Indian Journal of Weed Science 49(1): 10–14, 2017
DOI: 10.5958/0974-8164.2017.00003.X

Integrated weed management in direct-seeded rice

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Received: 22 January 2017; Revised: 27 February 2017

ABSTRACT

A field investigation was conducted during *Kharif* season of 2014 and 2015 at Varanasi, Uttar Pradesh, to study the effect of integrated weed management on weed flora, yield and economics of direct seeded rice (*Oryza sativa* L.). Penoxsulam 35 g/ha at 10 DAS *fb* 1 hand weeding at 35 DAS reduced weed density of various weed flora, *viz. Echinocloa colona* (7.27%), *Echinocloa crus-galli* (6.58%), *Cynodon dactylon* (7.57%) among grasses; *Cyperus iria* (8.01%), *Cyperus difformis* (8.26%) and *Fimbristylis miliacea* (8.67%) among sedges and *Ammannia baccifera* (10.12%) and *Caesulia axillaris* (10.10%) among broad-leaved weeds besides other weeds (11.72%) in comparison to penoxsulam 35 g/ha at 20 DAS *fb* 1 hand weeding at 35 DAS. Penoxsulam 35 g/ha at 10 DAS *fb* 1 hand weeding at 35 DAS markedly improved growth attributes, *viz.* plant height, number of tillers/m^2, dry matter accumulation, leaf area index and chlorophyll content at 60 DAS and yield attributes, *viz.* panicle length, panicle weight, number of panicles/m^2, number of grains/panicle and test weight. Penoxsulam 35 g/ha at 10 DAS *fb* 1 hand weeding at 35 DAS statistically influenced the grain and straw yields and harvest index over all other treatments except hand weeding at 15 and 35 DAS. Highest net return (43790.76) and benefit: cost ratio (2.15) was also observed under penoxsulam 35 g/ha at 10 DAS *fb*1 HW at 35 DAS.

Key words: Bispyribac-Na, Chlorimuron-ethyl, Direct-seeded rice, Economics, Integrated weed management

Weed infestation in direct-seeded rice (DSR) fields remains the single largest constraint limiting their productivity. An effective early weed management tactic is imperative for any DSR production technology aiming at achieving higher productivity and profitability (Jaya Suria *et al.* 2011). Aerobic edaphic conditions under non-flooded conditions in DSR stimulate germination of diverse weed species. Weeds in DSR compete for moisture, nutrients, light and space and reduce the grain yield by 50 to 91% (Rao *et al.* 2007). Weed problem in direct-seeded rice can be managed by implementing integrated weed management. Chemical control proved to be a viable strategy with higher economic returns (Khaliq *et al.* 2012). Ehsanullah *et al.* (2012) observed that the post-emergence application of bispyribac-sodium was the most effective in reducing the total density and dry weight over weedy, followed by penoxsulam. However, weeds in direct-seeded rice cannot be controlled by herbicide alone because of various flushes of weeds during life cycle of crop. Therefore, it was imperative to identify effective integrated chemical and manual practices with their economics. Integrated weed management systems have the potential to reduce herbicide use and to provide more robust weed management over the long term (Swanton and Weise 1991). The present study was taken up to assess the suitable integration of different herbicides along with manual weeding on weed flora, yield and economics in direct-seeded rice.

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MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 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 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 block design, comprising 10 treatments replicated thrice. Rice variety *'MTU-7029'* was sown by zero till drill during the last week of June in both the years using the seed rate of 30 kg/ha and 20 cm row-row spacing. 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 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 according to the treatments using knap-sack sprayer fitted with even-fan nozzle using with 300 L/ha.

