Indian Journal of Agricultural Sciences **85** (10): 1260–8, October 2015/Article

Research Articles

Effect of seedlings age, cultivars and weed management on weed dynamics, nutrient removal and yield of rice *(Oryza sativa)* under system of rice intensification (SRI)

U N SHUKLA[1], V K SRIVASTAVA[2], SMITA SINGH[3], U S RAM[4] and A K PANDEY[5]

Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh 221 005

Received: 16 February 2015; Accepted: 29 July 2015

ABSTRACT

A field experiment was conducted to study the effect of age of seedlings, cultivars and weed management on weed dynamics, NPK removal and yield of rice *(Oryza sativa* L.*)* under SRI at Banaras Hindu University, Varanasi during 2010 and 2011 in split-plot design replicated thrice. The tender aged seedling (10 days) and hybrid rice cultivar PHB 71 had significantly marked potential to minimize the weed dynamics of grassy weeds (*Echinochloa* spp. and *Cynodon dactylon*), sedges (*Fimbristylis miliacea* and *Cyperus* spp.) and BLWs (*Ammania baccifera* and *Ludwigia parviflora*) significantly that resulted in marked reduction on total weed density, weed dry weight, weed index resulted in higher weed control efficiency over older seedling (15 days) of NDR 359. Four times cono-weeding at 10, 20, 30 and 40 DAT minimised grassy weeds over rest of the weeding treatments, but at par with pre and post-emergence application of pretilachlor + bispyribac-Na herbicides in respect of sedges and BLWs with total weed density that resulted in improving weed index due to higher weed control efficiency over 15 days old seedlings and other weed management treatment during both the years of study. Similarly, transplanting of younger seedlings (10 days) of PHB 71 produced significantly higher rice yield under 4 times cono-weeding closely followed by pre and post-emergence application of pretilachlor + bispyribac-Na. Significantly lower NPK removal by weeds at 45 DAT recorded with 10 days old seedling of PHB-71 under 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4), though remained at par with pre and post-emergence application of pretilachlor + bispyribac-Na.

Key words: Age of seedlings, Cultivars, SRI, WCE, Weed density, Weed dry weight, WI, Yield

In India, rice *(Oryza sativa* L.*)* is grown in an area of 43.50 million ha with a production of 105 million tonnes, which contributes 45% of the total food grain production of the country. The components of system of rice intensification (SRI) are young seedlings, limited irrigation, aerated soil conditions and conservation of land, water and biodiversity with utilization of the hitherto ignored biological power of plant and solar energy, are the novelties of SRI.

Stoop *et al.* (2002) reported that young seedlings below 10 days of age are transplanted in SRI, which produce higher number of tillers than normal rice production systems, which contribute to higher grain yields (Krishna *et al.* 2008). The age of seedlings at transplanting determines the total and productive tillers and known to improve the ability of plants to perform better under induced water stress conditions in SRI and giving rise to high grain yield. By and large, due to production of more number of tillers and leaf plant has competitive effect on minimization of weed dynamics. Similarly, Haden *et al.* (2007) observed that weed competitive cultivar more effectively suppressed the dry weight of sedges, grasses and BLW than control variety.

Weed competition is one of the prime yield-limiting biotic constraints in SRI. Weeds compete with crops for water, light, nutrients and space. Weeds are the important competitors in their early growth stages resulting in reduced the growth of crops and finally grain yield (Shukla *et al.* 2014). At wider spacing (25 ×25 cm) more weeds were observed with SRI than the conventional cultivation. As a consequence of alternate dry and wetting, an aggressive flush of both terrestrial and aquatic weeds come up in the early stage of crop growth. Frequent aerobic condition of soil and high temperature favour the growth of grassy

[1]Assistant Professor (e mail: umanaths7@gmail.com), Department of Agronomy, College of Agriculture, Agriculture University, Jodhpur, Rajasthan 342 304; [2]Professor (e mail: vksrivatava_bhu@rediffmail.com), Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi 221 005; [3]Technical Assistant (e mail: sapnapuat@gmail.com), Department of Agronomy, College of Agriculture, JNKVV Rewa, Madhya Pradesh 486 001; [4]Ph D (e mail: usabhu@gmail.com), Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi 221 005; [5]Ph D (e mail: asheeshpandey84@gmail.com), Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh 224 229

weeds in rice (Choudhary and Suri 2014).This probably can resolve by the use of cono-weeding. However, farmers are also reluctant to use mechanical device for weeding at 10, 20 and 30 days old crop in main field with a false concept that it may damage the root and shoot system. Instead of mechanical weeding, cono-weeding conjunctive with herbicidal method offers an advantage to save labour and money in weed control (Roy 2012).

MATERIALS AND METHODS

A field experiment was carried out during *kharif* 2010 and 2011 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India ($25^0$18' N Latitude; $83^0$03' E longitude;altitude of 75.7 m ASL) in Northern Gangetic alluvial plains having sub-tropical climate. The cumulative rainfall received during the investigation was 715.8 mm and 1191.3 mm during 2010 and 2011, respectively, which was 39.41% higher rainfall in 2011 over 2010.The soil of experimental plot was sandy-clay-loam (50.4% sand, 26.3% silt and 23.3% clay), low in organic carbon (0.47% and 0.49%) and nitrogen (198.0 and 202.1 kg/ha), but medium in phosphorus (21 and 22 kg/ha) and potassium (219.3 and 224.5 kg/ha) during 2010 and 2011 before transplanting, respectively. However, soil having optimum range of pH (7.42 and 7.45) and EC (0.16 and 0.17 dS/m) during both the year of investigation, respectively that encouraged better growth of crops during investigation.

