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Research Article

BIOEFFICACY AND PHYTOTOXICITY OF HERBICIDES IN RICE AND THEIR RESIDUAL EFFECT ON SUCCEEDING GREENGRAM

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Abstract: Comparative efficacy of pre- and post-emergence herbicides in direct sown rice and their residual effect on succeeding greengram crop was studied at Agricultural College Farm, Bapatla during kharif and rabi of 2015-16 and 2016-17. Among the herbicides tested only bispyribac-sodium had a slight phtotoxic effect on direct sown rice. Phytotoxicity of bispyribac-sodium was characterized slightly stunted plant growth and leaves fail to expand fully and became yellowish as observed at 14 days after application. However, those symptoms disappeared, and the rice plants recovered within a week. Further, it was observed that none of the herbicides applied at tested rates had adverse effect on succeeding greengram.

Keywords: *Direct sown rice, Pre emergence application, Post emergence application, Phytotoxicity, Green gram*

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Introduction

India and China are the leading producers as well as consumers of rice. In India, rice is grown in an area of 44.1 million hectares with a production of 108.9 million tonnes and productivity of 2391 kg ha^{-1}. In Andhra Pradesh, it is grown in an area of 2.4 million hectares with a production of 7.24 million tonnes and productivity of 3022 kg ha^{-1} [1]. Rice suffers from various biotic and abiotic production constraints among which weed competition is one of the major yields limiting biotic constraint. The reduction in paddy yield due to weed competition ranges from 9-51% [2]. The direct and most important effect of weeds is the reduction in crop yields due to competition for water nutrients and sunlight, with impaired quality of grains while causing some nuisance at the time of harvest [3]. Success of DSR is mainly depends on effective weed control with all the possible means.

Herbicides are commonly used for weed control in high-input crop production systems. Due to extensive and injudicious application, most of the unused fractions of herbicides however, may persist within soils. Hence, information regarding persistence and residual effect of herbicides in soil is essential to use them safely and effectively. For that bioassay remains a major tool for qualitative and quantitative determination of herbicides residue in soil. Considering above facts, an attempt has been made to study the Bio-efficacy of sequential application of herbicides in direct sown rice-greengram sequence

Materials and Methods

A field experiment was conducted during Kharif 2015 and 2016 on effect of weed control practices on bioefficacy of weeds and grain yield of direct sown rice at the Agricultural College Farm, Bapatla, Guntur, Andhra Pradesh. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction (pH 8.0 and 7.5), low in organic carbon (0.45 and 0.48%), low in available nitrogen (212 and 230 kg ha^{-1}) and available phosphorus (17 and 18 kg ha^{-1}) and medium in available potassium (261 and 285 kg ha^{-1}). There were fourteen treatments, and the details of which are given hereunder.

T1) Pre-emergence application of pyrazosulfuron ethyl @ 25 g a.i. ha^{-1}fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1}at 25 DAS

T2) Pre-emergence application of pyrazosulfuron ethyl @ 25 g a.i. ha^{-1}fb Post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DAS

T3) Pre-emergence application of bensulfuron methyl @ 60 g a.i. ha^{-1} + Pretilachlor with safener at 500 g a.i. ha^{-1} fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1} at 25 DAS

T4) Pre-emergence application of bensulfuron methyl @ 60 g a.i. ha^{-1} + pretilachlor with safener at 500 g a.i. ha^{-1} fb post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DAS

T5) Pre-emergence application of oxadiargyl @ 75 g a.i. ha^{-1} fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1}at 25 DAS

T6) Pre-emergence application of oxadiargyl @ 75 g a.i. ha^{-1} fb post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DAS

T7) Pre-emergence application of pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1} at 25 DAS fb post-emergence application of metsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1} applied at 45 DAS

T8) Pre-emergence application of pyrazosulfuron ethyl @ 25 g a.i. ha^{-1}fb post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DASfbpost-emergence application of metsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1} applied at 45 DAS

