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Growth, yield and economic potential of rice (*Oryza sativa*) as influenced by different age of seedlings, cultivars and weed management under system of rice intensification

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ABSTRACT

A field experiment was conducted to study the growth, yield and economic potential of rice as influenced by different age of seedlings, cultivars and weed management under system of rice intensification on sandy-clay-loam soil at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University during the two consecutive *kharif* (rainy) seasons of 2010 and 2011. The experiment was laid out in split-plot design with two ages of seedlings with two cultivars assigned to main plots and seven weed management treatments were allocated as sub-plot treatments has replicated thrice. Transplanting of younger age seedling (10 days) of PHB 71 recorded significantly higher growth attributes, viz. plant height, no. of green leaves/hill and dry matter accumulation with yield attributing characters. Similarly, ten days old seedlings of PHB 71 also produced significantly higher yield (grain and straw) that fetched maximum benefit in respect to gross return, net return and B: C ratio over old aged seedling (15 days) of NDR 359 during 2010 and 2011. Among weed management, cono-weeding 4 times at 10, 20, 30 and 40 days after transplanting (DAT) recorded significantly higher growth attributes, yield attributes and yield, but sequential application of pre and post-emergence herbicides, i e pretilachlor + bispyribac-Na was found economically feasible under SRI due to lesser labour requirement.

Key words: Cultivars, Economics, Growth, Seedlings age, SRI, Yield potential, Weed management

System of rice intensification (SRI) developed in Madagascar, is a system approach to increase rice productivity with less external and expensive inputs. SRI method of cultivation is slowly gaining momentum all over the world including India. The SRI is a type of methodology to increase rice productivity by modifying micro-climate and soil condition. Important principles of SRI are wider spacing facilitating greater root growth and better tiller production. The plant geometry and spatial configuration exploit the initial vigour of the genotypes with enhanced soil aeration creating congenial condition for better establishment. Early transplanting of rice seedlings assumes special significance in obtaining higher yields in SRI cultivation. Rice seedlings lose much of their growth potential if they are transplanted more than 15 days after they emerge in the nursery. Seedlings should be transplanted before the fourth phyllochron stage begins to preserve and exploit maximum tillering potential and affect grain yield ultimately. It was reported that younger seedlings of 9 and 12 days produced significantly higher grain yield than other aged seedlings, viz. 15 days, 18 days and 21 days (Manjunatha *et al.* 2010).

SRI method has potential to produce 16.6% higher grain yield over normal transplanting due to higher growth attributes and total biomass (Singh *et al.* 2013). Similarly, choice and adoptability of cultivars showed wider variability for different methods, viz. SRI and normal transplanting. However, SRI method recorded nearly 46-48% higher yield with hybrids as well as 5.2 to 17 % due to inbred cultivars at DRR, Hyderabad (Mahender Kumar 2003). In the recent-past, weed control was achieved by herbicidal application supplemented with hand weeding proved most effective against all kind of weeds. But, the escalating cost of agrochemicals together with phytotoxicity effects and costly labour poses the farming community to think to mechanical measures. Mechanical weeding can be done by unskilled labour and is generally economical, non-polluting and also solves residual problem of herbicides fate in soil. Nutrient drain by weeds in rice ecosystem is exorbitant to the crop and ultimately suffers due to lack of nutrients in soil profile. The trend of continuous cultivation without on compensating

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extraction of nutrients by weeds in field needs to be mitigated. The technology in which weed control is accomplished through incorporation of weeds *in-situ* aided by mechanical means may help in effective recycling of the depleted nutrients together with aeration of the root zone. Thus, mechanical weed control offers wider scope in SRI culture. Therefore, present field experiment was planned to study the growth, yield and economic potential of rice as influenced by different age of seedlings, cultivars and weed management under system of rice intensification.

MATERIALS AND METHODS

The experiment was conducted during 2010 and 2011 at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, situated in the South Eastern part of Varanasi city at 25°18' N latitude, 83°03' E longitude and at an altitude of 75.7 meters above the mean sea level in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. The cumulative rainfall received during the period of experimentation was 715.8 mm and 1191.3 mm during 2010 and 2011, respectively. The soil of experimental plot was sandy-clay-loam textural class (50.38 % sand, silt 26.31% and clay 23.31%) with low in organic carbon (0.47 and 0.49%) and nitrogen (198.03 and 202.07 kg/ha), but medium in phosphorus (21.42 and 22.30 kg/ha) and potassium (219.32 and 224.53 kg/ha) before the transplanting during 2010 and 2011, respectively. However, soil having optimum range of pH and EC that favoured better crop stand during investigation.