The experiment was laid-out in splitplot design replicated thrice. The treatments comprised 2 ages of seedlings (A_1-10 days and A_2-15 days) with 2 cultivars (C_1-PHB-71 and C_2-NDR 359) as assigned to main plots. Each main plot were further divided into 7 subplot to accommodate 7 weed management treatments, i.e W_1 (Weedy Check), W_2 (2 hand weeding at 20 and 30 DAT), W_3 (2 cono-weeding at 10 and 20 DAT), W_4 (4 cono-weeding at 10, 20, 30 and 40 DAT), W_5 (Pretilachlor (50 EC) as pre-emergence @ 0.75 kg *a.i*/ha + one cono-weeding at 20 DAT), W_6 (Bispyribac Sodium salt (10 SC) as post-emergence @ 25 g *a.i*/ha + one cono-weeding at 40 DAT) and W_7 (Pretilachlor (50 EC) as pre-emergence @ 0.75 kg *a.i*/ha + Bispyribac Sodium salt (10 SC) as post-emergence @ 25 g *a.i*/ha).

For 15 days of seedling, nursery bed was raised 5days before the sowing of 10 days old seedlings to synchronize the transplanting of rice at a time. The single seedling was taken out along with mud without damaging roots for transplanting. The single seedlings were transplanted shallow at the intersection marked of 25 ×25 cm using index finger and thumb. Light irrigation was given on the next day of transplanting. Within a week, gapfilling was done with the same seedlings. Water was given only on appearing of hair line cracks. Half of the total (120 kg N/ha) quantity of nitrogen along with the full dose of phosphorus (60 kg P_2O_5/ha), potassium (40 kg K_2O/ha) and zinc sulphate (25 kg/ha) were applied just before transplanting on puddled surface and incorporated into the top 15 cm soil manually with the help of spade. The urea fertilizer was top dressed into two equal instalments @ 30 kg N/ha at active tillering and remained 5-7 days beforepanicle initiation. Among weed management, cono-weeding and herbicides (pre and post-emergence) were applied as per treatments. Species wise weed density (No./m^2), total weed density (No./m^2) and weed dry weight (g/m^2) at 60 DAT and yield were observed.Weed control efficiency (%) and weed index were determined using standard procedures. All the data were statistically analysed to draw a valid conclusions.

RESULTS AND DISCUSSION

Weed density

The two age of seedling produced marked variation and significantly reduced the weed population of grasses, sedges and broad-leaves weeds (Table 1, 2). Tender age seedling, i.e 10 days old seedlings (A_1) showed higher potential to minimize density of *Echinochloa* spp., *Cynodon dactylon, Fimbristylis miliacea, Cyperus* spp., *Ammania baccifera* and *Ludwigia parviflora* significantly over 15 days old seedlings along with marked reduction in total weed density.Transplanting of juvenile age of seedling (10 days) significantly suppress weeds due to enough coverage of leaves and tiller production through early utilization of phyllochronic potential resulted in 25.81 and 25.53% higher weed control over aged seedling (15 days) at 60 DAT during 2010 and 2011, respectively (Anitha and Chellappan 2011).

Significant variations also produced due to competitive cultivars in reduction of population of weeds. Transplanting of competitive rice hybrid PHB 71 smothered *Echinochloa* spp., *Cynodon dactylon, Fimbristylis miliacea* and *Cyperus* spp. significantly over poor competitive cultivar NDR 359 at 60 DAT, but it was at par with respect to the density of broad leaved weeds (*Ammania baccifera* and *Ludwigia parviflora*) during both the years of study. Similarly, significantly minimum population of total weeds was also recorded under PHB 71, which showed 13.18 and 13.62% higher weed minimization potential and proved significantly superior to NDR 359. However, significantly maximum weed density was recorded under NDR 359 cultivar probably due to lesser foliage and shy in tillering habit.

Data further revealed that total weed density considerably reduced due to application of different weeding treatments (Table 4). Significantly higher reduction in weed population of grasses (*Echinochloa* spp. and *Cynodon dactylon*) was recorded by 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4) which proved significantly superior over rest of weeding practices. However, it remained at par with pre and post-emergence spraying of pretilachlor + bispyribac-Na (W_7) herbicide in respect of sedges (*Fimbristylis miliacea* and *Cyperus* spp.) and broad leaved weeds (*Ammania baccifera* and *Ludwigia parviflora*), but it established their superiority over rest of treatments including weedy check at 60 DAT during both

Table 1 Species wise weed density as influenced by age of seedlings, cultivars and weed management under SRI at 60 DAT