T9) Pre-emergence application of bensulfuron methyl @ 60 g a.i. ha^{-1} + pretilachlor with safener at 500 g a.i. ha^{-1} fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1} at 25 DASfbpost-emergence application of metsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1} applied at 45 DAS

T10) Pre-emergence application of bensulfuron methyl @ 60 g a.i. ha^{-1} + pretilachlor with safener at 500 g a.i. ha^{-1} fb post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DASfbpost-emergence application of metsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1} applied at 45 DAS

T11) Pre-emergence application of oxadiargyl @ 75 g a.i. ha^{-1} fb post-emergence application of azimsulfuron @ 20 g a.i. ha^{-1} at 25 DAS fbpost-emergence application of metsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1} applied at 45 DAS

Table-1 *Phytotoxic effect of different herbicide treatments on direct seeded rice as influenced by weed management practices during kharif 2015-16 and 2016-17*

Treatments	Dose (g ha^{-1})	Time (DAS)	7days after application		14 days after application	
			2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	0	0	0	0
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	0	0	1	1
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	0	0	1	1
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	0	0	0	0
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	0	0	1	1
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	1	1
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	1	1
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	1	1
Weed free	-	-	-	-	-	-
Weedy check	-	-	-	-	-	-

0- No injury, 1 - Slight stunting and yellowing of leaves, 10 - Complete kill of crop, - Treatment without herbicides

Table-2 *Initial and final plant population of rice (No. m^{-2}) of direct seeded rice as influenced by weed management practices during kharif 2015-16 and 2016-17*

Treatments	Dose (g ha^{-1})	Time (DAS)	Initial plant population		Final plant population	
			2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	36.7	32.7	36.4	32.9
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	36.4	32.1	35.6	32.5
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	37.0	33.4	36.9	33.8
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	37.2	33.4	36.4	33.3
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	36.4	32.0	35.4	32.3
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	36.1	31.4	35.2	32.6
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	36.4	33.2	36.6	33.0
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	37.1	33.1	36.5	32.6
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	38.3	34.3	37.7	34.3
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	37.6	34.2	37.3	34.0
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	36.8	32.9	36.3	32.4
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	36.2	32.3	35.4	32.1
Weed free	-	-	38.4	35.2	38.2	34.4
Weedy check	-	-	35.6	31.1	33.3	30.1
SEm±			0.8	1.0	0.9	1.2
CD (P = 0.05)			NS	NS	NS	NS

Table-3 *SPAD chlorophyll meter values (SCMR values) at different growth stages of direct seeded rice as influenced by weed management practices during kharif 2015-16 and 2016-17*

Treatments	Dose (g ha^{-1})	Time (DAS)	30DAS		60DAS		At harvest	
			2015	2016	2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	30.6	31.5	37.6	38.2	28.2	29.6
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	30.0	30.9	36.7	38.5	25.6	29.5
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	30.8	32.6	38.6	38.6	30.1	30.2
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	30.6	32.5	38.4	37.7	26.4	30.1
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	30.6	30.4	37.1	35.6	27.1	29.3
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	30.8	29.7	36.1	35.2	24.5	27.7
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	30.3	31.8	39.2	41.8	29.4	31.4
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	28.2	30.7	38.6	39.9	26.6	30.2
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	30.7	33.5	39.6	42.6	30.1	32.6
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	30.5	32.9	39.4	42.4	29.5	31.4
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	30.3	31.4	39.1	40.6	28.9	30.4
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	30.5	29.7	38.6	38.8	27.8	29.8
Weed free	-	-	31.4	34.3	40.0	42.4	31.1	31.5
Weedy check	-	-	29.5	29.4	34.3	34.4	23.2	27.0
SEm±	-	-	1.4	1.6	2.1	2.8	2.6	1.8
CD (P = 0.05)	-	-	NS	NS	NS	NS	NS	NS

