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Efficacy of sequential application of herbicides on weed management, rice nutrient uptake and soil nutrient status in dry direct-seeded rice-greengram sequence

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ABSTRACT

A field experiment was conducted on sandy loam soils of Agricultural College Farm, Bapatla, Andhra Pradesh, India, during 2015-16 and 2016-17 in direct-seeded rice (DSR) to test the efficacy of sequential application of herbicides on weed management, rice nutrient uptake and productivity and to assess herbicides residual effect on succeeding greengram. The maximum total nitrogen, phosphorus and potassium uptake at maturity of rice was recorded with pre-emergence application (PE) of bensulfuron-methyl + pretilachlor with safener (ready-mix) at 500 g/ha *fb* post-emergence application (PoE) of azimsulfuron 20 g/ha at 25 days after seeding (DAS) *fb* metsulfuron-methyl and chlorimuron-ethyl (ready-mix) 4 g/ha PoE 45 DAS. The soil available nutrient status and the uptake of nitrogen, phosphorus and potassium by succeeding greengram was not influenced by different weed management treatments applied in DSR.

INTRODUCTION

Rice is the staple food crop of the tropics, in general and India in particular. “Rice is Life” aptly describes the importance of rice in food and nutritional security for the Asian countries. India is the second largest producer of rice in the world grown in an area of 43.8 million hectares with a production of 118.4 million tonnes and productivity of 2.7 t/ha (GOI 2021). In Andhra Pradesh, it is grown in an area of 2.21 million hectares with a production of 8.23 million tons and productivity of 3.73 t/ha (Reserve Bank of India 2020). Weed infestation is the major biotic constraint for higher productivity especially in dry direct-seeded rice (DSR) (Rao *et al.* 2007, 2017). The degree of competition and extent of yield losses vary greatly with method of rice cultivation. Weeds compete with crop plants for moisture, nutrients, light, space and other growth factors and in the absence of effective control measures, deplete considerable amount of applied nutrients resulting in a significant yield loss (Rao *et al.* 2007). Thus, the present study was carried out with an objective to assess the efficacy of sequential application of herbicides on weed management, rice productivity, nutrient uptake and soil nutrient status in direct-seeded rice-greengram sequence.

MATERIALS AND METHODS

A field study was carried out during rainy season of *(Kharif)* 2015 and 2016 at the Agricultural College Farm, Bapatla, Guntur, Andhra Pradesh under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.0 and 7.5 during 2015 and 2016, respectively, low in organic carbon (0.45 and 0.48%), low in available nitrogen (212 and 230 kg/ha) and available phosphorus (17 and 18 kg/ha) and medium range in available potassium (261 and 285 kg/ha).

The field was dry ploughed with tractor drawn cultivar and harrowed with rotavator. The area was divided into required number of plots as per layout plan. Irrigation channels were formed so as to give sufficient water to each plot. A seed rate of 50 kg/ha was adopted and the cultivar was ‘*Samba mahsuri (BPT-5204)*’. Seeds were weighed separately for each plot and sown in solid rows in the furrows opened by line markers at 25 cm interval. The field was irrigated immediately after sowing the dry seeds to get good germination. Application of fertilizers was done as per the recommendation *i.e.* 120 kg N, 60 kg P and 60 kg K/ha in the form of urea, single superphosphate and muriate of potash, respectively. Nitrogen was applied in 3 equal splits at sowing,

active tillering and panicle initiation stage. Entire quantity of phosphorus was applied as basal. Potassium was applied in 2 splits 2/3 as basal and 1/3 at panicle initiation stage along with urea. Weed flora from the experimental field were collected randomly selected quadrats each of 0.25/m^2 area (0.5 x 0.5 m) in the sampling rows of each plot at 30, 60 days after seeding (DAS) and at maturity. Weeds in each quadrat were grouped into grasses, sedges and broad-leaved weeds and these groups were added to obtain total weed density (no./m^2). The weed samples were initially shade dried followed by oven dried at 60°C till to a constant weight to measure total dry weight of weeds (biomass) in g/m^2.