Treatment	*Echinochloa* spp. (no./m²)		*Cynodon dactylon* (no./m²)		*Fimbristylis miliacea* (no./m²)		*Cyperus* spp. (no./m²)	
	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedlings (2)								
A_1-10 days	3.6* (15.6)	3.2 (12.5)	2.2 (4.7)	2.2 (4.5)	2.3 (5.5)	2.1 (4.3)	2.23 (4.9)	2.41 (5.9)
A_2-15 days	4.1 (20.1)	3.7 (16.1)	2.6 (6.6)	2.5 (6.3)	2.7 (7.6)	2.4 (5.9)	2.60 (6.9)	2.81 (8.2)
SEm±	0.10	0.08	0.06	0.05	0.04	0.03	0.05	0.04
CD (P=0.05)	0.29	0.27	0.19	0.18	0.16	0.09	0.18	0.16
Cultivars (2)								
C_1-PHB-71	3.6 (16.30)	3.6 (13.07)	2.3 (5.15)	2.2 (4.9)	2.4(6.1)	2.2(4.8)	2.3 (5.6)	2.5 (6.6)
C_2-NDR-359	3.9 (19.39)	3.2 (15.56)	2.5 (6.12)	2.4 (5.9)	2.6(6.9)	2.3(5.4)	2.5 (6.3)	2.7 (7.4)
SEm±	0.10	0.08	0.06	0.05	0.04	0.03	0.05	0.04
CD (P=0.05)	0.29	0.27	0.19	0.18	0.16	0.09	0.18	0.16
Weed management (7)								
W_1- Weedy check	7.8 (61.4)	6.9 (49.3)	3.5 (11.7)	3.4 (11.2)	4.0 (15.6)	3.5 (12.2)	3.8 (14.3)	4.1 (16.9)
W_2-2HW at 20 and 30 DAT	3.8 (14.3)	3.4 (11.5)	2.3 (4.9)	2.3 (4.7)	2.6 (7.1)	2.5 (5.6)	2.6 (6.5)	2.9 (7.7)
W_3- 2 CW at 10 and 30 DAT	4.6 (21.1)	4.2 (16.9)	2.9 (7.8)	2.8 (7.5)	2.9 (8.3)	2.6 (6.5)	2.8 (7.5)	3.0 (8.9)
W_4- 4 CW at 10, 20, 30 and 40 DAT	1.5 (1.9)	1.4 (1.5)	1.8 (2.7)	1.7 (2.6)	1.7 (2.3)	1.5 (1.8)	1.6 (2.1)	1.7 (2.5)
W_5- Pretilachlor fb 1 CW at 20 DAT	3.6 (12.3)	3.2 (9.9)	2.5 (6.1)	2.4 (5.8)	2.4 (5.5)	2.2 (4.3)	2.3 (5.0)	2.5 (5.9)
W_6- Bispyribac fb 1 CW at 40 DAT	3.2 (9.7)	2.9 (7.8)	2.3 (4.7)	2.2 (4.5)	2.2 (4.3)	1.9 (3.3)	2.1 (3.9)	2.3(4.6)
W_7-Pretilachlor fb Bispyribac	2.2 (4.3)	1.9 (3.4)	1.4 (1.6)	1.4 (1.5)	1.7 (2.5)	1.5 (2.0)	1.7 (2.3)	1.8 (2.7)
SEm±	0.10	0.09	0.06	0.05	0.05	0.03	0.04	0.05
CD (P=0.05)	0.26	0.23	0.17	0.14	0.14	0.07	0.13	0.14

*Figures in the parentheses indicate original values.

the years of experimentations. Similar trends were also observed in total density of weeds. The continuous cono-weeding knock down the flushes of weeds in to the soil, whereas application of pretilachlor + bispyribac-Na (W_7) as pre and post-emergence spray showed broad spectrum efficacy against grasses, sedges and BLWs and reduced weed density significantly. However, significantly higher population of weeds was found associated with weedy check as compared to other treatments (Thura 2010).

Weed dry weight

Dry matter accumulation in weeds significantly influenced by age of seedlings (Table 5). Tender age of seedling (10 days old) markedly decreased the total weed dry weight (TWDW), up to 32.71% and 28.04% as compared to old age of seedling (15 days) at 60 during 2010 and 2011, respectively.

It is evident from the data that TWDW drastically reduced by cultivars. Rice hybrid PHB 71 recorded significantly lower TWDW (24.93 and 18.54%) and proved superior to NDR 359 during 2010 and 2011, respectively. The variety (NDR 359) showed its lower efficiency for weeds minimization on the account of weed dynamics as well as total weed dry due to shy in foliage and tillering habit in contrast to hybrid during both the years of observations.

Use of cono-weeder showed its capability to reduce weeds by cutting and churning of weeds into the soil and brought down weed population effectively, besides TWDW. Similarly, significantly lower quantity of TWDW was recorded under 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4) and established its superiority over other weed management treatments. However, it remained at par with application of herbicide as pre and post-emergence, i.e pretilachlor + bispyribac-Na (W_7). The results are in conformity of Singh and Singh (2010). Weedy check (W_1) showed comparatively higher weed dry weight over other weeding treatments under trial during both the years.

Weed control efficiency and weed index

Data revealed that younger age seedling (10 days) brought up higher weed control efficiency (WCE) and lower weed index (WI) than older aged seedling (15 days) at 60 DAT during 2010 and 2011, respectively (Table 7). The WI

Table 2 Species wise weed density as influenced by age of seedlings, cultivars and weed management under SRI at 60 DAT

