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S Sridhara
Department of Agronomy Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Pradeep Gopakkali
Department of Agronomy Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Basavaraj Naik T
Department of Agronomy Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

S Pradeep
Coordinator, Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Shilpa HD
Department of Agronomy Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Correspondence
S Sridhara
Department of Agronomy Organic Farming Research Center, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Weed management in transplanted rice through flucetosulfuron 10 % WG and its residual effect on succeeding green gram

S Sridhara, Pradeep Gopakkali, Basavaraj Naik T, S Pradeep and Shilpa HD

Abstract
The Field experiment entitled on Weed management in transplanted rice through Flucetosulfuron 10 % WG and its residual effect on succeeding green gram was conducted at College of Agriculture, Navile, Shivamogga, University of Agricultural and Horticultural Sciences, Shivamogga, during *kharif* 2013 and 2014 and *rabi* 2014-2015. Weed control treatments consisted of Flucetosulfuron 10% WG at different doses (15 to 30 g a.i. ha^{-1}) and other herbicides Bispyribac Sodium 10 % SC 20 g a.i. ha^{-1}, Azimsulfuron 50 % DF 35 g a.i. ha^{-1} and hand weeding. Dominant weed flora observed in the experimental plots among grasses were *Echinochloa* sp. (*colonum* & *crusgalli*) and *Leptochloa chinensis* among sedges *Cyperus difformis* and *Cyperus iria* whereas in case of broadleaf weeds (BLW) *Ludwigia parviflora*, *Eclipta prostrata*, *Alternanthera sessilis*, *Fimbristylis miliacea* and *Marselia quadrifolia*. Application of Flucetosulfuron 10% WG @ 25g a.i. ha^{-1} gave consistently good control of all category of weeds, *i.e*., grasses, sedges and broadleaf weeds and was on par with 10 % WG @ 30 g a.i. ha^{-1} dose and these herbicides did not cause any phytotoxicity in preceding rice crop as well as succeeding crop green gram and recorded significantly higher grain yield in transplanted rice.

Keywords: Bioefficacy, herbicide, transplanted, rice, greengram

Introduction
Rice is a primary staple food in India and cultivated on about 44 million hectares area, occupying 30 % of the total cultivated area (Anon., 2017) [2]. It is grown under varied agro-climatic conditions under transplanted and wet sown to direct seeded rainfed condition. The assured availability of rice is recognized as an essential factor in the self-sufficiency of the country's food grain production. However, the release of new genotypes and their wide-scale adoption increased the greater scope for enhancing rice production in the country. The demand for rice in India is expected to be 100 million tonnes by 2015 and 140 million tonnes by 2025. The dominance of grassy weeds particularly *Echinochloa colonum /E. Crusgalli* and other weed infestation became one of the important constraints in its production. Most of the weed flora in rice is C_4 type which becomes a strong competitor of rice for various growth factors. On an average, uncontrolled weed growth in transplanted rice causes yield losses from 15-45 % depending upon the type of weed flora and their density along with soil and climatic conditions. Rice grain production in India is presently reported to suffer a yearly loss of more than 15 million tonnes due to weeds competition, especially grassy weeds. Besides yield reduction, weeds deplete nutrients from soil to the extent of 11.0, 3.0 and 10.0 kg ha^{-1} of N, P_2O_5, and K_2O, respectively (Singh *et al*., 2011) [7]. Although many herbicides are available in the market for controlling weeds in transplanted rice, most of them are pre-emergence herbicides, with high dose, costly, persistent, narrow spectrum, nonselective and more pollutant. Weeds emerging later in the season are escaping from the treatment of pre-emergence herbicides and are not controlled effectively. Further, continuous use of the same herbicide for several years may lead to shifting of weed flora and build up of resistance in certain weeds. Hence, there is a need to identify alternate promising herbicides for effective weed control in transplanted rice to give options to the farmers from this high efficacy, low volume, broad spectrum, and more selective, post-emergence herbicides. Such herbicides had become popular all over the world having the high level of activity, application flexibility with excellent selectivity and low mammalian toxicity even at a shallow dose with the broad spectrum of weed control. Some newly developed herbicide applied at different concentrations to facilitate post-emergence application to manage late emerged weeds in transplanted rice. Application of this herbicide at low concentrations can ensure control weeds in transplanted rice resulting higher uptake of nutrients by the crop to produce higher grain yields and

