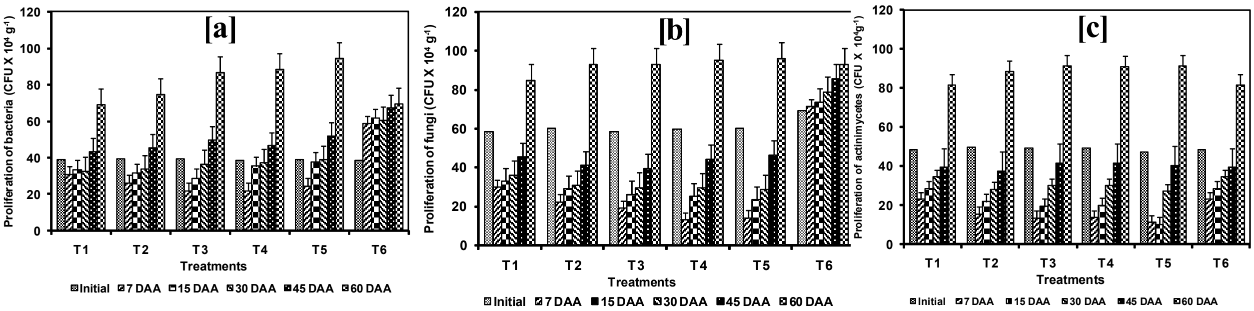

Figure 2. Microbial populations in soil as affected by weed control treatments at different time intervals during 2018 [a=bacteria, b=fungi, c=actinomycetes]; DAA, days after application. Error bars represent LSD (p=0.05).

microorganisms might be reflected by reducing their abundance and activity. Later on, degraded organic herbicides provide carbon-rich substrates which in turn maximize the microbial population in the rhizosphere (Jarvan *et al.* 2014) and influence the transformations and availability of plant nutrients in the soil (Das and Debnath 2006).

Nutrient removal by weeds

Uptake of N, P and K by weeds was positively correlated with weed biomass **(Figure 3a and 3b)**. Total uptake of N, P and K was significantly lowest at 60 DAA with the application of glufosinate ammonium 0.45 kg/ha due to effective control of all the categories of weeds in 2017 **(Figure 3)**. In 2018, the same treatment caused lower nutrient removal; being statistically at par with the application of glyphosate 41% SL. Nutrient removal by weeds increased continuously with decreasing herbicide efficiency index. Because of no herbicide application, the maximum nutrient was removed under weedy check treatment. The findings of Dayaram (2013) were similar with these results. Raj and Syriac (2017) also observed that minimum removal of soil available nutrients by weeds was recorded from the higher dose post-emergent herbicidal application followed by its lower doses. Similarly, an increase in nutrient uptake by increasing the weed population was also reported by Babar and Velayudham (2012).

Nutrient uptake by tea

The nutrient uptake by tea plants was inversely proportional to nutrient uptake by weeds **(Figure 3)**. All weed control treatments were significantly (p=0.05) superior to weedy check in increasing NPK uptake by tea at 60 DAA. Total nutrient uptake was significantly improved with the highest dose of glufosinate ammonium closely followed by its subsequent lower dose in 2018 **(Figure 3a)**. Better control of weeds resulted from herbicide application minimized the crop-weed competition and enhanced nutrient availability as well as uptake **(Figure 3b)**. Nutrient uptake by crop is also a function of nutrient content in the dry matter production. This results were in agreement with the findings of Nath *et al.* (2014).

Soil physico-chemical properties

Results depicted that the application of tested herbicides had no significant influence on different

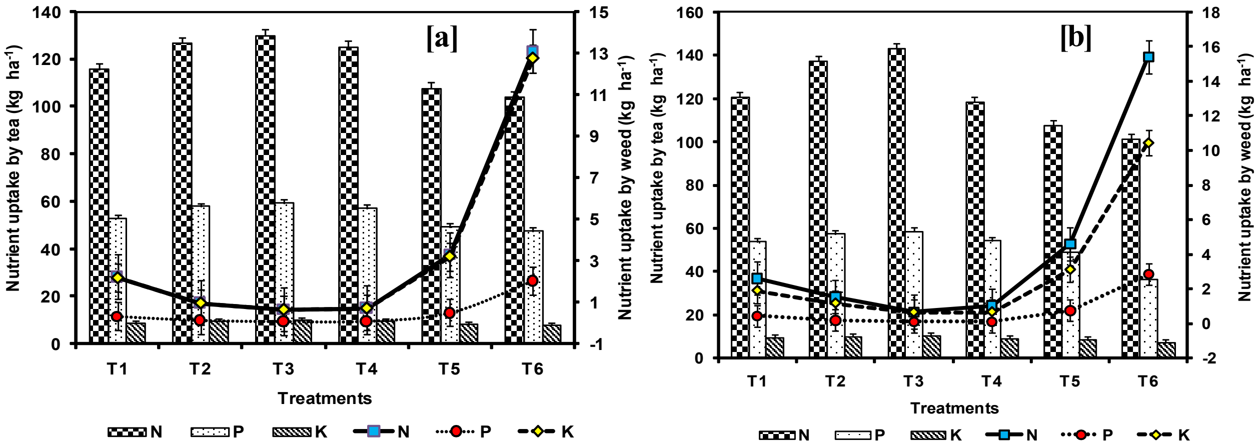

Figure 3. Nutrient uptake (kg/ha) by tea (column) and weed (line) during 2017 [a] and 2018 [b].

Error bars represent LSD (p=0.05).

Table 5. Effects of different weed control treatments on green tea leaf quality at harvest (mean data of 2 years)

Treatment	Moisture (%)	Water extract (%)	Total Ash (%)	WSA (%)	AWSA (%)	AIA (%)	CF (%)	AOA (%)	TPC (µg/ml)
Glufosinate ammonium (0.27 kg/ha)	7.25	34.25	5.94	60.92	2.19	0.20	4.96	51.02	0.010
Glufosinate ammonium (0.34 kg/ha)	7.55	34.32	6.08	61.28	1.84	0.14	5.14	49.61	0.020
Glufosinate ammonium (0.45 kg/ha)	7.43	34.24	5.97	61.62	2.23	0.17	5.01	50.00	0.017
Glyphosate (1.23 kg/ha)	7.21	34.10	6.14	61.57	1.98	0.18	4.87	49.52	0.042
Paraquat dichloride (0.6 kg/ha)	7.15	33.94	6.21	60.84	2.13	0.12	5.11	50.21	0.024
Untreated control	7.57	34.28	6.32	61.37	2.08	0.18	5.08	51.32	0.031
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

WSA, Water soluble ash; AWSA, Alkalinity of Water Soluble Ash; AIA, Acid insoluble ash; CF, Crude Fibre; AOA, Antioxidant Activity; TPC, Total Polyphenol Content; NS, Non-significant

physico-chemical properties *viz.* soil pH, electrical conductivity (EC), bulk density (BD) and water holding capacity (WHC) in both the years of study.

The critical appraisal of N, P and K availability at harvest stage revealed that two doses of glufosinate ammonium *viz.* 0.45 kg/ha and 0.34 kg/ha and the application of glyphosate 1.23 kg/ha were more effective in maintaining a high level of available N, P and K content in the soil during both the years **(Table 4)**. The maximum removal of all three major nutrients was observed in the weedy check situation. This might be due to severe competition exerted by the rapid growth of weed population throughout the experimental periods having a competitive advantage in absorbing more soil available nutrients over the crop. Improvement of soil nutrient availability due to the control of weeds was also reported earlier by Dayaram (2013).

Quality assessment of tea leaf

The cultivation of tea from the Darjeeling region is globally well known for its fine quality and flavour. The results obtained from the present study revealed that the tested herbicides had no significant influence to alter the tea leaf quality **(Table 5)**. However, the moisture content of tea leaf which is related to its storage and stability was ranged from 7.15 to 7.57 and the values of water extract per cent were greater than 32% irrespective of all treatments (**Table 5**), which met the all standard values of ISO 3702 (2011). The other values namely, total ash per cent, water-soluble ash and its alkalinity, acid insoluble ash and crude fibre per cent, and total polyphenol content also met the all standard values of ISO 3702 (2011). The phenolic compounds that are present in tea leaves are known to be one of the main factors in determining the drinking quality (Yao *et al.* 2005).

Conclusion

The present experiment discerns the effectiveness of herbicides on various weed floras in the tea garden, their residual effects on non-target organisms and soil properties. It can be concluded that herbicide glufosinate ammonium 13.5% SL 0.45 kg/ha had the highest potential to control diversified weed flora in tea garden within a critical crop-weed infestation period that resulted in about 19% yield increment of green tea leaves over control without showing any phytotoxicity on plants. There was no long-term adverse effect of the applied herbicides on the microbial population in soil rhizosphere and on soil available nutrients. Additionally, the improvement of nutrient uptake by tea leaves was also observed with the same treatment. The results of this study also concluded that the bio-chemical quality parameters of the tea were within the safe limit and can be used for both domestic consumption and commercial intension.

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REFERENCES

Alexander M. 1978. *Introduction to Soil Microbiology*. New Delhi: Wiley Eastern Ltd.

Armoskaite V, Ramanauskiene K, Maruska A, Razukas A, Dagilyte, A, Baranauskas A. and Briedis V. 2011. The analysis of quality and antioxidant activity of green tea extracts. *Journal of Medicinal Plants Research* **5** (5): 811–816.

Babar SR. and Velayutham A. 2012. Weed management practices on nutrient uptake, yield attributes and yield of rice under system of rice intensification. *Madras Agricultural Journal* **99** (1-3): 51–54.

Bandana B, Sharma N, Joshi R, Gulati A. and Sondhia S. 2015. Dissipation kinetics of glyphosate in tea and tea-field under northwestern mid-hill conditions of India. *Journal of Pesticide Science* **40**(3): 1–5.

Banerjee H, Garai S, Sarkar S, Ghosh D, Samanta S. and Mahato M. 2019. Efficacy of herbicides against canary grass and wild oat in wheat and their residual effects on succeeding green gram in coastal Bengal. *Indian Journal of Weed Science* **51**: 246. https://doi.org/10.5958/0974-8164.2019.00052.2.

Banerjee S, Kundu K, Bera S. and Soren C. 2018. Bio-efficacy and phytotoxicity of glufosinate ammonium13.5% SL on weed flora of tea. *Journal of Crop and Weed* **14**(3): 161–164.

Bera S. and Ghosh RK. 2013. Soil Microflora and weed management as influenced by atrazine 50% WP in sugarcane. *Universal Journal of Agricultural Research* **1**(2): 41–47.

Biswas B, Timsina J, Patra SR, Mishra B, Chakraborti R, Patra A, Mahato B, Banerje P, Ghosh PK, Mukherjee J, Das S, Sarkar S, Adhikary S, Mondal M, Kanthal S, Baidya S, Banerjee S, Mondal B. and Ray BR. 2019. Climate change-resilient rice production technology: A high yielding, water efficient and remunerative option for South Asian farmers. *Global Journal of Agricultural and Allied Sciences* **1**: 20–29. https://doi.org/10.35251/gjaas.2019.003.

Chauhan BS. and Opena J. 2013. Weed management and grain yield of rice sown at low seeding rates in mechanized dry-seeded systems. *Field Crops Research* **141**: 9–15. DOI: 10.1016/j.fcr.2012.11.002

Dang MV. 2002. *Effects of Tea Cultivation on Soil Quality in the Northern Mountainous Zone*, Vietnam. Ph.D. Thesis. University of Saskatchewan, Canada.

Das AC and Debnath A. 2006. Effect of systemic herbicides on N_2-fixing and phosphate solubilizing microorganisms in relation to availability of nitrogen and phosphorus in paddy soils of West Bengal. *Chemosphere* **65**:1082–1086.

Das TK, Sakhuja PK. and Zelleke H. 2010. Herbicide efficacy and non-target toxicity in highland rainfed maize of Eastern Ethiopia. *International Journal of Pest Management* **56**:315–325.

Dayaram RN. 2013. *Bio-efficacy of Post-emergence Micro Herbicides in Transplanted Rice (Oryza sativa L.)*. 134p. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur.

Everman WJ, Mayhew CR, Burton JD, York AC. and Wilcut JW. 2009. Absorption, translocation, and metabolism of 14C-glufosinate in glufosinate-resistant corn, goosegrass (*Eleusine indica*), large crabgrass (*Digitaria sanguinalis*), and sicklepod (*Senna obtusifolia*), *Weed Science* **57**(1): 1–5.

FSSAI 2015. *Manual of Methods of Analysis of Foods Beverages (Coffee, Tea, Cocoa, Chicory) Sugar and Sugar Products & Confectionery Products). Lab Mannual-4*, pp. 24-28.

Ghosh SK, Saha S, Mukharjee J. and Ghosh RK. 2005. Bio-efficacy and phytotoxicity of glyphosate + 2,4-D for weed control in Tea. *Biennial Conference of Indian Society of Weed Science (ISWS) at PAU, Ludhiana.* April 6-9, 2005. Extended Summary, pp. 262.

Ilango RVJ, Saravanan M, Parthibaraj R. and Kumar PM. 2010. Evaluation of excel mera-71 weeds control in tea fields. *Newsletter - UPASI Tea Research Foundation* **20**(1): 1.

ISO 3720. 2011. Black tea – Definition and basic requirements.

Jackson MI. 1967. Soil Chemical Analysis. pp. 183-408. Prentice Hall of India Pvt. Ltd., New Delhi.

Jarvan M, Edesi L, Adamson A. and Vosa T. 2014. Soil microbial communities and dehydrogenase activity depending on farming systems. *Plant Soil Environment* **60**(10): 459–463.

Kumar A, Ghosh A, Mondal D, Ghosh R. and Bandopadhyay P. 2017. Bio-efficacy of ammonium salt of glyphosate 71% SG for weed dynamics in tea (*Camellia sinensis*L.) and its effect on soil microflora. *International Journal of Current Microbiology and Applied Sciences* **6**(8):2160–2170. doi: https://doi.org/10.20546/ijcmas.

Kundu R, Mondal M, Garai S, Poddar R. and Banerjee S. 2020a. Efficacy of herbicides against broad-spectrum weed floras and their effect on non-target soil micro-organisms and productivity in sugarcane (*Saccharum* sp.). *Current Journal of Applied Science and Technology* **39**: 23–32. https://doi.org/10.9734/cjast/2020/v39i230493.

Kundu R, Mondal R, Garai S, Mondal M, Poddar R and Banerjee S. 2020b. Weed management efficiency of post-emergence herbicides in direct-seeded rice and their residuality on soil microorganisms. *Journal of Experimental Biology and Agricultural Sciences* **8**(3): 276–286.

Mirghasemi ST, Daneshian J. and Baghestani MA. 2012. Investigating of increasing glyphosate herbicide efficiency with nitrogen in control of tea weeds. *International Journal of Agriculture and Crop Sciences* **4**(24): 1817–1820.

Mishra MM, Dash R and Mishra M. 2016. Weed persistence, crop resistance and phytotonic effects of herbicides in direct-seeded rice. *Indian Journal of Weed Science* **48**(1):13–16.

Mondal M, Gunri SK, Sengupta A. and Kundu R. 2018. Productivity enhancement of *Rabi* groundnut (*Arachis Hypogaea* L.) under polythene mulching and rhizobium inoculation under new alluvial zone of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences* **7**(9): 2308-2313. https://doi.org/10.20546/ijcmas.2018.709.286.

Mulwa RM and Mwanza LM. 2006. Biotechnology approaches to developing herbicide tolerance/selectivity in crops. *African Journal of Biotechnology* **5**(5): 396–404.

Nath CP, Saha M, Pandey PC, Das TK, Meena RK. and Paul T. 2014. Bioefficacy evaluation of different herbicides on weed population, grain yield and nutrient uptake in direct seeded puddled rice (*Oryza sativa* L.). *Annals of Agricultural Research New Series* **35**:217–223.

Patra PS, Paul T, Tamang A, Choudhury A. and Biswas M. 2016. Evaluation of bio-efficacy and phytotoxicity of glufosinate ammonium 13.5% SL in tea (*Camellia sinensis* L.). *American Journal of Research Communication* **4**: 103-115.

Raj SK. and Syriac EK. 2017. Nutrient availability and nutrient uptake as influenced by the post emergence application of herbicide mixtures. *Journal of Tropical Agriculture* **55** (2): 152–160.

Reddy KN, Zablotowicz RM, Bellaloui, N. and Ding, W. 2011. Glufosinate Effects on Nitrogen Nutrition, Growth, Yield, and Seed Composition in Glufosinate-Resistant and Glufosinate-Sensitive Soybean. *International Journal of Agronomy* **2011**(9)**:**1–9. https://doi.org/10.1155/2011/109280.

Reddy KN. 2003. Impact of rye cover crop and herbicides on weeds, yield, and net return in narrow-row transgenic and conventional soybean (*Glycine max*). *Weed Technology* **17**(1): 28–35.

Senseman SA. 2007. “Glufosinate,” in *Herbicide Handbook*. 247-248pp. Weed Science Society of America, Lawrence, Kan, USA.

Tea Board of India. 2017. http://www.indiatea.org.

Wilson SW. 2005. Keys to the families of flugoromorpha with emphasis on plant hoppers of potential economic importance in the Southeastern United States (*Hemiptera: Auchenorhyncha*). *Florida Entomologist* **88**:464–481.

Yao L, Caffin N, D’Arcy B, Jiang Y, Shi J, Singanusong R, Liu X, Datta N, Kakuda Y. and Xu Y. 2005. Seasonal variations of phenolic compounds in Australia-grown tea (*Camellia sinensis*). *Journal of Agricultural and Food Chemistry* **53** (16): 6477–6483.

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Weed management in dry direct-seeded rice: Assessing the impacts on weeds and crop

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ABSTRACT

Weeds are the major biotic stress limiting productivity, profitability and sustainability of direct-seeded rice (DSR). Effective weed control determines the success of DSR. Therefore, a field study was undertaken to assess the impacts of potential pre- and post-emergence herbicides in sequence and integrated use of herbicides with other methods on weeds and DSR. Eleven weed control treatments comprising of six combinations of pre- and post-emergence herbicides, two brown manuring, one herbicide with manual weeding, and two control (weed-free check and unweeded control) were evaluated in a randomized complete block design with three replications. Results showed that grassy weeds were most dominant, constituting 66.0–91.8% of total weed dry weight across the treatments. Unit increase in weed density (per m^2) and weed dry weight (g/m^2) could reduce rice grain yield by 14.5 and 11 kg/ha, respectively. All weed control treatments impacted weed interference, crop growth and yield significantly. Sequential applications of pendimethalin (1.0 kg/ha) as pre-emergence and ready-mixture of penoxsulam + cyhalofop-butyl (130 g/ha) at 25 days after sowing (DAS) significantly reduced weed dry weight by 87.6% at harvest, and was superior to other treatments. This treatment increased rice grain yield (3.92 t/ha) by 378.9% over unweeded control, gross benefit: cost (2.30) by 31.4% over weed-free check, and gave highest overall impact index (1.27) with an economic threshold level of 9.0 weeds/m^2, and found to be the best weed control option in DSR. Likewise, brown manuring followed by application of metsulfuron-methyl 10% + chlorimuron-ethyl 10% (20 g/ha Almix) at 40 DAS led to 80.3% reduction in weed dry weight, causing significant improvements in crop growth and grain yield (3.67 t/ha) with 30.3% higher gross benefit: cost over weed-free check, and could become a profitable alternative weed control option in DSR.