Treatment	*Ammania baccifera* (no./m²)		*Ludwigia parviflora* (no./m²)		Total weeds density (no./m²)		Total weeds dry weight (g/m²)	
	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedlings (2)								
A_1-10 days	1.9* (3.6)	1.7 (2.7)	2.0 (3.8)	1.8 (3.0)	5.9 (40.3)	5.3 (32.6)	4.1 (18.9)	3.7 (15.7)
A_2-15 days	2.2 (4.9)	2.0 (3.8)	2.3 (5.3)	2.1 (4.2)	6.9 (54.3)	6.3 (43.9)	5.0 (28.1)	4.4 (21.8)
SEm±	0.033	0.030	0.042	0.037	0.13	0.12	0.161	0.125
CD (P=0.05)	0.116	0.105	0.146	0.128	0.45	0.43	0.558	0.434
Cultivars (2)								
C_1-PHB-71	2.0 (4.0)	1.8 (3.1)	2.1 (4.3)	1.9 (3.4)	6.2 (43.9)	5.5 (35.4)	4.2 (20.2)	3.9 (16.8)
C_2-NDR-359	2.1 (4.5)	1.9 (3.5)	2.2 (4.8)	2.0 (3.8)	6.7 (50.7)	6.0 (41.0)	4.9 (26.9)	4.3 (20.7)
SEm±	0.04	0.03	0.04	0.03	0.13	0.12	0.16	0.13
CD (P=0.05)	0.15	0.12	0.15	0.12	0.45	0.43	0.56	0.43
Weed management (7)								
W_1- Weedy check	3.2 (10.2)	2.9 (7.9)	3.4 (11.0)	3.0 (8.7)	11.4 (129.9)	10.2 (104.7)	7.9 (63.5)	7.2 (52.4)
W_2-2 HW at 20 and 30 DAT	2.3 (4.6)	2.0 (3.6)	2.3 (5.0)	2.1 (4.0)	6.7 (45.3)	6.1 (36.5)	4.8 (22.9)	4.2 (17.7)
W_3- 2 CW at 10 and 20 DAT	2.4 (5.4)	2.2 (4.2)	2.5 (5.8)	2.2 (4.6)	7.7 (59.1)	6.9 (48.0)	5.4 (29.7)	4.8 (23.2)
W_4- 4 CW at 10, 20, 30 and 40 DAT	1.4 (1.5)	1.3 (1.2)	1.4 (1.6)	1.3 (1.3)	3.6 (13.0)	3.3 (10.6)	2.6 (6.6)	2.4 (5.2)
W_5- Pretilachlor fb 1 CW at 20 DAT	2.0 (3.5)	1.8 (2.8)	2.1 (3.8)	1.9 (3.0)	6.2 (38.6)	5.6 (31.3)	4.4 (19.2)	3.9 (15.1)
W_6- Bispyribac fb 1 CW at 40 DAT	1.8 (2.8)	1.6 (2.2)	1.9 (3.0)	1.7 (2.4)	5.5 (30.1)	5.0 (24.5)	3.9 (15.1)	3.5 (11.8)
W_7-Pretilachlor fb Bispyribac	1.5 (1.7)	1.4 (1.3)	1.5 (1.8)	1.4 (1.4)	3.9 (15.3)	3.5 (12.2)	2.8 (7.8)	2.5 (6.0)
SEm±	0.02	0.03	0.05	0.04	0.15	0.14	0.18	0.13
CD (P=0.05)	0.10	0.10	0.14	0.13	0.43	0.42	0.52	0.38

* Figures in the parentheses indicate original values.

Table 3 Interaction effects of age of seedlings and weed management on total density of weeds (No./m²) under SRI at 60 DAT

Treatment	2010		Mean	Treatment	2011		Mean
	Age of seedlings				Age of seedlings		
	A_1-10 days	A_2-15 days			A_1-10 days	A_2-15 days	
W_1	10.7* (114.8)	12.0 (145.1)	11.4 (129.9)	W_1	9.6 (92.4)	10.8 (116.9)	10.2 (104.7)
W_2	6.1 (36.8)	7.4 (53.9)	6.7 (45.3)	W_2	5.5 (29.6)	6.6 (43.3)	6.1 (36.5)
W_3	7.0 (48.9)	8.4 (69.6)	7.7 (59.1)	W_3	6.3 (39.8)	7.5 (56.1)	6.9 (48.0)
W_4	3.3 (10.2)	4.0 (15.7)	3.6 (13.0)	W_4	3.0 (8.3)	3.7 (12.9)	3.3 (10.6)
W_5	5.9 (34.0)	6.6 (42.9)	6.2 (38.5)	W_5	5.3 (27.7)	5.9 (34.9)	5.6 (31.3)
W_6	5.2 (26.2)	5.9 (34.1)	5.5 (30.1)	W_6	4.7 (21.2)	5.3 (27.8)	5.0 (24.5)
W_7	3.4 (11.2)	4.4 (19.3)	3.9 (915.3)	W_7	3.1 (9.0)	4.0 (15.5)	3.5 (12.2)
Mean	5.9 (40.3)	6.9 (54.3)		Mean	5.3 (32.6)	6.3 (43.9)	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
A at same W	0.15		0.46	A at same W	0.11		0.35
W at same/diff. A	0.13		0.37	W at same/diff. A	0.08		0.24

markedly decreased due to lower infestation of weeds and an indicative of higher efficacy of the treatments for improving WCE and caused higher grain yield SRI (Roy 2012).