The crop was raised under irrigated condition recommended package of practices. Species-wise weed density and their biomass were measured at 60 DAS by placing a quadrate of 0.50 m^2 randomly at 2 places in each plot. Data on weed density and biomass were subjected to square root transformation before analysis. At 60 DAS, weed control efficiency (Tripathi and Mishra1971) and weed index (Gill and Kumar 1969) was calculated using weed biomass and grain yield, respectively. Biometric characters, *viz.* growth attributes (leaf area index was recorded by portable leaf canopy analyzer whereas, chlorophyll content was measured with SPAD), yield attributes and yields (grain and straw) of crop were recorded at 60 DAS and at harvest. Nutrient (N, P, K and Zn) uptake by weeds and crop was calculated multiplying weed biomass and crop dry matter, respectively with their nutrient contents at 60 DAS. Prevailing price of inputs in the market during 2014 and 2015 were used to calculate the economics of integrated weed management treatments. The net return and benefit: cost ratio (BCR) was worked out on the basis of gross returns (₹/ha) and cost of cultivation (₹/ha). Duncan multiple range test (DMRT) was used for comparing treatment means (Gomez and Gomez 1984). The biometric data on weed growth and yield averaged for two years for statistical analysis.

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora observed in experimental field included *Echinocloa colona* (L.) Link. (13.74%), *Echinocloa crus-galli* (L.) Beauv (13.74%), *Cynodon dactylon* L. Pers. (10.19%) among grasses; *Cyperus iria* L. (10.62%), *Cyperus difformis* L. (10.09%) and *Fimbristylis miliacea* (L.) Vahl. (10.93%) among sedges and *Ammannia baccifera* L. (10.14%) and *Caesulia axillaris* Roxb. (10.17%) among broad-leaved weeds besides other weeds (10.26%).

Density of weed species and their biomass varied statistically at 60 DAS irrespective of integrated weed management treatments (**Table 1** and **2**). Penoxsulam 35 g/ha at 10 DAS *fb* one HW at 35 DAS recorded lower weed density of all weed species in comparison to penoxsulam 35 g/ha at 20 DAS *fb* one HW at 35 DAS and both treatments were statistically at par to each other except *Fimbristylis miliacea* during both the years. Penoxsulam 35 g/ha at 10 DAS *fb* one HW at 35 DAS reduced weed density of *Echinocloa colona* (7.27%), *Echinocloa crus-galli* (6.58%), *Cynodon dactylon* (7.57%) among grasses; *Cyperus iria* (8.01%), *Cyperus difformis* (8.26%) and *Fimbristylis miliacea* (8.67%) among sedges and *Ammannia baccifera* (10.12%) and *Caesulia axillaris* (10.10%) among broad-leaved weeds besides other weeds (11.72%) in comparison to weedy treatment. This could be attributed to alone application of penoxsulam 35 g/ha, which had effective control of both narrow and broad-leaved weeds at early crop stages while later on one manual weeding controlled weeds comprehensively. This result was in conformity with Dalamas *et al.* (2006). However, bispyribac-Na 25 g/ha at 10 DAS *fb* 1 HW at 35 DAS had lower weed density of all weed species as compared to bispyribac-Na 25 g/ha at 20 DAS *fb* 1 HW at 35 DAS and both treatments were statistically similar to each other (**Table 1**). Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS recorded lower weed biomass of all weed species in comparison to penoxsulam 35 g/ha at 20 DAS *fb* one HW at 35 DAS and both treatments were statistically at par to each other during both the years. However, bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* one HW at 35 DAS had lesser weed biomass of all weed species as compared to bispyribac-Na 12.5g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS *fb* one HW at 35 DAS and both treatments were statistically similar to each other except *Cynodon dactylon* (**Table 2**). These findings were in conformity with Khare *et al.* (2014) in direct-seeded rice.

At 60 DAS, penoxsulam 35 g/ha at 10 DAS *fb* one HW at 35 DAS resulted in higher weed control efficiency as compared to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS, bispyribac Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS, bispyribac Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS, bispyribac Na 12.5 g/ha + azimsulfuron 15 g/ha at 10 DAS *fb* 1 HW at 35 DAS, bispyribac-Na 12.5g/ha + azimsulfuron 15 g/ha at 20 DAS *fb* 1 HW at 35 DAS, bispyribac Na 25 g/ha at 10 DAS *fb* 1 HW at 35 DAS, bispyribac-Na 25 g/ha at 20 DAS *fb* 1 HW at 35 DAS and weedy (**Table 2**).