Economic return to the farmers. High doses of herbicides can cause substantial injury on succeeding crops, especially on soils low in clay content. There is an urgent need to optimize the use of these herbicides to minimize possible adverse effects on succeeding crops and the environment. Herbicide residue analysis is getting more important now days, in the aspect of environmental safety. Bioassay is one of the most important, efficient and cost-effective techniques for assessing herbicide residue in the soil. Information available on these new broad-spectrum low dose post-emergence herbicides is meager. Therefore, evaluation of new post-emergence herbicides for their bio-efficacy for managing weeds in transplanted rice is imperative. Keeping in this view, the present investigation entitled with "Weed management in transplanted rice through Flucetosulfuron 10 % WG and its residual effect on succeeding green gram" experiment was carried out at Department of Agronomy, the University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Material and methods

The investigation was carried out during *kharif* 2013-2014 on sandy loam soil at the University of Agricultural and Horticultural Sciences, Shivamogga. The experiment was laid out in Randomized Complete Block Design and replicated thrice with a plot size of 6.0 m × 5.0 m. The treatment was Flucetosulfuron in two different doses (20 and 25 g a.i.ha^{-1}), Bispyribac Sodium 10 % SC 20 g a.i.ha^{-1}, Azimsulfuron 50 % DF 35 g a.i.ha^{-1}, hand weeding. Uniform application of herbicides was done by spraying with the help of knapsack sprayer fitted with WFN nozzle. For the application of herbicides, a water volume of 350 liters $hectare^{-1}$ was used. Hand weeding was done at 20^{th} and 60^{th} day after transplanting (DAT). Species-wise total weed count did the observation for bio-efficacy of different herbicides at 7, 15, 30 and 45 days after application (DAA) of herbicides. A quadrant of $0.25m^2$ size was thrown randomly at five spots in each treatment and species-wise weed count was collected and recorded data presented as species-wise weeds m^{-2}. The data on the dry weight of total weeds was recorded at 60 days after transplanting (DAT). Grain yield, plant height and panicle number per m^{-2} were also recorded at the time of harvest. The data were analyzed statistically using a suitable transformation like the square root of (X +1) depending on the extent of variations. For the calculation of weed index formula of Gill and Vijay Kumar (1966) was used as follow:

$$\text{Weed index (\%)} = \frac{\text{Paddy yield from hand weeding - Paddy yield from the treatment}}{\text{Paddy yield from hand weeding}} \times 100$$

Phytotoxicity

Phyto-toxic effect of Flucetosulfuron 10 % WG on crop was observed on 1, 3, 5, 7 and 10 days after application as per the protocol of Central Insecticide Board and Registration Committee (C.I.B. and R.C) for the phytotoxic symptoms like; a.) Leaf tips/tipped injury, b.) Wilting, c.)Vein clearing d.)Necrosis, e.) Epinasty and f.) Hyponasty and bioassay studies were made to study the residual effect of herbicides on succeeding crop green gram in net plot area. Immediately after the harvest of the main crop, green gram was sown in each treatment by opening the furrows at 30 cm apart manually. The crop was supplemented with the recommended dose of fertilizer at the time of sowing and irrigated to ensure uniform crop growth. At 30 DAS plant population and 60 days after sowing the plant height was recorded and yield of green gram was recorded at harvest.The Phytotoxicity on the succeeding crop was assessed in all the treatments of the herbicide Flucetosulfuron 10 % WG applied @ 15, 20 and 25 g a.i. ha^{-1} along with standards and untreated check in transplanted rice. The observations on leaf epinasty, hyponasty, necrosis, wilting and vein clearing were recorded at 10, 20 and 30 DAS. The level of Phytotoxicity was estimated by a visual assessment on Phytotoxicity Rating Scale (PRS), where 0 = No Crop injuries, 10 = Heavy injury or complete destruction of the green gram plants (Anonymous, 1981) [1].

Results and discussion

1. Effect on weeds

a) Weed flora

During *Kharif*- 2013 and 2014 major weed flora was observed in the experimental plots. Among grasses, *Echinochloa* sp. (*colonum* & *crusgalli*) & *Leptochloa chinensis* among sedges *Cyperus difformis* and *Cyperus iria* whereas in case of broad leaf weeds (BLW) *Ludwigia parviflora*, *Eclipta prostrata*, *Alternenthera sessilis*, *Fimbristylis miliacea* and *Marselia quadrifolia* were dominated weeds.