Cultivars also played important role in controlling weeds due to their profused leaves and tillering with vigorous rooting nature (Dass *et al*. 2015). Variation due to cultivars on WCE was noted highest under hybrid cultivar

Table 4 Interaction effects of cultivars and weed management on total density of weeds (No./m^2) under SRI at 60 DAT

Treatment	2010		Mean	Treatment	2011		Mean
	Cultivars				Cultivars		
	C_1-PHB-71	C_2-NDR-359			C_1-PHB-71	C_2-NDR-359	
W_1	11.0 (120.7)	11.8 (139.1)	11.4 (129.9)	W_1	9.9 (97.2)	10.6 (112.2)	10.2 (104.7)
W_2	6.5 (41.9)	7.0 (48.8)	6.7 (45.3)	W_2	5.8 (33.7)	6.3 (39.3)	6.1 (36.5)
W_3	7.5 (56.4)	7.9 (61.9)	7.7 (59.1)	W_3	6.8 (45.7)	7.1 (50.3)	6.9 (48.0)
W_4	3.4 (10.87)	3.9 (15.0)	3.6 (13.0)	W_4	3.0 (8.9)	3.6 (12.4)	3.3 (10.6)
W_5	6.1 (36.7)	6.4 (40.2)	6.2 (38.5)	W_5	5.5 (29.8)	5.7 (32.8)	5.6 (31.3)
W_6	5.2 (27.3)	5.8 (32.9)	5.5 (30.1)	W_6	4.7 (22.3)	5.2 (26.7)	5.0 (24.5)
W_7	3.7 (13.3)	4.2 (17.2)	3.9 (15.3)	W_7	3.3 (10.7)	3.7 (13.8)	3.5 (12.2)
Mean	6.2 (43.9)	6.7 (50.7)		Mean	5.6 (35.5)	6.0 (41.0)	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
C at same W	0.15		0.46	C at same W	0.11		0.35
W at same/diff. C	0.13		0.37	W at same/diff. C	0.08		0.24

* Figures in the parentheses indicate original values.

Table 5 Interaction effects of age of seedlings and weed management on total dry weight of weeds (g/m^2) under SRI at 60 DAT-2010

Treatment	2010		Mean	Treatment	2011		Mean
	Age of seedlings				Age of seedlings		
	A_1-10 days	A_2-15 days			A_1-10 days	A_2-15 days	
W_1	7.4* (53.9)	8.5 (73.0)	7.9 (63.5)	W_1	6.8 (46.1)	7.7 (58.7)	7.2 (52.4)
W_2	4.2 (17.3)	5.4 (28.4)	4.8 (22.9)	W_2	3.8 (13.9)	4.7 (21.4)	4.2 (17.7)
W_3	4.8 (23.0)	6.1 (36.4)	5.4 (29.7)	W_3	4.4 (18.7)	5.3 (27.6)	4.8 (23.2)
W_4	2.3 (4.8)	3.0 (8.4)	2.6 (6.6)	W_4	2.1 (3.9)	2.6 (6.4)	2.4 (5.2)
W_5	4.1 (16.0)	4.8 (22.5)	4.4 (19.2)	W_5	3.7 (13.0)	4.2 (17.2)	3.9 (15.1)
W_6	3.8 (12.3)	4.3 (18.0)	3.9 (15.1)	W_6	3.2 (10.0)	3.8 (13.7)	3.5 (11.8)
W_7	2.4 (5.3)	3.2 (10.3)	2.8 (7.8)	W_7	2.2 (4.2)	2.8 (7.7)	2.5 (6.0)
Mean	4.1 (18.9)	5.0 (28.1)		Mean	3.73 (15.7)	4.4 (21.8)	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
A at same W	0.17		0.51	A at same W	0.10		0.32
W at same/diff. A	0.14		0.40	W at same/diff. A	0.08		0.24

Table 6 Interaction effects of cultivars and weed management on total dry weight of weeds (g/m^2) under SRI at 60 DAT

Treatment	2010		Mean	Treatment	2011		Mean
	Cultivars				Cultivars		
	C_1-PHB-71	C_2-NDR-359			C_1-PHB-71	C_2-NDR-359	
W_1	7.5* (55.5)	8.4 (71.4)	7.9 (63.5)	W_1	7.0 (48.4)	7.5 (56.4)	7.2 (52.4)
W_2	4.4 (19.3)	5.1 (26.4)	4.8 (22.9)	W_2	4.0 (15.5)	4.5 (19.8)	4.2 (17.7)
W_3	5.1 (25.9)	5.8 (33.5)	5.4 (29.7)	W_3	4.6 (21.0)	5.0 (25.3)	4.8 (23.2)
W_4	2.3 (5.0)	2.9 (8.2)	2.6 (6.6)	W_4	2.1 (4.1)	2.6 (6.2)	2.4 (5.7)
W_5	4.2 (16.9)	4.7 (21.6)	4.4 (19.2)	W_5	3.78 (13.7)	4.1 (16.5)	3.9 (15.1)
W_6	3.6 (12.6)	4.2 (17.7)	3.9 (15.1)	W_6	3.3 (10.3)	3.7 (13.4)	3.5 (11.8)
W_7	2.6 (6.1)	3.1 (9.4)	2.8 (7.8)	W_7	2.3 (4.9)	2.7 (7.0)	2.5 (6.0)
Mean	4.2 (20.2)	4.9 (26.9)		Mean	3.9 (16.8)	4.3 (20.7)	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
C at same W	0.17		0.51	C at same W	0.10		0.32
W at same/diff. C	0.14		0.40	W at same/diff. C	0.08		0.24

* Figures in the parentheses indicate original values.