There were fourteen treatments:- pyrazosulfuron-ethyl 25 g/ha pre-emergence (PE) followed by (*fb*) azimsulfuron 20 g/ha post-emergence (PoE); pyrazosulfuron-ethyl 25 g/ha *fb* bispyribac-sodium 25 g/ha PoE; bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE; bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE; oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE; oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE; pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE, oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; weed free and weedy check.

Herbicides were sprayed using a knapsack sprayer fitted with a flat-fan nozzle with a recommended spray volume of 500 l/ha. Pre-emergence herbicides (pyrazosulfuron-ethyl and oxadiargyl) were applied uniformly at 3 DAS by using knapsack sprayer. Bensulfuron methyl + pretilachlor with safener applied uniformly at 3 days after sowing (DAS) by mixing the herbicide with dry sand at 50 kg/ha and broadcasted uniformly under thin film of water. The post-emergence herbicides *i.e.* azimsulfuron, bispyribac-sodium were applied at 25 DAS, and metsulfuron-methyl + chlorimuron-ethyl was applied at 45 DAS by using knapsack sprayer. After harvest and threshing of crop, grain yield was recorded in net plot wise and converted to grain yield per hectare. Plant samples collected to estimate the uptake of nitrogen, phosphorus and potassium at harvest of the direct-seeded rice and greengram. The oven dried pant samples were chopped and ground into fine powder. The analysis of N, P and K was made by following methodology of Bremner, (1965), Koeing and Johnson, (1942) and Jackson, 1973, respectively. Immediately after harvest of direct-seeded rice and greengram during both the annual cropping cycles, soil samples were drawn from individual plots of the replications and analyzed for post-harvest fertility status of N, P and K by respective standard procedures. N uptake was calculated using the formula:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient concentration (\%)x weight of dry matter (kg/ha)}}{100}$$

Statistical analysis was done by analysis of variance for randomized complete block design as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on total weed density in dry direct-seeded rice

All the weed management practices significantly reduced the total weed density in rice during both the years of study at all the stages of crop growth compared to weedy check. At 30 and 60 DAS, among the herbicide combinations, significantly the lowest total weed density was recorded with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE and it was at par with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE. A similar trend in treatments response was observed at harvest as well. None of the herbicide treatments were as effective as weed free, which was significantly lowest weed density than rest of the treatments at all stages of observation during both the years of study (**Table 1**). The present findings are inconformity with Hossain and Mondal (2014), Rammu Lodhi (2016) and Ajay Singh *et al.* (2017).

Effect on total weed biomass in dry direct-seeded rice

Significantly higher weed biomass was observed in weedy check. The lowest weed biomass was with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/

ha PoE and it was at par with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE in herbicide combinations during both the years of study at 30 and 60 DAS and harvest (**Table 2**). The results of this study are in agreement with Madhukumar *et al*. (2013), Rammu Lodhi (2016) and Vijay Singh *et al.* (2016).

Effect on grain yield of dry direct-seeded rice

The maximum grain yield (5.11 and 5.31 t/ha, respectively) was obtained with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE and it was at par with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE and pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE (**Table 3**). Among all the weed management treatments, the highest grain yield (5450 and 5455 kg/ha during 2015-16 and 2016-17, respectively) was recorded in weed free treatment, which was significantly superior to rest of the treatments except bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE,, which was however, comparable to the treatments bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE and pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE. The lowest grain yield (2.16 and 2.53 t/ha during 2015 and 2016,

Table 1. Total weeds density at different growth stages of dry direct-seeded rice as influenced by weed management treatments during *Kharif* season 2015-16 and 2016-17

