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Research Paper

Effect of live mulches, cover crops and herbicides on weed flora, growth and yield of direct-seeded rice (*Oryza sativa*)

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ABSTRACT

A field investigation was conducted during the rainy season of 2014 and 2015 at Varanasi, Uttar Pradesh, to study the effect of live mulches, cover crops and herbicides on weed flora, growth and yield in direct-seeded rice (*Oryza sativa* L.). At 60 days after sowing (DAS), amongst the weed management treatments, *Sesbania* cover crop followed by (*fb*) bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS reduced weed density of various weeds and dry weight than sunnhemp (*Crotalaria juncea* L.) cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS thus resulting in the lowest weed index except hand weeding at 15 and 35 DAS. *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS markedly improved plant height, tillers/m^2, dry-matter accumulation, leaf-area index, chlorophyll content and yield attributes, viz. panicle length, panicle weight, panicles/m^2, grains/panicle and 1,000-grain weight. *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS improved the grain and straw yields with higher gross returns, net returns and benefit: cost ratio than sunnhemp 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 exhibited lower nutrients (NPK and Zn) uptake by weeds and higher nutrients (NPK and Zn) uptake by crop than hand-weedings at 15 and 35 DAS.

Key words **:** Azimsulfuron, Bispyribac Na, Direct-seeded rice, Economics, *Sesbania*, Sunnhemp

Direct-seeded rice (DSR) is becoming more popular as an alternative to transplanted rice, as it is more remunerative if the crop managed properly (Sharma *et al.,* 2007). India ranks first in acreage (43.86 million ha), second in production (104.80 million tonnes) after China and average productivity of rice is 2,390 kg/ha. The area under direct-seeded rice (DSR) systems is expected to increase in the future because of labour and water shortages. Weeds, however, are the major constraints to DSR production. To achieve effective, long-term and sustainable weed control in DSR, there is need to integrate different weed-management options, such as the use of cover crops, live mulches and appropriate herbicide mixtures, timing and doses. Aerobic edaphic conditions under non-flooded conditions in DSR stimulate germination of diverse weed species. Season-long weed competition in DSR may cause yield reduction up to 72–80% (Sunil *et al.*, 2010; Raj *et al.,* 2013). Weed problem in DSR can be managed by implementing integrated weed management. Brown manuring with 2, 4-D significantly reduces weed population and weed dry weight compared to other incorporation method (Anitha *et al*., 2009). Singh *et al.* (2007) reported that, *Sesbania* coculture 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 various flushes of weeds during crop growth. It is imperative to identify effective weed-management practices using live mulches and cover crops and to work out their feasibility. Therefore, present study was taken up to assess the efficacy of herbicides along cover crops and live mulches on weed flora and yield of direct-seeded rice.

MATERIALS AND METHODS

A field experiment was conducted during the rainy season of 2014 and 2015 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was sandy clay loam, with *p*H 7.40, low in available organic carbon (0.41%),

