



Impact of live mulches, cover crops and herbicides on weeds and yield of direct-seeded rice

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ABSTRACT

A field investigation was conducted during the rainy seasons of 2014 and 2015 at Varanasi, Uttar Pradesh, to study the impact of live mulches, cover crops and herbicides on weeds and yield in direct-seeded rice (*Oryza sativa* L.). *Sesbania* cover crop followed by *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had lesser weed density and dry weight of grasses, sedges and broad-leaved weeds than sunhemp cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had higher harvest index in comparison to sunhemp cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS improved grain and straw yields with higher gross and net returns, and benefit:cost ratio as compared to sunhemp cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS.

INTRODUCTION

Direct-seeded rice is becoming more popular as an alternative to transplanted rice, as it is more remunerative if the crop managed properly (Sharma *et al.* 2007). However, weeds are the main biological constraints to the production of DSR (Rao *et al.* 2007, Chauhan and Johnson 2010), which may cause 60-80% reduction in grain yield of rice. Sunil *et al.* (2010) reported that season-long weed competition in direct-seeded rice may cause yield reduction up to 80%. Raj *et al.* (2013) found 72% reduction in grain yield due to the infestation of non-grassy, broad-leaved weeds and sedges in DSR. Brown manuring of green manure crops with 2,4-D significantly reduced weed population and weed dry weight compared to other incorporation method (Anitha *et al.* 2009). Singh *et al.* (2007) reported that *Sesbania* co-culture reduced broad-leaf and grass weed density by 76-83% and 20-33%, respectively, and total weed biomass by 37-80% compared with a sole rice crop. However, weeds in DSR cannot be controlled by incorporation of cover crops and live mulches alone because of multiple flushes of weeds during crop growth. The present study was taken up to assess the efficacy of herbicides along with cover crops and live mulches and to study the impact of integrated weed management on weeds and yield of DSR.

MATERIALS AND METHODS

A field experiment was conducted during the rainy seasons of 2014 and 2015 at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was sandy clay loam, with pH 7.40, low in available organic carbon (0.41%), available nitrogen (207.47 kg/ha), and medium in available phosphorous (23.85 kg/ha) and potassium (219.60 kg/ha). The experiment was laid out in a randomized complete block design and replicated thrice, comprising 9 treatments, *viz.* *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS, sunhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS, *Sesbania* cover crop *fb* *Sesbania* co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS, sunhemp cover crop *fb* sunhemp co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS, *Sesbania* co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS, sunhemp co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS, bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS, hand weeding at 15 and 35 DAS and weedy check during both the years. Sowing of *Sesbania* and sunhemp as cover crops was done in plots allotted to cover crop before sowing of rice manually using seed rate of 25 kg/ha 25 days before sowing of rice. Co-culture was also sown along with sowing of rice manually. In other experimental plots, rice was also sown manually using seed rate of 30 kg/

ha. In cover crops treated plot, one week after sowing of rice, cover crops were cut and placed as green mulch in between the two rows of rice. A recommended dose of fertilizer (150 kg N, 60 kg P₂O₅ and 60 kg K₂O) was applied through urea, single super phosphate and muriate of potash. Full dose of phosphorus and potassium were applied as basal application while nitrogen was applied half as basal and remaining half in two equal splits at tillering and panicle initiation stages of rice. Application of alone and tank mixed post-emergence herbicides was done as per the treatments using knapsack sprayer fitted with flat-fan nozzle. The spray volume of post-emergence herbicides was 300 L/ha. The crop was raised under irrigated condition under the recommended package of practices. Species-wise weed density and their dry weight were measured at 30, 60, 90 DAS and harvest by placing a quadrat of 0.5 x 0.5 m randomly at 2 places in each plot. These were subjected to square root transformation before analysis. Weed index (Gill and Kumar 1969) was also calculated on the basis of grain yield. Biometric characters, viz. yield attributes and yields (grain and straw) of rice were recorded at harvest. Prevailing price of inputs in the market during 2014 and 2015 were used to calculate the economics. The data on weeds and yields were averaged for two years before statistical analysis. LSD test (Gomez and Gomez 1984) was used for comparing treatment means.