Direct-seeded rice (DSR) is emerging as a profitable and sustainable rice production system to address the mounting scarcity of fresh water, labour and energy in agriculture sector. Dry seeding of rice avoids need for ponding water vis-à-vis transplanting, thus requires ~36% less water (Mohammad *et al.* 2018) and ~60% less labour (Kumar and Ladha 2011) compared to traditionally grown puddled transplanted rice (TPR), depending on season and types of DSR. However, unlike TPR, it lacks the initial 'head start' over weeds and is subjected to high weed pressure due to dry tillage and alternate wetting and drying conditions. In absence of effective weed control measures, yield losses are greater in DSR than in TPR, which vary from 50-91% (Rao *et al.* 2007, Sen *et al.* 2018). Effective weed management is therefore, key for sustainable rice production under dry-seeded situation. Currently, herbicide has become the most important weed management tool as it offers timely, effective, economical and practical way of weed control. However, sole applications of either pre- or post-emergence herbicides could not control diverse weeds effectively in DSR (Awan *et al.* 2015). Again, over-dependence on similar herbicide(s) may lead to weed shift and/or herbicide-resistant weeds. Fewer studies have highlighted the higher efficacy of sequential applications of pre- and post-emergence herbicides on weeds compared to their sole applications (Awan *et al.* 2015, Chauhan *et al.* 2015). Pre-emergence herbicides initially control germinating weeds and late-emerging weeds are controlled by selective post-emergence herbicides. Response of herbicides is location-specific, depends on climate, soil and types of weeds, and therefore, needs to be evaluated across locations. Further, brown manuring (co-culture of *Sesbania* with rice and subsequent killing with 2, 4-D) has been reported to smother weeds in DSR and enhance rice yield (Maity and Mukherjee 2011, Nawaz *et al*. 2017). In view of these facts, an experiment was formulated with a hypothesis that sequential applications of pre- and post-emergence herbicides and/or integration of herbicides with brown manuring may provide desirable weed control in DSR, leading to higher productivity and profitability.

The experiment was initiated at ICAR–Indian Agricultural Research Institute (IARI), New Delhi, India (28°38' N, 77°10' E and 228.6 m above mean sea-level) under natural weed infestations during the rainy season of 2016. Eleven weed control treatments (**Table 1**) were evaluated in a randomized complete block design with three replications. The field was dry-cultivated before sowing and rice cultivar '*Pusa Sugandh 5*' (125-130 days' duration) was directly sown using a seed drill with a seed rate of 25 kg/ha at 20-cm row spacing. Crop was managed uniformly throughout the growth period, except for weed control. Pre- (at 1 DAS) and post-emergence (at 25 DAS) herbicides were applied with a knapsack sprayer calibrated to deliver 500 litres water per ha through flat-fan nozzle. For brown manuring (BM), *Sesbania* seeds (25 kg/ha) were sown in between the rice rows and subsequently, knocked down with 2, 4-D (0.5 kg/ha) at 28 DAS. An area of 50 cm (along the rows) × 40 cm (across the rows) was randomly selected from two places in each plot and weed samples were collected at 60 DAS and harvest from that area, and categorized into grasses, broad-leaved weeds and sedges. Collected weed samples were first air-dried for 2 days and then oven-dried at 65±5°C until constant dry weight (~48 h), which is more reliable estimate for bio-efficacy evaluation of weed control treatments (Das 2001). Weed control index (WCI), that portrays per cent reduction in weed dry weight per unit area was determined as per Das (2008). Rice crop was harvested at physiological maturity and grain yield was recorded at 14% moisture content. Minimum support price (MSP) was used to calculate the economics. Analysis of data was performed through analysis of variance (ANOVA) using the F-test. Weed data with coefficient of variation (CV) >20% were transformed through square-root method $[(x+0.5)^{1/2}]$ prior to ANOVA to improve the homogeneity of variance (Das 1999). Multiple comparisons of treatment means were made using least significant difference (LSD) method at p=0.05 (Fisher 1960). The relationships between rice grain yield and weed density and dry weight were evaluated using regression analysis.

The economic threshold based on weed density at 60 DAS (end of critical period of weed competition) was worked out as per Uygur and Mennan (1995).

$$Y = [\{(100/He \times Hc) + Ac\}/(Gp \times Yg)] \times 100$$

Where, Y= yield reduction (%) at a weed density; He= herbicide/control efficiency; Hc= herbicide cost; Ac= application cost; Gp= grain price; Yg= weed-free yield

Different impact indices, *viz*. weed persistence index (WPI), weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were worked out as suggested by Mishra and Misra (1997) using the following formulae.

$$WPI = [WD_C \div WD_T] \times [WDM_T \div WDM_C]$$

$$WMI = [Y_T/Y_C] \div [(WDM_C - WDM_T) \div WDM_C]$$

$$AMI = (WMI - 1)$$

$$IWMI = (WMI + AMI) \div 2$$

Likewise, crop resistance index (CRI; Das 2008), treatments efficiency index (TEI; Krishnamurthy *et al*. 1975), weed intensity (WIn; Rana and Kumar 2014) and crop intensity (CIn; Rana and Kumar 2014) were calculated as per following formulae.

$$CRI = (CDM_T \div CDM_C) \times (WDM_C \div WDM_T)$$

$$TEI = [(Y_T - Y_C)/Y_T] \div (WDM_T / WDM_C)$$

$$WIn\ (\%) = [\text{weed density} \div (\text{weed + crop density})] \times 100$$

$$CIn\ (\%) = 100 - WIn$$

Where, Y_T and Y_C, yield in treated and unweeded control (UWC) plot, respectively; WD_T and WD_C, weed density (no./m^2) in treated and UWC plot, respectively; WDM_T and WDM_C, weed dry weight (g/m^2) in treated and UWC plot, respectively; CDM_T and CDM_C, crop dry matter (g/m^2) in treated and UWC plot, respectively.

Overall impact index (OII) was estimated in two steps (Rana *et al*. 2019). Firstly, by calculating the unit value of a parameter under a particular treatment and dividing it by the respective arithmetic mean of all treatments for that parameter. And, secondly, the OII of a treatment was determined as the mean of unit values of all the parameters under consideration.

$$Uij = Vij \div AMj$$

$$OII_i = \frac{1}{N}\sum_{i=1}^{N} U_{ij}$$

Where, Uij, unit value for ith treatment corresponding to jth parameter; Vij, actual value of jth parameter for ith treatment; AMj, arithmetic mean for j[th] parameter; OIIi, overall impact index for i[th] treatment; and N, total number of parameters under consideration.

Weed flora distribution

Weed flora under unweeded situation (~UWC) comprised of *Echinochloa crus-galli* (L.) Beauv., *Leptochloa chinensis* (L.) Nees. (grassy weeds); *Eclipta alba* L., *Digera arvensis* Forsk., *Trianthema portulacastrum* L. (broad-leaved weeds); and *Cyperus rotundus* L., and *C. iria* L. (sedges). Weed flora composition differed greatly across the treatments having herbicides with different site-specific modes of action. Grassy weeds were more dominant constituting about 66.0–91.8% of total weed dry weight across the treatments, followed by (~*fb*) broad-leaved weeds (5.1–15.3%) and sedges (2.8–19.0%).

Weed interference

Weed control treatments brought about 74.1-89.7% reduction in grassy weeds dry weight at 60 DAS and 57.7-87.6% reduction in total weed dry weight at harvest compared to UWC (**Table 1**). The sequential applications of pendimethalin (1.0 kg/ha) *fb* ready-mix of penoxsulam + cyhalofop-butyl (130 g/ha) led to lowest grassy weed dry weight at 60 DAS (30 g/m^2) and harvest (41.7 g/m^2) and had highest WCI (87.6%). Singh *et al.* (2016) reported similar higher efficacy of herbicide mixture penoxsulam + cyhalofop-butyl on complex weed flora in DSR. This might be attributed to broad-spectrum activity of sequential herbicides combination against weeds. Pre-emergence pendimethalin controlled initial flushes of weeds. Late-emerging weeds were effectively controlled by herbicides mixture, *i.e.,* penoxsulam + cyhalofop-butyl with two different modes of action. Penoxsulam (acetolactate/ acetohydroxy acid synthase inhibitor) is effective against broad-spectrum weeds and cyhalofop-butyl (acetyl-coenzyme A carboxylase inhibitor) effectively controls grassy weeds. Later, rice crop through vigorous/ rapid canopy formation also smothered late-emerging weeds and reduced weed interference. Thus, this combination found to be most effective against diverse weeds in DSR. Likewise, weed interference was lower in pendimethalin *fb* bispyribac-Na (65 g/m^2) and brown manuring *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% 20 g/ha (Almix) (66 g/m^2) treated plots with 80.6% and 80.3% reductions (WCI) in weed dry weight over UWC, respectively (**Table 1**).

Pendimethalin *fb* bispyribac-Na although gave better weed control initially, the effect declined at later stages. This was due to lower persistence and activity of bispyribac-Na against weeds like *Dactyloctenium aegyptium*, *L. chinensis etc* (Awan *et al.* 2015). Integration of BM with herbicides (BM *fb* Almix) led to better weed suppression through smothering by live *Sesbania* mulch on initial weeds (Maity and Mukherjee 2011), and then by a combination of surface dead mulch and Almix applied at 40 DAS on late-emerging weeds. Again, BM was more effective against broad-leaved weeds and led to 79.4–83.5% reduction in their biomass compared to UWC (**Table 1**). Singh *et al.* (2007) reported similar results. However, the BM without the application of a grass-killer herbicide was unable to suppress grassy weeds initially resulting in significantly higher dry weight of grassy weeds at subsequent stages.

Crop growth and yield

Rice crop growth and grain yield differed significantly due to variable weed control efficiencies of the treatments. The BM *fb* Almix led to highest mean relative growth rate (RGR) of rice (60.77 mg/g/ day), which was 51.1% higher than that in UWC at 60 DAS (**Table 1**), and was closely followed by that in the pendimethalin *fb* penoxsulam + cyhalofop-butyl, mainly because of relatively lower weed interference. Highest grain yield (4.4 t/ha) and harvest index (40.02%) were recorded in weed-free check (WFC) with 430.1% increase in grain yield over UWC. Among the herbicide treatments, pendimethalin *fb* penoxsulam + cyhalofop-butyl gave highest grain yield (3.92 t/ha) and harvest index (38.0%) of rice (**Table 1**).

Rice grain yield in this treatment increased by 378.9% over UWC. Higher crop growth in this treatment might have led to greater accumulation of photosynthates in sources that translocated to sink at later growth stages, resulting in significant yield improvement. Pendimethalin *fb* bispyribac-Na (3.70 t/ha) and BM *fb* Almix (3.67 t/ha) were the next best treatments. Crop growth and yield are directly related to efficiency of a weed control practice. With highest WCI, pendimethalin *fb* penoxsulam + cyhalofop-butyl provided season-long weed control that facilitated better crop growth through more tillering and higher accumulation of photosynthates resulting in significant improvement in yield. The sequential applications of pre- and post-emergence herbicides having higher bio-efficacy against diverse weeds leading to better crop growth and yield has been highlighted earlier in DSR (Chauhan *et al.* 2015, Singh *et al.* 2016, Baghel *et al.* 2018, 2020), and in vegetable pea (Kaur *et al.* 2020). *Sesbania* BM also increased rice yield by 342.2% over UWC. The BM suppressed initial weed flushes through space capture, and late-emerging weeds through surface dead mulch after getting knocked down by 2, 4-D. Later, the application of Almix could supplement weed control in the BM treatment and led to lower weed interference, higher crop growth and yield (Maity and Mukherjee 2011). Improved soil condition in the BM was also responsible for higher yield (Nawaz *et al.* 2017).

Grain yield was negatively correlated with weed density (y = -14.543x + 3999.2; R^2 = 0.733) and dry weight (y = -10.855x + 3947.8; R^2 = 0.744) at 60 DAS (end of critical period of weed competition). This implied that grain yield decreased with corresponding increase in weed density and dry weight, and *vice-versa*. These linear equations could explain 73.3% and 74.4% of the variations in rice grain yield (y) due to weed density and dry weight (x) during the critical period of weed competition in DSR, respectively. With every unit increase in weed density (per m^2) or weed dry weight (g/m^2), rice grain yield is subjected to reduce by 14.5 kg/ha and 11 kg/ha, respectively. Economic threshold (*i.e.,* weed density at which cost of weed control equals the economic benefits accrued from that control measure, and justifies adoption of control measure) across the weed control options varied between 4.9-27.1 weeds/m^2 (**Table 2**) during critical period of weed competition in DSR. Economic threshold level increased with increasing cost of weed control as in the case of manual weeding (WFC), attributable to higher wages. Contrarily, weed control through herbicides incurred lower costs, resulting in lower economic threshold level. The economic threshold level at which controlling weeds became economically worthwhile at the most effective weed control option (pendimethalin *fb* penoxsulam + cyhalofop-butyl) was 9.0 weeds/m^2.

Table 1. Weed interference, crop growth and grain yield in direct-seeded rice

Treatment	Weed dry weight (g/m^2) at 60 DAS			Weed dry weight (g/m^2) at harvest	WCI (%)	Mean RGR (mg/g/day)	Grain yield (t/ha)	Harvest index (%)
	Grasses	BLWs	Sedges					
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 20 g/ha at 25 DAS	41.0	4.5	10.0	65.0	80.6	54.96	3.70	36.83
Pendimethalin 1.0 kg/ha *fb* penoxsulam (1%) + cyhalofop-butyl (5%) 130 g/ha at 25 DAS	30.0	5.0	7.0	41.7	87.6	58.45	3.92	38.00
Pendimethalin 1.0 kg/ha *fb* fenoxaprop-p-ethyl 75 g/ha at 25 DAS	59.2	13.5	17.0	116.7	65.2	56.52	2.67	32.25
Pendimethalin 1.0 kg/ha *fb* Almix (metsulfuron-methyl 10% + chlorimuron-ethyl 10%) 20 g/ha at 25 DAS	54.0	5.0	6.0	76.0	77.3	54.69	3.10	35.08
Pretilachlor 0.75 kg/ha *fb* cyhalofop-butyl 80 g/ha at 25 DAS	58.8	13.3	15.2	106.2	68.3	55.28	2.70	32.55
Pretilachlor 0.75 kg/ha *fb* ethoxysulfuron 15 g/ha at 25 DAS	75.2	4.2	4.2	142.0	57.7	49.59	1.88	30.50
Pendimethalin 1.0 kg/ha *fb* one hand weeding at 25 DAS	50.0	4.9	10.2	75.0	77.6	55.84	3.50	36.10
Brown manuring (BM)	56.0	3.5	4.0	81.0	75.8	57.59	3.07	34.93
BM *fb* Almix 20 g/ha at 40 DAS	45.0	2.8	5.0	66.0	80.3	60.77	3.67	36.82
Weed-free check	0	0	0	0	100.0	54.16	4.40	40.02
Unweeded control	290.0	17.0	9.0	335.3	0	40.22	0.83	25.13
LSD (p=0.05)	12.21	1.52	2.59	17.91	-	8.12	0.35	1.26

BLWs: Broad-leaved weeds; WCI: Weed control index; RGR: Relative growth rate

Table 2. Economics of weed control treatments

Treatment	Gross returns (x10^3 ₹/ha)	GR_{UWC} (x10^3 ₹/ha)	NR_{UWC} (x10^3 ₹/ha)	Gross benefit: cost	ET (weeds/m^2)
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 20 g/ha at 25 DAS	62.21	47.16	42.73	2.23	8.1
Pendimethalin 1.0 kg/ha *fb* penoxsulam (1%) + cyhalofop-butyl (5%) 130 g/ha at 25 DAS	65.53	50.48	45.33	2.30	9.0
Pendimethalin 1.0 kg/ha *fb* fenoxaprop-p-ethyl 75 g/ha at 25 DAS	45.86	30.81	26.26	1.64	9.4
Pendimethalin 1.0 kg/ha *fb* Almix (metsulfuron-methyl 10% + chlorimuron-ethyl 10%) 20 g/ha at 25 DAS	52.54	37.49	34.65	2.00	5.0
Pretilachlor 0.75 kg/ha *fb* cyhalofop-butyl 80 g/ha at 25 DAS	46.35	31.31	27.44	1.70	7.7
Pretilachlor 0.75 kg/ha *fb* ethoxysulfuron 15 g/ha at 25 DAS	32.73	17.68	15.04	1.26	4.9
Pendimethalin 1.0 kg/ha *fb* one hand weeding at 25 DAS	59.05	44.00	37.20	1.96	10.8
Brown manuring (BM)	52.02	36.97	33.98	1.98	5.3
BM *fb* Almix 20 g/ha at 40 DAS	61.66	46.61	42.94	2.28	6.2
Weed-free check	73.03	57.98	39.98	1.75	27.1
Unweeded control	15.05	0	0	0.64	0
LSD (p=0.05)	5.74	-	-	0.21	-

GR_{UWC}, Gross returns over UWC; NR_{UWC}, Net return over UWC; ET, Economic threshold density

Table 3. Impact assessment indices of weed control treatments

Treatment	TEI	WPI	CRI	WMI	AMI	IWMI	WIn	CIn	OII
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 20 g/ha at 25 DAS	4.47	0.88	15.29	5.48	4.48	4.98	12.65	87.35	1.16
Pendimethalin 1.0 kg/ha *fb* penoxsulam (1%) + cyhalofop-butyl (5%) 130 g/ha at 25 DAS	6.00	0.86	20.79	5.52	4.52	5.02	9.89	90.11	1.27
Pendimethalin 1.0 kg/ha *fb* fenoxaprop-p-ethyl 75 g/ha at 25 DAS	2.42	0.89	7.51	4.55	3.55	4.05	21.50	78.50	0.84
Pendimethalin 1.0 kg/ha *fb* Almix (metsulfuron-methyl 10% + chlorimuron-ethyl 10%) 20 g/ha at 25 DAS	3.66	0.98	11.58	4.76	3.76	4.26	14.44	85.56	1.00
Pretilachlor 0.75 kg/ha *fb* cyhalofop-butyl 80 g/ha at 25 DAS	2.50	0.90	7.75	4.56	3.56	4.06	20.91	79.09	0.86
Pretilachlor 0.75 kg/ha *fb* ethoxysulfuron 15 g/ha at 25 DAS	2.17	1.05	6.28	3.14	2.14	2.64	21.39	78.61	0.66
Pendimethalin 1.0 kg/ha *fb* one hand weeding at 25 DAS	3.76	0.89	12.34	5.38	4.38	4.88	15.00	85.00	1.08
Brown manuring (BM)	3.65	0.94	11.31	4.71	3.71	4.21	15.01	84.99	0.99
BM *fb* Almix 20 g/ha at 40 DAS	4.67	0.97	15.22	5.38	4.38	4.88	11.46	88.54	1.16

TEI, Treatment efficiency index; WPI, Weed persistence index; CRI, Crop resistance index; WMI, Weed management index; AMI, Agronomic management index; IWMI, Integrated weed management index; WIn, Weed intensity; CIn, Crop intensity; OII, Overall impact index

Economics

The weed-free situation (WFC) fetched highest gross returns owing to highest grain and straw yields, followed by the pendimethalin *fb* penoxsulam + cyhalofop-butyl (**Table 2**). Despite lower gross returns (by 7501.5 ₹/ha or 10.3%), the latter herbicide treatment (*i.e.,* pendimethalin *fb* penoxsulam + cyhalofop-butyl) gave 13.4% and 31.4% higher net returns over UWC (NR_{UWC}) and gross benefit: cost over WFC, respectively, because of higher grain yield and relatively lower cost of weed control in this treatment. Brown manuring *fb* Almix although had relatively lower grain yield and gross returns, led to 7.4% and 30.3% higher NR_{UWC} and gross benefit: cost over WFC, respectively, and found to be the next best weed control option in DSR in terms of profitability. Reduction in cost of herbicide and comparatively higher grain yield resulted in better profitability in this treatment. In contrast, Nawaz *et al*. (2017) and Paliwal *et al*. (2017) reported higher profitability of BM than herbicidal weed control.

Impact assessment

Among the weed control options, the sequential applications of pendimethalin *fb* penoxsulam + cyhalofop-butyl resulted in highest treatment efficiency index (6.0) followed by BM *fb* Almix (**Table 3**). It also led to highest crop resistance index (20.79), weed management index (5.52), agronomic management index (4.52), integrated weed management index (5.02), and crop intensity (90.11), indicating higher efficacy of this treatment on weeds. Lowest weed persistence index (0.86) and weed intensity (9.89) were also obtained from it, highest being in pretilachlor *fb* ethoxysulfuron. Overall impact index indicated higher bio-efficacy of sequential applications of pendimethalin *fb* penoxsulam + cyhalofop-butyl and BM *fb* Almix in controlling diverse weed flora in DSR (**Table 3**).