Table 7 Weed control efficiency, weed index and yield of rice as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	Weed control efficiency (%)		Weed index (%)		Yield (tonnes/ha)	
	2010	2011	2010	2011	2010	2011
Age of seedlings (2)						
A_1-10 days	64.6	65.8	13.9	13.8	6.5	6.7
A_2-15 days	61.2	62.5	14.3	14.2	6.2	6.3
SEm±					0.06	0.06
CD (P=0.05)					0.21	0.22
Cultivars (2)						
C_1-PHB-71	63.5	65.1	12.0	12.0	6.9	7.0
C_2-NDR-359	62.3	63.2	16.2	16.1	5.9	6.0
SEm±					0.06	0.06
CD (P=0.05)					0.21	0.22
Weed management (7)						
W_1- Weedy check	0.00	0.00	53.9	53.7	3.4	3.5
W_2-2HW at 20 and 40 DAT	64.0	66.2	12.4	12.3	6.5	6.6
W_3-2 CW at 10 and 2 20 DAT	52.9	55.4	15.8	15.5	6.3	6.4
W_4- 4 CW at 10, 20, 30 and 40 DAT	89.8	90.2	0.00	0.00	7.4	7.6
W_5- Pretila-chlor fb 1 CW at 20 DAT	69.3	70.9	11.2	11.1	6.6	6.7
W_6- Bispyri-bac fb 1 CW at 40 DAT	76.1	77.2	4.3	4.1	7.1	7.2
W_7-Pretilachlor fb Bispyribac	88.2	88.9	1.3	1.3	7.3	7.5
SEm±					0.06	0.07
CD (P=0.05)					0.17	0.19

PHB 71 as compared to variety NDR 359. Similarly, the differences between cultivars recorded 4.16 and 4.10% lesser weed index under PHB 71 than NDR 359 cultivar during 2010 and 2011, respectively. Hybrid cultivar showed their high competitive potential against weed control in contrast to other variety during study.

In present study, 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4) was considered as weed free plot to work out WI. Efficacy of different treatments under weed management varied due to their nature and mode of weed control. However, highest WCE was recorded under 4 times cono-weeding at 10, 20, 30 and 40 DAT closely followed by pre and post-emergence application of herbicide, i.e pretilachlor + bispyribac-Na (W_7) that brought down yield losses under respective treatments resulted in improving weed index in respect to weed free plot (4 times cono-weeding).

Rice grain yield

Age of seedling played pivotal role in increasing grain yield. Grain yield was recorded relatively more in year 2011 over 2010 (Table 7). Younger age of seedling (10 days) utilized phyllochronic potential to produce significantly higher grain yield (6.5 and 6.7 tonnes/ha) over older aged seedling (15 days old) with mean grain yield of 6.2 and 6.3 tonnes/ha during 2010 and 2011, respectively (Dass *et al.* 2015). In respect of relative increment in grain yield due to younger seedling over elder aged seedling was recorded 4.9% during each year of investigation (Singh *et al.* 2013).

Among cultivars, PHB 71 showed great potential to exploit hybrids vigour to produce higher grain yield and showed superiority over NDR 359 under SRI. Cultivar PHB 71 recorded significantly higher grain yield (6.9 and 7.0 tonnes/ha) over NDR 359 (5.9 and 6.0 tonnes/ha) during 2010 and 2011, respectively. Vigorous growth habit of PHB 71 proved instrumental in producing 24.27% higher grain yield over NDR 359. The results were parallel with the findings of Dass *et al.* (2015).

Data revealed that 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4) recorded significantly higher grain yield (7.4 and 7.6 tonnes/ha) over rest of the treatments and revealed 53.8% increment in grain yield over weedy check. Pre and post-emergence application of pretilachlor + bispyribac herbicide (W_7) also proved significant in increasing the grain yield (7.3 and 7.5 tonnes/ha) during 2010 and 2011, respectively. However, increased mean yield over weedy check was 53.2% during each year and established significant superiority over other weed management treatments. Post-emergence spray of bispyribac + 1 cono-weeding at 40 DAT (W_6) also proved significant in increasing yield (7.1 and 7.2 kg/ha) and showed its superiority over other treatments (Pandey 2009).

N, P and K removal by weeds

Amongst the age of seedlings (Table 8) significantly lesser amount of N (30.8% and 26.0%), P (31.8% and 27.1%) and K (30.7% and 26.2%) were removed by weeds due to lesser weed population that bought lower weed dry weight in younger age seedling (10 days) at 45 DAT over 15 days old seedling during 2010 and 2011, respectively. The result was parallel with the findings of Roy (2012).

Among cultivars, significantly lower amount of NPK removed by weeds under hybrid (PHB-71), which was 22.3% and 15.8%, 23.4% and 16.5% and, 23.4% and 16.5% lesser removal of N, P and K than that recorded under variety NDR 359. It might be due to vigourness and potentialities of hybrids cultivar to produces more tillers as well as foliage to cover wider space quickly under SRI that etiolated the weeds ultimately poor accumulation of dry matter in weeds (Deepa and Jayakumar 2008).