The experiment was laid out in split-plot design replicated thrice. The treatments comprised two ages of seedlings (A_1-10 days and A_2-15 days) with two cultivars (C_1-PHB-71 and C_2-NDR-359) as assigned to main plots. Each main plot were further divided into seven sub-plot to accommodate seven weed management treatments, i.e W_1 (Weedy Check), W_2 (Two hand weedings at 20 and 30 DAT), W_3 (Two cono-weedings at 10 and 20 DAT), W_4 (Four cono-weedings 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 five days before the sowing of ten 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 cm × 25 cm using index finger and thumb. Light irrigation was given on the next day of transplanting. Within a week, gap filling 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 before panicle initiation. Among weed management, cono-weeding and herbicides (pre and post-emergence) were applied as per treatments. Plant height, leaves/hill and dry matter accumulation/hill among crop growth characters and yield were observed. Economics were also calculated and compared for the selection of superior treatment combination. All the data were statistically analysed to draw a valid conclusion.

RESULTS AND DISCUSSION

Growth attributes

An inspection of the data revealed that in general shoot elongation continued to increase with advancement in age of the plants (Table 1). Plant height, no. of green leaves and dry matter accumulation markedly increased due to transplanting of 10 days old seedling (A_1). Younger seedlings provided sufficient nutrients for vegetative growth by effective utilization of phyllochronic concept. However, save energy from the nursery seedlings by early transplanting and diverted toward tiller production during grand vegetative growth as well as for reproductive phase. Thus, leads to increased growth and yield attributes that may lead to enhanced grain and straw yields (Singh *et al.* 2013, Sridevi and Chellamuthu 2007). Amongst cultivars, plant height (128.10 and 130.67 cm), no. of green leaves/hill (37.09 and 39.55), LAI (4.80 and 5.01) and dry matter accumulation/hill (73.83 and 77.48 g) significantly increased due to hybrid PHB 71 over variety NDR 359 during 2010 and 2011, respectively. The efficient photosynthetic performance of rice hybrids is probably due to the increased cytokinin content in their roots at later growth stages contributing to higher grain yield (Singh *et al.* 2013). In weed management, cono-weeding four times at 10, 20, 30 and 40 DAT showed 4.03% and 4.41% higher dry matter accumulation over herbicidal treatment (pretilachlor + bispyribac-Na) and increment was steamily higher over weedy check, which recorded 66.35% and 64.07% higher values during 2010 and 2011, respectively. Significant reduction in crop-weed competition was observed under cono-weeding due to the *in-situ* weed management and add as a green manure, which favoured the crop by improving and ensuring moisture, nutrients, light and space through marked reduction in weed interference that facilitates vigorous growth and development of crop. Similarly, mechanical weeding also enhanced growth attributes by creating better soil aeration that accelerates the transformation of nutrient and their translocation toward the active site resulted into higher growth and development (Vijayakumar *et al.* 2006).

Yield attributes

Transplanting of early aged seedling (A_2-10 days old)

Table 1 Plant height of rice as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	Plant height (cm)		No. of leaves/hill		Dry matter accumulation (g/hill)	
	2010	2011	2010	2011	2010	2011
Age of seedlings (2)						
A_1-10 days	128.20	130.60	36.91	39.23	69.89	73.82
A_2-15 days	122.20	124.79	34.56	37.02	66.31	70.22
SEm±	1.17	1.26	0.62	0.62	0.59	0.65
CD(P=0.05)	4.06	4.37	2.13	2.16	2.03	2.23
Cultivars (2)						
C_1-PHB-71	128.10	130.67	37.09	39.55	73.83	77.48
C_2-NDR-359	122.30	124.72	34.37	36.70	62.36	66.56
SEm±	1.17	1.26	0.62	0.62	0.59	0.65
CD(P=0.05)	4.06	4.37	2.13	2.16	2.03	2.23
Weed management (7)						
W_1- Weedy check	103.50	106.09	22.93	25.35	28.24	31.69
W_2-2 HW at 20 and 30 DAT	122.12	124.79	32.91	34.95	69.25	73.58
W_3- 2 CW at 10 and 20 DAT	117.82	119.98	30.24	32.40	65.24	68.79
W_4- 4 CW at 10, 20, 30 and 40 DAT	139.09	141.43	46.82	49.51	83.92	88.20
W_5- Pretilachlor fb 1 CW at 20 DAT	127.27	129.81	34.89	37.11	72.60	76.39
W_6- Bispyribac fb 1 CW at 40 DAT	131.07	133.43	38.58	41.40	76.87	81.17
W_7-Pretilachlor fb Bispyribac	135.53	138.34	43.76	46.17	80.54	84.31
SEm±	0.96	0.97	0.66	0.69	0.50	0.55
CD(P=0.05)	2.72	2.77	1.89	1.95	1.43	1.58