This study showed that the sequential applications of pendimethalin (1.0 kg/ha) as pre-emergence *fb* ready-mixture of penoxsulam + cyhalofop-butyl (130 g/ha) at 25 DAS resulted in better control of diverse weeds, resulting in higher rice growth, productivity and profitability. It may be adopted for effective weed control in DSR in the Indo-Gangetic Plains and in other areas with similar agro-ecologies. Furthermore, integration of *Sesbania* brown manuring with herbicide Almix 20 g/ha applied at 40 DAS can also be a profitable alternative for effective weed management in DSR.

REFERENCES

Awan TH, Cruz PC and Chauhan BS. 2015. Efficacy and economics of different herbicides, their weed species selectivity, and the productivity of mechanized dry-seeded rice. *Crop Protection* **78**: 239–246.

Baghel JK, Das TK, Pankaj, Mukherjee I, Nath CP, Bhattacharyya R, Ghosh S and Raj R. 2020. Impacts of conservation agriculture and herbicides on weeds, nematodes, herbicide residue and productivity in direct-seeded rice. *Soil and Tillage Research* **201**: 104634.

Baghel JK, Das TK, Rana DS and Paul S. 2018 Effect of weed control on weed competition, soil microbial activity and rice productivity in conservation agriculture-based direct-seeded rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **63**(2): 129–136.

Chauhan BS, Ahmed S and Awan TH. 2015. Performance of sequential herbicides in dry-seeded rice in the Philippines. *Crop protection* **74**: 124–130.

Das TK. 1999. Is transformation of weed data always necessary? *Annals Agricultural Research* **20**(3): 335–341.

Das TK. 2001. Towards better appraisal of herbicide bio-efficacy. *Indian Journal of Agricultural Sciences* **71**: 676–678.

Das TK. 2008. *Weed Science: Basics and Applications*. Jain Brothers, New Delhi, India, 901 p.

Fisher RA. 1960. *The Design of Experiment*. Hoffman Publication Company Inc., New York.

Kaur R, Das TK, Banerjee T, Raj R, Singh R and Sen S. 2020. Impacts of sequential herbicides and residue mulching on weeds and productivity and profitability of vegetable pea in North-western Indo-Gangetic Plains. *Scientia Horticulturae* **270**: 109456.

Krishnamurthy K, Rajashekara BG, Raghunatha G, Jagnath MK and Prasad TVR. 1975. Herbicidal efficiency index in sorghum. *Indian Journal of Weed Science* **7**(2): 75–79.

Kumar V and Ladha JK. 2011. Direct seeding of rice: recent developments and future research needs. *Advances in Agronomy* **111**: 297–413.

Maity SK and Mukherjee PK. 2011. Effect of brown manuring on grain yield and nutrient use efficiency in dry direct seeded kharif rice (*Oryza sativa* L.). *Indian Journal of Weed Science* **43**(1&2): 61–66.

Mishra M and Misra A. 1997. Estimation of integrated pest management index in jute–A new approach. *Indian Journal of Weed Science* **29**: 39–42.

Mohammad A, Sudhishri S, Das TK, Singh M, Bhattacharyya R, Dass A, Khanna M, Sharma VK, Dwivedi N and Kumar M. 2018. Water balance in direct-seeded rice under conservation agriculture in north-western indo-gangetic plains of India. *Irrigation Science* **36**(6): 381–393.

Nawaz A, Farooq M, Lal R, Rehman A, Hussain T and Nadeem A. 2017. Influence of sesbania brown manuring and rice residue mulch on soil health, weeds and system productivity of conservation rice–wheat systems. *Land Degradation and Development* **28**(3): 1078–1090.

Paliwal A, Singh VP, Bhimwal JP, Joshi N, Singh SP, Pratap T, Guru SK and Kumar A. 2017. Rice productivity under different weed management and establishment methods. *Indian Journal of Weed Science* **49**(1): 5–9.

Rana SS and Kumar S. 2014. *Research Techniques in Agronomy*. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, 64 p.

Rana SS, Badiyala D and Sharma N. 2019. Imazethapyr and its Ready-mix Combinations for Weed Control in Pea under Palam Valley Conditions of Himachal Pradesh. *Pesticide Research Journal* **31**(1): 66–73.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct seeded rice. *Advances in Agronomy* **93**: 153–255.

Sen S, Kaur R, Das TK, Shivay YS and Sahoo PM. 2018. Bio-efficacy of sequentially applied herbicides on weed competition and crop performance in dry direct-seeded rice (*Oryza sativa*). *Indian Journal of Agronomy* **63**(2): 230–233.

Singh S, Ladha JK, Gupta RK, Bhushan L, Rao AN, Sivaprasad B and Singh PP. 2007. Evaluation of mulching, intercropping with Sesbania and herbicide use for weed management in dry-seeded rice (*Oryza sativa* L.). *Crop Protection* **26**(4): 518–524.

Singh VP, Dhyani VC, Singh SP, Kumar A, Manalil S and Chauhan BS. 2016. Effect of herbicides on weed management in dry-seeded rice sown under different tillage systems. *Crop Protection* **80**: 118–126.

Uygur FN and Mennan H. 1995. A study on economic threshold of *Galium aparine* L. and *Bifora radians* Bieb. in wheat fields in Samsun-Turkey, pp. 347–354. In: *ANPP Seizième Conférence Du Columa Journées Internationale Surla Lutte Contre Les Mauvaises Herbes 6-8 décembre. Conference Proceedings* Vol. 1.

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Crop establishment method and planting density effects on weeds, insects and productivity of rice

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ABSTRACT

The effect of establishment methods and seedling density on weed dynamics, pest incidence and productivity of transplanted rice were evaluated in a field study, conducted in summer 2019 at Ludhiana, India.Three rice establishment methods [rice transplanted on puddled flat soil (PFTR), rice transplanted on unpuddled raised bed (UBTR), rice transplanted on unpuddled ridge (URTR)] in main plots, and three planting densities (20, 25, 33 seedling hills/m^2) in sub-plots were evaluated in a split-plot design. It was found that UBTR and URTR methods had higher weed biomass than PFTR at 20 and 70 days after transplanting (DAT). All three establishment methods gave similar rice grain yield. Increase in planting density from 20 to 33 seedling hills/m^2 reduced weed biomass at 20 and 70 DAT but at 45 DAT, all the planting densities had similar weed biomass. Likewise, there was consistent decline in rice grain yield due to reduction in planting densities but differences among consecutive planting densities were not significant. The incidence of insect-pest remained below economic threshold level under all treatments.

India is major producer and consumer of rice after China (FAO 2018). Punjab state with geographical area of 1.53% of India, is contributing 30-48% to the national buffer stock and plays a key role in food security of India (Kumar and Kaur 2019). Therefore, sustainability of rice production system in Punjab is important for ensuring Indian food security. The conventional system of rice production *i.e.* puddle transplanted rice (PTR) is water, labor and energy intensive, which threaten the sustainability of rice production system. Puddling of rice fields alone consumes79 to 150 mm irrigation water (Yadav *et al.* 2011). It has been reported that PTR system requires up to 5000 litres water to produce one kg of rice (Bouman 2009). The excessive pumping of groundwater for rice cultivation under Punjab conditions has resulted in decline of water table by 0.4-1.0 m per year, leading to increased pumping cost and water scarcity (Hira 2009). Repeated puddling destroys soil structure and creates shallow hard pan, which, besides affecting the performance of rice as well as succeeding wheat crop, also make the conditions favorable for emission of methane (CH_4), thereby, contributing to global warming (Rao and Matsumoto 2017, Dhillon and Mangat 2018).

In view of declining water table and deteriorating soil physical conditions associated with conventional system of rice establishment, alternative establishment methods, transplanting rice on beds or ridges under unpuddled conditions were recommended in 2007 (Anonymous 2007). In spite of substantial saving of irrigation water, better soil physical conditions and some other environment related benefits, these alternative methods could not find favor among rice farmers, probably, in part due to higher weed pressure (Rao and Matsumoto 2017). Apart from establishment method, seedling density is another important factor which influence weed growth and grain yield (Dass *et al*. 2017). Farmers, in general, transplant lesser number of seedlings (18-22 seedlings/m^2) in comparison to recommended (33 seedling/m^2). Dense transplanting (28 seedling/m^2) had lower weed pressure than 21 seedling/m^2 (Aggarwal and Singh 2015). The published data on interaction among establishment method and seedling density on weed dynamics and rice grain yield is not available under Indo-Gangetic plains region in India. Keeping in view the above, the present study was undertaken.

A field experiment was conducted at Punjab Agricultural University, Ludhiana, India [30°56' N latitude; 75°52' E longitude; 247 m altitude] located in the Indo–Gangetic Plain Region (IGPR) during summer season *(Kharif)* 2019. Experimental site is characterized as sub-tropical, semi–arid with an annual rainfall of 759 mm, out of which about 80% is received from June to September (Prabhjyot-Kaur *et al.* 2016).The soil was sandy–loam, low in available N and high in available–P and medium in available–K and soil organic carbon (SOC) status of soil pH and electrical conductivity were normal. The treatments included three rice establishment methods (rice transplanted on puddled flat soil (PFTR), rice transplanted on unpuddled raised bed (UBTR), rice transplanted on unpuddled ridges (URTR) in main plots, and three planting densities (20, 25, 33 seedling hills/m^2) in sub plots and each treatment replicated three times. The beds (of 15 cm height) and ridges (of 30 cm height) were prepared by tractor drawn bed maker and ridger. The total size of bed was 67.5 cm with 37.5 cm bed top and 30 cm furrow. Similarly, the spacing between two ridges was kept 60 cm (top to top). In case of PFTR, seedlings were transplanted at 15, 20 and 25 cm spacing in 20-cm spaced rows for 20, 25 and 33 seedlings/m^2. In case of UBTR, rice seedling were transplanted in the middle of slope in two rows on both side of bed (67.5 cm; 37.5 cm bed and 30 cm furrow) at 9, 12 and 15 cm spacing in 33.75 cm spaced rows. In case of URTR, two rows of rice seedlings were transplanted in the middle of slope on both sides of ridge (60 cm spacing) at 10, 13 and 16 cm spacing in 30 cm spaced rows.

Rice variety '*PR 121*' was transplanted on 24 June, 2019 using 30-days old seedlings. The crop was supplied with 105 kg nitrogen (N) and 25 kg $ZnSO_4$/ha; N was applied through urea in three equal splits; as basal at 21 days after transplanting (DAT) and at 42 DAT and $ZnSo_4$ applied as basal. In PFTR, the field was kept ponded (6.5 cm) for first two weeks after transplanting and afterwards irrigation was applied two days after the draining of ponded water. The un puddled ridge and bed plots were supplied with four extra irrigations during first two weeks to keep the field in saturation and afterward alternate wetting and drying was followed. After 15 DAT, crop was irrigated as per the demand. The depth of each irrigation water was 6.5 cm (except 10.0 cm at puddling) in PFTR but 5.0 cm in un-puddled ridge and bed treatments. The crop was raised as recommended package of practices for the region. Pretilachlor 0.75 kg/ha as pre- (2 DAT) and bispyribac-sodium 25 g/ha as post-emergence (20 DAT) were sprayed in all the plots. Weed biomass was recorded at 20, 45 and 70 DAT. Later, all plots were hand weeded. Insect pest also pose a biotic stress to crop, hence to assess the influence of different treatments on insect-pest, data was recorded at 40, 55, 70, 85 days after transplanting and before harvest of the crop as per standard protocol (Anonymous 2019). The data on plant growth and grain yield parameters were recorded from five representative plants per plot. Grain yield obtained from net plot was adjusted at 14% moisture and expressed as t/ha. Data were subjected to statistical analysis using SAS 9.3 software package.

Major weed flora in experimental field included *Echinochloa crus-galli*, *Echinochloa colona*, *Leptochloa chinensis*, *Cyperus difformis, Cyperus iria* and *Ammania baccifera*. Among establishment methods, FPTR had significantly lower weed biomass than UBTR and URTP while UBTR and URTR had similar weed biomass at 20 and 70 DAT. Weed biomass did not vary statistically among establishment methods at 45 DAT (**Table 1**). Sequential application of pretilachlor and bispyribac provided effective control of weeds in all establishment methods. Hence, weed biomass was at par at 45 DAT. After 45 DAT, there was resurgence of weeds, which was significantly higher in un-puddled than in puddled conditions. In flat puddle field, surface remained fully covered with ponded water

Table 1. Interactive effects of rice establishment method and planting density on weeds biomass at 20, 45 and 70 DAT

Planting density (rice seedling/m^2)	Rice establishment method weed biomass (g/m^2)											
	20 DAT				45 DAT				70 DAT			
	Flat	Bed	Ridge	Mean	Flat	Bed	Ridge	Mean	Flat	Bed	Ridge	Mean
33	5.1	8.2	8.0	7.1	4.8	5.5	5.6	5.3	11.4	41.9	27.7	27.0
25	6.4	10.3	9.1	8.6	5.5	6.4	6.0	6.0	15.8	69.6	58.9	48.1
20	7.6	11.5	10.3	9.8	5.8	6.7	6.3	6.2	24.7	110.8	104.9	80.1
Mean	6.4	10.0	9.1		5.4	6.2	6.0		17.3	74.1	63.8	
LSD (p=0.05)	Establishment method: 1.1; Planting density: 0.9, Interaction: NS				Establishment method: NS; Planting density: NS, Interaction: NS				Establishment method: 25.6; Planting density: 5.1, Interaction: 8.8			

Flat- Puddled transplanted; Ridge- un-puddled transplanted; Bed- unpuddled transplanted which decreased weed emergence, whereas, the tops of un-puddled bed and ridge were not inundated and hence weeds emerged on these tops which increased weed biomass. The differences among establishment methods were quite less at 20 DAT but increased at 70 DAT. Seedling densities also had significant effect on weed biomass. Reduction in seedling density from 33 hills to 20 hills/m^2 caused significant increase in weed biomass at 20 and 70 DAT but not at 45 DAT.

The damage by different pests was below economic threshold level (ETL) under different treatments (ETL for stem borer and plant hopper (PH) is 5% dead hearts and 5 PH/hill, respectively) (**Table 2**). It was found that dead hearts and white ears were not influenced by establishment methods and planting densities. The plant hopper (PH) population was observed to be more under ridge transplanting method except at 40 DAT, where differences were not significant. Increasing seedling densities results in higher PH population but differences between consecutive planting densities were not significant. The higher PH population under ridge transplanting method as well as dense planting can be ascribed higher tiller density under respective treatments. Soni and Tiwari (2016) also reported that damage and population of insect-pest varied with establishment method.

Planting methods did not cause significant effect on growth and yield attributes of rice including tiller density, panicle density, grains/panicle and sterility (**Table 3**) resulting into similar rice grain yield under all planting methods. It can be inferred that though all three methods gave similar rice yield but there was 11.3% saving in irrigation water under bed/ridge transplanting over flat-puddle transplanting (data not presented). However, the higher weed pressure under un-puddle bed/ridge method may hamper crop productivity and also results in maximizing weeds seed production, which may increase weed pressure in future. Proper weed management is more critical under these alternate methods of establishments and hence further studies are needed to identify appropriate methods to manage weeds (Rao *et al.* 2017).

Planting density had significant influence on tiller, panicle density and panicle weight. However, grains/panicle and sterility did not vary significantly. Decrease in planting density from 33 to 25 hills/m^2 caused significant drop in tiller and panicle density. Panicle weight was highest under 20 hills/m^2. The highest rice grain yield was recorded at 33 hills/m^2, which was at par to 25 hills/m^2 but significantly higher than 20 hills/m^2 (**Table 3**). The statistical parity in grain yield under 33 and 25 hills/m^2 as well as 25

Table 2. Effect of rice establishment methods and planting density on insect-pests damage at different growth stages of rice

Treatment	Dead heart (%)				Pre-harvest WE (%)	Plant hopper population/hill			
	40 DAT	55DAT	70DAT	85DAT		40 DAT	55 DAT	70 DAT	85 DAT
Rice establishment method									
Flat (puddled)	0.87	1.28	2.78	1.64	2.63	0.53	0.98	1.35	2.28
Beds(un-puddled)	1.89	2.19	3.79	2.60	3.35	0.46	0.80	1.17	1.80
Ridges (un-puddled)	0.83	1.36	2.41	1.54	2.20	0.91	1.55	2.64	3.58
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.22	0.13	0.61
Planting density (rice seedling/m^2)									
33	1.55	1.81	3.35	2.09	3.25	0.73	1.29	1.84	2.82
25	1.30	1.75	3.13	2.12	3.19	0.64	1.09	1.69	2.49
20	0.75	1.28	2.50	1.56	2.52	0.53	0.95	1.64	2.35
LSD (p=0.05)	NS	NS	NS	NS	NS	0.15	0.17	NS	0.24

WE; white ears

Table 3. Effect of rice establishment method and planting density on growth, yield attributes and grain yield of rice

Treatment	Plant height (cm)	Tiller density (no./ m^2)	Days to 50% flowering	Panicle (no./m^2	Panicle weight (g)	Filled grains (no./panicle)	Un filled grains (no./panicle)	Sterility (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Rice establishment method											
Flat (puddled)	99.8	343.4	109.8	331.2	3.20	113.2	12.5	9.9	7.83	9.76	44.5
Beds(un-puddled)	100.1	344.4	110.6	327.6	3.13	108.2	12.4	10.3	7.58	9.16	45.3
Ridges (un-puddled)	100.5	350.9	108.1	325.2	3.20	117.8	14.2	10.7	7.73	10.13	43.3
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting density (rice seedling/m^2)											
33	101.2	373.6	109.6	369.6	3.06	109.5	12.3	10.0	8.01	9.89	44.7
25	99.8	337.5	109.3	316.7	3.20	115.2	12.6	9.8	7.76	9.88	44.0
20	99.4	327.6	109.6	297.8	3.28	114.5	14.2	11.0	7.36	9.28	44.2
LSD (p=0.05)	NS	19.5	NS	28.6	0.12	NS	NS	NS	0.47	NS	NS

and 20 hills/m^2 can be ascribed to the higher tillering ability of genotypes '*PR 121*' sown in the experiment. Hence, further studies on this aspect need to be conducted with different genotypes having varying tillering ability and other yield related traits.

REFRENCES

Aggarwal N and Singh A. 2015. Crop performance, nutrient uptake vis-a-vis weed suppressive ability of mechanically transplanted rice (*Oryza sativa*) as influenced by age of seedlings and planting density. *Indian Journal of Agronomy* **60**: 255–260.

Anonymous. 2007. Package of Practices for crops of Punjab (*Kharif* 2007) PAU, Ludhiana. 8p.

Anonymous. 2019. *Indian Institute of Rice Research Progress Report*, 2018, Vol. 2, Crop Protection, Indian Institute of Rice, Rajendranagar, Hyderabad.

Bouman BAM. 2009. How much water does rice use? *Rice Today* **8**: 28–29.

Dass A, Shekhawat K, Choudhary AK, Sepat S, Sanjay Singh Rathore SS, Mahajan G, Chauhan BS. 2017. Weed management in rice using crop competition-a review. *Crop Protection* **95**: 45–52.

Dhillon BS and Mangat GS. 2018. Direct-seeded rice in Punjab: Opportunities and challenges. pp. 535–38. In: *Technology for Rice Production*. Technical papers of National seminar on "*Sustaibale Rice Production Technology for Increasing the Farmers' Income*" held during January 20-21, 2018 at Indra Gandhi Krishi Vishavvidyalaya, Raipur (Chhatisgarh).

FAO. 2018. Rice market monitor. *FAO Rome* **21**(1): 4.

Hira GS. 2009.Water management in northern states and food security of India. *Journal of Crop Improvement* **23**: 136–157.