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available nitrogen (207.47 kg/ha), and medium in available phosphorus (23.85 kg/ha) and potassium (219.60 kg/ha). The experiment was laid out in a randomized block design, replicated thrice, comprising 9 treatments, viz. *Sesbania* cover crop followed by (*fb*) bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 days after sowing (DAS), sunnhemp 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, sunnhemp cover crop *fb* sunnhemp 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, sunnhemp 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-weedings at 15 and 35 DAS and weedy during both the years. Sowing of *Sesbania* and sunnhemp as cover crops was done in plots allotted to cover crop before sowing of rice manually, using seed rate of 25 kg/ha 15 days before sowing of rice. Co-culture was also sown along with sowing of rice by manually. In other experimental plots, rice was also sown manually using seed rate of 30 kg/ha. In cover crops treated plot 1 week after sowing rice, cover crops were cut and placed as green mulch between the 2 rows of rice. A recommended dose of fertilizer (150 kg N, 60 kg P_2O_5 and 60 kg K_2O) was applied through urea, single super phosphate and muriate of potash. Full dose of P and K were applied basal, while N was applied half as basal and remaining half in 2 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 knap-sack sprayer fitted with flat-fan nozzle. The spray volume of post-emergence herbicides was 300 litres/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 60 DAS by placing a quadrate of 0.50 m × 0.50 m randomly at 2 places in each plot. These were subjected to square-root transformation before analysis. Weed-control efficiency (Tripathi and Mishra, 1971) and weed index (Gill and Kumar, 1969) was also calculated at 60 DAS. Nutrient (N, P, K and Zn) uptake by weeds and crop was calculated multiplying weed dry weight and crop dry-matter with their respective nutrient contents at 60 DAS. Biometric characters, viz. growth attributes, yield attributes and yields (grain and straw), of crop were recorded at 60 DAS and at harvest stages. Prevailing price of inputs in the market during 2014 and 2015 were used to calculate the economics. The data on weed, crop growth and yield, nutrient uptake were averaged for 2 years before statistical analysis. Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984) was used for comparing treatment means.

RESULTS AND DISCUSSION

Density and dry weight of weeds

The major weed flora with their relative composition observed in experimental field included *Echinocloa colona* (L.) (13.83%) *Echinochloa crus-galli* (L.) Beauv. (13.70%), *Cynodon dactylon* (L.) Pers. (10.16%) among grasses; *Cyperus iria* L. (10.59%), *Cyperus difformis* L. (10.25%) and *Fimbristylis miliacea* (L.) Rottb. (10.90%) among sedges; and *Ammannia baccifera* (L.) Roxb (10.12%) and *Caesulia axillaris* (L.) Roxb. (10.14%) among broad-leaf weeds besides other weeds (10.27%) at 60 DAS.

Density of weed species and their dry weight varied significantly at 60 DAS due to integrated weed-management treatments (Tables 1, 2). At 60 DAS, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS resulted in significantly lower weed density than rest of the treatments except hand-weeding at 15 and 35 DAS and it was comparable with sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. 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 suppressing weeds. *Sesbania* cover crop *fb* *Sesbania* co-culture *fb* 2, 4 D 0.5 kg/ha at 30 DAS showed lesser weed density of all weed species than sunnhemp cover crop *fb* sunnhemp coculture *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 all weed species in comparison to sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were statistically at par with each other. This might be due to sowing of *Sesbania* cover crop reduced dry-matter accumulation of weeds before sowing and after sowing, whereas post-emergence herbicides bispyribac and azimsulfuron checked subsequent weed flushes at 15 DAS. *Sesbania* co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS exhibited lesser weed dry weight of all weed species than sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS and both the treatments were statistically similar to each other (Table 2). The vigorous growth and better canopy coverage of live mulches suppressed the growth of weeds.

At 60 DAS, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS recorded higher weed-control efficiency than sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS,

Table 1. Effect of weed management on weed density (/m^2) at 60 days after sowing in direct-seeded rice (average of 2 years)