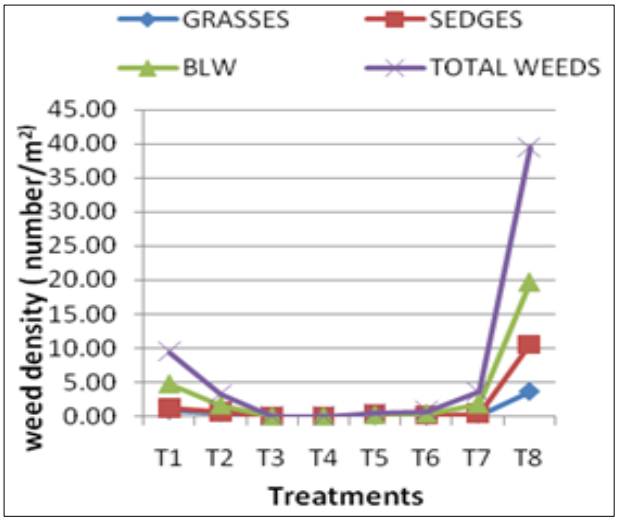
b) Weed Density

Among different herbicides, at 7 days after application of Flucetosulfuron 10% WG @ 25 g a.i. ha^{-1} and 30 g a.i. ha^{-1}as post-emergence gave good control of all categories of weeds (grasses, sedges, BLW and total weed count) were 0.0 m^{-2} and are significantly on par with each other during both the seasons. Whereas under unweeded control situation higher densities of grasses (2.7 and 4.6 m^{-2}), sedges (9.6 and 4.2 m^{-2}), broadleaved weeds (11.2 and 7.2 m^{-2}) and total weed count of (23.50 and 16.00 m^{-2}) were recorded during the first and second season, respectively (fig. 1). Observation data after 15 days after the application of herbicides (fig.1) also indicates the superiority of new herbicide Flucetosulfuron 10 % WG @ 30 g a.i. ha^{-1} and followed by 25 g a.i. ha^{-1}. At this observation day, application of Flucetosulfuron 10% WG @ 30 g a.i. ha^{-1} recorded higher density of grasses, sedges, BLW and total weed population were 0.0 m^{-2} during both the seasons and application of Flucetosulfuron 10 % WG @ 25 g a.i.ha^{-1} recorded density of grasses (0.0, 0.2 m^{-2}), sedges (0.0, 0.0 m^{-2}) and BLW (0.2, 0.5 m^{-2}) with a total weed population (0.23, 0.7 m^{-2}) during the first and second season, respectively, followed by Bispyribac sodium 10% SC @ 20 g a.i. ha^{-1}, Azimsulfuron 50 % DF @ 35 g a.i. ha^{-1}, Flucetosulfuron 10% WG @ 20 g a.i. ha^{-1}, hand weeding and Flucetosulfuron 10 % WG @ 15 g a.i. ha^{-1}during both the seasons. Whereas under unweeded control situation, more number of grasses (3.4, 7.0 m^{-2}), sedges (10.4, 5.2 m^{-2}) and BLF (12.8, 8.9 m^{-2}) and total weed count were observed (26.6, 21.1 m^{-2}) during first and second season, respectively. Observation data for 30 and 45 days after the application of herbicides represented in (Fig 1) indicated similar trend of weed control as on 15 days after the application of herbicides where Flucetosulfuron 10% WG @ 30 g a.i. ha^{-1} dose was giving best control of all category of weeds with a total weed population (0.07and 0.8 m^{-2}) at 30 days after application and (3.50 and 3.80 m^{-2}) at 45 days after application followed by application of Flucetosulfuron 10 % WG @ 25 g a.i. ha^{-1} dose recorded a total weed count of (0.77 and 1.5 m^{-2}) at 30 days after application and (4.57 and 4.7 m^{-2}) at 45 days after application during first and second season, respectively, Bispyribac sodium 10% SC @ 20 g a.i. ha^{-1} recorded total weed population (6.27 and 2.5 m^{-2}) at 30 days after