Four times cono-weeding at 10, 20, 30 and 40 DAT (W_4) recorded significantly lower N, P and K removal by weeds. However, it was statistically at par with pre and post-emergence spraying of pretilachlor + bispyribac-Na,

Table 8 Nitrogen, phosphorus and potassium (N, P and K) removal by weeds at 45 DAT as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	NPK removal by weeds at 45 DAT					
	Nitrogen removal (kg/ha)		Phosphorus removal (kg/ha)		Potassium removal (kg/ha)	
	2010	2011	2010	2011	2010	2011
Age of seedlings (2)						
A_1-10 days	1.8 (3.0)	1.6 (2.5)	1.0 (0.5)	0.9 (0.4)	1.8 (3.2)	1.7 (2.7)
A_2-15 days	2.1 (4.3)	1.9 (3.4)	1.1 (0.7)	1.0 (0.5)	2.2 (4.6)	1.9 (3.6)
SEm±	0.04	0.03	0.02	0.01	0.05	0.04
CD (P=0.05)	0.16	0.13	0.07	0.04	0.18	0.16
Cultivars (2)						
C_1-PHB-71	1.8 (3.2)	1.6 (2.7)	1.0 (0.5)	0.9 (0.4)	1.9 (3.4)	1.7 (2.8)
C_2-NDR-359	2.0 (4.1)	1.8 (3.2)	1.1 (0.6)	1.0 (0.5)	2.1 (4.4)	1.9 (3.5)
SEm±	0.04	0.03	0.02	0.01	0.05	0.04
CD (P=0.05)	0.16	0.13	0.07	0.04	0.18	0.16
Weed management (7)						
W_1- Weedy check	3.2 (9.5)	2.9 (8.0)	1.4 (1.4)	1.3 (1.1)	3.3 (10.3)	3.0 (8.6)
W_2-2 HW at 20 and 30 DAT	2.0 (3.6)	1.8 (2.8)	1.0 (0.6)	1.0 (0.4)	2.1 (3.9)	1.9 (3.0)
W_3-2 CW at 10 and 20 DAT	2.2 (4.6)	2.0 (3.6)	1.1 (0.7)	1.0 (0.6)	2.3 (5.0)	2.1 (3.9)
W_4-4 CW at 10, 20, 30 and 40 DAT	1.2 (1.1)	1.1 (0.8)	0.8 (0.2)	0.8 (0.1)	1.2 (1.1)	1.1 (0.9)
W_5-Pretilachlorfb 1 CW at 20 DAT	1.9 (3.0)	1.7 (2.4)	1.0 (0.5)	0.9 (0.4)	1.9 (3.3)	1.8 (2.6)
W_6-Bispyribacfb 1 CW at 40 DAT	1.7 (2.4)	1.5 (1.9)	0.9 (0.4)	0.9 (0.3)	1.7 (2.6)	1.6 (2.0)
W_7-Pretilachlor fb Bispyribac	1.3 (1.2)	1.2 (1.0)	0.8 (0.2)	0.8 (0.2)	1.3 (1.3)	1.2 (1.0)
SEm±	0.04	0.03	0.02	0.01	0.04	0.03
CD (P=0.05)	0.13	0.10	0.06	0.03	0.13	0.10

* Figures in the parentheses indicate original values

Table 9 Interaction effects of age of seedlings and weed management on grain yield of rice (tonnes/ha) under SRI

Treatment	2010		Mean	Treatment	2011		Mean
	Age of seedlings				Age of seedlings		
	A_1-10 days	A_2-15 days			A_1-10 days	A_2-15 days	
W_1	3.6	3.3	3.4	W_1	3.6	3.3	3.5
W_2	6.7	6.3	6.5	W_2	6.8	6.4	6.6
W_3	6.4	6.1	6.3	W_3	6.5	6.2	6.4
W_4	7.6	7.2	7.4	W_4	7.7	7.4	7.6
W_5	6.7	6.5	6.6	W_5	6.8	6.6	6.7
W_6	7.3	6.9	7.1	W_6	7.4	7.1	7.2
W_7	7.5	7.1	7.3	W_7	7.6	7.3	7.5
Mean	6.5	6.2		Mean	6.7	6.3	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
A at same W	0.88		0.26	A at same W	0.10		0.30
W at same/diff. A	0.68		0.19	W at same/diff. A	0.76		0.21

but showed its superiority over rest of treatments.The results revealed that 4 times cono-weeding 10, 20, 30 and 40 DAT minimized N, P, K removal by weeds up to followed by pretilachlor + bispyribac-Na (W_7) over weedy check at 45 DAT during 2010 and 2011, respectively (Shet *et al.* 2009).

Interactive effects on total weeds density and weed dry weight at 60 DAT

Age of seedlings and cultivars proved significant in controlling weed flora under different weed management (Table 3, 6). The total weed dynamics as well as TWDW was significantly lowered under the juvenile aged seedling

Table 10 Interaction effects of cultivars and weed management on grain yield of rice (tonnes/ha) under SRI

\Treatment	2010		Mean	Treatment	2011		Mean
	Cultivars				Cultivars		
	C_1-PHB-71	C_2-NDR-359			C_1-PHB-71	C_2-NDR-359	
W_1	3.7	3.2	3.4	W_1	3.8	3.2	3.5
W_2	7.1	5.9	6.5	W_2	7.3	6.0	6.6
W_3	6.9	5.6	6.3	W_3	7.0	5.7	6.4
W_4	7.8	7.0	7.4	W_4	8.0	7.2	7.6
W_5	7.2	6.0	6.6	W_5	7.4	6.1	6.7
W_6	7.6	6.6	7.1	W_6	7.7	6.7	7.2
W_7	7.7	6.9	7.3	W_7	7.8	7.1	7.5
Mean	6.9	5.9		Mean	7.0	6.0	
	SEm ±		*CD (P=0.05)*		*SEm ±*		*CD (P=0.05)*
A at same W	0.88		0.26	A at same W	0.10		0.30
W at same/diff. A	0.68		0.19	W at same/diff. A	0.76		0.21

(10 days) of hybrid PHB 71 with 4 times cono-weeding at 10, 20, 30 and 40 DAT (W_4), but it was at statistically on par with pre and post-emergence herbicides, *i.e.* pretilachlor + bispyribac-Na (W_7) during 2010 and 2011. Similar trends with respect to TWDW under NDR-359 were also recorded.These findings were parallel with the findings of Kolo and Umaru (2012) and Anitha and Chellappan (2011).