Table-4 *Grain yield and straw yield of direct seeded rice as influenced by weed management practices during kharif 2015-16 and 2016-17*

Treatments	Dose (g ha^{-1})	Time (DAS)	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
			2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	3844	3619	4917	4782
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	3604	3521	4799	5085
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	4118	4203	5017	5623
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	3674	3923	4766	6045
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	3593	3423	4754	4970
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	3302	3261	4500	4861
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	4714	4687	5672	6411
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	4599	4661	5479	6585
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	5107	5313	5840	6828
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	4828	5014	5774	6706
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	4666	4601	5811	6056
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	4371	4437	5633	6378
Weed free	-	-	5450	5455	5925	6893
Weedy check	-	-	2159	2529	3506	4145
SEm±	-	-	233	298	239	453
CD (P = 0.05)	-	-	678	865	694	1316

Table-5 *Phytotoxic effect of different herbicide treatments on greengramin rice-greengram sequence during 2015-16 and 2016-17 rabi season*

Treatments	Dose (g ha^{-1})	Time (DAS)	7days after application		14 days after application	
			2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	0	0	0	0
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	0	0	0	0
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	0	0	0	0
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	0	0	0	0
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	0	0	0	0
Weed free	-	-	-	-	-	-
Weedy check	-	-	-	-	-	-

0- No injury, 1 - Slight stunting and yellowing of leaves, 10 - Complete kill of crop, - Treatment without herbicides

Table-6 *Initial and final plant population of greengram (No. m-2) as influenced by weed management practices in rice-greengram sequence during 2015-16 and 2016-17 rabi season*

Treatments	Dose (g ha^{-1})	Time (DAS)	Initial plant population		Final plant population	
			2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	33.7	35.0	28.0	30.3
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	34.0	37.3	27.7	35.0
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	38.3	39.7	32.7	33.3
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	36.7	37.7	31.0	32.7
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	34.7	36.0	29.0	30.3
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	30.3	35.3	25.0	31.0
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	37.3	44.3	31.0	38.7
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	37.0	40.0	30.7	35.0
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	38.7	43.0	33.3	38.3
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	37.0	36.0	30.7	31.0
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	34.7	41.0	29.3	36.3
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	31.3	40.3	26.0	35.7
Weed free	-	-	40.0	45.7	35.0	40.7
Weedy check	-	-	29.7	32.7	24.7	27.0
SEm±			3.1	3.3	2.9	3.2
CD (P = 0.05)			NS	NS	NS	NS

Table-7 *Seed yield, haulm yield and harvest index of greengram as influenced by weed management practices in rice greengram sequence during 2015-16 and 2016-17 rabi season*

Treatments	Dose (g ha^{-1})	Time (DAS)	Seed yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Harvest index (%)	
			2015	2016	2015	2016	2015	2016
Pyrazosulfuron ethyl *fb*Azimsulfuron	25 *fb* 20	Pre *fb* Post	548	632	1041	1277	34.5	33.2
Pyrazosulfuron ethyl *fb*Bispyribac-sodium	25 *fb* 25	Pre *fb* Post	532	624	972	1274	35.4	32.8
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron	60 + 500 *fb* 20	Pre *fb* Post	556	652	1106	1303	33.5	33.5
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium	60 + 500 *fb* 25	Pre *fb* Post	548	548	1035	1207	34.6	31.6
Oxadiargyl *fb*Azimsulfuron	75 *fb* 20	Pre *fb* Post	537	625	923	1408	36.8	30.7
Oxadiargyl *fb*Bispyribac-sodium	75 *fb* 25	Pre *fb* Post	529	617	1019	1237	34.2	33.5
Pyrazosulfuron ethyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	559	652	1063	1187	33.3	34.4
Pyrazosulfuron ethyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	25 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	537	655	997	1286	35.1	33.9
Bensulfuron methyl + Pretilachlor with safener *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 20*fb* 4	Pre *fb* Post *fb* Post	571	662	1072	1280	34.7	34.3
Bensulfuron methyl + Pretilachlor with safener *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	60 + 500 *fb* 25*fb* 4	Pre *fb* Post *fb* Post	565	656	1064	1272	34.7	34.2
Oxadiargyl *fb*Azimsulfuron *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 20 *fb* 4	Pre *fb* Post *fb* Post	530	649	964	1263	35.6	34.2
Oxadiargyl *fb*Bispyribac-sodium *fb*Metsulfuron methyl + Chlorimuron ethyl	75 *fb* 25 *fb* 4	Pre *fb* Post *fb* Post	534	642	957	1293	35.8	33.5
Weed free	-	-	585	662	1057	1298	35.8	33.8
Weedy check	-	-	523	594	976	1253	34.9	31.9
SEm±	-	-	19	31	49	99	0.9	1.7
CD (P = 0.05)	-	-	NS	NS	NS	NS	NS	NS