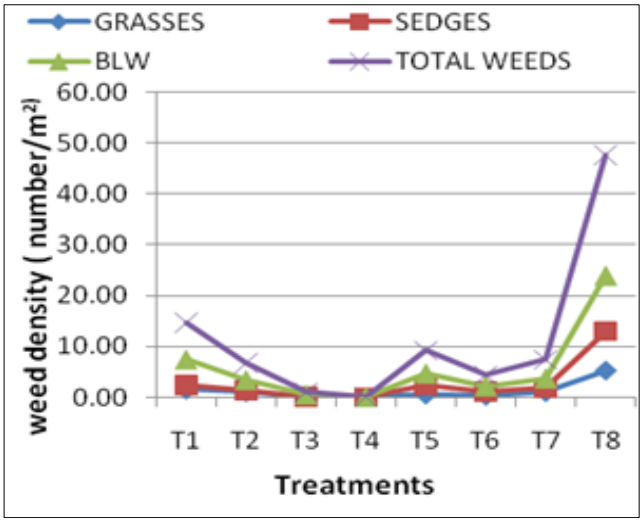
application and (11.40 and 6.2 m^{-2}) at 45 day application during first and second season, respectively, Azimsulfuron 50 % DF @ 35 g a.i. ha^{-1} recorded total weed count (9.0 and 3.9 m^{-2}) at 30 days after application and (15.63 and 7.8 m^{-2}) at 45 days after application during the first and second season, respectively, Flucetosulfuron 20 g a.i. ha^{-1} recorded total weed count (4.9 and 4.9 m^{-2}) at 30 days after application and (12.83 and 9.9 m^{-2}) at 45 day days after application during the first and second season, respectively and whereas Hand weeding recorded total weed count (7.6 and 11.7 m^{-2}) at 30 days after transplanting and (17.53 and 15.6 m^{-2}) at 45 days after transplanting during the first and second season, respectively. The treatments Flucetosulfuron 10 % WG @ 30 g a.i.ha^{-1} and Flucetosulfuron 10 % WG @ 25 g a.i. ha^{-1} were at par with each other and statistically far superior as compared to standard check herbicides. Whereas untreated control treatment was recorded maximum total weed count, *i.e.*, (27.27and 25.6m^{-2}) at 30 days after application and (36.27 and 29.2 m^{-2}) at 45 days after application during the first and second season, respectively. Moreover, at 60 DAT similar pattern of weed control was observed with new herbicide, Flucetosulfuron 10% WG @ 25 and 30 g a.i. ha^{-1}dose. These doses were superior to standard check chemicals *viz*, Bisbyribac sodium 10% SC @ 20 g a.i. ha^{-1} and Azimsulfuron 50% DF @ 35g a.i. $ha^{-1}$and Single hand weeding and Flucetosulfuron @ 20 g a.i. ha^{-1} during both the seasons. Similar observation was made by (Singh. 2014 and Kumaran *et al*., 2015) [8, 4]. Under untreated control situation at 60 DAT, more densities of sedges (13.10 and 8.10 m^{-2}), grasses (5.20 and 23.17 m^{-2}) and BLW (17.90 and 15.20 m^{-2}) and total weed count (36.20, 46.47 m^{-2}) were recorded during the first and second season, respectively (Table 1).