Nutrient depletion by weeds at 60 DAS

Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS recorded significantly lesser nutrient (NPK and Zn) depletion by weeds as compared to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS, bispyribac Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS, bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS, bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 10 DAS *fb* 1 HW at 35 DAS, bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 20 DAS *fb* 1 HW at 35

DAS, bispyribac-Na 25 g/ha at 10 DAS *fb* 1 HW at 35 DAS and bispyribac-Na 25 g/ha at 20 DAS *fb* 1 HW at 35 DAS in direct-seeded rice (**Table 3**). Nutrient removal by weeds depends on weed dry matter accumulation in respective treatments. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had lesser weed dry weight in comparison to rest of the treatment except hand weeding. Our results are also supported by Brar and Bhullar (2013).

Effect on crop

At 60 DAS, penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS resulted higher plant height, number of tillers/m^2, dry matter accumulation (g/running m), leaf area index and chlorophyll content in comparison to penoxsulam 35 g/ha at 20 DAS *fb*1 HW at 35 DAS and both treatments were statistically similar to each other except chlorophyll content. However, bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS had higher plant height, number of tillers/m^2, dry matter accumulation (g/running m), leaf area index and chlorophyll content as compared to bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS and bispyribac-Na 12.5g/ha + azimsulfuron 15 g/ha at 10 DAS *fb* 1 HW at 35 DAS and all these treatments were statistically similar to each other (**Table 3**). Penoxsulam 35 g/ha at 10 DAS *fb*1 HW at 35 DAS had better performance of growth attributes due to marked reduction in competition for growth resources due to reduction in weed density and weed dry weight (**Table 1** and **2**).

Integrated weed management treatments had significant variation in yield attributes and yield (**Table 4**). Amongst the integrated weed management treatments, penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS resulted higher panicle length, panicle weight (g/panicle), number of panicle/m^2, number of grains/panicle and test weight in comparison to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS and both treatments were statistically similar to each other. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS recorded lowest weed index except hand weeding at 15 and 35 DAS. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had highest grain yield over rest of the treatments except hand weeding at 15 and 35 DAS. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS and penoxsulam 35 g/ha at 20 DAS *fb*1 HW at 35 DAS recorded 114.8 and 103.8% increase in grain yield over weedy.

Nutrient uptake by crop at 60 DAS

At 60 DAS, hand weeding at 15 and 35 DAS resulted in the highest nutrient (NPK and Zn) uptake by crop followed by penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS, which had significantly higher nutrient(NPK and Zn) uptake in comparison to rest of

Table 1. Effect of integrated weed management on weed density (no./m^2) at 60 days after sowing in direct-seeded rice