Treatment	Total weeds density (no./m^2)					
	30 DAS		60 DAS		At harvest	
	2015	2016	2015	2016	2015	2016
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	6.3 (39.7)	6.0 (36.0)	10.2 (103.3)	10.2 (104.7)	8.1 (65.3)	8.5 (72.0)
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	6.4 (40.7)	6.4 (40.3)	10.2 (103.3)	9.9 (97.7)	8.4 (70.3)	8.4 (70.3)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	4.8 (22.3)	5.0 (24.3)	8.8 (76.3)	8.9 (79.3)	6.5 (42.3)	6.9 (46.7)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	4.8 (22.3)	5.1 (25.7)	8.7 (75.7)	9.0 (80.0)	7.0 (48.0)	6.7 (44.0)
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	6.2 (38.7)	6.2 (38.0)	10.5 (109.3)	10.3 (106.0)	8.6 (74.0)	8.7 (76.0)
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	6.5 (42.0)	6.2 (37.7)	10.9 (117.7)	10.8 (116.3)	9.0 (81.3)	9.1 (81.7)
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.9 (34.7)	6.2 (38.3)	7.3 (52.7)	7.6 (57.7)	6.1 (37.3)	6.0 (35.0)
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	6.1 (37.3)	6.3 (39.7)	7.5 (55.7)	7.7 (58.3)	6.4 (40.0)	6.3 (38.7)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4.4 (19.0)	4.8 (23.7)	5.8 (33.0)	6.6 (43.3)	4.7 (21.3)	4.4 (19.0)
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.1 (26.3)	5.5 (29.3)	6.4 (40.7)	6.8 (45.7)	5.4 (28.3)	5.5 (29.3)
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	6.2 (37.7)	6.1 (37.3)	7.6 (57.3)	7.5 (56.3)	6.1 (36.7)	6.6 (43.3)
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	6.5 (42.3)	6.6 (42.7)	7.8 (60.3)	7.7 (59.0)	6.4 (40.3)	6.4 (41.0)
Weed free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)
Weedy check	10.8 (117.3)	11.2 (124.3)	13.5 (182.0)	13.2 (173.0)	10.7 (114.3)	11.3 (127.7)
LSD (p = 0.05)	0.8	0.8	0.9	0.7	0.5	0.6

DAS: Days after seeding; PE : Pre-emergence PoE: Post-emergence; *fb*: Followed by; Data in parentheses are original values

respectively) was in untreated weedy check plot, which was significantly lower than any of the herbicide treatment. These results were in agreement with the findings of Naseeruddin and Subramanyam (2013), Hossain and Mondal (2014), Rammu Lodhi, (2016), and Ajay Singh *et al.* (2017)

Residual effect of on seed yield of succeeding greengram

The seed yield of succeeding greengram crop after rice were statistically at par during both the years of study. This indicates lack of any adverse impact of herbicides applied to rice on succeeding greengram due to their degradation in the soil resulting in no residual effect left to affect the seed yields of greengram as reported by Kumaran *et al.* (2015).

Effect on rice nutrient uptake

The highest uptake of nitrogen, phosphorous and potassium at maturity of dry direct-seeded rice was recorded with weed free treatment which was significantly superior to rest of the treatments. However, weed free did not differ statistically with bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE; bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE ; pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE and oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE in nitrogen, phosphorous and potassium uptake (**Table 4, 5** and **6**). All the weed management practices treatments distinctly increased the nitrogen, phosphorous and potassium uptake over weedy check. Increased rice productivity under various weed management practices was obviously due to effective weed control right from the initial stages up to maturity that resulted in higher nutrient uptake. The present findings are in agreement with those of Mandhata Singh *et al* (2010).

Nitrogen, phosphorous and potassium uptake estimated at harvest of greengram was not influenced by herbicidal treatments taken up in preceding rice crop during both the years.

Table 2. Total weeds biomass at different growth stages of direct seeded rice as influenced by weed management treatments during *Kharif* 2015-16 and 2016-17