C) Weed Dry Weight

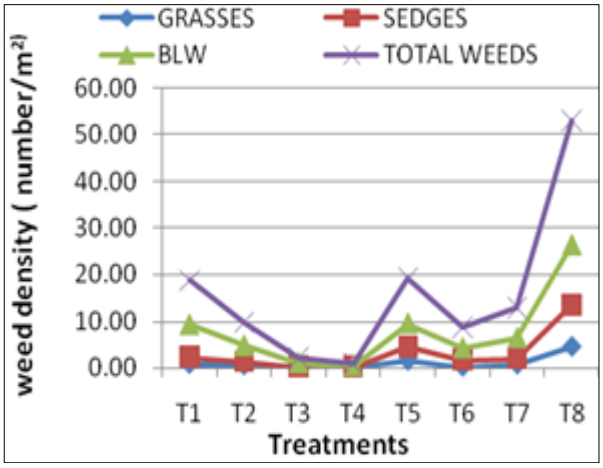
The total weed dry weight was recorded at 60 DAT and represented in Table 2. Among different treatments of Flucetosulfuron 10 % WG @ 30 g a.i. ha^{-1} and Flucetosulfuron @ 25 g a.i. ha^{-1} recorded minimum weed dry weight *i.e.*, 18.00 and 23.00 g m^{-2} and 25.97 and 33.63 g m^{-2} during first and second season, respectively and are significantly on par with each other. They were also proven best among all treatment followed by the same chemical @ 20 g a.i. ha^{-1} recorded 65.70, 71.23 g m^{-2} total weed dry weight during 2013 and 2014, respectively. Flucetosulfuron 10% WG @ 25 g a.i. ha^{-1} showed there superiority over standard check herbicides Bisbyribac Sodium 10 % SC @ 20 g a.i. ha^{-1} recorded (55.70, 48.93 g m^{-2} during first and second season, respectively) and Azimsulfuron 50 % DF @ 35g a.i. ha^{-1} recorded (78.30, 65.20 g m^{-2} during first and second season, respectively). Whereas untreated plot recorded maximum total weed dry weight, *i.e.*, 173.10, 247.40 g m^{-2} during the first and second season, respectively.



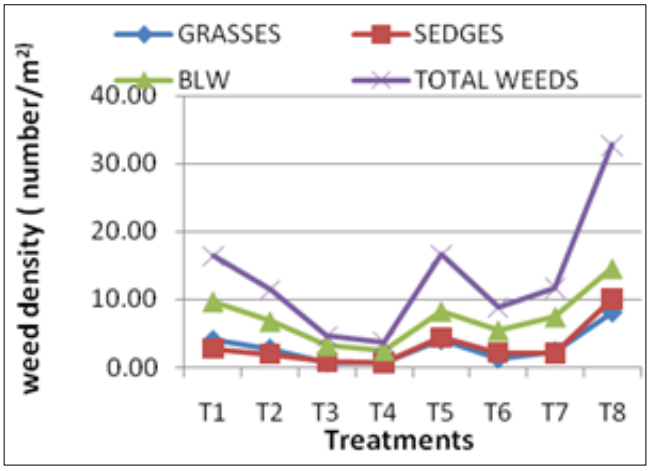
7 Days after herbicide application



14 Days after herbicide application



30 Days after herbicide application



45 Days after herbicide application

Fig 1: weed density in transplanted rice at different interval of herbicides application

d) Yield and weed index

At harvest, maximum grain yield was recorded at 8783.33 and 8583.33 kg ha^{-1} in Flucetosulfuron 10 % WG @ 30 g a.i. ha^{-1} and in application of Flucetosulfuron 10 % WG @ 25 g a.i. ha^{-1} recorded yield 8516.67and 8416.67 kg ha^{-1}during first and second season, respectively and were significantly on par with each other. These herbicidal treatments higher grain yield was recorded due to better control of weeds at critical crop growth stages thus providing the favorable environment for better growth and development which leads to enhanced grain yield Singh and Singh (2004) [8]. Flucetosulfuron 10% WG @ 25 g a.i. ha^{-1}was superior than standard check herbicides *i.e*., Bisbyribac Sodium 10 % SC @ 20 g a.i. ha^{-1} recorded (8433.33 and 8266.67 kg ha^{-1}during first and second season, respectively), Azimsulfuron 50 % DF @ 35 g a.i. ha^{-1} recorded (8283.33 and 8116.67 kg ha^{-1}during first and second season, respectively), Flucetosulfuron 10% WG @ 20 g a.i. ha^{-1} recorded 8416.67 and 8100.00 kg ha^{-1} during first and second season, respectively and two hand weeding recorded (9050.00 and 8683.33 kg ha^{-1}during first and second season, respectively) (Table 3). Under untreated control condition minimum, *i.e*., 5983.33, 6450.00 kg ha^{-1} grain yield was recorded during the first and second season, respectively. The productivity of rice is considerably affected by weed intensity at crop growth stages. Singh and Singh (2004) [8] reported that the grain yield reduction in rice is directly related to increasing weed density, dry weight and intensity of weed interference throughout the crop period. Due to heavy competition of weeds for nutrients, space, water and light lower grain yield was recorded in unweeded control plot. Observation for plant height, weed index and a total number of panicles m^{-2} was also recorded and represented in (Table 3) which also indicates the superiority of Flucetosulfuron 10 %WG @ 25-30 g a.i. ha^{-1}doses.