Treatment	*E. colona*	*E. crus-galli*	*C. dactylon*	*C. iria*	*C. difformis*	*F. miliacea*	*A. baccifera*	*C. axillaris*	Other species
T_1 Bispyribac-Na 25 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.45^{efg} (1.60)	1.36^{ef} (1.35)	1.30^{fg} (1.18)	1.33^{de} (1.28)	1.32^{de} (1.25)	1.43^{ef} (1.55)	1.39^{de} (1.43)	1.43^{def} (1.53)	1.47^{de} (1.67)
T_2 Bispyribac Na 25 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.52^{def} (1.80)	1.41^{ef} (1.48)	1.40^{ef} (1.47)	1.43^{cd} (1.57)	1.39^{d} (1.43)	1.54^{fg} (1.87)	1.48^{cd} (1.70)	1.48^{de} (1.68)	1.51^{de} (1.78)
T_3 Bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.58^{de} (2.00)	1.47^{de} (1.65)	1.51^{de} (1.78)	1.51^{bc} (1.80)	1.55^{c} (1.90)	1.62^{de} (2.12)	1.59^{c} (2.02)	1.54^{cd} (1.88)	1.56^{cde} (1.93)
T_4 Bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.70^{cd} (2.38)	1.58^{cd} (2.00)	1.63^{cd} (2.17)	1.58^{bc} (1.98)	1.58^{c} (2.00)	1.69^{cd} (2.35)	1.61^{c} (2.10)	1.66^{bc} (2.27)	1.65^{bcd} (2.22)
T_5 Bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.86^{bc} (2.97)	1.65^{bc} (2.22)	1.67^{bc} (2.30)	1.62^{b} (2.12)	1.67^{bc} (2.30)	1.77^{b} (2.63)	1.79^{b} (2.72)	1.69^{bc} (2.35)	1.73^{bc} (2.50)
T_6 Bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.91^{b} (3.17)	1.76^{b} (2.60)	1.80^{b} (2.73)	1.66^{b} (2.25)	1.72^{b} (2.47)	1.81^{b} (2.78)	1.85^{b} (2.93)	1.74^{b} (2.53)	1.79^{b} (2.70)
T_7 Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.28^{g} (1.15)	1.24^{f} (1.03)	1.17^{g} (0.88)	1.21^{e} (0.97)	1.20^{e} (0.95)	1.26^{h} (1.08)	1.29^{e} (1.17)	1.29^{ef} (1.17)	1.37^{e} (1.37)
T_8 Penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.35^{fg} (1.33)	1.29^{f} (1.17)	1.23^{g} (1.02)	1.26^{e} (1.10)	1.24^{e} (1.05)	1.32^{fg} (1.25)	1.32^{de} (1.25)	1.33^{f} (1.28)	1.41^{e} (1.50)
T_9 Weed free	0.71^{h} (0.00)	0.71^{g} (0.00)	0.71^{h} (0.00)	0.71^{f} (0.00)	0.71^{f} (0.00)	0.71^{h} (0.00)	0.71^{f} (0.00)	0.71^{g} (0.00)	0.71^{f} (0.00)
T_{10} Weedy	4.04^{a} (15.80)	4.02^{a} (15.65)	3.48^{a} (11.62)	3.55^{a} (12.10)	3.46^{a} (11.50)	3.60^{a} (12.45)	3.47^{a} (11.55)	3.47^{a} (11.58)	3.49^{a} (11.68)
CV (%)	6.06	5.85	4.54	5.73	4.03	4.65	5.73	5.98	6.18

Data were subjected to square root ($\sqrt{X + 0.5}$) transformation; figures in parentheses are original values the integrated weed management treatments (**Table 3**). Bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS had higher nutrients (NPK and Zn) uptake by crop as compared to bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS and both the treatments were statistically similar to each other. This might be due to the lower weed density, dry weight and higher weed control efficiency and higher grain yield in penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS. These results were in close conformity with those reported by Khare *et al*. (2014).

Table 2. Effect of integrated weed management on weed biomass (g/m²) and weed control efficiency (%) at 60 days after sowing in direct-seeded rice