RESULTS AND DISCUSSION

Density and dry weight of weeds

At 30, 60, 90 DAS and at harvest, *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had significantly lower weed

density of grasses as compared to rest of the treatments except hand weeding at 15 and 35 DAS and it was comparable with sunhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS except at 30 DAS (Table 1, 2 and 3). At 30, 60, 90 DAS and at harvest, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had significantly lower weed density of sedges and broad leaved weeds as compared to rest of the treatments except hand weeding at 15 and 35 DAS and it was comparable with sunhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. *Sesbania* cover crop *fb* *Sesbaniaco*-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS had lesser weed density of grasses as compared to sunhemp cover crop *fb* sunhemp co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS and both treatments were statistically similar to each other except at 30 DAS. *Sesbania* cover crop *fb* *Sesbania* co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS had lesser weed density of sedges and broad-leaved weeds as compared to sunhemp cover crop *fb* sunhemp co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS and both treatments were statistically similar to each other. This might be due to effective suppression of weeds by *Sesbania* cover crop at the time of crop emergence as it covered the soil and did not allow weed seeds to germinate along with crop. Similar hypothesis had been also proposed by Nelson *et al.* (1991) who reported that rapid development of dense ground covering by the crop suppress weeds.

Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS recorded lower weed dry weight of grasses in comparison to sunhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were

Table 1. Effect of weed management on grassy weed density and dry weight at different stages in direct-seeded rice (average data of two years)

Treatment	Density (no./m ²)				Dry weight (g/m ²)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
<i>Sesbania</i> cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.2(4.4)	2.3(4.7)	2.3(4.7)	3.6(4.3)	1.7(2.5)	1.8(2.7)	1.8(2.9)	2.8(2.5)
Sunhemp cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.4(5.5)	2.3(4.8)	2.3(4.8)	3.7(4.5)	1.9(3.0)	1.8(2.7)	1.9(2.9)	2.9(2.6)
<i>Sesbania</i> cover crop <i>fb</i> <i>Sesbaniaco</i> -culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.8(7.3)	2.3(4.9)	2.3(4.9)	4.5(6.8)	2.1(4.0)	1.8(2.7)	1.9(3.0)	3.5(3.8)
Sunhemp cover crop <i>fb</i> sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.9(7.7)	2.3(4.9)	2.3(4.9)	4.6(7.2)	2.2(4.3)	1.8(2.8)	1.9(3.0)	3.5(4.0)
<i>Sesbaniaco</i> -culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.9(8.1)	2.3(5.0)	2.3(5.0)	4.7(7.8)	2.2(4.5)	1.8(2.8)	1.9(3.0)	3.6(4.3)
Sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	3.1(9.0)	2.4(5.0)	2.4(5.0)	4.9(8.0)	2.3(4.9)	1.8(2.8)	1.9(3.1)	3.7(4.4)
Bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.7(6.8)	2.3(4.8)	2.3(4.8)	4.2(5.9)	2.1(3.8)	1.8(2.7)	1.9(3.0)	3.3(3.3)
Hand weeding at 15 and 35 DAS	0.7(0)	0.7(0)	0.71(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)
Weedy check	5.5(29)	5.6(31)	6.0(35)	11.0(43)	4.1(17)	5.0(24)	4.5(20)	8.2(24)
LSD (p=0.05)	0.10	0.02	0.04	3.02	0.14	0.04	0.03	2.14

Data were subjected to square root ($\sqrt{x+0.5}$) transformation; figures in parentheses are original values

statistically comparable to each other except at 30 DAS. *Sesbaniaco-culture fb* 2, 4 D 0.5 kg/ha at 30 DAS had lesser weed dry weight of grasses as compared to sunhemp co-culture *fb* 2, 4 D 0.5 kg/ha at 30 DAS and both treatments were statistically similar to each other (Table 1). *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS recorded lower weed dry weight of sedges and broad-leaved weeds in comparison to sunhemp cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were statistically at par to each other. These findings are in conformity with the result of Khaliq *et al.* (2012). *Sesbania* co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS had lesser weed dry weight of sedges and broad-leaved weeds as compared to sunhemp co-culture *fb* 2,4-D 0.5 kg/ha at 30 DAS and both treatments were statistically

similar to each other (Table 2 and 3). The vigorous growth and better canopy coverage of live mulches suppressed the growth of weeds.