Table 1: Efficacy of Flucetosulfuron 10% WG on total weed population (Number m^{-2}) and dry weight (g m^{-2}) at 60 days after transplanting during *Kharif* – 2013 & 2014

Treatments		Dose g a.i. ha^{-1}	Total weed count(number m^{-2}) at 60 DAT							
			First season				Second season			
			Grasses	Sedges	BLW	Total number of weeds	Grasses	Sedges	BLW	Total number of weeds
T_1	Flucetosulfuron 10% WG	15	4.60	3.10	11.50	19.20	6.90	2.43	9.83	19.17
T_2	Flucetosulfuron 10% WG	20	3.10	1.90	7.90	12.90	4.10	2.03	7.70	13.83
T_3	Flucetosulfuron 10% WG	25	0.60	0.60	3.40	4.60	1.93	1.13	3.50	6.57
T_4	Flucetosulfuron 10% WG	30	0.50	0.50	2.60	3.60	1.30	0.83	2.97	5.10
T_5	Hand weeding	--	3.90	4.50	9.20	17.60	6.40	5.57	8.47	20.43
T_6	Bisbyribac Sodium 10 % SC	20	1.40	2.70	7.30	11.40	2.33	1.73	5.60	9.67
T_7	Azimsulfuron 50 % DF	35	2.80	3.00	9.90	15.70	3.80	1.60	7.20	12.60
T_8	Control	--	5.20	13.10	17.90	36.20	23.17	8.10	15.20	46.47
CD @ 5%			0.09	0.09	0.12	0.51	0.25	0.18	9.83	0.63

Table 2: Efficacy of Flucetosulfuron 10% WG on total weed population (Number m^{-2}) and dry weight (g m^{-2}) at 60 days after transplanting during *Kharif* – 2013 & 2014

Treatments		Dose g a.i. ha^{-1}	Total weed dry weight (g m^{-2}) at 60 DAT							
			First season				Second season			
			Grasses	Sedges	BLW	Total weeds	Grasses	Sedges	BLW	Total weeds
T_1	Flucetosulfuron 10% WG	15	27.60	12.40	57.50	97.50	41.40	9.73	49.17	100.30
T_2	Flucetosulfuron 10% WG	20	18.60	7.60	39.50	65.70	24.60	8.13	38.50	71.23
T_3	Flucetosulfuron 10% WG	25	3.60	2.40	17.00	23.00	11.60	4.53	17.50	33.63
T_4	Flucetosulfuron 10% WG	30	3.00	2.00	13.00	18.00	7.80	3.33	14.83	25.97
T_5	Hand weeding	--	23.40	18.00	46.00	87.40	38.40	22.27	42.33	103.00
T_6	Bisbyribac Sodium 10 % SC	20	8.40	10.80	36.50	55.70	14.00	6.93	28.00	48.93
T_7	Azimsulfuron 50 % DF	35	16.80	12.00	49.50	78.30	22.80	6.40	36.00	65.20
T_8	Control	--	31.20	52.40	89.50	173.10	139.00	32.40	76.00	247.40
CD @ 5%			0.25	0.21	0.28	1.04	0.63	0.40	0.67	1.70

Table 3: Efficacy of Flucetosulfuron 10 % WG on plant height, number of panicles m^{-2} at harvest, grain yield (kg ha^{-1}) and weed index (%) in transplanted rice during *Kharif* –2013 & 2014