Treatment	*Echinochloa colona*	*Echinochloa crus-galli*	*Cynodon dactylon*	*Cyperus iria*	*Cyperus difformis*	*Fimbristylis miliacea*	*Ammannia baccifera*	*Caesulia axillaris*	Others
Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.5 (1.9)	1.3 (1.2)	1.2 (1.0)	1.2 (1.1)	1.2 (1.0)	1.2 (1.1)	1.3 (1.3)	1.2 (1.1)	1.3 (1.2)
Sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.6 (2.1)	1.3 (1.3)	1.2 (1.1)	1.3 (1.3)	1.3 (1.2)	1.3 (1.3)	1.4 (1.6)	1.3 (1.2)	1.3 (1.4)
Sesbania cover crop *fb Sesbania* co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.8 (2.9)	1.5 (2.0)	1.5 (1.8)	1.5 (1.7)	1.5 (1.8)	1.5 (2.8)	1.5 (1.8)	1.5 (1.7)	1.5 (1.8)
Sunnhemp cover crop *fb* sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.8 (3.0)	1.6 (2.1)	1.6 (2.0)	1.5 (2.0)	1.6 (2.0)	1.6 (2.1)	1.6 (1.9)	1.5 (1.8)	1.5 (2.0)
Sesbania co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.9 (3.1)	1.6 (2.2)	1.6 (2.1)	1.6 (2.1)	1.6 (2.1)	1.6 (2.3)	1.6 (2.1)	1.6 (2.1)	1.6 (2.1)
Sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	2.0 (3.5)	1.7 (2.4)	1.6 (2.1)	1.6 (2.2)	1.6 (2.3)	1.7 (2.4)	1.6 (2.3)	1.6 (2.3)	1.7 (2.3)
Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.8 (2.8)	1.4 (1.6)	1.3 (1.4)	1.4 (1.6)	1.4 (1.6)	1.5 (1.6)	1.4 (1.6)	1.4 (1.5)	1.4 (1.6)
Hand-weeding at 15 and 35 DAS	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	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	4.0 (15.8)	4.0 (15.6)	3.4 (11.6)	3.5 (12.1)	3.4 (11.5)	3.6 (12.4)	3.4 (11.5)	3.4 (11.5)	3.4 (11.7)
SEm±	0.08	0.06	0.03	0.06	0.02	0.03	0.15	0.07	0.05
CD (0.05)	0.21	0.17	0.09	0.18	0.07	0.08	0.50	0.24	0.23

Data were subjected to square-root ($\sqrt{X+0.05}$) transformation; figures in parentheses are original values

Sesbania cover crop *fb Sesbania* co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, sunnhemp cover crop *fb* sunnhemp coculture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, *Sesbania* coculture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, sunnhemp 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 (Table 2). This might be due to lower weed dry-matter accumulation under this treatment . Chongtham *et al.*, (2016) also reported similar findings in direct seeded rice.

Nutrient depletion by weeds

Amongst the integrated weed-management treatments, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS resulted in significantly lesser nutrient (NPK and Zn) uptake by weeds than sunnhemp 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, sunnhemp cover crop *fb* sunnhemp 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, sunnhemp 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 (Table 3). These results are in close conformity with those reported by Menon *et al.* (2014).

Growth attributes

At 60 DAS, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS resulted in higher plant height, tillers/m^2, dry-matter accumulation (g/running m), leaf-area index and chlorophyll content in comparison to sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and both treatments were statistically similar to each other except for chlorophyll content. *Sesbania* co-culture *fb* 2, 4 D 0.5 kg/ha at 30 DAS had higher plant height, tillers/m^2, dry-matter accumulation (g/running m), leaf-area index and chlorophyll content than sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS and both the treatments were statistically at par to each other (Table 3). The cover crops and live mulches might have controlled weeds at initial stage, resulting in the minimum competition from weeds for growth factors like moisture, nutrient, light and space (Table 1). Mechanical undercutting to kill the

Table 2. Effect of weed management on weed dry weight (g/m^2) and weed-control efficiency (%) at 60 days after sowing in direct-seeded rice (average of 2 years)