produced significantly more panicles/m^2 (261.55 and 269.92), panicle length (30.31 and 31.25 cm), panicle weight (5.03 and 5.72 g), grains/panicle (202.03 and 214.15), 1000-grain weight (25.00 and 26.34 g) and lowest sterility (12.30% and 10.83%), which was 4.34% and 3.22%, 4.16% and 4.26%, 5.57% and 5.24% 8.92% and 8.92%, 3.48% and 2.89% higher over transplanting of older age seedling (A_2-15 days old) during 2010 and 2011, respectively (Table 2). Similar results were also reported by Singh *et al.* (2013) and Krishna *et al.* (2008). However, days to maturity remained unaffected by age of seedlings. The increased yield attributes may be accounted due to concept of phyllochronic utilization that follow by younger age seedling. Thus, improved the growth attributes, viz. production of green leaves/hill and higher leaf area index which are the major source of photosynthetic activity in rice. Furthermore, efficient partitioning of assimilates into the leaf, stems and roots encourage production of tiller and finally resulted into higher production of yield attributes (Vijayakumar *et al.* 2006). Improvement in these growth attributes proved instrumental for higher production of panicles/m, panicle length (cm), panicle weight (g) and grains/panicle and resulted in higher grain and straw yield under 10 days old seedling. Similarly, rice hybrids PHB 71 recorded significantly higher no. of panicles/m^2 (267.57 and 276.85), panicle length (30.31 and 31.25 cm), panicle weight (5.27 and 5.88 g), number of grains/panicle (227.28 and 240.91) except test weight than inbred cultivar NDR 359 and recorded 8.74% and 8.15%, 11.38% and 9.71%, 14.23% and 10.54%, 30.15% and 30.15% higher over NDR 359, however days to maturity remained unaffected. Hybrid has capability to produces higher growth resulted in higher yield attributes. Genetic traits of hybrid PHB 71 allowed the rice plant to transform more energy into the production of more no. of yield attributes increased yield potential by about 20% over high yielding variety (Singh *et al.* 2013).

Cono-weeding four times at 10, 20, 30 and 40 DAT produced higher no. of panicles/m^2, panicle length, panicle weight, no. of grains/panicle and test weight followed by herbicidal application of pretilachlor + bispyribac-Na treatment over weedy check. Weed free condition was observed under cono-weeding due to churning and decomposition of weed biomass. Decomposed biomass provides mineralized nutrients to the plant by improving activity of micro-organism. Because of cono-weeding creates aeration around rhizosphere of rice plants, which act as oxidizer catalyst to enhance the micro-organism activity that increased the yield attributes and yield of rice under SRI (Anonymous 2011 and Vijayakumar *et al.* 2006).

Yield potential

Younger age of seedling (10 days old) utilized phyllochronic potential to produce significantly higher grain yield (6 531 and 6 662 kg/ha), straw yield (8 603 and 8 620 kg/ha) and biological yield (15 134 and 15 281 kg/ha) over older aged seedling (15 days old) during 2010 and 2011, respectively (Table 3). However, harvest index was not influenced by ages of seedlings. Transplanting of younger aged seedling (10 days old) proved marked improvement in growth, yield attributes and yield. Profuse root growth and tillering increases assimilates synthesis and divert to support