Interactive effects on grain yield of rice

Age of seedlings, cultivars and weed management interaction also produced significant variation on grain yield during both the years of experimentation (Table 9, 10). Planting at tender age of seedling (10 days) of PHB 71 significantly produced higher grain yield and showed its superiority to 15 days old seedling of NDR 359 under 4 times cono-weeding followed by pre and post-emergence herbicidal treatment of pretilachlor + bispyribac-Na. Amongst weed management treatments, 4 times cono-weeding and pretilachlor + bispyribac-Na were at par with each other under both the ages of seedlings of PHB 71 and NDR 359, but significantly superior over weedy check during each year of study. Resource utilization efficiency of hybrids are quite higher due to early transplanting of seedling, while cono-weeder facilitated more organic matter pooling through weed biomass incorporation into the soil, which after decomposition helped in nutrient recycling besides churning the soil surface, leading to biochemically enriched soil rhizosphere for more availability and uptakes of nutrients by plants and ultimately transformed into higher yield (Kolo and Umaru 2012). Thus, it is concluded that planting of hybrid rice PHB 71 with younger age seedling (10 days) following cono-weeding 4 times at 10, 20, 30 and 40 DAT under SRI can provide better opportunity to produce higher rice yield on long term basis tomeet future demand of the country.

ACKNOWLEDGEMENT

The first author is grateful to Indian Council of Agricultural Research for awarding ICAR-Senior Research Fellowship during Ph D programme.

REFERENCES

Anitha S and Chellappan M. 2011.Comparison of the SRI recommended practices, and farmers' methods of rice production in the humid tropics of Kerala, India. *Journal of Tropical Agriculture* **49** (1-2): 64–71.

Dass A, Chandra S, Choudhary A K, Singh G and Sudhishri S. 2015.Influence of field re-ponding pattern and plant spacing on rice root–shoot characteristics, yield, and water productivity of two modern cultivars under SRI management in Indian Mollisols. *Paddy and Water Environment*. [DOI: 10.1007/s10333-015-0477-z].

Deepa S and Jayakumar R. 2008. Studies on uptake of N, P and K as influenced by different rates (doses) of pretilachlor in transplanted rice. *Madras Agricultural Journal* **95** (7-12): 333–8.

Haden V R, Daxbury J M, Tommaso D I and Losey J E. 2007.Dynamics of weed community in the system of rice intensification. *Journal of Sustainable Agriculture* **30** (4): 5–26.

Kolo M G M and Umaru, I. 2012. Weed competitiveness and yield of inter-and intra-specific upland rice under different weed control practices at Badeggi, Niger State, Nigeria. *African Journal of Agricultural Research* **7** (11): 1 687–93.

Krishna A, Biradapatil, N K, Manjappa, K and Channappagoudar B B. 2008. Evaluation of SRI, seedling age and spacing on seed yield and quality in Samba Masuhri (BPT-5204) rice. *Karnataka Journal of Agricultural Sciences* **21**(1): 20–5.

Pandey S. 2009. Effect of weed control methods on rice cultivars under the system of rice intensification. Ph D thesis, Institute of Agriculture and Animal Science, Rampur, Chitwan (Nepal).

Roy S. 2012. Effect of age of seedlings and weed management practices on productivity of rice under SRI. Ph D thesis, GBPUA &T, Pantnagar, Uttarakhand.

Shet J N, Gireesh R M, Sheshadri C and Lokesh G Y T. 2009.Uptake of nutrients by rice and weeds of influenced by different weed management practices in drum seeded rice. *International Journal of Agricultural Sciences* **5** (2): 490–3.

Shukla U N, Srivastava V K, Singh S, Sen A and Kumar V.

2014.Growth, yield and economic potential of rice as influenced bydifferent age of seedlings, cultivars and weed management under SRI. *Indian Journal of Agricultural Sciences* **84**(5): 628–36.

Singh K, Singh S R, Singh, J K, Rathore R S, Pal S, Singh S P and Roy R. 2013. Effect of age of seedling and spacing on yield, economics, soil health and digestibility of rice genotypes under SRI. *Indian Journal of Agricultural Sciences* **83** (5): 479–83.

Singh M and Singh R P. 2010. Efficacy of herbicides under different methods of direct-seeded rice establishments. *Indian Journal of Agricultural Sciences* **80** (9): 815–9.

Stoop W A, Uphoff N and Kassam A. 2002. A review of agricultural research issues raised by the system of rice intensification from Madagascar: opportunities for improving farming systems for resource-poor farmers. *Agricultural Systems* **71** (3): 249–74.

Thura S. 2010. Evaluation of weed management practices in the system of rice intensification. M Sc thesis, Yezin Agricultural University, Myamar.