Kumar R and Kaur A. 2019. *Statistics of Punjab Agriculture*, PAU, Ludhiana.

Prabhjyot-Kaur, Sandhu SS, Singh H, Kaur N, Singh S and Kaur A. 2016. *Climatic Features and their Variability in Punjab*. AICRPAM, School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. 78 p.

Rao AN, Wani SP, Ahmed S, Ali HH and Marambe B. 2017. An overview of weeds and weed management in rice of South Asia. pp. 247–281. In: *Weed management in rice in the Asian-Pacific Region.* Asian-Pacific Weed Science Society (APWSS); (Eds. Rao AN and Matsumoto H), The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India.

Soni VK and Tiwari SN. 2016. Effects of cultivation methods and cultivars on the incidence of major insect pest of rice. *International Journal of Plant Protection* **9**: 21–25.

Yadav S, Humphreys E, Kukal SS, Gill G, Rangarajan R. 2011.Effect of water management on dry seeded and puddled transplanted rice Part 2: Water balance and water productivity. *Field Crops Research* **120**: 123–132.

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Bio-efficacy of pre-and post-emergence herbicides on weed control and yield of rainfed lowland rice

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ABSTRACT

A field experiment was conducted at Sri Venkateswara Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India to study the performance of sequential application of pre-emergence (PE) and post-emergence (PoE) herbicides for broad-spectrum weed control in rainfed lowland rice and their residual effect on succeeding greengram. The major weed flora associated with rainfed lowland rice were *Cyperus rotundus* L. (55%), *Digitaria sanguinalis* L. Scop (12%) and *Commelina benghalensis* L.(7%) and other weeds (26%). The lowest density and dry weight and increased growth and yield components were recorded with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha. The higher grain and straw yields and benefit-cost ratio were obtained with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha. Pre-emergence application of pretilachlor, oxadiargyl and pendimethalin reduced the plant population of rice by 12.10, 5.94 and 4.46%, respectively compared to unweeded check. Sequential application of PE and PoE herbicides applied to rainfed lowland rice did not affect the germination of greengram, however the best weed management practice in rice continuing its superiority in obtaining higher seedling vigour index and dry matter production at 15 DAS.

Rice (*Oryza sativa* L.) is the most important cereal crop of the world, by contributing staple diet of 70% of world's population and plays a crucial role in the economic and social stability of the world. In India, it is cultivated in an area of 44.50 million hectares with a total production of 115.60 million tonnes and productivity of 2.28 t/ha. The resources for crop production, *viz*. land, water, nutrients and labour are becoming scarce in recent years. Due to increasing scarcity of the water, escalating labour costs and non-availability of labour timely, direct seeding of rice seems to be the only viable alternative to transplanted rice. Weeds are the main constraints in direct-seeded rice since the inherent weed control from standing water at crop establishment is lost. Yield loss due to weeds varies significantly due to nature, extent and intensity of weed problems and depend on the ecology in which the rice crop is grown. Uncontrolled weed growth in direct-seeded rice, wet seeded rice and transplanted rice reduced the grain yield by 75.8, 70.6 and 62.6%, respectively compared to the best weed management practices (Singh *et al.* 2005). PE application of pendimethalin 1.0 kg/ha alone is not sufficient to obtain broad-spectrum weed control due to diversified weed flora and heavy infestation of perennial sedges and broad-leaved weeds. PoE application of bispyribac-sodium 25 g/ha is not effective in controlling perennial sedge and resistant biotypes of grassy and broad-leaved weeds, which are the most common in dry direct-seeded rice (DSR) ecosystem. There is a need to evaluate some of the new generation PoE herbicides for obtaining broad-spectrum weed control including perennial sedge, *Cyperus rotundus* in DSR. Therefore, the present experiment was conducted to find out suitable herbicides for sequential application in rainfed low land rice.

A field experiment was conducted during *Kharif* 2018 at wetland farm of Sri Venkateshwara Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India. The soil was sandy clay loam in texture with low in organic carbon (0.25%), slightly alkaline in reaction (pH-8.2), low available nitrogen (238 kg/ha) and medium in available phosphorus (24.5 kg/ha) and available potassium (268 kg/ha). The experiment was laid out in a randomized block design with twelve treatments and replicated thrice. The weed management practices consisted of sequential application of oxadiargyl, pendimethalin and pretilachlor each at 100, 1000 and 750 g/ha, respectively as PE applied at one DAS followed by new generation PoE herbicides, *viz*. penoxsulam + cyhalofop-p-butyl, florpyrauxifen-benzyl and halosulfuron-methyl each 130, 25 and 67.5 g/ha, respectively were applied at 20 DAS. PE application of pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha, two hand weedings at 20 and 40 DAS and unweeded check were also included (**Table 1**). Rice variety '*MTU-1010*' was sown on 13th August 2018 at 20 x 10 cm with seed rate of 75 kg/ha. The rice crop was irrigated with 5 cm depth of water at each irrigation whenever necessary upto 40 DAS and then the crop was converted to land submergence for better growth and development. A uniform dose of 120 kg N, 60 kg P and 60 kg K per ha was applied in the form of urea, single super phosphate and muriate of potash, respectively. Iron and zinc sulphate was applied each at 50 and 25 kg/ha, respectively at the time of last ploughing to overcome the deficiencies of iron and zinc.

The required quantities of PE and PoE herbicides were applied at one and 20 DAS, respectively by using spray fluid at 500 L/ha with the help of battery operated knapsack sprayer fitted with flat fan nozzle as per the treatments. Category wise weed density and dry weight was recorded at 80 DAS. Weed density and weed dry weight of all categories of weeds were recorded at 40, 60 and 80 DAS and showed more or less similar trend. To avoid repetition of the data, only 80 DAS was presented. Phytotoxicity scoring of all PE and PoE herbicide on rice was evaluated in 0-10 scale at 10th and 5th day after its application as suggested by Singh and Rao (1976). The plant population/m^2 in PE herbicide applied plots was recorded at 15 DAS. The growth parameters, yield attributing parameters and yield of rainfed lowland rice were recorded at harvest. Greengram '*LGG - 460'* was sown in undisturbed layout after the harvest of rice at a spacing of 30 x 10 cm to know the residual effect of herbicides applied to rainfed lowland rice. Germination per cent, dry matter production and seedling vigour index were recorded at 15 DAS. Seedling vigor index was calculated by multiplying the germination per cent and seedling length.

Weed growth

The major weed flora found in the experimental field was *Cyperus rotundus* L. (55%), *Digitaria sanguinalis* L. Scop. (12%), *Commelina benghalensis* L. (7%), *Boerhavia erecta* L. (5%), *Trichodesma indicum* R.Br. (5%), *Dactyloctenium aegyptium* (L.) Willd. (3%), *Digera arvensis* Forssk. (3%), *Cleome viscosa* L. (2%) and other weeds (8%) in unweeded check plots. All the weed management practices significantly influenced the density and dry weight of all the categories of weeds associated with rainfed lowland rice (**Table 1**). The lowest density and dry weight of grasses were noticed with PE application of pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha, which was at par with two HW at 20 and 40 DAS. PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha recorded significantly lesser density of sedges, which was comparable with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha whereas the lowest dry weight of sedges was recorded with PE application of oxadiargyl 100 g/ha *fb* halosulfuron-methyl 67.5 g/ha. PoE application of halosulfuron-methyl 67.5 g/ha or florpyrauxifen-benzyl 25 g/ha controlled predominant sedge, *Cyperus rotundus*. Nazreen and Subramanyam (2018) reported that PoE application of halosulfuron-methyl 67.7 g/ha was very effective in controlling purple nutsedge in maize and Mehar Chand *et al.* (2014) also found similar effect in sugarcane.

Pre-emergence application of pretilachlor 750 g/ha *fb* halosulfuron-methyl 67.5 g/ha or florpyrauxifen-benzyl 25 g/ha resulted in reduced density of broad-leaved weeds whereas lesser dry weight was noticed with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha or florpyrauxifen-benzyl 25 g/ha. Pendimethalin was effective in controlling broad-leaved weeds and grasses at early stages whereas florpyrauxifen-benzyl was effective in controlling broad-leaved weeds and sedges similar to synthetic aux in herbicides. The highest weed control efficiency was computed with sequential application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha. The best treatment was pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha in recording higher weed control efficiency. All the pre-emergence herbicides *fb* PoE application of penoxsulam + cyhalofop-p-butyl 130 g/ha treatments failed to obtain broad-spectrum weed control due to poor performance of penoxsulam + cyhalofop-p-butyl 130 g/ha against perennial sedge*, Cyperus rotundus.*

Crop growth parameters

All the pre-and post-emergence herbicides did not show any phytotoxicity symptoms on rice crop, however pre-emergence application of oxadiargyl 100 g/ha and pretilachlor 750 g/ha resulted in phytotoxicity rating of '1' and '2', respectively in 0-10 scale where 0 indicate no phytotoxicity and 10 indicates complete destruction of crop plants at 10 DAS and the crop was recovered within 20 DAS. PE application of pretilachlor, oxadiargyl and pendimethalin at 750, 100 and 1000 g/ha, respectively reduced the plant population by 12.10, 5.94 and 4.46%, respectively compared to unweeded control.

Table 1. Weed density, weed dry weight and weed control efficiency as influenced by different pre-and post-emergence herbicides in rain fed lowland rice at 80 DAS

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)				WCE (%)
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	
Oxadiargyl *fb* penoxsulam + cyhalofop-p-butyl 100+130 g/ha (1 and 20 DAS)	2.82 (7.0)	8.77 (76.0)	4.04 (15.0)	9.96 (98.0)	4.47 (19.0)	13.85 (191.0)	10.07 (101.0)	17.65 (311)	33.2
Pendimethalin *fb* penoxsulam +cyhalofop-p-butyl 1000+130 g/ha (1 and 20 DAS)	2.70 (6.0)	7.95 (62.0)	3.78 (13.0)	9.11 (81.0)	4.24 (17.0)	12.45 (154.0)	9.49 (89.0)	16.17 (260.0)	43.9
Pretilachlor *fb* penoxsulam +cyhalofop-p-butyl 750+130 g/ha (1 and 20 DAS)	2.44 (5.0)	8.62 (73.0)	3.60 (12.0)	9.55 (90.0)	3.85 (14.0)	13.45 (180.0)	9.09 (82.0)	16.63 (276.0)	40.6
Oxadiargyl *fb* florpyrauxifen-benzyl100+25 g/ha (1 and 20 DAS)	3.36 (10.0)	3.69 (13.0)	2.76 (7.0)	5.53 (30.0)	5.00 (24.0)	4.53 (20.0)	8.81 (77.0)	11.03 (121.0)	74.0
Pendimethalin *fb* florpyrauxifen-benzyl 1000+25 g/ha (1 and 20 DAS)	2.88 (7.0)	2.82 (7.0)	3.41 (11.0)	5.09 (25.0)	4.84 (23.0)	4.42 (19.0)	5.74 (32.0)	8.58 (74.0)	84.3
Pretilachlor *fb* florpyrauxifen-benzyl 750+25 g/ha (1 and 20 DAS)	3.26 (10.0)	3.91 (14.0)	2.64 (6.0)	5.57 (30.0)	4.70 (21.0)	5.98 (35.0)	8.48 (71.0)	11.29 (127.0)	72.6
Oxadiargyl *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	3.10 (9.0)	2.94 (8.0)	3.55 (12.0)	5.38 (29.0)	5.06 (25.0)	4.04 (15.0)	7.98 (63.0)	10.19 (103.0)	77.8
Pendimethalin *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	3.16 (9.0)	2.64 (6.0)	3.21 (9.0)	5.03 (24.0)	5.27 (27.0)	6.12 (37.0)	6.20 (37.0)	10.10 (101.0)	78.3
Pretilachlor *fb* halosulfuron-methyl 750+67.5 g/ha (1 and 20 DAS)	3.05 (8.0)	3.87 (14.0)	2.36 (5.0)	5.29 (27.0)	5.40 (28.0)	5.70 (32.0)	6.78 (45.0)	10.29 (105.0)	77.4
Pendimethalin *fb* bispyribac-sodium 1000+25 g/ha (1 and 20 DAS)	1.99 (3.0)	7.08 (49.0)	2.36 (5.0)	7.61 (57.0)	3.20 (9.0)	11.02 (121.0)	5.69 (32.0)	12.75 (162.0)	65.2
HW twice (20 and 40 DAS)	2.29 (4.0)	6.27 (38.0)	2.76 (7.0)	7.09 (49.0)	3.67 (13.0)	9.89 (97.0)	6.66 (44.0)	12.41 (154.0)	66.9
Unweeded control	5.70 (32.0)	9.69 (93.0)	5.02 (24.0)	12.25 (149.0)	9.40 (88.0)	15.23 (231.0)	12.14 (146.0)	21.59 (465.0)	-
LSD (p=0.05)	0.40	0.44	0.43	0.43	0.65	0.54	1.03	0.84	

Original figures in parentheses were subjected to square root transformation before statistical analysis; *fb*- followed by

In contrary, Kundu *et al.* (2017) observed that PE application of pretilachlor 30.7% EC at any dose did not show phytotoxic symptoms in DSR on sandy loam soils of Nadia, West Bengal. The reduction in plant population in the present experiment in pre-emergence herbicides applied plots is mainly due to high moisture content in the top layers of the soil as a result of 12 mm of rainfall received at 10 hours after herbicide application. The highest values of the growth parameters, *viz.* plant height, leaf area index and tillers/m^2 were recorded with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha, which was statistically similar to pre-emergence application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha. Sequential application of pendimethalin 1000 g/ha *fb* PoE application of any one of the above said PoE herbicide obtained broad-spectrum weed control, which in turn lead to elevated growth parameters as a result of better availability of growth resources. These results were in-line with the findings of Choubey *et al*. (2006). Pre-emergence application of oxadiargyl 100 g/ha *fb* penoxsulam + cyhalofop-p-butyl 130 g/ha resulted in lesser values of all the growth parameter due to its poor weed control and offered competition for growth resources in penoxsulam + cyhalofop-p-butyl applied plots.

Yield components and yield

Different weed management practices significantly influenced the yield attributing characters and yield of rainfed lowland rice. Yield attributing characters, *viz.* panicles/m^2 and filled grains/panicle recorded at their highest with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha and it was comparable with PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha. The increase in yield attributes might be attributed due to complete control of all the categories of weeds. The lowest spikelet sterility was computed with above said treatments. Higher grain and straw yield of rainfed lowland rice was obtained with pre-emergence application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha due to its superiority in suppressing weed growth (**Table 2**). The reduction in grain and straw yield due to heavy weed infestation in unweeded check plots was 73.87 and 66.11%, respectively compared to the best treatment. The lowest values of the yield components and yield were recorded with pre-emergence application of oxadiargyl 100 g/ha *fb* penoxsulam + cyhalofop-p-butyl 130 g/ha due to poor performance of these herbicides in controlling weeds especially perennial sedge, *Cyperus rotundus*. Singh *et al*. (2005) also stated that uncontrolled weed

Table 2. Effect of pre-and post-emergence herbicides on growth parameters at harvest, yield components and yield of rainfed lowland rice and their residual effect on succeeding greengram

Treatment	Plant population /m^2	Plant height (cm)	LAI	Tillers/ m^2	Panicles /m^2	Filled grains /panicle	Spikelet sterility (%)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio	Residual crop (greengram)		
											Germination (%)	SVI	DMP (kg/ha)
Oxadiargyl *fb* penoxsulam + cyhalofop-p-butyl 100+130 g/ha (1 and 20 DAS)	44.67	64	1.84	136	104	60.67	23.0	1.75	2.68	1.11	91.33	1787	219
Pendimethalin *fb* penoxsulam +cyhalofop-p-butyl 1000+130 g/ha (1 and 20 DAS)	45.67	66	1.91	156	113	65.67	22.0	1.93	2.82	1.20	88.83	1756	229
Pretilachlor *fb* penoxsulam +cyhalofop-p-butyl 750+130 g/ha (1 and 20 DAS)	43.00	65	1.86	140	113	65.67	22.6	1.84	2.72	1.17	90.00	1763	214
Oxadiargyl *fb* florpyrauxifen-benzyl 100+25 g/ha (1 and 20 DAS)	45.00	69	2.41	213	166	73.33	20.0	2.36	3.36	1.57	91.17	1802	236
Pendimethalin *fb* florpyrauxifen-benzyl 1000+25 g/ha (1 and 20 DAS)	47.33	74	3.21	301	201	82.33	17.3	3.52	4.65	2.30	88.37	1785	245
Pretilachlor *fb* florpyrauxifen-benzyl 750+25 g/ha (1 and 20 DAS)	42.67	68	2.18	192	152	72.67	21.3	2.10	3.01	1.41	89.50	1748	230
Oxadiargyl *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	45.33	69	2.43	259	181	75.00	19.6	2.67	3.69	1.55	90.83	1830	248
Pendimethalin *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	46.33	72	3.10	283	197	82.00	17.6	3.43	4.57	1.96	89.10	1838	252
Pretilachlor *fb* halosulfuron-methyl 750+67.5 g/ha (1 and 20 DAS)	42.67	72	2.83	273	196	81.33	18.3	3.28	4.43	1.91	90.17	1799	241
Pendimethalin *fb* bispyribac-sodium 1000+25 g/ha (1 and 20 DAS)	46.67	67	2.06	171	149	71.33	22.3	2.05	2.98	1.32	91.23	1830	209
HW twice (20 and 40 DAS)	49.00	70	2.69	266	184	76.67	19.0	2.82	3.88	1.67	89.50	1772	239
Unweeded control	48.67	59	1.45	106	78	53.00	25.3	0.92	1.58	0.67	89.17	1691	198
LSD (p=0.05)	1.86	3.0	0.36	21	12.3	5.21	2.04	0.29	0.34	0.15	NS	26.4	8.26

growth in direct-seeded rice resulted in reduced grain yield by 75.8% in sandy loam soils. Higher benefit-cost ratio was obtained with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha due to less cost of herbicides. The next best weed management practice in obtaining higher benefit-cost ratio was PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.7 g/ha.

Residual effect

All the pre-and post-emergence herbicides applied to rainfed lowland rice did not show any inhibitory effect on growth and development of succeeding greengram. Germination of greengram was not affected by any of the pre-emergence herbicides applied to rice crop. However, the highest seedling vigour index of succeeding greengram was computed with pre-emergence application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha applied to rice. This might be due to effect of sequential application of pendimethalin as PE *fb* halosulfuron-methyl as PoE in rainfed lowland rice and continued their herbicidal activity upto early stages of the succeeding greengram. Nazreen and Subramanyam (2018) also reported that halosulfuron-methyl 67.5 g/ha applied to maize did not affect the germination and growth of succeeding greengram.

Based on the above findings, it might be concluded that PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha applied at 20 DAS resulted in higher grain yield and benefit-cost ratio, apart from broad-spectrum weed control. PoE application of halosulfuron-methyl 67.5 g/ha was effective in reducing the density and dry weight of *Cyperus rotundus* and it was closely followed by florpyrauxifen-benzyl 25 g/ha. All the PE and PoE herbicides applied to rice did not show any inhibitory effect on succeeding greengram.

REFERENCES

Choubey M, Khajanji SN, Rama Mohan S and Dewangan YK. 2006. Effect of halosulfuron-methyl on weed control in direct-seeded drilled rice under puddle conditions of Chhattisgarh plains. *Plant Archives* **6**(2): 685–687.

Kundu CK, Biswas U, Kundu A, Bera PS and Sathish G. 2017. Studies on bio-efficacy and phytotoxicity of pretilachlor 30.7% EC in direct seeded rice. *International Journal of Chemical Studies* **5**(5): 1847–1850.

Mehar Chand, Samar Singh, Dharam Bir, Narender Singh and Vijay Kumar. 2014. Halosulfuron methyl: A new post-emergence herbicide in India for effective control of *Cyperus rotundus* in sugarcane and its residual effects on the succeeding crops. *Sugar Technology* **16**(1): 67–74.