Treatment	*Echinochloa colona*	*Echinochloa crus-galli*	*Cynodon dactylon*	*Cyperus iria*	*Cyperus difformis*	*Fimbristylis miliacea*	*Ammannia baccifera*	*Caesuliaa-xillaris*	Others	Weed-control efficiency (%)
Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.3 (1.4)	1.1 (0.7)	0.8 (0.2)	1.1 (0.7)	1.1 (0.7)	1.1 (0.8)	0.8 (0.1)	1.1 (0.8)	1.2 (0.9)	90.7
Sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.4 (1.5)	1.1 (0.8)	0.8 (0.2)	1.1 (0.9)	1.2 (0.8)	1.2 (0.9)	0.8 (0.2)	1.2 (0.9)	1.2 (1.0)	89.5
Sesbania cover crop *fb Sesbania* co-culture *fb*2, 4-D 0.5 kg/ha at 30 DAS	1.6 (2.1)	1.3 (1.2)	0.9 (0.4)	1.3 (1.2)	1.3 (1.3)	1.3 (1.3)	0.8 (0.2)	1.3 (1.2)	1.3 (1.4)	85.4
Sunnhemp cover crop *fb* sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.6 (2.1)	1.3 (1.3)	0.9 (0.4)	1.3 (1.4)	1.4 (1.4)	1.4 (1.5)	0.8 (0.2)	1.3 (1.3)	1.4 (1.5)	84.1
Sesbania co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.6 (2.2)	1.3 (1.4)	1.0 (0.4)	1.4 (1.4)	1.4 (1.4)	1.4 (1.6)	0.8 (0.2)	1.4 (1.6)	1.4 (1.6)	83.2
Sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	1.7 (2.5)	1.4 (1.5)	1.0 (0.5)	1.4 (1.6)	1.4 (1.6)	1.5 (1.7)	0.9 (0.3)	1.5 (1.7)	1.5 (1.7)	81.6
Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	1.5 (2.0)	1.2 (1.0)	0.9 (0.3)	1.2 (1.1)	1.3 (1.1)	1.3 (1.2)	0.8 (0.2)	1.2 (1.1)	1.3 (1.2)	86.9
Hand-weeding at 15 and 35 DAS	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	100
Weedy	3.4 (11.3)	3.2 (9.7)	1.7 (2.6)	3.0 (8.5)	2.9 (8.1)	3.0 (8.8)	2.4 (5.4)	2.9 (8.6)	3.0 (8.8)	0
SEm±	0.03	0.06	0.03	0.04	0.02	0.05	0.04	0.03	0.03	
CD (0.05)	0.10	0.17	0.09	0.09	0.07	0.13	0.09	0.09	0.08	

Data were subjected to square-root ($\sqrt{X+0.05}$) transformation; figures in parentheses are original values

cover crop in *Sesbania* might have left a thick evenly distributed layer of weed-suppressing mulch 1 week after sowing rice. This surface mulch may limit further weed development through its effect on light transmittance, soil temperature and soil moisture (Teasdale, 1993).

Nutrient uptake by crop

Weed management treatments brought significant variation in nutrient uptake by rice compared with weedy (Table 3). Hand-weeding at 15 and 35 DAS resulted in the highest nutrients (NPK and Zn) uptake by crop. *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS recorded significantly higher nutrient (NPK and Zn) uptake than sunnhemp 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, sunnhemp cover crop *fb* sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, *Sesbania* coculture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, sunnhemp coculture *fb* 2, 4-D 0.5 kg/ha at 30 DAS, bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. This might be due to more grain yield in respective cover crops treated weed-management treatments. Our results confirm with the findings of Menon and Prameela (2015).

Yield attributes and yield

Weed-management treatments resulted in marked increase in yield attributes and lower weed index, which had significantly higher grain and straw yields over weedy (Table 4). *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS resulted in higher panicle length, panicle weight (g/panicle), panicles/m^2, grains/panicle and 1,000-grain weight in comparison to sunnhemp 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 sunnhemp cover crop *fb*

Table 3. Effect of weed management on plant height, number of tillers, dry-matter accumulation, leaf-area index (LAI), chlorophyll content and N, P, K (kg/ha) and Zn (g/ha) uptake by weeds and crop at 60 DAS in direct-seeded rice (average of 2 years)