Treatment	*E. colona*	*E. crusgalli*	*C. dactylon*	*C. iria*	*C. difformis*	*F. miliacea*	*A. baccifera*	*C. axillaris*	Other species	WCE (%)
T_1 Bispyribac-Na 25 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.23^{ef} (1.03)	1.16^{ef} (0.84)	0.88^{fg} (0.27)	1.19^{de} (0.91)	1.18^{de} (0.89)	1.26^{ef} (1.10)	0.78^{b} (0.11)	1.28^{def} (1.15)	1.32^{de} (1.25)	85.41
T_2 Bispyribac Na 25 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.33^{de} (1.27)	1.19^{ef} (0.92)	0.91^{ef} (0.34)	1.27^{cd} (1.11)	1.23^{d} (1.02)	1.35^{de} (1.33)	0.78^{b} (0.11)	1.33^{de} (1.26)	1.35^{de} (1.34)	84.10
T_3 Bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.39^{cd} (1.44)	1.23^{de} (1.02)	0.95^{de} (0.41)	1.33^{bc} (1.28)	1.36^{c} (1.35)	1.41^{cd} (1.50)	0.78^{b} (0.11)	1.38^{cd} (1.41)	1.40^{cde} (1.45)	86.73
T_4 Bispyribac-Na 12.5 g/ha + azimsulfuron 15 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.48^{c} (1.68)	1.32^{cd} (1.24)	1.00^{cd} (0.50)	1.38^{bc} (1.41)	1.39^{c} (1.42)	1.47^{bc} (1.67)	0.78^{b} (0.11)	1.48^{bc} (1.70)	1.47^{bcd} (1.66)	86.27
T_5 Bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.62^{b} (2.14)	1.37^{bc} (1.37)	1.01^{c} (0.53)	1.41^{b} (1.50)	1.46^{bc} (1.63)	1.54^{b} (1.87)	0.79^{b} (0.12)	1.50^{bc} (1.76)	1.54^{bc} (1.88)	87.58
T_6 Bispyribac-Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron methyl) 2 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.65^{b} (2.23)	1.45^{b} (1.61)	1.06^{b} (0.63)	1.45^{b} (1.60)	1.50^{b} (1.75)	1.57^{b} (1.98)	0.79^{b} (0.12)	1.55^{b} (1.90)	1.59^{b} (2.03)	85.97
T_7 Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS	1.10^{g} (0.71)	1.07^{f} (0.64)	0.84^{g} (0.20)	1.09^{e} (0.69)	1.08^{e} (0.67)	1.13^{g} (0.77)	0.78^{b} (0.10)	1.17^{f} (0.88)	1.23^{e} (1.03)	92.53
T_8 Penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 DAS	1.16^{fg} (0.84)	1.11^{f} (0.72)	0.86^{g} (0.23)	1.13^{e} (0.78)	1.12^{e} (0.75)	1.18^{fg} (0.89)	0.78^{b} (0.11)	1.21^{ef} (0.96)	1.27^{e} (1.13)	91.59
T_9 Weed free	0.71^{h} (0.00)	0.71^{g} (0.00)	0.71^{h} (0.00)	0.71^{f} (0.00)	0.71^{f} (0.00)	0.71^{h} (0.00)	0.71^{c} (0.00)	0.71^{g} (0.00)	0.71^{f} (0.00)	100.00
T_{10} Weedy	3.27^{a} (10.22)	3.19^{a} (9.70)	1.78^{a} (2.67)	3.01^{a} (8.59)	2.94^{a} (8.17)	3.06^{a} (8.84)	2.51^{a} (5.81)	3.03^{a} (8.69)	3.04^{a} (8.76)	0.00
CV (%)	4.39	5.02	2.51	5.13	3.59	4.14	2.71	5.46	5.65	-

Data were subjected to square root ($\sqrt{x + 0.5}$) transformation; figures in parentheses are original values; Letters in common are not significantly different