Treatment	Total weeds biomass (g/m^2)					
	30 DAS		60 DAS		At harvest	
	2015	2016	2015	2016	2015	2016
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	5.4 (29.2)	5.2 (26.1)	10.2 (104.4)	9.1 (82.1)	7.8 (59.9)	10.2 (103.5)
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	6.0 (35.1)	6.0 (35.4)	9.5 (89.2)	8.7 (74.9)	10.2 (105.2)	9.5 (90.4)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	3.4 (11.1)	3.5 (11.6)	6.4 (40.5)	6.8 (45.4)	5.6 (31.3)	6.0 (35.5)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	3.6 (12.6)	3.7 (13.5)	6.8 (45.2)	6.9 (46.7)	6.5 (42.4)	6.4 (40.5)
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	5.5 (29.5)	5.5 (29.4)	10.3 (104.8)	10.0 (99.3)	10.1 (102.7)	9.4 (87.8)
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	5.7 (32.2)	5.3 (28.0)	10.2 (103.9)	10.5 (110.4)	10.1 (103.6)	10.5 (110.8)
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.1 (25.5)	5.2 (26.5)	6.3 (40.2)	6.8 (46.0)	6.4 (40.9)	6.6 (44.0)
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.4 (28.8)	5.8 (32.7)	6.4 (40.6)	6.5 (42.8)	7.3 (53.0)	5.8 (34.2)
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	3.2 (9.5)	3.4 (11.9)	4.1 (16.1)	4.7 (21.9)	3.6 (12.7)	3.6 (12.4)
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	3.9 (14.7)	4.0 (15.3)	4.7 (22.1)	4.9 (24.2)	4.2 (17.5)	4.5 (19.7)
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.6 (30.9)	5.3 (27.6)	6.7 (44.7)	6.8 (46.1)	6.1 (36.3)	7.1 (49.5)
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5.8 (33.8)	5.7 (31.9)	7.6 (58.0)	7.2 (52.5)	6.8 (47.1)	7.0 (48.6)
Weed free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)
Weedy check	10.9 (117.8)	10.6 (112.8)	15.8 (249.6)	14.0 (196.8)	16.7 (282.1)	18.6 (347.8)
LSD (p = 0.05)	0.7	0.8	1.0	0.9	1.5	1.2

DAS: Days after seeding; PE: Pre-emergence PoE: Post-emergence; *fb*: Followed by; Data in parentheses are original values

Table 3. The grain yield of rice-greengram sequence as influenced by weed management treatments during *Kharif* season 2015-16 and 2016-17

Treatment	Grain yield kg/ha				Return per rupee investment of rice-greengram system	
	Rice		Greengram			
	2015	2016	2015	2016	2015	2016
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	3844	3619	548	632	1.42	1.58
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	3604	3521	532	624	1.23	1.49
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	4118	4203	556	652	1.47	1.81
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	3674	3923	548	548	1.21	1.38
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	3593	3423	537	625	1.26	1.47
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	3302	3261	529	617	1.07	1.34
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4714	4687	559	652	1.63	1.93
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4599	4661	537	655	1.48	1.90
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	5107	5313	571	662	1.72	2.11
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4828	5014	565	656	1.56	1.94
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4666	4601	530	649	1.52	1.87
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	4371	4437	534	642	1.37	1.75
Weed free	5450	5455	585	662	1.41	1.70
Weedy check	2159	2529	523	594	0.63	1.05
LSD (p=0.05)	678	865	NS	NS	-	-

DAS: Days after seeding; PE: Pre-emergence PoE: Post-emergence; *fb*: Followed by

Table 4. Nutrient uptake of direct-seeded rice at harvest as influenced by weed management treatments during *kharif* 2015-16 and 2016-17

Treatment	Nutrient uptake (kg/ha)					
	N		P		K	
	2015	2016	2015	2016	2015	2016
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	87.2	89.0	22.1	24.5	98.6	100.1
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	82.2	86.0	19.7	23.0	95.6	103.0
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	97.8	107.6	24.5	28.8	107.8	120.9
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	88.8	99.8	20.9	27.8	99.0	125.6
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	80.1	83.1	19.4	22.0	95.3	101.4
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	73.8	76.6	17.6	20.2	87.3	96.6
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	115.2	124.0	28.7	36.3	123.1	137.6
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	109.8	120.6	25.8	34.1	119.7	139.4
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	125.5	139.1	33.7	41.1	132.8	151.3
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	118.3	129.5	30.3	37.8	128.1	145.9
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	111.4	117.6	28.0	33.2	123.0	128.6
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	104.9	110.8	24.5	31.5	116.1	132.9
Weed free	132.6	144.0	36.3	43.5	137.9	155.0
Weedy check	53.1	61.9	11.3	15.7	66.0	79.1
LSD (p=0.05)	16.6	27.1	5.4	8.1	15.5	24.7

DAS: Days after seeding; PE: Pre-emergence PoE: Post-emergence; *fb*: Followed by

Table 5. The influence of weed management treatments on the soil fertility status (kg/ha) after the harvest of direct-seeded rice as during *Kharif* 2015-16 and 2016-17