Treatments		Dose ha^{-1}		Plant height (cm)		Number of panicles m^{-2}		Grain yield (kg ha^{-1})		Weed index (%)	
		g a.i.	Formulation (g or ml)	First season	Second season	First season	Second season	First season	Second season	First season	Second season
T_1	Flucetosulfuron 10% WG	15	150	94.80	95.57	165.00	159.33	8250.00	7966.67	8.85	8.25
T_2	Flucetosulfuron 10% WG	20	200	95.80	96.17	168.33	162.00	8416.67	8100.00	7.00	6.71
T_3	Flucetosulfuron 10% WG	25	250	95.87	95.13	170.33	168.33	8516.67	8416.67	5.87	3.07
T_4	Flucetosulfuron 10% WG	30	300	95.47	95.17	175.67	171.67	8783.33	8583.33	2.95	1.15
T_5	Hand weeding	--	--	95.40	96.03	181.00	173.67	9050.00	8683.33	0.00	0.00
T_6	Bisbyribac Sodium 10 % SC	20	200	93.43	94.97	168.67	165.33	8433.33	8266.67	6.81	4.79
T_7	Azimsulfuron 50 % DF	35	70	94.87	95.37	165.67	162.33	8283.33	8116.67	8.48	6.52
T_8	Control	--	--	96.73	98.27	119.67	129.00	5983.33	6450.00	33.88	25.70
CD @ 5 %				0.09	3.37	0.26	0.26	1.87	1.86	0.67	0.57

2. Phytotoxicity in transplanted rice and succeeding greengram

Data represented in (Table 4) indicates the phytotoxicity study of new herbicide, Flucetosulfuron 10 % WG at proposed recommended, double and triple doses *i.e*., 15, 20, 25 and 30 g a.i.ha^{-1}and resulted that, these doses did not cause any phytotoxicity symptoms at 1, 3, 5, 7 and 10 days after application of herbicides in transplanted rice during *kharif* and 10, 20, 30 days after sowing of greengram these crops did not show any kind of phytotoxicity symptoms such as epinasty, hyponasty, necrosis, wilting and vein clearing during both the *kharif* and *rabi* seasons. Similar trend was also observed in the data of plant population and plant height which was recorded at 30 and 60 DAS respectively. In case of yield data, there was no significant difference found in the treatments (Table 5) but the minimum yield was recorded in untreated check plot.

Table 4: Phytotoxicity ratings recorded at different days after spraying of herbicides on transplanted rice and green gram crop as influenced by weed control treatments.

Treatments	*Kharif* (2013-2014) (Rice)						*Rabi* (2013-14 and 2014-2015) (Greengram)		
	Days after herbicide application						Days after sowing		
	1	3	5	7	10	30	10	20	30
T_1	0	0	0	0	0	0	0	0	0
T_2	0	0	0	0	0	0	0	0	0
T_3	0	0	0	0	0	0	0	0	0
T_4	0	0	0	0	0	0	0	0	0
T_5	0	0	0	0	0	0	0	0	0
T_6	0	0	0	0	0	0	0	0	0
T_7	0	0	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0	0	0

Table 5: Germination percentage, Plant population, Plant height and Yield of the succeeding greengram.

Treatments	Germination (percent)		Plant Population (at 30 DAS)		Plant Height (at 60 DAS)		Yield at harvest (Kg ha^{-1})	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
T_1	89.60	87.81	957.00	937.86	55.83	53.29	864.95	882.60
T_2	90.00	88.20	957.00	937.86	55.62	53.09	874.45	892.30
T_3	90.01	88.21	967.66	948.31	55.90	53.36	991.62	1011.86
T_4	90.70	88.89	958.66	939.49	56.16	53.60	968.50	988.27
T_5	89.60	87.81	954.33	935.24	55.93	53.39	875.27	893.13
T_6	90.13	88.33	953.33	934.26	55.36	52.85	830.22	847.16
T_7	89.86	88.06	947.33	928.38	55.36	52.85	759.07	774.56
T_8	91.20	90.31	968.36	952.31	59.35	56.21	707.23	742.53
SE(m)±	1.74	1.62	1.23	1.21	0.41	0.38	0.27	0.27
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

Based on this two season study of bio-efficacy of Flucetosulfuron 10% WG during *kharif*- 2013 and 2014 on transplanted rice and residual effect on succeeding green gram during *rabi* 2013-14 and 2014-15, we can conclude that Flucetosulfuron 10% WG @ 25g a.i. ha^{-1} gave consistently good control of all category of weeds, *i.e*., grasses, sedges and broad leaf weeds and was at par with Flucetosulfuron 10% WG @ 30 g a.i. ha^{-1}dose and these herbicides did not cause any phytotoxicity in preceding crop rice and on succeeding crop green gram during *kharif* and *rabi*. Hence, Flucetosulfuron 10 % WG can be used safely @ 25 g a.i. against weed complex in transplanted rice during *kharif* without any deleterious effect on succeeding crop.

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