T12) Pre-emergence application of oxadiargyl @ 75 g a.i. ha^{-1} fb post-emergence application of bispyribac-sodium @ 25 g a.i. ha^{-1} at 25 DASfb post-emergence application ofmetsulfuron methyl and chlorimuron ethyl @ 4 g a.i. ha^{-1}applied at 45 DAS

T13) Weed free;

T14) Weedy check

Herbicides were sprayed using a knapsack sprayer fitted with a flat-fan nozzle at a spray volume of 500 l ha^{-1}. A seed rate of 50 kg ha^{-1} was adopted in rice. Seeds were weighed separately for each plot and sown in solid rows in the furrows opened by line markers at 25 cm interval in both the years. Recommended dose of fertilizer (120:60:60 kg NPK ha^{-1}) was applied uniformly in three equal splits. Irrigation comprised of alternate drying and wetting followed by intermittent irrigation at seven days interval up to 15 days before harvest. The efficacy of different treatments on weeds was evaluated at crop maturity. Quadrates (0.25 m2) were placed in each plot at random to determine the weed density. Weed seedlings within these quadrates were counted and the efficacy of weed control treatments was evaluated by comparing the density with the untreated control. After harvest and threshing of crop, grain yield was recorded in net plot wise and converted to grain yield per hectare. The data of each year was analyzed separately. The data on weeds were transformed by square root transformation by adding one before being subjected to ANOVA [4].

Results and Discussion

Crop Injury Score

Phytotoxicity scoring (crop injury score) as effected by different weed management practices recorded at 7 and 14 days after application is presented in [Table-1]. Among the herbicides tested only bispyribac-sodium had a slight phototoxic effect on rice. Phytotoxicity of bispyribac-sodium was characterized slightly stunted plant growth and leaves fail to expand fully and became yellowish as observed at 14 days after application. However, those symptoms disappeared, and the rice plants recovered within a week. Plants treated with all other herbicides revealed that none of these herbicidal treatments showed any phytotoxic effect on rice crop during both the years of investigation. These findings are in accordance with the results of Parvez Anwar *et al*. (2012) [5].

Observations recorded on phytotoxicity revealed that none of the herbicidal treatments applied to rice showed any phytotoxic effect on succeeding greengram crop during both the years of study [Table-5].

Initial and final plant Population (No. m^{-2})

There was no significant influence of weed management treatments on rice plant population during both the years of study [Table-2]. Data pertaining to initial and final plant population of greengram (No. m^{-2}) as influenced by herbicidal treatments was recorded at 20 DAS and at maturity in greengram crop are presented in Table 6. The germination of the crop was not accomplished by the herbicidal treatments and none of the weed control treatments or weedy check could alter this parameter to a statistically perceptible magnitude. There was no explicit variation in initial plant population during both the years of study.