Table 2 Yield attributes of rice as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	Panicle (No./m²)		Panicle length (cm)		Panicle weight (g)		No. of grains/panicle		Test weight (g)		Days to maturity	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedlings (2)												
A_1-10 days	261.55	269.92	30.31	31.25	5.03	5.72	202.03	214.15	25.00	26.34	125.91	127.71
A_2-15 days	250.21	261.23	29.05	29.92	4.75	5.42	184.01	195.05	24.13	25.58	124.42	126.93
SEm±	2.31	2.48	0.23	0.23	0.023	0.024	4.63	5.09	0.19	0.21	1.08	1.22
CD(P=0.05)	8.02	8.60	0.79	0.81	0.079	0.084	16.05	17.62	0.64	0.71	NS	NS
Cultivars (2)												
C_1-PHB-71	267.57	276.85	31.47	32.14	5.27	5.88	217.28	230.91	22.86	24.10	125.86	128.03
C_2-NDR-359	244.19	254.30	27.89	29.02	4.52	5.26	168.76	178.29	26.27	27.82	124.48	126.61
SEm±	2.31	2.48	0.23	0.23	0.023	0.024	4.63	5.09	0.19	0.21	1.08	1.22
CD(P=0.05)	8.02	8.60	0.79	0.81	0.079	0.084	16.05	17.62	0.64	0.71	NS	NS
Weed management (7)												
W_1- Weedy check	163.73	175.26	25.31	26.45	3.23	3.69	159.31	168.87	20.32	21.34	118.50	120.51
W_2-2HW at 20 and 30 DAT	257.19	262.35	29.24	29.94	4.85	5.46	183.43	194.43	23.86	25.29	123.90	125.99
W_3- 2 CW at 10 and 20 DAT	251.05	263.04	28.77	29.46	4.66	5.06	172.42	182.77	23.30	24.94	122.89	124.96
W_4- 4 CW at 10, 20, 30 and 40 DAT	294.32	299.02	32.56	33.38	5.76	6.75	228.07	241.76	26.44	27.91	131.16	134.03
W_5- Pretilachlor fb 1 CW at 20 DAT	265.97	279.55	29.32	30.62	4.98	5.72	194.14	206.61	24.88	26.40	123.89	124.98
W_6- Bispyribac fb 1 CW at 40 DAT	274.24	289.00	30.93	31.76	5.22	5.93	200.23	211.43	25.64	26.94	126.63	128.80
W_7-Pretilachlor fb Bispyribac	284.67	290.82	31.62	32.48	5.54	6.37	213.53	226.35	27.51	28.92	129.21	131.97
SEm±	2.46	2.70	0.25	0.25	0.024	0.029	4.68	5.23	0.18	0.22	0.90	1.11
CD(P=0.05)	6.98	7.66	0.71	0.72	0.069	0.081	13.28	14.85	0.52	0.63	2.56	3.17

greater grain filling leads to higher panicle weight and test weight that ultimately improve rice grain yield. Panicle and test weight are the index of yield determining character of rice and results were parallel with the findings of Singh *et al.* (2013). Jain and Upadhyay (2008) also reported similar results. Instead of age of seedling, rice hybrids PHB 71 showed great potential to exploit hybrid vigour to produce higher grain, straw and biological yield and showed marked superiority over inbred cultivars (NDR 359) under SRI. Vigourous growth habit of PHB 71 proved instrumental to produce 24.27% higher grain yield over NDR 359 during each year of experimentation. However, the increment was recorded more during second year mainly due to efficient rainfall as compared to first year of experiment. Harvest index remained unaffected by cultivars. Improvement in yield mainly due to the production of higher no. of tillers and grains by rice hybrid as compared to inbred cultivars by efficient utilization and conversion of resources into assimilates (Singh *et al.* 2013 and Reddy *et al.* 2008). Production potential, vigourness (genetic traits) and physiological efficiency of hybrid are responsible to differentiate hybrid from variety in their growth habits, rooting pattern, input utilization for obtaining better yield under SRI, in addition to that, dry matter partitioning is an added input by rice hybrid PHB 71 which may impart into grain and straw as well as biological yield (Singh *et al.* 2013 and Kumar *et al.* 2010). It was also observed that four times cono-weeding recorded significantly higher grain yield (7 408 and 7 556 kg/ha) and biological yield (16 644 and 16 807 kg/ha) as compared to rest of the treatments except sequential application of pre and post-emergence combination of pretilachlor + bispyribac-Na treatment, where it was on par in increasing the grain yield. Conversely of above, straw yield (9 316 and 9 333 kg/ha) was significantly higher under application of pretilachlor + bispyribac-Na (W_7) treatment over rest of the weed management treatments, but remained at par with four times cono-weeding and integration of herbicidal and mechanical weeding treatments (bispyribac-Na + 1 cono-weeding). Similarly, significantly higher harvest index recorded under 4 times cono-weeding over rest of the weed management treatments. As a result of lesser weed infestation conditions under cono-weeding which enabled the crop