Yield attributes and yield

Weed management treatments resulted in lower weed index, which had significantly higher grain and straw yields over weedy check (Table 4). *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS resulted in higher number of panicle/m², number of grains/panicle and test weight in comparison to sunhemp cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were statistically similar to each other. The increase in grain yield under *Sesbania* cover crop *fb* bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and sunhemp cover crop *fb*

Table 2. Effect of weed management on sedges weed density (no./m²) and dry weight (g/m²) at different stages in direct-seeded rice (average data of two years)

Treatment	Density (no./m ²)				Dry weight (g/m ²)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
<i>Sesbania</i> cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.7(2.3)	1.4(1.5)	1.4(1.5)	1.6(2.2)	1.5(1.7)	1.2(1.0)	1.2(1.0)	1.4(1.6)
Sunhemp cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.9(3.0)	1.4(1.5)	1.4(1.5)	1.7(2.6)	1.6(2.1)	1.2(1.1)	1.2(1.1)	1.5(1.8)
<i>Sesbania</i> cover crop <i>fb</i> <i>Sesbaniaco-culture fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.1(4.1)	1.4(1.5)	1.4(1.5)	2.0(3.6)	1.8(2.9)	1.3(1.1)	1.3(1.1)	1.7(2.5)
Sunhemp cover crop <i>fb</i> sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.2(4.3)	1.4(1.6)	1.4(1.6)	2.1(4.1)	1.9(3.0)	1.3(1.1)	1.3(1.1)	1.8(2.9)
<i>Sesbania</i> co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.2(4.5)	1.4(1.6)	1.4(1.6)	2.0(4.2)	1.9(3.2)	1.3(1.1)	1.3(1.1)	1.9(3.0)
Sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.3(4.9)	1.5(1.6)	1.5(1.6)	2.3(4.6)	2.0(3.4)	1.3(1.1)	1.3(1.1)	1.9(3.3)
Bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.0(3.7)	1.4(1.5)	1.4(1.5)	1.9(3.2)	1.8(2.7)	1.3(1.1)	1.3(1.1)	1.7(2.3)
Hand weeding at 15 and 35 DAS	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)
Weedy check	3.8(14)	4.1(16)	4.9(23)	4.9(24)	3.3(10)	3.7(13)	4.1(17)	4.2(17)
LSD (p=0.05)	0.13	0.04	0.02	0.14	0.12	0.03	0.04	0.12

Data were subjected to square root ($\sqrt{x+0.5}$) transformation; figures in parentheses are original values

Table 3. Effect of weed management on broad-leaved weed density (no./m²) and dry weight (g/m²) at different stages in direct-seeded rice (average data of two years)

Treatment	Density (no./m ²)				Dry weight (g/m ²)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
<i>Sesbania</i> cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.1(4.1)	1.7(2.4)	1.7(2.4)	2.0(3.7)	1.6(2.0)	1.3(1.3)	1.3(1.3)	1.5(1.9)
Sunhemp cover crop <i>fb</i> bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.3(4.7)	1.7(2.5)	1.7(2.5)	2.2(4.2)	1.7(2.4)	1.3(1.3)	1.3(1.3)	1.6(2.1)
<i>Sesbania</i> cover crop <i>fb</i> <i>Sesbaniaco-culture fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.6(6.2)	1.7(2.5)	1.7(2.5)	2.4(5.5)	2.0(3.3)	1.4(1.3)	1.4(1.3)	1.8(2.9)
Sunhemp cover crop <i>fb</i> sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.7(6.6)	1.8(2.6)	1.8(2.6)	2.5(5.9)	2.0(3.5)	1.4(1.4)	1.4(1.4)	1.9(3.1)
<i>Sesbania</i> co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.7(7.0)	1.8(2.6)	1.8(2.6)	2.7(6.6)	2.1(3.7)	1.4(1.4)	1.4(1.4)	2.0(3.6)
Sunhemp co-culture <i>fb</i> 2,4-D 0.5 kg/ha at 30 DAS	2.8(7.4)	1.8(2.6)	1.8(2.7)	2.8(7.1)	2.1(3.9)	1.4(1.4)	1.4(1.4)	2.1(3.8)
Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.5(5.6)	1.7(2.5)	1.7(2.5)	2.3(4.9)	1.9(3.0)	1.4(1.3)	1.3(1.3)	1.7(2.6)
Hand weeding at 15 and 35 DAS	0.7(0.0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.71(0)	0.7(0)
Weedy check	4.5(19)	5.2(27)	5.9(34)	6.0(36)	3.3(10)	4.2(17)	4.8(22)	4.4(19)
LSD (p=0.05)	0.26	0.17	0.15	0.13	0.12	0.16	0.15	0.14