Treatment	Plant height (cm)	Number of tillers /m^2	Dry matter accumulation (g/running m)	LAI	Relative chlorophyll content (SPAD value)	Nutrient uptake by weeds at 60 DAS				Nutrient uptake by crop at 60 DAS			
						N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (g/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (g/ha)
Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	53.6	157.6	33.1	2.8	43.6	79.3	45.4	85.7	2485.2	14.8	3.1	18.0	612.7
Sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	53.3	157.3	32.9	2.8	43.0	90.5	51.8	97.6	2835.7	14.5	2.9	17.7	604.4
Sesbania cover crop *fb Sesbania* co-culture *fb*2, 4-D 0.5 kg/ha at 30 DAS	52.5	156.5	32.0	2.8	42.5	124.2	71.1	134.0	3905.7	13.8	2.6	16.9	580.6
Sunnhemp cover crop *fb* sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	52.1	156.0	31.7	2.8	42.3	134.6	77.2	145.4	4242.8	13.6	2.4	16.6	571.6
Sesbania co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	51.8	155.5	31.5	2.7	42.0	142.1	81.4	153.5	4482.0	13.3	2.1	16.3	559.7
Sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	51.4	155.0	31.0	2.7	41.7	155.9	89.2	168.2	4916.6	12.9	2.0	15.9	549.2
Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	53.2	157.0	32.8	2.8	42.8	111.5	63.7	120.1	3494.3	14.3	2.7	17.4	598.5
Hand-weeding at 15 and 35 DAS	55.6	161.0	38.3	2.9	45.1	0.0	0.0	0.0	0.0	17.2	4.1	21.2	742.5
Weedy	38.6	129.8	18.3	1.4	37.4	983.6	410.3	840.7	25790.5	7.4	1.0	9.1	287.3
SEm±	0.43	0.21	0.40	0.10	0.10	0.02	0.04	0.04	0.19	0.09	0.20	0.74	7.34
CD (0.05)	1.29	0.53	1.30	0.20	0.40	0.07	0.15	0.11	0.56	0.13	0.61	0.75	21.99

Table 4. Effect of weed management on yield attributes, yields, weed index, harvest index and economics of direct seeded rice (average of 2 years)

Treatment	Panicle length (cm)	Panicle weight (g/panicle)	Panicles/ m^2	Grains/ panicle	1,000-grain (g)	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Harvest index (%)	Gross returns (×10³₹/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio (₹/ha)
Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	21.9	2.5	241.8	108.6	18.8	5.0	5.9	2.4	45.7	81.8	44.2	2.2
Sunnhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	21.9	2.5	240.8	108.0	18.8	4.7	5.7	7.8	45.2	77.4	39.8	2.1
Sesbania cover crop *fb* *Sesbania* co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	21.8	2.4	240.1	107.0	18.8	4.6	5.7	10.3	44.9	75.5	39.8	2.1
Sunnhemp cover crop *fb* sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	21.8	2.4	239.8	106.5	18.7	4.6	5.6	11.4	44.7	74.6	39.0	2.1
Sesbania co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	21.8	2.4	239.5	106.0	18.7	4.5	5.6	12.3	44.8	73.8	39.6	2.2
Sunnhemp co-culture *fb* 2, 4-D 0.5 kg/ha at 30 DAS	21.8	2.4	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	21.9	2.5	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	23.3	2.9	250.5	111.6	20.7	5.1	6.1	0.0	45.8	83.9	37.9	1.8
Weedy	16.6	1.6	213.3	69.3	15.9	2.3	3.3	54.6	41.6	3.8	7.4	1.2
SEm±	0.50	0.03	0.21	0.31	0.51	1.02	2.01	–	0.71	1.02	2.35	1.23
CD (0.05)	1.41	0.11	0.65	0.84	1.44	3.00	6.23	–	2.64	3.23	6.94	3.74

bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS was 115.31% and 103.40% over weedy. This could be due to significantly higher weed-control efficiency and lower weed index than 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 revealed the 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 (Tables 1, 2) and restricting the competition by weeds for growth resources which helped in improving yield attributes and yield.

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 resulted in higher gross returns than sunnhemp 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.

Thus, it may be concluded that *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 days after sowing should be raised for minimizing weed growth and to obtain higher yield and remuneration in direct-seeded rice.

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