Nazreen S and Subramanyam D.2017. Sequential application of pre- & post-emergence herbicides to control mixed weed flora in maize. *Indian Journal of Weed Science* **49**(3): 293–294.

Singh S, Singh G, Singh VP and Singh AP. 2005. Effect of establishment methods and weed management practices on weeds and rice in rice-wheat cropping system. *Indian Journal of Weed Science* **37**(1&2): 51–57.

Singh DJC and Rao KN. 1976. *Screening Technique in Weed Control by Chemicals*. Sreelakshmi publications, Bapatla, Andhra Pradesh.

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Effect of live mulches and herbicides on weeds and yield of direct-seeded rice under irrigated conditions

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ABSTRACT

A field experiment was conducted at Mata Gujri College, Fatehgarh Sahib, Punjab during rainy season of 2017 to study the effect of live mulches and herbicides in direct-seeded rice under irrigated condition. The experiment was laid out in a split-plot design with three replications. The live mulch include *Sesbania rostrata*, *Vigna unguiculata* and *Sesamum indicum* while weed management treatments were pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-Na 25 g/ha (PoE), bispyribac-Na 25 g/ha + carfentrazone 20 g/ha (PoE), bispyribac-Na 25 g/ha + ethoxysulfuron 18 g/ha (PoE) and pendimethalin 1.0 kg/ha (PE) along with weed free and weedy checks. Results indicated that higher yield attributes and yield were recorded under live mulch with *Sesbania rostrata*, which was statistically at par with live mulch with *Vigna unguiculata* and significantly superior over live mulch with *Sesamum indicum*. Among herbicides, application of bispyribac-Na 25 g/ha + carfentrazone 20 g/ha being at par with bispyribac-Na 25 g/ha + ethoxysulfuron 18 g/ha was significantly superior over other treatments.

Rice (*Oryza sativa* L.) is the principle source of food for more than half of the world population. Puddling and transplanting, the most common methods of rice establishment, require large amount of water (on an average 2500 litres) to produce 1.0 kg of rice (Bouman 2009), and amounts for about 30-40% of the total cost of cultivation (Chaudhary and Varshney 2003). Under this situation, direct-seeding of rice (DSR) seems a viable alternative in rescuing farmers (Farooq *et al*. 2011). The direct-seeding involves sowing of pre-germinated/soaked/dry seeds in wet (saturated) puddle/dry soils. Weed competition in DSR is, however a major problem that reduces the grain yield by 50-60% (Maity and Mukherjee 2008). Therefore, appropriate weed management strategies are required for the success of DSR. Brown manuring/live mulch helps smothering weeds, conserving moisture and adding about 15 kg N/ha without adding much on cost of production (Singh *et al.* 2007). Intercropping of green manuring crops with rice followed by killing them with post-emergence herbicides at 30 DAS reduces weed densities by about 40-50% (Gaire *et al*. 2013). It is a sustainable practice in suppressing weed growth and supplying nitrogen for soil fertility (Oyeogbe *et al.* 2017). The use of on-farm perennial leguminous species as mulching material can improve agricultural sustainability by limiting inputs (Mulvaney *et al*. 2017). Herbicides offer the most effective, economical and practical way of weed management. Pre-emergence herbicides in combination with post-emergence herbicides are needed to control weeds in DSR because of diverse weed flora. Application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone (25 + 20 g/ha) was at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron (25 + 18 g/ha) which was significantly superior over other treatments in respect to minimizing weed density and weed dry weight, weed index and maximizing weed control (Kumar and Singh 2018).

A field experiment was conducted at Mata Gujri College, Fatehgarh Sahib (Punjab), during *Kharif* season of 2017. The soil was alluvial having clay loam in texture with normal soil reaction (7.9), medium organic carbon (0.62%), medium available N (280.15 kg/ha), and medium in available P_2O_5 (30.84 kg/ha) and low available K_2O (130.84 kg/ha). The experiment was laid out in a split-plot design with 18 treatment combinations (3 live mulch and 6 weed management practices and three replications. The live mulch was subjected to main plots, *viz*. live mulch with *Sesbania rostrata*, *Vigna unguiculata* and

Sesamum indicum and weed management was kept in sub-plots, *viz*. weedy free, weed check, pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-Na 25 g/ha (PoE), bispyribac-Na 25 g/ha + carfentrazone 20 g/ha (PoE), bispyribac-Na 25 g/ha + ethoxysulfuron 18 g/ha (PoE) and pendimethalin 1.0 kg/ha (PE). Recommended dose of N, P_2O_5 and K_2O were applied at 120, 60 and 40 kg/ha, respectively. Half of total nitrogen and full dose of phosphorus, and potassium were applied to rice crop as basal before sowing. Remaining half dose of nitrogen in the form of urea was top dressed in two equal splits, at active tillering and panicle initiation stages. Sowing was done manually with the help of spade at a row spacing of 20 cm. Rice variety '*PR 126*' was seeded directly in soil using 30 kg seed/ha on 12^{th} June 2017. Direct-seeding was done by sowing pre-germinating seed in prepared seedbed. *S. rostrata*, *V. unguiculata* and *S. indicum were* sown on 14 June 2017 in the row spacing of rice using 50 kg/ha, 40 kg/ha and 4 kg/ha, respectively. The plot was kept moist for two weeks for establishment of seedlings by through irrigation and thereafter three irrigations were required applied. Pendimethalin was sprayed in the evening on the day of sowing while bispyribac-Na applied as mix tank with carfentrazone and ethoxysulfuron sprayed 25 days after sowing. The herbicides were sprayed with a knapsack sprayer fitted with flat-fan nozzle using spray volume of 500 L/ha. Weed density and weed dry weight data were collected at 30, 60, 90 DAS and at harvest stage. Weed density (no./m^2) was counted randomly from plot. Weed samples were sun dried for two days and kept in an oven drying at 70 ± 2 ^{0}C for 48 hours till their weight become constant. The data on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Grain yield and its attributes were also recorded during the course of investigation at crop maturity.

Effect on density and dry matter of weeds

The major annual grasses in DSR were *Echinochloa crus-galli, Echinochloa colona* and *Leptochloa chinensis*, perennial sedge *Cyperus rotundus* and *C. iria* and broad-leaved weeds such as *Commelina diffusa* and *Caesulia axillaris*. The live mulch had no significant influences on the total density of different group of weeds (grasses, sedge and broad-leaved weed) at 30 DAS while it influenced significantly at 60, 90 DAS and at harvest stage. However, the total weed density, and their dry weight influenced significantly due to application of different live mulch treatments (**Table 1**). The data revealed that the minimum weed density and total weed dry matter were recorded under live mulch with *Sesbania rostrata* which was found at par with *V. unguiculata* and significantly inferior with *S. indicum*. This can be attributed to low vigorous growth of weeds due to smothering effect of *S. rostrata* and *V. unguiculata*. These mulches also fix atmospheric nitrogen into soil for better crop growth. Higher density and dry weight of weeds were recorded under live mulch with *S. indicum,* which might have been due to the fact that the treatment is not cover crop or leguminous crop. At initial stage of crop, it is unable to suppress the density and their dry weight of weeds. Poor establishment of crop due to higher density and their dry weight of weeds in these treatments was the some as reported earlier (Kumar and Singh 2016, Mulvaney *et al.* (2017).

Among herbicides, bispyribac-Na 25 g/ha + carfentrazone 20 g/ha was at par with bispyribac-Na 25 g/ha+ ethoxysulfuron 18 g/ha and it was significantly superior over others treatments in respect of minimizing weed density and their dry weight at different stages. This might be attributed to more bio-efficiency of bispyribac- Na which effectively controled the diversified weeds as was reported by Yadav *et al.* (2011).

Interaction effect of live mulch and weed management practices was found significant for total weed density and dry weight at 60 days after sowing (**Table 2**). Irrespective of weed control methods, minimum weed density and weed dry weight was recorded under mulching with *S. rostrata*. The minimum weed density and dry weight of weeds was recorded with application of bispyribac-Na 25 g/ha + carfentrazone 20 g/ha. Application of bispyribac-Na 25 g/ha + carfentrazone 20 g/ha combined with *S. rostrata* mulch was most effective in reducing the weed density and weed dry weight and found at par with bispyribac-Na 25 g/ha *fb* ethoxysulfuron 18 g/ha, but significantly superior over other treatments. These results were also in conformity with earlier findings (Singh *et al.* 2013, Kumar *et al.* 2015).

Weed control efficiency and weed index

The data clearly indicated that live mulch with *S. rostrata* (59.51%) recorded the highest WCE and closely to as similar to live mulch with *V. unguiculata* (56.67%). However, the minimum WCE was recorded in live mulch with *S. indicum* (54.81%) at 60 DAS (**Table 1**). Probably, *S. rostrata* was found most effective to suppress weed growth in term of density and their dry matter at all stages of crop growth over the *V. unguiculata* and *S. indicum*. Behera and Das (2019) also reported similar results. The weed control efficiency under bispyribac-Na 25

Table1. Effect of live mulch and weed management on total weed density, total weed dry weight, WCE and WI in direct-seeded rice

Treatment	Total weed density (no./m^2)				Dry matter of weeds (g/m^2) at DAS				WCE (%) at 60 DAS	WI (%)
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest		
Live mulche										
Live mulch with *Sesbania rostrata*	10.2(120)	10.4(122)	9.5(110)	10.2(127)	5.3(33)	9.5(112)	9.6(120)	9.9(123)	59.51	20.14
Live mulch with *Vigna unguiculata*	10.3(124)	10.8(12)	9.9(118)	11.0(134	5.3(33)	9.7(120)	9.7(125)	10.3(131)	56.67	20.20
Live mulch with *Sesamum indicum*	10.4(126)	11.1(130)	10.3(129)	11.4(136)	5.4(35)	10.5(129)	10.3(130)	10.9(147)	55.81	20.27
LSD (p=0.05)	NS	0.43	0.55	0.61	NS	0.41	0.48	0.58	-	-
Weed management practice										
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 25 g/ha	9.57(91)	12.6160)	11.8(139)	13.0(149)	5.1(25)	11.5(128)	11.5(131)	12.4(155)	56.02	25.03
Bispyribac-Na 25 g/ha+ carfentrazone 20 g/ha	12.5(156)	9.4(90)	8.8(76)	9.9(88)	6.6(43)	8.2(77)	8.1(78)	9.6(92)	75.55	7.45
Bispyribac-Na 25 g/ha + ethoxysulfuron 18 g/ha	12.9(165)	9.5(92)	9.3(85)	9.7(103)	6.7(44)	8.4(78)	8.4(80)	9.6(93)	76.01	7.75
Pendimethalin 1.0 kg/ha	9.59(93)	14.3(210)	13.2(173)	14.6(195)	5.0(25)	12.4(167)	12.9(170)	13.6(184)	44.40	28.15
Weed free	0.71(0)	0.7(0)	0.7(0)	0.7(0)	0.71(0)	0.71(0)	0.7(0)	0.7(0)	100	0
Weed check	16.5(278)	18.0(320)	15.4 239)	17.5(257)	8.0(64)	17.7(259)	16.7(266)	17.3(298)	0	53.19
LSD (p=0.05)	0.76	0.52	0.44	0.50	0.31	0.71	0.74	0.79	-	-

Figures in parentheses are the original values, which were subjected to square root transformation before statistical analysis

Table 2. Interaction effect of live mulch and weed management on total weed density and total dry weight in direct-seeded rice

Treatment	Total weed density at 60 DAS (no./m^2)			Total weed dry matter at 60 DAS (g/m^2)		
	Live mulch with *Sesbania rostrata*	Live mulch with *Vigna unguiculata*	Live mulch with *Sesamum indicum*	Live mulch with *Sesbania rostrata*	Live mulch with *Vigna unguiculata*	Live mulch with *Sesamum indicum*
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 25 g/ha	12.17 (150)	12.60 (160)	13.13 (171)	11.09(122)	11.11 (124)	12.25 (150)
Bispyribac-Na 25 g/ha + carfentrazone 20 g/ha	8.81(76)	9.79(96)	9.74(94)	7.48 (55)	8.57 (73)	8.62 (74)
Bispyribac- Na 25g/ha + ethoxysulfuron 18g/ha	8.56(75)	9.81(96)	9.96(97)	8.14 (65)	8.50 (71)	8.65 (73)
Pendimethalin 1.0 kg/ha	13.57 (181)	14.39 (206)	14.85 (220)	12.41(155)	12.90 (166)	13.30 (76)
Weed free	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)	0.71(0)
Weed check	18.47(350)	17.47 (310)	17.99 (320)	17.08(291)	16.49 (270)	19.53 (380)
Weed management at same level of live mulch		0.31			0.22	
LSD (p=0.05)		1.10			1.42	
Live mulch at different level of weed management		0.30			0.40	
LSD (p=0.05)		0.99			1.15	

Figures in parentheses are the original values, which were square root transformed before analysis

g/ha + ethoxysulfuron 18 g/ha (76.01%) and bispyribac-Na 25 g/ha + carfentrazone 20 g/ha (75.55%) was at par. Similar results were also reported earlier by Gill and Walia (2014). Among weed management treatments, minimum weed index was recorded under bispyribac-Na 25 g/ha + carfentrazone 20 g/ha (7.45%) closely followed by bispyribac-Na 25 g/ha + ethoxysulfuron 18g/ha (7.75%).

Effect on yield attributes and yield

The live mulch and herbicides had significant effect on yield attributes but live mulch did not significantly influence the test weight and harvest index (**Table 3**). The data indicated that the maximum grain yield (4.77 t/ha) and yield attributes, *i.e.* effective tiller/m^2 (207.67), no. of grains/panicle (131.39), panicle length (30.10 cm), weight of panicle (3.30 g) and test weight (24.14 g) recorded under live mulch with *S. rostrata* was at par with *V. unguiculata,* but significantly higher than *S. indicum*. This could be due to lower total weed infestation and dry matter accumulation as a result these treatments consequently improved the crop growth (Thakur *et al.* 2011, Sarangi *et al*. 2016).

The maximum yield attributes and yield were recorded in weed free plots (**Table 3**). Among the weed management treatments, the maximum grain yield and yield attributes were recorded with application of bispyribac-Na 25 g/ha + carfentrazone 20 g/ha, which was at par with bispyribac- Na 25 g/ha+ ethoxysulfuron 18 g/ha but significantly superior over other herbicidal treatments. This might be due to higher weed control efficiency and the lowest weed index in these treatments. The similar results were recorded by Walia *et al.* (2012). Thus, the application of live mulch of *Sesbania rostrata* with bispyribac-Na 25 g/ha *fb* carfentrazone 20 g/ha may be recommended for weed management and higher yield in rice under irrigated condition of central Punjab.

Table 3. Effect of live mulch and weed management on yield attributes and yields of crop in direct-seeded rice

Treatment	No. of effective tillers/m^2	Panicle weight (g)	No. of grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Test weight (g)
Live mulche								
Live mulch with *Sesbania rostrata*	207.67	3.30	131.39	4.77	6.71	11.42	40.86	24.14
Live mulch with *Vigna unguiculata*	196.94	3.17	126.78	4.64	6.48	11.04	40.82	22.33
Live mulch with *Sesamum indicum*	190.33	3.06	117.33	4.42	6.18	10.47	40.53	21.55
LSD (p=0.05)	12.34	0.18	7.64	0.26	0.37	0.67	0.54	1.62
Weed management practice								
Pendimethalin 1.0 kg/ha *fb* bispyribac-Na 25 g/ha	204.00	3.25	126.33	4.32	6.26	10.49	40.33	22.54
Bispyribac-Na 25 g/ha + carfentrazone 20 g/ha	218.33	3.45	136.44	5.47	7.18	12.57	42.66	24.04
Bispyribac-Na 25 g/ha + ethoxysulfuron 18 g/ha	213.56	3.43	133.44	5.30	7.08	12.42	42.89	24.10
Pendimethalin 1.0 kg/ha	194.44	3.00	124.11	4.11	6.04	10.16	40.49	20.82
Weed free	227.89	3.65	139.44	5.80	7.37	12.76	42.20	25.10
Weed check	131.67	2.29	91.22	2.68	4.80	7.48	35.85	19.44
LSD (p=0.05)	10.89	0.17	6.09	0.44	0.36	0.73	NS	1.13

REFERENCES

Bouman BAM. 2009. How much water does rice use. *Rice Today* **8**(1): 28–29.

Behera B and Das TK. 2019. Brown manure species, weeds and maize in a co-culture in the field: who stands more competitive? *Pesticide Research Journal* **31**(1): 129–134.

Chaudhary VP and Varshney BP.2003. Performance evaluation of self- propelled rice transplanted under different puddle field conditions and sedimentation periods. *Agricultural Mechanical Asia, Africa, Latin America* **34**: 23–33.

Farooq M, Siddique KHM, Rehman H, Aziz T, Wahid A and Lee D. 2011. Rice direct seeding experiences and challenges. *Soil Tillage Research* **111**: 87–98.

Gaire R, Dahal KR, and Amgain LP. 2013. Effect of different mulching materials on weed dynamics and yield of direct seeded rice in Chitwan, Nepal. *Agronomy Journal of Nepal* **3**: 72–81.

Gill JS and Walia SS. 2014. Influence of FYM, brown manuring and nitrogen levels on direct seeded and transplanted rice (*Oryza sativa* L.). *Research Journal Agriculture Environment Management* **3**: 417–26.

Kumar S and Singh RK.2016. Interaction effect of nitrogen schedule and weed management on weeds, nutrient depletion and yield of direct seeded rice. *Indian Journal of Weed Science* **48**(4): 372–377.

Kumar S and Singh RK. 2018. Response of nitrogen schedule and weed management practices on weed flora in direct seeded rice (*Oryza sativa* L.) under irrigated conditions. *Agriways* **6**(1): 69–78.

Kumar S, Singh RK, Meena RN and Singh SP. 2015. Effect of nitrogen scheduling and weed management on weed density, growth and yield of direct-seeded rice (*Oryza sativa* L.). *Research on Crops* **16**(4): 643–652.

Maity SK and Mukherjee PK. 2008. Integrated weed management in dry direct seeded rainy season rice. *Indian Journal Agron*omy **53**(2): 116–120.

Mulvaney MJ, Wood CW, Balkcom KS, Kemble J, Shannon DA. 2017. No-till with high biomass cover crops and invasive legume mulches increased total soil carbon after three years of collard production. *Agroecology Sustainable Food* **41**(1): 30–45.

Oyeogbe AI, Das TK, Bhatia A and Singh SB. 2017. Adaptive nitrogen and integrated weed management in conservation agriculture: impacts on agronomic productivity, greenhouse gas emissions, and herbicide residues. *Environment Monitor Assessment* **189**(4): 198.

Sarangi DR, Sahoo TR, Sethy S, Chourasia M, Prasad SM, Mohanta RK and Sadangi BN. 2016. Effect of replacing a part of nitrogenous fertilizer by brown manuring in direct seeded rice: a field study. *Oryza* **53**(2): 226–228.

Singh A, Singh RK, Kumar P and Singh S. 2013. Growth, weed control and yield of DSR as influenced by different herbicides. *Indian Journal of Weed Science* **45**(4): 235–238.

Singh Y, Gupta RK, Singh B and Gupta S. 2007. Efficient management of fertilizer nitrogen in wet direct seeded rice (*Oryza sativa* L.) in North West India. *Indian Journal Agriculture Science* **77**: 561–564.

Thakur R, Majhi, Shushama, Upasani RR, Pal SK and Singh MK. 2011. Impact of integrated weed management on dry matter partitioning and productivity of direct-seeded rice. *SAARC Journal of Agriculture* **9**(1): 37–43.

Walia US, Walia SS, Sidhu AS and Nayyar S. 2012. Bio-efficacy of pre- and post-emergence herbicides in direct-seeded rice in Central Punjab. *Indian Journal of Weed Science* **44**(1): 30–33.

Yadav S, Humphreys E, Kukal SS, Gill, G and Rangarajan R. 2011. Effect of water management on dry seeded and puddled transplanted rice part 2: Water balance and water productivity. *Field Crops Research* **120**: 123–132.