Data were subjected to square root ($\sqrt{x+0.5}$) transformation; figures in parentheses are original values

Table 4. Effect of weed management on yields, weed index, harvest index and economics of direct-seeded rice (average data of two years)

Treatment	No. of panicle (/m ²)	No. of grains /panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Harvest index (%)	Gross returns (x10 ³ /ha)	Net returns (x10 ³ /ha)	B:C ratio
<i>Sesbania</i> cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	241.8	108.6	18.8	5.0	5.9	2.4	45.7	81.8	44.2	2.2
Sunhemp cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	240.8	108.0	18.8	4.7	5.7	7.8	45.2	77.4	39.8	2.0
<i>Sesbania</i> cover crop fb <i>Sesbaniaco</i> -culture fb 2,4-D 0.5 kg/ha at 30 DAS	240.1	107.0	18.8	4.6	5.7	10.3	44.9	75.5	39.8	2.1
Sunhemp cover crop fb sunhemp co-culture fb 2,4-D 0.5 kg/ha at 30 DAS	239.8	106.5	18.7	4.6	5.6	11.4	44.7	74.6	39.0	2.0
<i>Sesbania</i> co-culture fb 2,4-D 0.5 kg/ha at 30 DAS	239.5	106.0	18.7	4.5	5.6	12.3	44.8	73.8	39.6	2.1
Sunhemp co-culture fb 2,4-D 0.5 kg/ha at 30 DAS	239.1	102.6	18.7	4.5	5.5	13.2	44.8	73.1	38.9	2.1
Bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	240.5	107.3	18.8	4.7	5.7	9.2	44.8	76.4	40.8	2.1
Hand Weeding at 15 and 35 DAS	250.5	111.6	20.7	5.1	6.1	0.0	45.8	83.9	37.9	1.8
Weedy check	213.3	69.3	15.9	2.3	3.3	54.6	41.6	3.8	7.4	1.2
LSD (p=0.05)	0.61	0.82	1.45	2.90	6.26	-	2.52	3.21	6.92	3.70

bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS was 115.3% and 103.4% over weedy. This could be due to the lowest weed index as compared to all other treatments except hand weeding at 15 and 35 DAS. *Sesbania* cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had highest harvest index in comparison to all integrated weed management treatments except hand weeding at 15 and 35 DAS. Due to effective suppression of weeds in cover crop treated plots (**Table 1, 2 and 3**) and restricting the competition by weeds for growth resources helped in improving yield and yield attributes.

Economics

The gross returns varied significantly due to different weed management treatments, which ultimately influenced the net returns and benefit: cost ratio amongst weed management treatments. *Sesbania* cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS had higher gross returns as compared to sunhemp cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were statistically similar to each other. The highest net returns and benefit: cost ratio were also observed in *Sesbania* cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS (**Table 4**). This could be attributed to higher grain yield and gross returns.

On the basis of above findings it was concluded that *Sesbania* cover crop fb bispyribac-Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS should be adopted for minimizing weed growth and also to obtain higher yield and monetary returns in direct-seeded rice..

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