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

Treatment	Plant height (cm)	No. of tillers/m²	Dry matter accumulation (g/running m)	Leaf area index	Chlorophyll content	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)
T_1	53.11^{b}	157.00^{cd}	32.86^{bc}	2.82^{a}	42.81^{cd}	$131.^{d}$	75^{d}	142^{d}	4118^{d}	13.24^{e}	2.09^{g}	16.28^{ef}	560.35^{f}
T_2	52.47^{bc}	156.50^{de}	32.31^{bc}	2.81^{a}	42.51^{de}	143^{b}	82^{b}	154^{b}	4488^{b}	12.64^{f}	1.84^{h}	15.65^{f}	535.99^{g}
T_3	52.09^{bcd}	156.00^{ef}	32.13^{bc}	2.80^{a}	42.38^{ef}	119^{f}	68^{f}	128^{f}	3743^{f}	13.74^{de}	2.46^{e}	16.79^{cde}	577.59^{def}
T_4	51.70^{cd}	155.50^{fg}	31.86^{cd}	2.79^{a}	42.06^{fg}	137^{c}	78^{c}	148^{c}	4306^{c}	13.47^{de}	2.21^{f}	16.49^{de}	564.69^{ef}
T_5	51.29^{cd}	155.00^{gh}	31.70^{cd}	2.78^{a}	41.78^{g}	111^{g}	63^{g}	120^{g}	3501^{g}	14.38^{bc}	2.71^{d}	17.50^{bc}	599.41^{bcd}
T_6	50.81^{d}	154.67^{h}	30.64^{d}	2.77^{a}	41.68^{g}	126^{e}	72^{e}	135^{e}	3957^{e}	13.98^{cd}	2.67^{d}	17.05^{cd}	585.40^{cde}
T_7	53.44^{b}	157.67^{b}	33.47^{b}	2.84^{a}	43.66^{b}	67^{i}	39^{i}	3^{i}	2110^{i}	14.92^{b}	3.12^{b}	18.16^{b}	618.30^{b}
T_8	53.19^{b}	157.33^{bc}	33.12^{bc}	2.83^{a}	43.06^{c}	75^{h}	43.3^{h}	82^{h}	2372^{h}	14.60^{b}	2.98^{c}	17.80^{b}	607.52^{bc}
T_9	55.68^{a}	161.00^{a}	38.33^{a}	2.95^{a}	45.18^{a}	0^{j}	0^{j}	0^{j}	0^{j}	17.25^{a}	4.12^{a}	21.24^{a}	742.58^{a}
T_{10}	38.60^{e}	129.83^{i}	18.32^{e}	1.41^{b}	37.48^{h}	1038^{a}	433^{a}	887^{a}	27225^{a}	7.40^{g}	1.01^{i}	9.19^{g}	287.37^{h}
CV (%)	1.47	0.22	2.38	4.82	0.54	0.15	0.19	0.19	0.12	2.21	2.62	2.35	2.10

Letters in common are not significantly different

Table 4. Effect of integrated weed management on yield attributes yields, weed index, harvest index and economics in direct-seeded rice

Treatment	Panicle length (cm)	Panicle weight (g/ panicle)	No. of panicle (/m^2)	No. of grains/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Harvest index (%)	Variable cost (x10^3 ₹/ha)	Additional cost of weed control (x10^3 ₹/ha)	Gross return (x10^3 ₹/ha)	Net return (x10^3 ₹/ha)	Benefit: Cost ratio (₹/ha)
T_1	21.90^b	2.52^b	241.3^c	104.0^d	18.8^b	4.52^{cd}	6.07^a	12.8	42.7^{cd}	39.31	8.02	74.04^{cd}	34.72^d	1.88^{de}
T_2	21.88^b	2.52^b	240.8^{cd}	103.0^e	18.8^b	4.49^d	6.06^a	13.4	42.5^{cd}	38.73	7.43	73.59^d	34.86^d	1.90^{cde}
T_3	21.87^b	2.51^b	240.5^{de}	102.0^f	18.8^b	4.62^{bcd}	6.08^a	10.9	43.1^{bcd}	38.62	7.32	75.53^{cd}	36.91^{bcd}	1.96^{bcde}
T_4	21.85^b	2.50^b	240.1^{ef}	101.1^g	18.8^b	4.57^{bcd}	6.07^a	11.8	42.97^{bcd}	39.20	7.91	74.80^{cd}	35.60^{cd}	1.91^{cde}
T_5	21.84^b	2.48^b	239.6^f	100.3^h	18.8^b	4.73^{bc}	5.87^a	8.7	44.64^{abc}	37.00	5.70	76.92^{cd}	39.92^b	2.08^{ab}
T_6	21.82^b	2.48^b	239.0^g	100.0^h	18.79^b	4.68^{bcd}	6.07^a	9.8	43.51^{bcd}	37.59	6.29	76.31^{cd}	38.72^{bcd}	2.03^{abc}
T_7	21.92^b	2.55^b	242.5^b	106.0^b	18.8^b	5.05^b	6.17^a	2.5	45.02^{ab}	38.22	6.92	82.01^{ab}	43.79^a	2.15^a
T_8	21.91^b	2.54^b	242.0^b	105.0^c	18.8^b	4.79^c	6.20^a	7.5	43.61^{bcd}	38.81	7.51	78.23^{bc}	39.42^{bc}	2.02^{bcd}
T_9	23.39^a	2.92^a	250.5^a	111.6^a	20.7^a	5.19^a	6.12^a	0.0	45.88^a	46.00	14.70	83.90^a	37.91^{bcd}	1.82^e
T_{10}	16.68^c	1.69^c	213.3^h	71.6^i	15.9^c	2.35^e	3.37^b	54.6	41.66^d	31.30		38.79^e	7.49^e	1.24^f
CV (%)	3.71	2.59	0.15	0.47	4.39	2.80	5.64	-	2.50			3.05	6.42	3.72