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Weed dynamics in wheat as affected by weed management practices under Doon valley conditions

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ABSTRACT

A field experiment was conducted at Agronomic Research Station of Doon (P.G) College of Agriculture Science and Technology, Rampur (Selaqui) Dehradun, Uttarakhand during 2018-19 to study the effect of different herbicides in wheat. The experimental soil was sandy loam in texture, slightly acidic in nature with low in N, high in available P and medium in K. The results revealed that post-emergence application of sulfosulfuron 25 g/ha, followed by metsulfuron-methyl 4.0 g/ha gave the highest yield of wheat which was at par with manual weeding at 30, 60 and 90 DAS. Based on the results, hand weeding at 30, 60 and 90 days after sowing in wheat recorded the lowest values of weed count and biomass with the highest weed control efficiency, and also showed superiority over rest of the treatments. Among the herbicides, sulfosulfuron at 25 g/ha applied as post-emergence produced grain yield of wheat 3.49 t/ha, which increased the grain yield of wheat to the tune of 24.2, 35.8, 46.0, 49.8 and 103% over carfentrazone, clodinafop propargyl, pendimethalin, pinoxaden and weedy check, respectively.

Wheat (*Triticum aestivum* L.) is the most important cereal crop of India next to rice and accounts for 31.5% of the total food grain basket of the country. An area of wheat 30.6 mha, with the production of 98.4 mt and average productivity of 3.21 t/ha in India was reported (Anonymous 2017). In Uttarakhand, area under wheat during 2016-17 was 3.4 lakh ha with an annual production of 8.82 lakh tons with productivity of 2.58 t/ha (Anonymous 2017).Weeds emerge with crop if not controlled in the critical stages of crop growth and these may cause reduction in yield from 10 to 40% depending upon the intensity and kind of weed infestation in crop. Weed control by manual weeding is highly expansive which can't be feasible and also non availability of agricultural labour is another crucial issue. Therefore, we need to select or opt the suitable chemical / herbicidal management in wheat based production system to sustain the profitability at reasonable cost. Herbicides offer most ideal, practical, effective and economical means of reducing early weed competition and crop production losses. However, continuous use of the same herbicides leads to built up of resistance in weeds. It is therefore, necessary to combine or change the method and strategies of weed control. Hence, the present investigation was undertaken.

A field experiment was carried out during 2018-19 *Rabi* season at Agronomic Research Station of Doon (P.G) College of Agriculture Science and Technology, Selaqui, Dehradun, Uttarakhand. The soil of the experimental field was sandy loam in texture with pH (6.47), low in available N(212.54 kg/ha), high (44.1 kg/ha) in P and medium (147 kg/ha) in K. Wheat (HD-2967) was shown on 2nd fortnight of November by using seed rate of 100 kg/ha at 5 cm depth with rows 22.5 cm apart. The experiment was laid out in randomized block design (RBD) with three replications comprising eight treatments, *viz*. weedy check, hand weeding (HW) at 30, 60 and 90 DAS, sulfosulfuron 25 g/ha, pinoxaden 5.0% EC 40 g/ha, carfentrazone-ethyl 40% DF 20 g/ha, pre-emergence pendimethalin 30% EC 750 g/ha, clodinafop 15% WP 60 g/ha, and metsulfuron-methyl 20% WG 4 g/ha were used. The crop was fertilized with recommended doses of N-P-K of 120-60-40 kg/ha through urea, single superphosphate and murate of potash, respectively. Half dose of nitrogen and full dose of P and K were applied as basal dose.

Remaining half dose of nitrogen was top dressed after the 1st irrigation. Herbicides were applied as pre-emergence at (0-3) DAS and post-emergence was at 34 DAS with manually operated knapsack sprayer with spray volume of 600 L/ha. Weed population and weed dry weight was recorded in each plot in quadrate of 1 x 1 m^2 and subjected to square root transformation before analysis. Data on wheat yield and yield parameters were also recorded at crop maturity. Weed index was calculated by the formula proposed by Gill and Kumar (1969).

Weed flora

In experimental crop, the most dominant weed species were; *Chenopodium album, Vicia sativa, Medicago denticulata, Fumaria parviflora, Rumex dentatus, Anagallis arvensis* as broad-leaved weeds and *Phalaris minor, Cynodon dactylon* and *Poa annua* among narrow-leaved weeds. All the weed control practices had significant differences on weed control during the period of experimentation in wheat crop.

Effect on weeds

Total weed density and weed biomass were affected significantly due to weed management practices (**Table 1**). Total weed count and weed biomass ranged from 0.53/m^2 and 0.26 g m^2 in plots with three hands weeding at 30, 60 and 90 DAS and to 249.5/m^2 and 7.51 g/m^2 in weedy check, respectively. Among the herbicide, post-emergence application of sulfosulfuron 25 g/ha followed by metsulfuron-methyl 4 g/ha proved its superiority over rest of the treatments and was at par with hand weeding at 30, 60 and 90 DAS. The reduction in biomass was mainly attributed to lower weed count under these treatments because of higher weed control efficiency. Lowest weed count and weed biomass also observed by Kumar *et al*. (2009) under post-emergence application of sulfosulfuron at 25 g/ha in wheat.

Weed control efficiency

Weed control efficiency (WCE) indicates genuine magnitude of reduction in weed dry matter by various weed control treatments. The WCE of various treatments was carried out at 90 DAS using the formula proposed by Gautam *et al*. (1975). Among the herbicides, sulfosulfuron 25 g/ha applied as post-emergence recorded the highest WCE of 99.7% which was at par with hand weeding at 30, 60 and 90 DAS treatment. Whereas, clodinafop 60 g/ha as PoE recorded lower WCE (59%) among the herbicides. The finding is in close conformity with the Kumar *et al*. (2013).

Effect on wheat crop

Herbicide application had significant effect on wheat grain and straw yield (**Table 1**). The highest grain yield of wheat (3.63t/ha) was recorded in hand weeding at 30, 60 and 90 DAS. Among the herbicides, sulfosulfuron at 25 g/ha applied as post-emergence produced grain yield of 3.49 t/ha, which increased the grain yield of wheat to the tune of 24.2, 35.8, 46.0, 49.8 and 103% over carfentrazone, clodinafop propargyl, pendimethalin, pinoxaden and weedy check, respectively. However, carfentrazone, clodinafop propargyl, pendimethalin and pinoxaden being at par with each other, increased the yield of wheat significantly as compared to weedy check. Sulfosulfuron 25 g/ha and metsulfuron-methyl 4 g/ha yielded similar to that of hand weeding at 30,60 and 90 DAS condition. The lowest weed index (3.9%) was observed in sulfosulfuron at 25 g/ha. Whereas, highest reduction in grain yield was found to the tune of 52.6% under weedy check conditions. The results are in close conformity with those of Sujoy *et al*. (2006) and Pandey and Kumar (2005).

Economics

Sulfosulfuron at 25 g/ha applied as post-emergence remunerated highest net return of ₹

Table 1. Effect of different weed management practices on weed count, weed biomass, yield and yield attributes of wheat

Treatment	Total weed density (no./m^2)	Weed biomass (g/m^2)	WCE (%)	Effective tillers/m^2	No. of spikelet/ spike	No. of grains/s pike	Test weight (g)	Weed index (%)
Sulfosulfuron 25 g/ha as post-emergence	6.07(35.9)	1.24(0.56)	99.7	140.7	3.7	37.1	45.01	3.9
Pinoxaden 40 g/ha as post-emergence	13.01(168.3)	2.45(5.03)	68.1	97.6	2.6	30.7	44.70	35.8
Carfentrazone 20 g/ha as post-emergence	11.40(129.1)	2.19(3.82)	72.7	122.5	2.9	33.1	44.8	22.6
Pendimethalin 750 g/ha as pre-emergence	8.55(72.23)	1.46(1.14)	84.3	91.7	3.5	31.1	43.52	34.2
Clodinafop 60 g/ha as post-emergence	13.49(181.2)	2.51(5.33)	59.2	83.0	3.2	34.7	44.07	29.2
Metsulfuron 4 g/ha as post-emergence	7.64(57.5)	1.25(0.57)	97.6	125.6	3.5	35.2	43.90	17.9
Three hand weeding at 30, 60 and 90 DAS	1.23(0.53)	1.12(0.26)	99.8	145.0	3.8	43.6	45.80	0.0
Weedy check	15.82(249.5)	2.91(7.51)	0	71.4	2.4	30.2	40.81	52.6
LSD (p=0.05)	1.78	4.82	-	80.7	0.7	8.39	4.09	8.05

DAS-Days after sowing; WCE - Weed control efficiency, *Data in parentheses are original values. Values are square root ($\sqrt{x+1}$)

Table 2. Effect of different weed management practices on economics in wheat

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	B:C ratio
Sulfosulfuron 25 g/ha as post-emergence	3.49	4.26	30.11	53.45	2.78
Pinoxaden 40 g/ha as post-emergence	2.33	3.21	30.49	26.95	1.88
Carfentrazone 20 g/ha as post-emergence	2.81	3.02	29.76	35.67	2.20
Pendimethalin 750 g/ha as pre-emergence	2.39	3.76	30.11	30.90	2.03
Clodinafop 60 g/ha as post-emergence	2.57	2.94	29.45	31.19	2.06
Metsulfuron 4 g/ha as post-emergence	2.98	4.02	29.26	43.81	2.50
Three hand weeding at 30, 60 and 90 DAS	3.63	4.52	35.45	51.87	2.46
Weedy check	1.72	2.76	29.15	15.01	1.51
LSD (p=0.05)	0.52	0.93	-	-	-

DAS-Days after sowing, prices of wheat ₹ 18450/t, straw ₹ 4500/t

53452/ha, which was higher by ₹ 38444, 26504, 22548, 22257, 1778, 9642 and ₹ 1584 with weedy check, pinoxaden, pendimethalin, clodinafop propargyl, carfentrazone, metsulfuron-methyl and hand weeding, respectively (**Table 2**). Benefit: Cost ratios were also followed the trend as the net returns. The highest B:C ratio of 2.78 was observed with sulfosulfuron at 25 g/ha as against lowest (1.51) in weedy check. The highest cost of cultivation in wheat involved where the weeds controlled by hand weeding.

Thus, it was concluded that in the valley conditions of Dehradun, post-emergence application of sulfosulfuron 25 g/ha gave excellent weed suppression in wheat crop which was at par with three hand weeding. It also produced maximum grain yield over rest of the herbicides. Except sulfosulfuron and metsulfuron-methyl, none of the herbicide could reach the performance of hand weeding at 30, 60 and 90 DAS in respect of weed count, weed biomass, yield and yield attributes of wheat.

REFERENCES

Anonymous. 2017. *Annual report.* Directorate of Economics and Statistics. DAC. Ministry of Agriculture and Farmers Welfare, Govt. of India.

Gautam KC, Mani VS and Sharma RK. 1975. A note on efficiency, selectivity and residual toxicity of some soil applied herbicide in soybean. *Indian Journal of Weed Science* **7**(10): 72–76.

Gill HS and Kumar Vijay. 1969. Weed index: A new method for reporting control trials. *Indian Journal of Agronomy* **14**(1): 96–98.

Kumar Sanjeev, Malik RS, Ashok Yadav and Malik RK. 2009. Performance of cultivars and sulfosulfuron against weeds in wheat, *Indian Journal of Weed Science* **39**(1&2): 44–47.

Kumar S, Rana SS, Rajesh and Chandler N.2013. Herbicide combinations for broad – spectrum weed control in wheat. *Indian Journal of Weed Science* **45**(1): 29–33.

Pandey IB and Kumar K. 2005. Response of wheat (*Triticum aestivum L.*) to seeding methods and weed management. *Indian Journal of Agronomy* **50**(1): 48–51.

Sujoy D, Sarkar AK, Bhattacharya SP and Saha A. 2006. Effect of various weed management practices in wheat. *Environment and Ecology* **24**(3): 620–622.

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Management of herbicide resistant *Phalaris minor* through sequential application of pre- and post-emergence herbicides in wheat

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ABSTRACT

A field study was conducted during winter season of 2017-18 at Department of Agronomy, CCS Haryana Agricultural University, Hisar under irrigated conditions to evaluate the management of *P. minor* through sequential application of pre-emergence (PE) and post-emergence (PoE) herbicide in wheat crop and their phytotoxic effect on the succeeding crop. Total fifteen treatments consisting of pre-emergence (PE) use of pendimethalin 1500 g/ha, clodinafop 60 and 120 g/ha (35 DAS), sulfosulfuron 25 g/ha (35 DAS), sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pinoxaden 50 g/ha (35 DAS), mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), PE of pendimethalin + metribuzin (RM) 2000 g/ha, PE pendimethalin + metribuzin (RM) *fb* clodinafop 60 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* sulfosulfuron 25 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* sulfosulfuron + metsulfuron 32 g/ha(35 DAS), PE pendimethalin + metribuzin (RM) *fb* pinoxaden 50 g/ha (35 DAS), PE pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), weedy check and weed free were take. The results of present study revealed that PE followed by PoE herbicides are effective for the control of resistant *P. minor* population. The sequential application of PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha followed by PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* sulfosulfuron + metsulfuron (RM) 32 g/ha and pinoxaden 50 g/ha were the most effective for control of resistant *P. minor* compared to alone PE or PoE herbicide. Grain yield and economics were also higher with these treatments.

As the harbinger of green revolution, wheat has played a key role in achieving self-reliance in the food production by the country. *Phalaris minor* Retz. (little seed canary grass) is a common weed of wheat in the rice-wheat cropping system in North-Western Indo-Gangetic Plains of India (Singh *et al.* 1995b, Franke *et al.* 2003, Punia *et al.* 2017). Haryana is the major wheat growing state in India with an area of 2.5 million ha (8% area of the national wheat area), 11.8 million tonnes of production (12.3% production share), and productivity of 4.72 t/ha (Anonymous 2015). Haryana still has the potential to increase the productivity of wheat with improved agronomic practices, including weed management. Although *P. minor* infests several winter season crops but morphological similarities, prolific seed production, un-synchronous and early maturity and continuous shattering of seeds before harvesting of the crop have ensured heavy prevalence of this weed in rice-wheat system.

Herbicides were largely accepted by the farmers to control this notorious weed. However, evolution of resistance against isoproturon, the most commonly used herbicide to contol *P. minor* in wheat during early 1990s was considered as one of the most serious cases of herbicide resistance in the world, resulted in total failure of crop under heavy infestation in Punjab and Haryana (Malik and Singh 1993, 1995, Walia *et al.* 1997). Therefore, new herbicides (clodinafop, sulfosulfuron, fenoxaprop and tralkoxydim) were recommended in resistance affected areas of rice- wheat cropping systems. The efficacy of these herbicides against *P. minor* was however reduced with development of multiple resistances in 2006. Excellent control of resistant *P. minor* and good grain yield were recorded in wheat fields with sequential use of pendimethalin and post-emergence herbicides clodinafop/pinoxaden and sulfosulfuron (Yadav *et al.* 2016, Kaur *et al.* 2016). Looking into the present scenario, it seems that in near future, the problem of the herbicide resistance in this weed may again pose a serious threat to the sustainability of wheat. Keeping this in view, the present study was conducted for management of herbicide resistance in *P. minor* using of pre- and post-emergence herbicides in wheat under field conditions.

The study was conducted during winter season of 2017-18 at CCS Haryana Agricultural University, Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.0, low in organic carbon (0.40%) and available nitrogen (167 kg/ha), medium in available phosphorus (19 kg/ha) and high in available potassium (295 kg/ha) status. Fifteen treatments were tried in a randomized block design replicated thrice in a plot size of 7 x 7 m^2. Wheat (cultivar '*HD 2967*') was seeded on 23rd November, 2017 using a seed rate of 100 kg/ha, in 20 cm spaced rows. The wheat seed was treated with Dursban (chlorpyriphos 20 EC) 4 ml/kg seed and Vitavax (carboxin) 2 g/kg seed, before sowing. Treatments included pendimethalin 1500 g/ha (pre-emergence), clodinafop 60 and 120 g/ha (35 DAS), sulfosulfuron 25 g/ha (35 DAS), sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pinoxaden 50 g/ha (35 DAS), mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), PE of pendimethalin + metribuzin (RM) 2000 g/ha, pendimethalin + metribuzin (RM) *fb* clodinafop 60 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* sulfosulfuron 25 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* sulfosulfuron + metsulfuron 32 g/ha (35 DAS), pendimethalin + metribuzin (RM) *fb* pinoxaden 50 g/ha (35 DAS), pre-emergence application of pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (35 DAS), weedy check and weed free. All PE herbicides were sprayed using 500 litres of water/ha and post-emergence herbicides were sprayed with the help of knap-sack sprayer fitted with flat-fan nozzles using 375 litres of water/ha. Total rainfall received during the cropping period was 29.9 mm.

The density of *P. minor* was determined by quadrate method (Misra and Puri 1954). The quadrate (0.25 m^2) was thrown randomly at four places in each plot at 30, 60, 90 DAS and harvest. The weeds inside the quadrate were counted and the average of four quadrates was taken. The actual values were subjected to square root transformation ($\sqrt{x+1}$) for analysis as suggested by Bartlett (1947) and Blackman and Roberts (1950). The weeds present within the quadrate from two places selected at random from each plot were taken for dry matter accumulation 30, 60, 90 DAS and at harvest. These samples were first dried under the sun and then kept in oven at 65±5^{0}C until a constant weight was achieved. The dried samples were weighed and the final dry weight of *P. minor* was expressed as g/m^2.

Visual phyto-toxicity on crop was recorded on 10 and 20 days after herbicide spray using 0-100 scale (where 0 = no mortality and 100 = complete mortality). Effective tillers were counted before harvest from one meter length of crop row at three places per plot, which were already marked for all replications. All other yield attributing characters, *viz.* number of grains/spike, test weight, grain yield and biological yield were recorded at harvest. To judge significant differences between means of two treatments, the critical difference (C.D.) was worked out by analysis of variance technique given by Fisher (1958).

Effect on weeds

All the weed control treatments significantly reduced density and dry weight of weeds as compared to untreated check at 90 DAS. The impact of various herbicide treatments on *P. minor* was taken through their impact on visual control, weed control efficiency, dry weight and weed density per square meter. It was visually observed that the sequential herbicide treatments had significant advantage over alone pre- or post-emergence herbicide treatments in controlling *P. minor*. The highest visual weed control (83%) at 90 DAS was observed with pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) at 2000 g/ha and 14.4 g/ha, respectively (**Table 1**). All the herbicide treatments significantly decreased the weed density and dry weight of *P. minor* than the weedy plots. The density of *P. minor* was significantly decreased with the successive use of pendimethalin + metribuzin (RM) 2000 g/ha *fb* PoE sulfosulfuron + metsulfuron (RM) 32 g/ha or sulfosulfuron 25 g/ha or pinoxaden 50 g/ha. Although, the lowest weed density and dry-matter was recorded with the use of pendimethalin + metribuzin (RM) *fb* mesosulfuron + iodosulfuron (RM) at 2000 g/ha and 14.4 g/ha and proved better among different treatments (**Table 1**). The post-emergence application of clodinafop 60 and 120 g/ha remained less effective than pre-emergence application of pendimethalin 1.5 kg/ha alone and pendimethalin + metribuzin (RM) 2000 g/ha, alone and had higher values for density and dry weight of weeds certainly due to occurrence of resistance problem. This is in conformity with the results of Punia *et al.* (2017) which reported that pre-emergence application of pendimethalin or pendimethalin + metribuzin (RM) although provided acceptable control of *P. minor,* however not adequate to control second flush of weeds after first irrigation.