SPAD Chlorophyll Meter Values (SCMR)

SPAD chlorophyll meter readings were recorded at different stages of rice during both the years of study presented in [Table-3]. At 30 DAS, there was no significant influence of weed management treatments on rice SCMR values during both the years of study. The maximum SCMR values were observed in weed free (T13) followed by treatments T9, T10, T7, T8, T11, T12, T10, T3, T4, T11, T2, T5 and T6during 2015-16 and 2016-17. Lowest SCMR values were recorded in weedy check (T14). Maximum SCMR values in T9 might be due to the better control of weeds by herbicides application there by plants utilize the more nutrients for its growth and development. Higher SCMR value in weed free (T13) might be due to the better availability of nutrients which ultimately increased the chlorophyll content Jaya Suria *et al*. (2011) [6]. The same trend was observed at 60 DAS and at harvest in both the years of study.

Grain Yield of direct sown rice (kg ha^{-1})

The highest grain yield (5284 and 5455 kg ha^{-1} during 2015-16 and 2016-17, respectively) was recorded under weed free treatment (T13), which was significantly superior to rest of the treatments except treatments T9, which was however, comparable to the treatments T10,T7, T11 and T8. The lowest grain yield (2159 and 2529 kg ha^{-1}) was obtained in untreated (T14) plot, which was significantly lower than any herbicidal treatment. These results are in agreement with the findings of Naseeruddin and Subramanyam (2013) [7], Hossain and Mondal (2014) [8], Lodhi, (2016) [9], and Singh *et al*. (2017)[10]

Straw Yield rice (kg ha^{-1})

Across the combinations of herbicides, pre emergence application of bensulfuron methyl + pretilachlor with safener fb post emergence application of azimsulfuron fb post emergence application of metsulfuron methyl and chlorimuron ethyl applied at 45 DAS(T9) produced the highest straw yield (5840 and 6828 kg ha^{-1}), which was however significantly superior to other treatments, but was at par with treatments T8, T7, T8, T11 and T12. This may be due to less weed competition with sequential application of herbicides as reported by Subhalakshmi and Venkataramana, (2008) [11] and Lodhi, (2016) [9] are in agreement with the observation made in the present study.

Seed yield of greengram (kg ha^{-1})

The seed yield of succeeding greengram crop after rice was non significant among the treatments during both the years of study [Table-7]. This indicates that there was no marked difference among the treatments and the impact of herbicides applied to rice. The applied herbicides which sufficiently got degraded in the soil had no residual effect left on the germination, dry matter, number of pods as well as seed and haulm yields of greengram. This phenomenal manifestation indicate that the different weed management practices applied to rice had neutral effect on growth and yield of succeeding greengram crop. Similar results were also reported by Kumaran *et al*. (2015) [12] that herbicides applied to rice crop had no residual effect on succeeding crops growth and yields.

Haulm yield of greengram (kg ha^{-1})

The haulm yield of succeeding greengram crop was also non-significant during the both the years of study, which indicated that the sequentially applied herbicides to rice had no effect on succeeding greengram haulm yield. This might be due to no residual effect of herbicides and their persistence in the soil to affect the succeeding crop [Table-7].

Harvest index (%)

The weed management measures did not influenced the harvest index of the succeeding greengram crop in both the years of study [Table-7]. It was summarized that there was no residual impact of pyrazosulfuron ethyl,bensulfuron methyl, Pretilachlor, oxadiargyl, azimsulfuron, bispyribac-sodium, metsulfuron methyl and chlorimuron ethyl applied as alone or in combination on succeeding greengram crops This indicated that the said herbicides can safely be used in rice.

Application of research: Herbicides and its residual toxicity on the succeeding crop

Research Category: Herbicides

Abbreviations: DAS: Days after sowing, SCMR: SPAD Chlorophyll Meter Values

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Study area / Sample Collection: Herbicide Residual Toxicity

Cultivar / Variety / Breed name: BPT 5204 for Rice and IPM 2-14

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