Letters in common are not significantly different

Economics

The gross return obtained by yield of crop varied significantly due to different treatments, which ultimately influenced the net returns and benefit: cost ratio. Penoxsulam 35 g/ha at 10 DAS *fb* 1 HW at 35 DAS had higher gross return as compared to penoxsulam 35 g/ha at 20 DAS *fb* 1 HW at 35 and both treatments were statistically similar to each other. Early post-emergence application of penoxsulam resulted in better control of weeds and variable cost of manual weeding was reduced at 35 DAS (**Table 4**). Consequently, the highest net return and benefit: cost ratio was observed under penoxsulam 35 g/ha at 10 DAS *fb*1 HW at 35 DAS. This could be attributed to higher grain yield of rice along with less labour and time required for manual weeding reducing cost of cultivation. Sairamesh *et al.* (2015) also supported these findings in direct-seeded rice.

Based on above findings it may be concluded that penoxsulam 35 g/ha at 10 DAS *fb*1 HW at 35 DAS should be applied for effective control of weeds, to obtain higher yield and net return in direct seeded rice.

REFERENCES

Brar HS and Bhullar MS. 2013. Nutrient uptake by direct-seeded rice and associated weeds as influenced by sowing date, variety and weed control. *Indian Journal of Agricultural Research* **47**(4): 353-358.

Damalas CA, Dhima KV and Eleftherohorinos IG. 2006. Control of early water grass (E*chinochloa oryzoides*) and late watergrass (E*chinochloa phyllopogon*) with cyhalofop, clefoxydim, and penoxsulam applied alone and in mixture with broadleaf herbicides. *Weed Technology* **20**(4): 992-998.

Ehsanullah KJ, Husain M, Farooq M, Babar M, Dogan MN and Lee D. 2012. Application of bispyribac-sodium provides effective weed control in direct planted rice on a sandy loam soil. *Weed Biology and Management* **12**(3):136-145.

Gill GS and Kumar V. 1969. Weed index, a new method for reporting control trials. *Indian Journal of Agronomy* **14(**2): 96-98.

Gomez KA and Gomez AA.1984. *Statistical Procedures for Agricultural Research* (2nd Edition), John Wiley and Sons Inc., New York, USA, 680 p.

Jaya Suria ASM, Juraimi AS, RahmanMdM, Man AB and Selamat A. 2011. Efficacy and economics of different herbicides in aerobic rice system. *African Journal of Biotechnology* **10**(41): 8007-8022.

Khaliq A, Riaz MY and Matloob A. 2012. Bio-economic assessment of chemical and non-chemical weed management strategies in dry seeded fine rice (*Oryza sativa* L.). *Journal of Plant Breeding and Crop Sciences* **22**: 1101-1106.

Khare TR, Sharma R, Singh SB and Sobhana V. 2014. Penoxsulam for weed management in direct-seeded and transplanted rice (*Oryza sativa* L.). *Pesticide Research Journal* **26**(2): 212-216.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct seeded rice. *Advances in Agronomy* **93**: 153-255.

Sairames KV, Rao AS, Subbaiah G and Rani PP. 2015. Bio-efficacy of sequential application of herbicides on weed control, growth and yield of wet-seeded rice. *Indian Journal of Weed Science* **47**(2): 201-202.

Swanton CJ and Weise SF. 1991. Integrated weed management: The rationale and approach. *Weed Technology* **5**: 657-663.

Tripathi RS and Mishra R. 1971. Phyto-sociological studies of the crop weed association at Varanasi. *Journal of Indian Botanical Society* **50**: 142-52.