Weed control efficiency (WCE) and weed index (WI) are vital parameters to assess the execution of various weed control treatments. At 90 DAS, highest weed control efficiency (87-94%) was obtained in treatments receiving sequential application of PE pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha sulfosulfuron + metsulfuron 32 g/ha /sulfosulfuron 25 g/ha and pinoxaden 50 g/ha (**Table 1**). Among herbicides, the lowest weed control efficiency was recorded in plots treated with clodinafop at 60 and 120 g/ha. The sequential application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron 14.4 g/ha or sulfosulfuron or alone mesosulfuron + iodosulfuron had lower weed index values while weedy treatment followed by different dose of clodinafop 60, 120 g/ha had maximum values of weed index due to low yield obtained on account of poor control of *P. minor* (**Table 1**).

Effect on crop

Visual phyto-toxicity recorded at 10 and 20 days after spraying of herbicides indicated that there were phytotoxic symptoms of few post-emergence herbicide treatments on wheat crop (0-100 scale). Among the herbicides treatment, mesosulfuron + iodosulfuron (RM) 14.4 g/ha caused to 5 and 3.43% phyto-toxicity at 10 and 20 DAS. The sequential application of pendimethalin + metribuzin (RM) 2.0 kg/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha also showed phytotoxicity of 5.0 and 2.0 per cent at 10 and 20 DAS, respectively on wheat and the phytotoxic symptoms in both the treatments disappeared with time and there was no phytotoxic symptoms on crop at 40 DAS. The data presented in **Table 2** revealed that weed control treatments significantly affected the effective tillers in wheat. Weed free treatment resulted in the highest number of effective tillers (456/m^2) whereas weedy check resulted in significantly the lowest number of effective tillers (408/m^2). Pre-emergence application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha (452/m^2) followed by post-emergence mesosulfuron + iodosulfuron (RM) alone 14.4 g/ha (439/m^2), pendimethalin + metribuzin (RM) 2000 g/ha *fb* pinoxaden 50 g/ha (436/m^2) produced higher number of effective tillers over other herbicide treatments and remained at par with weed free check. Post-emergence application of clodinafop 60 g/ha (409/m^2) and 120 g/ha (417/m^2) being at par with sulfosulfuron 25 g/ha (426/m^2) produced significantly the lowest number of effective tillers. This might be credited to viable weed control prompting less management challenge from weeds. Consequently, the wheat plants could completely use the accessible assets of space, sunlight based radiation, soil dampness and supplements bringing about improved photosynthesis and increasingly dry weight aggregation (Kaur *et al.* 2015).

Table 1. Effect of different treatments on visual control, density, dry matter of *P. minor*, WCE at 90 DAS and weed index

Treatment	Visual control of *P. minor* (%) 90 DAS	*P. minor* density (no./ m^2) 90 DAS	Dry matter (g/m^2) 90 DAS	Weed control efficiency (%) 90 DAS	Weed index (%)
Pendimethalin (1500 g/ha) PE	40	2.20(3.83)	66.64	51	12.31
Clodinafop (60 g/ha) at 35 DAS	24	2.33(4.43)	72.08	47	28.14
Clodinafop (120 g/ha)at 35 DAS	35	2.30(4.28)	62.56	54	25.01
Sulfosulfuron (25 g/ha) at 35 DAS	40	2.11(3.46)	46.24	66	9.41
Sulfosulfuron + metsulfuron (RM) (32 g/ha) at 35 DAS	48	2.16(3.66)	40.80	70	7.88
Pinoxaden (50 g/ha) at 35 DAS	52	2.22(3.93)	29.92	78	11.76
Mesosulfuron + iodosulfuron (RM)(14.4 g/ha) at 35 DAS	62	2.07(3.29)	16.32	88	2.30
Pendimethalin + metribuzin (2000 g/ha) PE	57	2.33(4.43)	38.08	72	6.89
Pendimethalin + metribuzin *fb* clodinafop (2000 *fb* 60 g/ha) PE at 35 DAS	53	2.10(3.43)	55.68	60	13.80
Pendimethalin + metribuzin *fb* sulfosulfuron (2000 *fb* 25 g/ha) PE at 35 DAS	61	2.17(3.72)	17.18	87	1.89
Pendimethalin + metribuzin *fb* sulfosulfuron + metsulfuron (2000 *fb* 32 g/ha) PE at 35 DAS	78	2.03(3.12)	13.96	89	3.07
Pendimethalin + metribuzin *fb* pinoxaden (2000 *fb* 50 g/ha) PE at 35 DAS	77	2.11(3.46)	13.6	90	4.34
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (2000 *fb* 14.4 g/ha) PE at 35 DAS	83	2.02(3.10)	8.16	94	1.21
Weedy check	0	3.21(9.30)	136	0	39.72
Weed free	100	1.0(0)	0	100	0
LSD (p=0.05)		0.10	5.58		

Table 2. Effect of different treatments on crop phyto toxicity, yield attributes, grain yield and B: C ratio

Treatment	Phytotoxicity (%) on crop			No. of effective tillers/m²	No. of grains/spike	Grain yield (t/ha)	B:C ratio
	10 DAS	20 DAS	40 DAS				
Pendimethalin (1500 g/ha) PE	0	0	0	429	47.95	4.77	2.06
Clodinafop (60 g/ha) at 35 DAS	0	0	0	409	46.55	3.91	1.61
Clodinafop (120 g/ha)at 35 DAS	0	0	0	417	46.91	4.08	1.65
Sulfosulfuron (25 g/ha) at 35 DAS	0	0	0	426	48.85	4.93	2.17
Sulfosulfuron + metsulfuron (RM) (32 g/ha) at 35 DAS	0	0	0	435	48.88	5.01	2.17
Pinoxaden (50 g/ha) at 35 DAS	0	0	0	433	49.57	4.90	2.09
Mesosulfuron + iodosulfuron (RM)(14.4 g/ha) at 35 DAS	5	3.43	0	435	49.78	5.22	2.31
Pendimethalin + metribuzin (2000 g/ha) PE	0	0	0	432	49.56	5.07	2.02
Pendimethalin + metribuzin *fb* clodinafop (2000 *fb* 60 g/ha) PE at 35 DAS	0	0	0	424	48.05	4.69	1.67
Pendimethalin + metribuzin *fb* sulfosulfuron (2000 *fb* 25 g/ha) PE at 35 DAS	0	0	0	439	49.80	5.27	2.06
Pendimethalin + metribuzin *fb* sulfosulfuron + metsulfuron (2000 *fb* 32 g/ha) PE at 35 DAS	0	0	0	432	48.61	5.35	2.11
Pendimethalin + metribuzin *fb* pinoxaden (2000 *fb* 50 g/ha) PE at 35 DAS	0	0	0	436	49.36	5.20	1.97
Pendimethalin + metribuzin *fb* mesosulfuron + iodosulfuron (2000 *fb* 14.4 g/ha) PE at 35 DAS	5	2	0	452	50.33	5.41	2.13
Weedy check	0	0	0	408	45.73	3.28	1.14
Weed free	0	0	0	456	50.49	5.44	1.19
LSD (p=0.05)				43.50	4.92	0.48	

Weeds growing throughout the crop-growing season significantly reduced the grain yield of wheat to the extent of 43-45%. All the herbicide treatments gave significantly higher grain yield as compared to weedy check. The sequential application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* mesosulfuron + iodosulfuron (RM) 14.4 g/ha recorded significant increase in grain yield (38-39%) over weedy check, and produced higher grain yield (5.41 t/ha) comparable to weed free (5.44 t/ha). Pre-emergence application of pendimethalin + metribuzin (RM) 2000 g/ha *fb* sulfosulfuron 25 g/ha (5.34 t/ha) being at par with PoE mesosulfuron + iodosulfuron 14.4 g/ha (5.22 t/ha) and produced higher grain yield than weedy check. Higher grain yield was attributed to the higher yield attributing characters in the weed free and herbicide treated plots. Application of pendimethalin + metribuzin 2000 g/ha (PE) *fb* mesosulfuron + iodosulfuron 14.4 g/ha (PoE) recorded the highest benefit: cost ratio (2.13).

REFERENCES

Balyan RS and Malik RK. 1989. Wild oat (*Avena ludoviciana*) competition with wheat (*Triticum aestivum*) effect of nitrogen fertilization, *Seasonal Report of Research Projects of Agronomy 2*.

Chhokar RS and Malik RK. 2002. Isoproturon resistant *Phalaris minor* and its response to alternate herbicides. *Weed Technology* **16**: 116–123.

Chhokar RS, and Malik RK. 1999. Effect of temperature on the germination of *Phalaris minor* Retz. *Indian Journal of Weed Science* **31**: 73–74.

Franke AC, McRoberts N, Marshall G, Malik RK, Singh S and Nehra AS. 2003. A survey of *Phalaris minor* in the Indian rice-wheat system. *Experimental Agriculture* **39**: 253–265.

Gupta OP 2015. *Modern Weed Management*. AGROBIOS, India

Kaur M, Punia SS, Singh J and Singh S. 2019. Pre- and post-emergence herbicide sequences for management of multiple herbicide-resistant little seed canary grass in wheat. *Indian Journal of Weed Science* **51**(2): 133–138.

Kaur N, Kaur T, Kaur KS and Bhullar MS. 2015. Development of cross resistance in *Phalaris minor* Retz. L. in Punjab. *Agricultural Research Journal* **53**(1): 69–72.

Malik RK and Singh S. 1993. Evolving strategies for herbicide use in wheat, resistance and integrated weed management.225–238. In: *Proceedings of International Symposium on "Integrated Weed Management for Sustainable Agriculture"*, Hisar, India. Nov. 18-20, 1993, Hisar, India.

Misra R and Puri GS. 1954. *Indian Manual of Plant Ecology*. Vasant Press, Dehradun.

Punia SS, Sharma SD, Yadav A and Sangwan N. 2006. Efficacy of pinoxaden 10 EC against grassy weeds in wheat. *Annals of Biology* **22**: 149–151.

Punia SS, Yadav DB, Amarjeet and Sindhu VK. 2017. Investigations on weed flora of wheat in Haryana. *Agricultural Research Journal* **54**(1): 136–138

Punia SS, Yadav DB, Kaur M and Sindhu VK.2017. Post emergence herbicides for the control of resistant little seed canary grass in wheat. *Indian Journal of Weed Science* **49**(1):15–19

Singh S, Malik RK, Balyan RS and Singh S. 1995b. Distribution of weed flora of wheat in Haryana. *Indian Journal of Weed Science* **27**: 114–121.

Walia US, Brar LS and Singh KJ 1997. Control of *Rumex spinosus* with sulfonylurea herbicides in wheat. *Indian Journal of Weed Science* **29**(3&4): 103–105.

Yadav DB, Yadav A, Punia SS and Chauhan BS 2016. Management of herbicide-resistant *Phalaris minor* in wheat by sequential or tank-mix applications of pre- and post-emergence herbicides in north-western Indo-Gangetic Plains. *Crop Protection* **89**: 239–247.

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On farm assessment of ready mix herbicide combinations for broad-spectrum weed control in wheat

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ABSTRACT

Farmers led on-farm trials were conducted in Morar and Bhitarwar blocks of district Gwalior during *Rabi* seasons of the year 2014-15 and 2015-16 in K.V.K. adopted villages to validate, refine and popularize the technologies recommended by Directorate of Weed Research, Jabalpur for managing grassy and broad-leaf weeds in wheat. Application of clodinafop + metsulfuron (60 + 2 g/ha) caused significant reduction in total weed counts (28.6 and 40.8/m^2) and weed dry weight (3.5 and 4.2 g/m^2) over farmer's practice (2,4-D at 500 g/ha) as it reduced the population of both grassy and broad-leaved weeds and produced the highest weed control efficiency (83 and 82.6%) over application of sulfosulfuron + metsulfuron (30 + 2 g/ha) (70.87 and 76.03%) and farmers' practice during both the year. Recommended practice of clodinafop + metsulfuron (60 + 2 g/ha) gave significantly higher grain yield (4.10 and 4.71 t/ha) over sulfosulfuron + metsulfuron (30 + 2 g/ha) and farmers practice. There were 21.42 and 22.46 and 12.18 and 9.87% increase in grain yield over farmers' practice respectively under clodinafop + metsulfuron (60 + 2 g/ha) and sulfosulfuron + metsulfuron (30 + 2 g/ha) during the year 2014-15 and 2015-16. The highest net returns (₹ 51003 and 65267/ha) and B:C ratio (2.78 and 3.45) were recorded under recommended practice of clodinafop + metsulfuron (60 + 2 g/ha).

Wheat (*Triticum aestivum* L. emend. Fiori and Paol.) is an important winter cereal of Madhya Pradesh. It is grown in 5.91 million hectare area with the production of 18.41 million tone (Anonymous 2015-16).Though the production and productivity of wheat have increased in the state during the last five years, but the present productivity level is still low as compared to other wheat growing states in the country. Weeds are considered as major bottlenecks in realizing potential yield of wheat. Uncontrolled weeds caused 30-80% reduction in wheat grain yield (Waheel *et al.* 2009, Kumar *et al.* 2011, Brar and Walia 2008). Herbicidal weed control has proved efficient in controlling weeds (Kahramanoglu and Uygur 2010). Pre village adoption Participatory Rural Appraisal (PRA) survey of the KVK villages *viz.* Badkisarai, Amrol and Kunarpur in Bhitarwar and Morar blocks, respectively of Gwalior district revealed that farmers of these villages usually apply 2,4-D for the control of broad-leaved weeds in wheat, but grassy weeds, *viz. Phalaris minor*, *Avena ludoviciana* and *Poa annua,* were posing major problems. The present study was therefore planned to carry out assessment of ready mix herbicidal combinations on farmer's fields with the objective to validate, assess and refine the recommended herbicidal weed management technologies over farmer's practice.

A framers led field experiment was conducted during *Rabi* seasons of the year 2014-15 and 2015-16 in K.V.K. adopted villages, *viz*. Kunarpur in Morar block and Badkisarai and Amrol in Bhitarwar blocks of the Gwalior district. The soil of the experimental plots was clay loam in texture, moderately alkaline in reaction (pH.7.8-8.4), low in organic carbon (0.37-0.48%) and available nitrogen (210-235 kg/ha), medium in available phosphorous (12.0-15.5 kg/ha) and available potassium (226-280 kg/ha). The experiment was conducted in a single replicated trial on 10 farmers fields having1000 m^2 area under each broad spectrum herbicide assessed and farmers practice (2,4-D at 500 g/ha). Each location was considered as separate replication and each weed control treatments thus replicated at different locations consisted clodinafop + metsulfuron (60 + 2 g/ha), sulfosulfuron + metsulfuron (30 + 2 g/ha) and farmer's practice (2,4-D at 500 g/ha) all applied at 30-35 DAS stage. Wheat variety '*GW 273*' and

'*Raj 4037*' were sown in lines 20 cm apart by using double chamber seed cum fertilizer seed drill with 100 kg/ha seed rate during last week of November and first week of December during both the year. Recommended dose of fertilizers (120 kg N, 60 kg P_2O_5 and 40 kg K_2O) was uniformly applied to all the three weed control treatments. Full dose of phosphorous and potassium and half dose of nitrogen were applied basal at the time of sowing and rest of nitrogen in two equal splits was top dressed at first and second irrigation stage during both the crop seasons. The crop was grown with all other similar package of practices under all the herbicidal weed control measures under taken for investigation.

The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using spray volume of 500 L/ha. Weed counts (no./m^2) and dry weight (g/m^2) were recorded by putting a quadrate (0.25 m^2) at two randomly selected spots in each plot at 60 DAS stage of the crop. Weed biomass was recorded by weighing the dried weeds from the treatment plots. Weed control efficiency was estimated on the basis of reduction in weed weight in comparison with farmers practice (2,4-D at 500 g/ha). The least significant difference (LSD) was calculated by multiplying standard error with 't' value (p=0.05) at error degree of freedom to compare the means of the treatments for valid inference. The different impact indices were worked out after Walia (2014).

Effect on weeds

The major weed flora of experimental fields was different in command and non-command villages. Weed flora in command area village consisted of *Phalaris minor* (58.6%), *Avena ludoviciana* (12.8%) and *Poa annua* (3.2%) with sporadic infestation of broad leaved weeds, *viz. Anagalis arvensis* (12.4%), *Rumex dentatus* (6.8%) and *Chenopodium album* (6.2%) in village Badkisarai under Harsi canal command area in Bhitarwar block in 2015-16 whereas in other non command area villages (Amrol and Kunarpur) the mixed weed flora, *viz. Chenopodium album*, (45.2%) *Chenopodium murale* (4.5%), *Anagalis arvensis* (18.2%), *Melilotus indica* (12.4%), *Phalaris minor* (5.3 %), *Rumex dentatus* (4.7%), *Melilotus alba* (6.5%) and *Avena ludoviciana* (3.2%) was observed during the year 2014-15.

The highest density for grassy weeds was found under farmer's practice (2,4-D at 500 g/ha) whereas ready mixed products of herbicides gave significant control of grassy and broad-leaved weeds (**Table 1**). Singh *et al.* (2002) also reported that clodinafop provides effective control of *Phalaris minor* biotypes. Application of clodinafop + metsulfuron (60 + 2 g/ha) gave significant reduction in total weed counts and weed dry weight over farmer's practice at 60 DAS stage of wheat. Sulfosulfuron + metsulfuron (30+2 g/ha) gave similar effect over mixed weed flora. This may be because it also has broad spectrum effect on prevailing weed species in wheat fields, however comparatively low performance was observed on *Phalaris minor*, *Avena ludoviciana* and *Poa annua* in command area village *i.e. Badkisarai.* Similar findings were reported by Kumar *et al.* (2013). The highest total weed density and weed dry weight was recorded under farmers practice. Application of clodinafop + metsulfuron (60 + 2 g/ha) gave the highest WCE (83.0 and 82.60%) during both the years *fb* sulfosulfuron + metsulfuron (30 + 2 g/ ha). Higher weed control efficiency to the extent of 95% was also obtained by Malik *et al.* (2013) with application of clodinafop + metsulfuron (60 + 2 g/ha) against complex weed flora in wheat crop.

Effect on crop

Application of clodinafop + metsulfuron (60 + 2 g/ha) resulted in significantly maximum number of spikes, spike length and grain yield (21.42 and 22.46% respectively) of wheat over farmer's practice and sulfosulfuron + metsulfuron (30 + 2 g/ha) during both the year (**Table 1** and **2**). Both the ready mix herbicide combinations were observed significantly superior over farmers practice during both the year, due to less crop weed competition for nutrients, water, space and light because of effective control of weeds. This in turns might have resulted in greater photosynthesis besides larger sink and stronger reproductive phase. These results are in close conformity with those reported by Punia *et al.* (2004) and Malik *et al.* (2013). The significantly lower values of yield attributes, *viz.* no. of spikes (per m^2), spike length and grain yield in farmer's practice might be due to no control of grassy weeds due to 2,4-D at 500 g/ha. Kumar *et al.* (2013) also observed non-significant differences among various herbicides studied with respect to test weight of wheat grains.

Weed persistence index was also observed the lowest under application of clodinafop + metsulfuron (60 + 2 g/ha) during both the year (**Table 1**).

Economics

Maximum values of net returns *i.e.* ₹ 51003 and 65267/ha and B:C ratio of 2.78 and 3.45 were recorded with clodinafop + metsulfuron (60 + 2 g/ha) followed by sulfosulfuron + metsulfuron (30 + 2 g/ha). The lowest net returns and B:C ratio were however observed with farmers practice during both the years.