Table 3 Yield, straw yield, biological yield and harvest index of rice as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	Yield (kg/ ha)		Straw yield (kg/ha)		Biological yield (kg/ha)		Harvest index (%)	
	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedlings (2)								
A_1-10 days	6 531	6 662	8 603	8 620	15 134	15 281	43.15	43.60
A_2-15 days	6 209	6 333	8 171	8 188	14 380	14 521	43.18	43.61
SEm±	61	63	90	91	150	151	0.087	0.088
CD(P=0.05)	212	217	314	316	519	524	NS	NS
Cultivars (2)								
C_1-PHB-71	6 860	6 996	8 845	8 862	15 705	15 858	43.68	44.12
C_2-NDR-359	5 881	5 998	7 929	7 946	13 809	13 944	42.59	43.01
SEm±	61	63	90	91	150	151	0.087	0.088
CD(P=0.05)	212	217	314	316	519	524	0.301	0.304
Weed management (7)								
W_1- Weedy check	3 426	3 494	5 021	5 035	8 447	8 529	40.56	40.97
W_2-2HW at 20 and 40 DAT	6 507	6 637	8 748	8 767	15 255	15 404	42.65	43.09
W_3- 2 CW at 10 and2 20 DAT	6 256	6 381	8 495	8 514	14 751	14 895	42.41	42.84
W_4- 4 CW at 10, 20, 30 and 40 DAT	7 408	7 556	9 237	9 252	16 644	16 807	44.51	44.96
W_5- Pretilachlor fb 1 CW at 20 DAT	6 591	6 722	8 698	8 716	15 288	15 438	43.11	43.54
W_6- Bispyribac fb 1 CW at 40 DAT	7 093	7 233	9 194	9 209	16 288	16 442	43.55	43.99
W_7-Pretilachlor fb Bispyribac	7 311	7 458	9 316	9 333	16 627	16 790	43.97	44.42
SEm±	72	73	100	101	169	171	0.097	0.098
CD(P=0.05)	204	209	283	285	480	488	0.277	0.280

Table 4 Interaction effects of age of seedlings and weed management on grain yield of rice (kg/ha) under SRI

Treatment	2010 Age of seedlings		Mean	Treatment	2011 Age of seedlings		Mean
	A_1-10 days	A_2-15 days			A_1-10 days	A_2-15 days	
W_1	3 571	3 280	3 426	W_1	3 642	3 346	3 494
W_2	6 710	6 304	6 507	W_2	6 844	6 430	6 637
W_3	6 418	6 094	6 256	W_3	6 546	6 216	6 381
W_4	7 575	7 240	7 408	W_4	7 726	7 385	7 556
W_5	6 684	6 497	6 591	W_5	6 818	6 627	6 722
W_6	7 272	6 914	7 093	W_6	7 416	7 050	7 233
W_7	7 489	7 133	7 311	W_7	7 639	7 276	7 458
Mean	6 531	6 209		Mean	6 662	6 333	
	SEm ±		CD (P=0.05)		SEm ±		CD (P=0.05)
A at same W	88		267	A at same W	102		308
W at same/diff. A	68		194	W at same/diff. A	76		217

to make maximum utilization of inputs for the growth that might be caused improvement in yield attributes with low spikelet sterility and resulted in higher grain yield (Vijayakumar *et al.* 2006).