Treatment	Soil fertility status (kg/ha)					
	2015-16			2016-17		
	Available N	Available P	Available K	Available N	Available P	Available K
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	190.2	12.6	147.1	183.5	14.7	137.4
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	194.2	13.2	148.4	186.3	14.4	141.6
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	190.2	12.1	144.5	176.7	13.5	134.1
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	192.3	12.2	146.1	179.0	13.9	138.4
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	196.7	14.3	150.0	187.3	14.5	138.4
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	198.9	14.5	151.8	189.3	14.8	142.9
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	181.4	12.6	142.9	177.8	13.8	139.3
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	184.1	12.4	144.2	175.2	14.2	138.1
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	179.1	11.6	141.4	174.0	13.2	133.4
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	180.7	12.7	143.3	178.2	13.6	137.4
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	186.6	12.5	145.5	177.1	14.1	140.7
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	191.5	12.9	146.7	183.2	14.4	143.5
Weed free	182.8	14.5	153.5	188.2	16.3	147.9
Weedy check	180.0	11.5	144.4	176.8	12.8	135.2
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

Table 6. The influence of weed management treatments on the nutrient uptake of greengram as in rice-greengram sequence during *Rabi* season 2015-16 and 2016-17

Treatment	Nutrient uptake (kg/ha)					
	N		P		K	
	2015	2016	2015	2016	2015	2016
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	26.9	32.3	4.3	5.4	24.1	28.4
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	26.6	31.4	4.0	5.2	21.9	27.8
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	28.0	32.3	4.6	5.8	24.7	29.1
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	27.0	28.8	4.1	4.7	23.3	26.1
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	25.3	33.1	3.9	5.5	21.9	30.7
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	26.8	31.2	4.1	5.1	23.1	27.3
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	27.9	31.4	4.2	5.1	24.3	27.0
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	26.5	32.7	3.9	5.6	23.0	29.0
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	27.8	33.4	4.3	5.6	24.4	28.5
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	27.6	32.9	4.5	5.6	23.8	28.7
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	26.6	32.1	4.1	5.4	22.1	28.2
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	26.3	32.2	4.0	5.6	22.0	28.0
Weed free	28.1	33.4	4.6	5.8	24.5	29.4
Weedy check	25.6	30.9	4.0	5.3	22.3	27.9
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

DAS: Days after seeding; PE: Pre-emergence PoE: Post-emergence; *fb*: Followed by

Table 7. The influence of weed management treatments on the soil fertility status as recorded after greengram harvest in rice-greengram sequence during 2015-16 and 2016-17 *Rabi* (winter) season

Treatment	Soil fertility status (kg/ha)					
	2015-16			2016-17		
	Available N	Available P	Available K	Available N	Available P	Available K
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE	208	10	131	204	11	119
Pyrazosulfuron-ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	213	11	132	207	12	125
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE	207	10	129	197	10	117
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	208	10	129	202	10	120
Oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE	214	12	133	210	11	123
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE	214	13	134	211	12	125
Pyrazosulfuron-ethyl 25 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	200	10	125	198	11	121
Pyrazosulfuron ethyl 25 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	202	10	130	196	11	120
Bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	195	9	125	193	9	117
bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	199	10	127	197	10	119
oxadiargyl 75 g/ha PE *fb* azimsulfuron 20 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	207	11	130	204	11	123
Oxadiargyl 75 g/ha PE *fb* bispyribac-sodium 25 g/ha PoE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	210	12	131	206	12	125
Weed free	212	11	133	209	13	128
Weedy check	201	10	128	195	10	118
LSD (p = 0.05)	NS	NS	NS	NS	NS	NS

DAS: Days after seeding; PE: Pre-emergence PoE: Post-emergence; *fb*: Followed by

Soil available nutrients

Soil available nutrients (nitrogen, phosphorous and potassium) after rice-greengram sequence was not influenced by the different weed management practices during both the years of study (**Table 7**).

The pre-emergence application of bensulfuron-methyl + pretilachlor with safener 60 + 500 g/ha PE *fb* post-emergence application of azimsulfuron 20 g/ha at 25 DAS *fb* post-emergence application of metsulfuron-methyl and chlorimuron-ethyl 4 g/ha applied at 45 DAS may be used for attaining effective weed management, maximum rice grain yield and nutrients uptake with no residual effect on succeeding greengram.

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