Table 1. Weed density, weed dry weight and impact assessment indices as influenced by application of ready mix herbicides in wheat crop

Treatment	Weed density (no./m²)		Weed dry weight (g/m²)		Impact assessment indices							
					Herbicide efficiency index (%)		Weed persistence index		Weed control efficiency (%)		% increase in yield over farmers practice	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
2,4-D 500 g/ha (Farmer's practice)	118.5	178.6	20.6	24.2	-	-	-	-	-	-	-	-
Clodinafop + metsulfuron (60 + 2 g/ha) 400 g/ha	28.6	40.8	3.5	4.2	1.26	1.29	0.70	0.74	83.0	82.6	21.42	22.46
Sulfosulfuron + metsulfuron (30 + 2 g/ha) 40 g/ha	60.5	54.5	6.0	5.8	0.42	0.41	1.36	0.79	70.87	76.03	12.18	9.87
LSD (p=0.05)	3.02	3.16*	1.36	1.15	-	-	-	-	-	-	-	-

Table 2. Effect of application of ready-mix herbicides on yield attributes, grain yield and economics of wheat on farmer's fields

Treatment	Spikes (no./m²)		Spike length (cm)		1000- grain weight (g)		Grain yield (t/ha)		Gross cost of cultivation (x103 ₹/ha)		Gross income (x103 ₹/ha)		Net income (x103 ₹/ha)		B:C ratio	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
2,4-D 500 g/ha (farmer's practice)	325	340	9.7	10.2	45.9	46.5	3.40	3.85	27.56	26.78	65.19	75.07	37.63	48.29	2.36	2.80
Clodinafop + metsulfuron (60 + 2 g/ha) 400 g/ha	448	452	11.2	12.6	46.6	47.6	4.10	4.72	28.61	27.67	79.61	91.94	51.00	65.27	2.78	3.45
Sulfosulfuron + metsulfuron (30 + 2 g/ha) 40 g/ha	396	406	10.5	11.5	45.8	46.8	3.80	4.23	28.31	27.54	74.78	82.48	46.47	54.95	2.64	2.99
LSD (p=0.05)	8.30	4.99	0.34	0.83	NS	NS	0.13	0.20	-	-	-	-	-	-		

On the basis of two years farmers led field assessment of ready mix herbicide combinations for weed control in wheat, it may be concluded that post emergence application of clodinafop + metsulfuron (60 + 2 g/ha) at 30-35 DAS could be a effective weed control practice for realizing higher productivity of wheat crop under mixed weed flora. The use of traditional herbicide with narrow spectrum weed control efficiencies could be avoided as they do not control the wide range of weed flora consist of broad-leaved weeds and grassy weeds like *Phalaris minor* and *Avena ludoviciana* in rice- wheat system.

REFERENCES

Anonymous. 2015-16. mpkrishi.mp.gov.in. District wise area-production and yield of crops in Madhya Pradesh (2011-12 -2015-16).

Brar AS and Walia US.2008.Effect of rice residues management techniques and herbicides on nutrient uptake by *Phalaris minor* Retz. *Indian Journal Weed Science* **40**(3&4): 121–127

Kumar S, Angiras NN and Rana SS. 2011. Bio-efficacy of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat. *Indian Journal Weed Science* **43**(3&4): 195–198.

Kahramanoglul and Uygur FN.2010.The effect of reduced doses and application timing of metribuzin on redroot pig weed (*Amaranthus retroflexus* L.) and wild mustard (*Sinapis arvensis* L.). *Turkish Journal of Agriculture and Forestry* **34**: 467–471.

Kumar S, Rana SS, Ramesh and Navell Chander. 2013. Herbicidal combinations for broad spectrum weed control in wheat. *Indian Journal Weed Science*45 (1): 29–33.

Malik RS, Yadav Ashok and Kumari, Ramesh. 2013. Ready mixed formulation of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat. *Indian Journal Weed Science* **45**(3): 179–182.

Punia SS, Malik RK and Shoeren Parvinder. 2004. Bio efficacy of tank mix combination of fenoxaprop and clodinafop with broad-leaf herbicides for broad spectrum weed control in wheat (*Triticum aestivum*). *Indian Journal of Ecology* **31**: 128–132.

Singh G, Singh M, Singh VP, Singh G and Singh M.2002. Effect of clodinafop-propargyl on weeds and wheat yield. *Indian Journal Weed Science* **34**(3-4): 165–167.

Waheel A, Qureshi R, Jakhar, GS and Tareen H. 2009. Weed community dynamics in wheat crop of district Rahim Yar Khan, Pakistan. *Pakistan Journal of Botany* **41**(1): 247–254.

Walia US. 2014. *Weed Management*. Kalyani Publishers, Ludhiana, 356p.

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Weed management in sunflower through sequential application of herbicides in Western Odisha

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ABSTRACT

Field experiment was conducted during the winter seasons of 2014-15 and 2015-16 to study the effect of sole and sequential application of herbicides on weed growth and productivity of sunflower (*Helianthus annuus* L.). *Echinochloa colona, Digitaria sanguinalis* and *Dactyloctenium aegyptium* among grasses; *Cyperus rotundus* and *Cyperus difformis* among sedges and *Cleome viscosa, Euphorbia hirta* and *Borreria hispida* among broad-leaved weeds, were predominant throughout the cropping period. Weed competition resulted in 31.3% yield loss in sunflower. Sequential application of oxyfluorfen 250 g/ha at 3 days after seeding (DAS) followed by (*fb*) quizalofop-ethyl 50 g/ha at 20 DAS resulted in the lowest weed density (41/m^2), total weed biomass (19.37 g/m^2), maximum nutrient uptake, yield (2.1 t/ ha) and benefit:cost ratio (1.82).

Sunflower is the most important oilseed crop of India. It is cultivated in an area of 4.0 lakh ha with a production of about 2.2 lakh tonnes and productivity of 555 kg/ha, which is lower than the world average of 1808 kg/ha (FAO 2017), indicating wider scope for improving the yield potential. Weed infestation is a major constraint causing lower sunflower yield. Uncontrolled weeds in sunflower caused yield loss of up to 62% (Sumathi *et al.* 2009). Heavy weed infestation in sunflower is mainly due to wider spacing, slower crop growth during early stages, higher fertilizers use and frequent irrigation. Manual weeding is difficult as it is highly labour intensive and time consuming. Herbicides are effective and viable option for weed management in sunflower (Shylaja and Sundari 2008). Several pre- and post-emergence herbicides have been reported (Singh and Singh 2006) to provide a good degree of weed control but the information on their efficacy in *Rabi* sunflower is inadequate. The application of herbicide once at pre-emergence stage may be inadequate in managing the whole spectrum of weeds. Sequential application of different herbicides ensures effective management (Tadavi *et al*. 2017) of composite weed flora. Hence, the present experiment was conducted to study the effectiveness of sole and sequential application of different herbicides for effectively managemenr of weeds and enhance productivity of *Rabi* sunflower.

The study was undertaken at Regional Research and Technology Transfer Station, OUAT, Chiplima, Sambalpur, Odisha during *Rabi* 2014-15 and 2015-16. The soil of the experimental field was sandy clay loam with pH 6.6, organic carbon 0.43% and available N ($KMnO_4$ method), P (Olsen) and K (NH_4OHC method) content of 268, 13.4 and 132 kg/ha, respectively. Eight treatments consisting of oxyfluorfen 250 g/ha at 3 days after seeding (DAS), oxadiargy l75 g/ha at 3 DAS, pendimethalin 1000 g/ha at 3 DAS, oxyfluorfen 250 g/ha at 3 DAS followed by (*fb*) quizalofop-ethyl 50 g/ha at 20 DAS, oxadiargy l75 g/ha at 3 DAS *fb* quizalofop-ethyl 50 g/ha at 20 DAS, pendimethalin 1000 g/ha at 3 DAS *fb* quizalofop-ethyl 50 g/ha at 20 DAS, weed free check and weedy control were tested in randomized block design with 3 replications. All data were analyzed through analysis of variance (ANOVA) using standard variance techniques suggested by Gomez and Gomez (1984). Sunflower cultivar '*Arjun*' was sown on 15 November, 2014 and 25 November, 2015 at a spacing of 60x30 cm and was harvested on 18, February, 2015 and 28 February 2016. A common fertilizer dose of 60 kg N + 90 kg P_2O_5 + 60 kg K_2O/ha was applied. Full dose of P_2O_5 and half dose of K_2O and N were applied as basal and remaining N and K_2O were top-dressed at 30 DAS. Required quantities of herbicides were applied as per treatment with manually operated knapsack sprayer fitted with flat-fan nozzle using a spray volume of 500 L of water/ha. Weed density (no./m^2) and weed biomass (g/m^2) were taken from random samples at 2 places in the field with the help of 1 m^2 quadrate at 50 DAS.

The weed samples collected in paper bags were air dried in shade initially followed by oven drying at 65^{0}C for 48 hours till they attain constant weight to determine biomass in g/m^2. Data on individual and total weed density and biomass were subjected to square root transformation ($\sqrt{x+1}$). Weed control efficiency (WCE) and weed index (W.I.) were calculated based on the weed biomass and sunflower seed yield, respectively. At the harvest, yield and yield-attributes of sunflower were recorded. Economics was computed using the prevailing market prices for inputs and outputs such as sunflower seed (₹ 37000/t), and manual labour (₹ 187/day); input price (₹/kg): sunflower seed, 700; urea, 5.52; diammonium phosphate, 24.45; muriate of potash, 17.44; oxyfluorofen, ₹ 180/100 ml; pendimethalin ₹ 400/l; oxadiargyl ₹ 300/50 g; quizalofop-ethyl ₹ 174/100 ml.

The predominant weeds of the experimental field were *Echinochloa colona, Digitaria sanguinalis, Dactyloctenium aegyptium, Brachiaria reptans* among the grasses; *Cyperus rotundus, Cyperus difformis* among the sedges and *Cleome viscose*, *Euphorbia hirta, Boerhavia erecta, Euphorbia thymifolia, Celosia argentea, Commelina benghalensis, Phylanthus niruri* among the broad-leaved weeds during both the years of study. The composition of grasses, sedges and broad-leaved weeds in weedy check plot was 25.1, 27.5 and 44.9%, respectively. Emergence of sedges and broad-leaved weeds were noticed earlier as compared to grasses.

Oxyfluorfen at 250 g/ha applied alone, effectively reduced density and biomass of the sedges (29.73/m^2 and 11.38 g/m^2) and broad-leaved weeds (65.16/m^2 and 20.99 g/m^2) (**Table 1**) as compared to pendimethalin and oxadiargyl. Pre-emergence application (PE) of pendimethalin 1000 g/ha was not much effective against broad-leaved weeds, but was effective against grasses (25.87/m^2 and 18.18 g/m^2).

Sequential application of oxyfluorfen at 250 g/ha *fb* quizalofop-ethyl at 50 g/ha recorded the lowest total weed density and biomass (41.04/m^2, 19.4 g/m^2), the highest weed control efficiency (84.1%) and the lowest weed index (7.1%), and uptake of N, P and K (8.33, 2.36 and 8.22 kg/ha) by weeds. The next best treatment was pendimethalin at 1000 g/ha *fb* quizalofop-ethyl at 50 g/ha (53.94/m^2, 21.45 g/m^2). Oxifluorfen or pendimethalin (PE) caused reduction in germination of emerging weed during initial period of growth, further post-emergence application of quizalofop-ethyl 50 g/ha has controlled the late emerging grassy weeds. These results were in agreement with Wanjari *et al*. (2000) and Sivasankar and Subramanyam (2011).

Oxadiargy at 175 g/ha PE (43.2%) alone or in combination with post-emergence application (PoE) of quizalofop-ethyl 50 g/ha applied at 20 DAS (71.8%) was not effective as that of oxyfluorfen or pendimethalin applied alone or in combination with PoE of quizalofop-ethyl in controlling weeds. The uptake of N, P and K by weeds was 23.0, 8.28 and 22.27 kg/ha respectively, in weedy control treatment due to heavy weeds infestation (**Table 3**).

Effect on crop

The sunflower yield and yield parameters were the highest under weed free treatments which were at par with herbicidal treatment of oxyfluorfen at 250 g/ha *fb* quizalofop-ethyl 50 g/ha at 20 DAS, and was significantly superior to pendimethalin 1000 g/ha at 3 DAS *fb* quizalofop–ethyl 50 g/ha at 20 DAS (**Table 2**). Overall seed yield was lower in 2015-16 than 2014-15. Plant height and hundred seed weight did not vary significantly among the treatments. Weed infestation caused 31.3% reduction in mean seed yield of *Rabi* sunflower. Similar yield reduction in *Rabi* sunflower due to weed competition was also reported by Pannacci *et al*. (2007) and Selvakumar *et al*. (2018). Weedy control recorded the lowest seed yield (1.6 t/ha).

Table 1. Effect of different weed management treatments on weed density and biomass, weed control efficiency at 50 days after seeding in *Rabi* sunflower (mean data of two years)

Treatment	Weed density (no/m^2)				Weed biomass(g/m^2)				W.C.E (%)	W.I. (%)
	Grasses	Sedges	BLWs	Total	Grasses	Sedges	BLWs	Total		
Oxyfluorfen 250 g/ha (PE)	5.27(27.6)	5.50(29.7)	8.13(65.2)	11.11(122.5)	4.43(18.7)	3.51(11.4)	4.68(21.0)	7.21(51.0)	58.1	15.6
Pendimethalin 1000 g/ha (PE)	5.16(25.9)	5.75(33.8)	8.38(69.3)	11.37(128.2)	4.37(18.2)	3.77(13.3)	4.93(23.3)	7.47(54.8)	54.9	20.1
Oxadiargyl 175 g/ha (PE)	6.52(42.3)	6.31(38.9)	9.76(94.3)	13.29(175.5)	4.60(20.5)	4.02(15.2)	5.86(33.4)	8.37(69.1)	43.2	23.3
Oxyfluorfen250 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	4.54(20.6)	4.32(18.0)	1.82(2.5)	6.48(41.0)	3.54(11.6)	2.81(7.0)	1.33(0.8)	4.51(19.4)	84.1	7.1
Pendimethalin 1000 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	3.98(15.1)	4.91(24.1)	3.96(14.7)	7.41(53.9)	2.86(7.3)	3.25(9.6)	2.37(4.6)	4.74(21.4)	82.4	8.3
Oxadiargyl 175 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	5.02(24.6)	5.25(28.2)	5.66(31.1)	9.21(83.8)	3.99(15.0)	3.40(10.7)	3.10(8.6)	5.94(34.3)	71.8	13.8
Weed free check	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	100	0
Weeedy control	8.96(79.4)	9.79(94.8)	16.89(142.4)	17.82(316.7)	6.28(38.4)	6.19(37.4)	6.84(45.9)	11.08(121.7)	0.00	31.3
LSD (p=0.05)	1.47	1.68	1.19	2.87	1.67	1.04	0.59	1.96		

Data subjected to square root transformation ($\sqrt{x+1}$), original value are in parentheses

Table 2. Effect of different weed management treatments on yield attributes, yield and economics of *Rabi* sunflower

Treatment	Plant height (cm)	Capitulum dia. (cm)	100 seed wt.(g)	Seeds/ capitulum	Seed yield (t/ha)			Stover yield (t/ha)			Cost of cultivation (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	B:C ratio
					2014-15	2015-16	Mean	2014-15	2015-16	Mean			
Oxyfluorfen 250 g/ha (PE)	126.5	13.36	4.02	892	2.1	1.7	1.9	4.0	3.8	3.9	44.04	26.93	1.61
Pendimethalin 1000 g/ha (PE)	125.2	13.02	4.01	850	2.0	1.6	1.8	3.9	3.4	3.7	40.84	26.35	1.64
Oxadiargyl 175 g/ha (PE)	123	12.89	4.03	826	1.9	1.6	1.7	3.8	3.2	3.5	38.74	25.74	1.66
Oxyfluorfen250 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	131	14.79	4.54	981	2.3	1.9	2.1	4.4	4.0	4.2	42.84	35.29	1.82
Pendimethalin 1000 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	129.6	14.42	4.51	950	2.3	1.9	2.1	4.2	4.0	4.1	46.52	30.68	1.65
Oxadiargyl 175 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	127.4	13.58	4.51	918	2.1	1.8	2.0	4.2	3.9	4.1	42.04	30.46	1.72
Weed free check	134.7	15.16	4.54	987	2.5	2.1	2.3	4.6	4.2	4.4	50.54	33.60	1.66
Weedy control	120.4	12.55	3.5	778	1.7	1.4	1.6	3.3	3.2	3.2	38.64	19.15	1.49
LSD (p=0.05)	NS	0.91	NS	40.33	0.4	0.2	0.4	0.9	0.2	0.4	3.50	2.38	0.63

Table 3. Effect of weed management treatments on NPK uptake by weeds and sunflower at harvest (data is mean of 2 years)

Treatment	Nutrient uptake by weeds (kg/ha)			Nutrient uptake by the crop (kg/ha)		
	N	P	K	N	P	K
Oxyfluorfen 250 g/ha (PE)	8.33	2.36	8.22	50.42	16.07	69.0
Pendimethalin 1000 g/ha (PE)	10.1	2.96	11.03	45.94	11.31	66.2
Oxadiargyl 175 g/ha (PE)	12.1	4.35	13.89	41.14	9.95	63.5
Oxyfluorfen250 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	3.29	0.58	3.08	63.05	24.7	79.5
Pendimethalin 1000 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	3.73	0.82	3.60	58.81	15.91	73.2
Oxadiargyl 175 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha (PoE)	5.97	1.54	6.45	51.29	13.68	71.1
Weed free check	0.00	0.00	0.00	66.55	25.56	79.9
Weedy control	23.00	8.28	22.27	33.53	9.00	56.8
LSD (p=0.05)	2.19	1.28	1.88	4.04	3.48	6.09

Pre-emergence application of oxyfluorfen 250 g/ha *fb* quizalofop-ethyl 50 g/ha at 20 DAS resulted in the highest uptake of N, P and K (63.05, 24.7, 79.5 kg/ha) and was at par with weed free check. Higher dry matter production of crop and corresponding nutrient contents of the tissues in these treatments resulted negligible competition offered by weeds for N, P and K uptake (**Table 3**).

Sequential application of oxyfluorfen 250 g/ha *fb* quizalofop-ethyl 50 g/ha at 20 DAS recorded the highest values of net return (₹ 35.28 x 10^3/ha) and benefit: cost ratio (1.82), which was closely followed by pendimethalin 1000 g/ha at 3 DAS *fb* quizalofop-ethyl 50 g/ha at 20 DAS (**Table 2**), and significantly superior to the weed free check.

It was concluded that broad-spectrum weed control throughout the crop growth period and the highest seed yield and maximum economic returns in *Rabi* sunflower may be obtained with oxyfluorfen 250 g/ha as PE *fb* quizalofop-ethyl 50 g/ha at 20 DAS.

REFERENCES

FAO. 2017. *Crop Production*. FAO stat. Food and Agriculture Organisation, Rome. Available at http: faostat.org/site/291/ default.aspx).

Gomez KA and Gomez AA. 1984. *Statistical procedures for agricultural research*. 2nd. Singapore: John Wiley and Sons.

Pannacci E, Graziani F and Covarelli G. 2007. Use of herbicides mixtures for pre and post – weed control in sunflower (*Helianthus annuus*). *Crop Protection* **26**: 1150–1157.

Selvakumar T, Srinivasan K and Rajendran L. 2018. Performance of chemical weed management in irrigated sunflower. *International Journal of Agricultural Sciences* **10** (20): 7395–7397.

Sumathi V, Koteswar Rao DS, Subramanyam D and Reddy DS. 2009. Effect of planting pattern and weed management on nutrient uptake and economics of *Rabi* sunflower and its associated weeds. *Indian Journal of Weed Science* **41**(1&2): 65–70.

Singh DK and Singh KN. 2006. Weed control in sunflower (*Helianthus annus* L.) under temperate conditions of Kashmir valley. *Indian Journal of Agronomy* **51**(3): 225–227.

Shylaja R and Sundari A. 2008. Weed management in sunflower. *Indian Journal of Weed Sciences* **49**(1&2): 94–95.

Siva Sankar K and Subramanya MD. 2011. Weed flora and yield of sunflower (*Helianthus annuus* L.) as influenced by pre and post emergence application of herbicides. *Indian Journal of Weed Science* **43**(1&2): 105–109.

Tadavi AG, Chorey AB, Gaikwad GS and Sawadhkar SM. 2017. Integrated weed management in sunflower. *International Journal of Current Microbiology and Applied Sciences* **6**(9): 1080–1088.

Wanjari RH, Yaduraju NT and Ahuja KN. 2000. Critical period of weed competition in spring sunflower. *Indian Journal of Weed Science* **32**(1&2):17–20.