Interactive effects

Age of seedlings, cultivars and weed management interaction produced significant variation on grain yield during both the years of study (Table 4). Planting of 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 (W_7). Amongst weed management treatments, four times cono-weeding and pretilachlor + bispyribac-Na (W_7) 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

Table 5 Interaction effects of cultivars and weed management on grain yield of rice (kg/ha) under SRI

Treatment	2010 Cultivars		Mean	Treatment	2011 Cultivars		Mean
	C_1-PHB-71	C_2-NDR-359			C_1-PHB-71	C_2-NDR-359	
W_1	3 696	3 156	3 426	W_1	3 769	3 219	3 494
W_2	7 130	5 884	6 507	W_2	7 273	6 002	6 637
W_3	6 895	5 617	6 256	W_3	7 033	5 729	6 381
W_4	7 798	7 017	7 408	W_4	7 954	7 158	7 556
W_5	7 231	5 950	6 591	W_5	7 375	6 069	6 722
W_6	7 590	6 597	7 093	W_6	7 739	6 727	7 233
W_7	7 678	6 945	7 311	W_7	7 831	7 084	7 458
Mean	6 860	5 881		Mean	6 996	5 998	
	SEm ±		CD (P=0.05)		SEm ±		CD (P=0.05)
A at same W	88		267	A at same W	102		308
W at same/diff. A	68		194	W at same/diff. A	76		217

soil rhizosphere for more availability and uptakes of nutrients by plants and ultimately transformed into higher yield. The results are in conformity of Kolo and Umaru (2012) and Parmar (2010).

Economics

It is evident from the data that economics of the crop significantly influenced by age of seedlings (Table 6). Transplanting of younger seedling (10 days) fetched significantly higher gross return (₹ 80 176.06 and ₹ 86 873.62/ha), net return (₹ 46 617.42 and ₹ 53 314.99/ha) and B: C ratio (2.39 and 2.59) over older age seedling (15 days) during 2010 and 2011, respectively. This might be due to higher grain and straw yield under younger seedling over older age of seedling (Singh *et al.* 2013). Menete *et al.* (2008) also confirmed that transplanting of younger aged seedling which produce more yield attributing traits resulted in higher economic returns. Similarly, rice hybrids PHB 71 showed great potential to harvest significantly higher gross return (₹ 83 920.87 and ₹ 90 952.94/ha), net return (₹ 49 802.23 and ₹ 56 833.51) and B:C ratio (2.46 and 2.67) over inbred cultivar NDR 359

Table 5 Cost of cultivation, gross return, net return and B: C ratio of rice as influenced by age of seedlings, cultivars and weed management under SRI

Treatment	Cost of cultivation (× 10^3 ₹ /ha)	Gross return (× 10^3 ₹ /ha)		Net return (× 10^3 ₹ /ha)		B: C ratio	
		2010	2011	2010	2011	2010	2011
Age of seedlings (2)							
A_1-10 days	33.56	80.18	86.87	46.62	53.31	2.39	2.59
A_2-15 days	33.57	76.21	82.58	42.64	49.01	2.27	2.46
SEm±	0.00	0.76	0.81	0.76	0.81	0.023	0.024
CD(P=0.05)		2.64	2.82	2.64	2.82	0.079	0.084
Cultivars (2)	0.00	0.00	0.00	0.00	0.00		
C_1-PHB-71	34.12	83.92	90.95	49.80	56.83	2.46	2.67
C_2-NDR-359	33.01	72.47	78.50	39.46	45.49	2.20	2.38
SEm±	0.00	0.76	0.81	0.76	0.81	0.023	0.024
CD(P=0.05)	0.00	2.64	2.82	2.64	2.82	0.079	0.084
Weed management (7)	0.00	0.00	0.00	0.00	0.00		
W_1- Weedy check	30.85	42.81	46.34	11.97	15.49	1.39	1.50
W_2-2 HW at 20 and 40 DAT	34.60	80.14	86.82	45.55	52.23	2.32	2.51
W_3- 2 CW at 10 and 20 DAT	33.35	77.18	83.60	43.83	50.25	2.31	2.50
W_4- 4 CW at 10, 20, 30 and 40 DAT	35.85	90.15	97.75	54.31	61.90	2.51	2.73
W_5- Pretilachlor fb 1 CW at 20 DAT	32.98	80.93	87.69	47.95	54.71	2.45	2.66
W_6- Bispyribac fb 1 CW at 40 DAT	33.85	86.85	94.10	53.00	60.25	2.57	2.78
W_7-Pretilachlor fb Bispyribac	33.48	89.28	96.78	55.80	63.30	2.67	2.89
SEm±	0.00	0.88	0.96	0.88	0.96	0.027	0.029
CD(P=0.05)	0.00	2.50	2.73	2.50	2.73	0.076	0.083

during 2010 and 2011, respectively. In spite of high cost of hybrid seed, this cultivar produced higher grain and straw yield which recorded higher monetary advantages over normal variety. Singh *et al.* (2013) reported that rice hybrid (PHB 71) gave highest economic advantages due to the production of higher yield as compared to inbred cultivar. These results were also supported by Jain and Upadhyay (2008). Among weed management treatments, weed control with four times cono-weeding (W_4) showed significantly higher gross return (₹ 90 152.92 and ₹ 97 745.91/ha) over rest of the weed management treatments including weedy check, but it was on par with combined application of pre and post-emergence application of pretilachlor + bispyribac-Na herbicide (W_7). However, net return (₹ 55 802.97 and ₹ 63 300.24/ha) and B:C ratio (2.67 and 2.89) were higher under sequential application of pre and post-emergence herbicides. However, it remained at par with integrated weed management treatment, i.e bispyribac-Na + 1 cono-weeding (W_6). This might be due to more no. of labour required under cono-weeding which is more costly inputs that increased cost of cultivation and ultimately lowered down B: C ratio as against herbicidal weeding. Because of, drudgery in operation and expenditure on labour was higher under cono-weeding as compared to expenditure incurred under herbicidal weeding to produce unit yield of rice. These results were supported by Kumar *et al.* (2012).

Correlation studies

Correlation matrix was also studied among yield attributes, yield, growth and weed is reflected from direct effect of that trait which will help for identifying the traits that contribute directly or indirectly to improve rice grain yield. Correlation matrix between traits were studied to show the association among traits and revealed a significant and positive correlation between yield attributes, yield and growth, however, all characters were significant but negatively correlated with weed density and weed dry weight (Table 6). Biological yield (r = 0.998), no. of panicles (r = 0.995), panicle length (r = 0.933), panicle weight (r = 0.972), no. of grains/panicle (r = 0.799), test weight (r = 0.770), dry matter accumulation (r = 0.997) were significantly and positively correlated with rice grain yield, whereas, all these characters were significantly, but negatively correlated with weed density and weed dry weight. However, increase in weed density could cause improvement in weed dry weight which showed significant and positive correlation between weed density and weed dry weight. Test weight significantly and positively associated with panicle weight only at 0.05 level of probability.

Coefficient of determination

A significant correlation between dry matter accumulation/hill (g), no. of panicles/m^2 and panicle weight (g) with grain yield and economics of rice, further justified the improvement in dry matter accumulation parallels increased in grain yield of rice and achieved highest at 86.06 g dry matter /hill. Similarly, gradual increment in no. of

Table 7 Correlation coefficient studies among growth, yield attributes and yield of rice

	Grain yield (q/ha)	Biological yield (q/ha)	No. of panicles	Panicle length (cm)	Panicle weight (g)	No. of grains/ panicle	Test weight (g)	Dry matter (g/hill)	Plant height (cm)	Weed density (no./m^2)	Weed dry weight (g/m^2)
Grain yield (q/ha)	1.000**										
Biological yield (q/ha)	0.998**	1.000**									
No. of panicles	0.995**	0.992**	1.000**								
Panicle length (cm)	0.933**	0.910**	0.926**	1.000**							
Panicle weight (g)	0.972**	0.955**	0.975**	0.975**	1.000**						
No. of grains/panicle	0.799**	0.763**	0.794**	0.955**	0.893**	1.000**					
Test weight (g)	0.770**	0.763**	0.798**	0.674*	0.791**	0.529	1.000**				
Drymatter accumulation (g/hill)	0.997**	0.993**	0.998**	0.932**	0.980**	0.805**	0.792**	1.000**			
Plant height (cm)	0.937**	0.916**	0.947**	0.961**	0.987**	0.895**	0.836**	0.950**	1.000**		
Weed density (no./m^2)	–0.979**	–0.973**	–0.984**	–0.914**	–0.977**	–0.788**	–0.872**	–0.987**	–0.967**	1.000**	
Weed dry weight (g/m^2)	–0.979**	–0.973**	–0.984**	–0.922**	–0.980**	–0.800**	–0.866**	–0.986**	–0.971**	1.000**	1.000**

Correlation coefficient is significant at *P=0.05 and **P=0.01 level of significance.

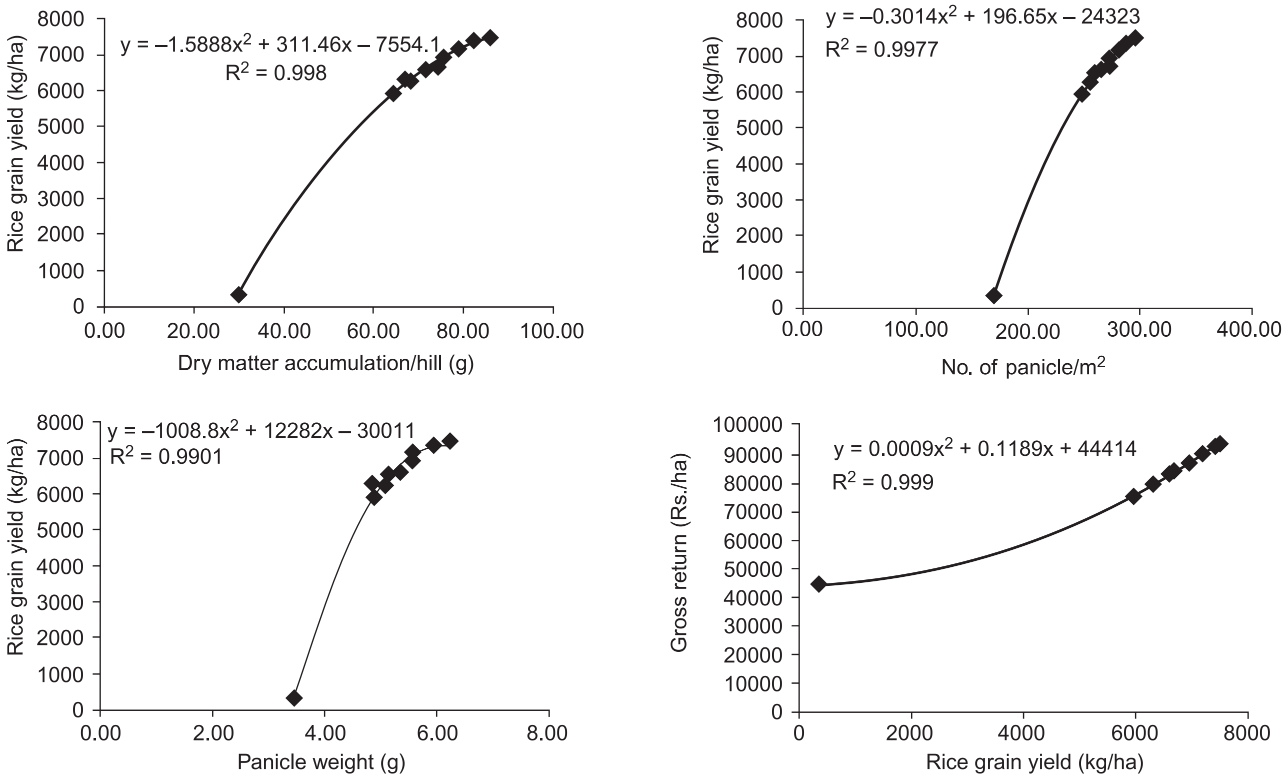

Fig 1 Relationship between dry matter accumulation/hill (g), no. of panicles/m^2 and panicle weight (g) with grain yield and economics of rice under different age of seedlings, cultivars and weed management (mean of two years data)

panicles/m^2 and panicle weight of rice had significant improvement in grain yield due to production of more grain per unit land area that might be obtained higher gross return. Dry matter accumulation/hill (g), no. of panicles/m^2 and panicle weight (g) polynomially related to grain yield of rice with coefficient of determination (R^2= 0.998, R^2= 0.997 and R^2= 0.990, respectively). In the same way significant correlation was also found between grain yield and gross return (R^2=0.999). It showed that with the increase of yield attributing characters under various age of seedlings, cultivars and weed management might have caused improvement in grain yield and ultimately results in higher gross return (Fig 1).

Thus, it concluded that transplanting of younger age seedling (10 days) of hybrid rice (PHB 71) with cono-weeding four times at 10, 20, 30 and 40 DAT under SRI can produced higher growth and yield attributes but in terms of economics, sequential application of pre and post-emergence herbicides, i e pretilachlor + bispyribac-Na proved cost effective rice production on long term basis to meet future projected need of the country.

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