

Effect of non-chemical weed management and planting geometry on weed growth, yield and economics in dry direct-seeded rice (*Oryza sativa*) cultivars

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ABSTRACT

A field experiment was conducted during the rainy (*khari*) seasons of 2015 and 2016 Varanasi, Uttar Pradesh, to study the effect of non-chemical weed management and planting geometry on weed growth, yield and profitability of dry direct-seeded rice (*Oryza sativa* L.) cultivars. The experiment consisted of 2 planting geometry (Seed drill sown crop and square planting), 2 cultivars ('Arize 6444' and 'PHB 71') and 5 non-chemical weed management treatments (weedy, 1 hoeing at 12 DAS *fb* hand-weeding at 30 DAS, 1 hoeing at 12 @ DAS *fb* *Sesbania* incorporated at 45 DAS, 1 hoeing at 12 DAS *fb* straw mulching @ 4 t/ha *fb* hand-weeding at 40 DAS, 1 hoeing at 12 DAS *fb* straw mulching (6 t/ha). Square planting recorded lower weed biomass, higher weed-control efficiency, grain yield (4.19 t/ha) and net returns (₹41,605.57/ha). Rice cultivar 'Arize 6444' also recorded lower weed biomass, higher weed-control efficiency, higher grain yield (4.24 t/ha) and net returns (₹42,256.73 /ha). One hoeing at 12 DAS *fb* hand weeding at 30 DAS reduced weed growth and increased weed-control efficiency, grain yield (4.85 t/ha) and net returns (₹57,018.94 /ha).

Key words: Cultivar, Dry direct-seeded rice, Non-chemical weed-management, Planting geometry

Irrigated rice occupies more than 50% of world rice area meeting more than 75% of global rice requirement (FAO, 2007). Unfortunately, this most important rice ecosystem is being increasingly endangered due to water scarcity threatening the world food security (Singh *et al.*, 2016). Increased production costs, labour shortages, increased wages, and decreased groundwater availability have resulted to switch over from traditional paddy nursery transplanting to dry direct seeding of rice (DSR) in many Asian countries, including India (Mahajan *et al.*, 2013). Direct-seeded rice needs only 34% of the total labour requirement and saves 29% of the total cost of the transplanted crop (Ho and Romli, 2000). It also allows early establishment of succeeding wheat crops, reduces methane emissions and ensures higher profit in areas with assured water supply (Balasubramanian and Hill, 2000). Apart from that, weeds are a major biotic stress in DSR, as they increase production costs and cause 40–100% yield loss (Choubey *et al.*, 2001). Weeds in DSR emerge simultaneously with germinating rice seedling, resulting in severe competition for nutrients, light, moisture and space. Herbicides are being

widely used in DSR but, with the threat of herbicide resistance and environmental pollution (Holt, 2001), interest has increased in non-chemical weed management (cultural) practices like mechanical weeding, manual weeding, *Sesbania* co-culture and straw mulching. Non-chemical weed management methods are mainly based on ecological principles which reduce weed growth and space capture by weed (Radosevich *et al.*, 1997). Mechanical weed control and hoeing may also suppress the weeds and increase grain yield in DSR (Rao *et al.*, 2007). The use of mechanical weeders is feasible only where rice is planted in rows (Chauhan, 2012). Intercropping of *Sesbania* can reduce both weed density and biomass to a great extent due to decreased light transmission through the canopy (Baumann *et al.*, 2000) as well as supply 58–79 kg N/ha when incorporated in alternate rows at 50 days of growth and increase rice growth under direct-seeded rice (Sharma and Ghosh, 2000). Application of rice straw for controlling weeds in different crops, indicated that rice straw can be used for mulching, which benefits in preventing weed growth as well as supplies organic matter for N-fixation by heterotrophic N-fixing microorganisms (Mendoza and Samson, 1999). Thus, use of rice straw as fertilizer as well as suppressing the weed growth due to its allelopathic potential can be a good approach to reduce the herbicide load.

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Crop residues are known to have a chemical (allelopathic) as well as a physical effect on the growth of subsequent crops and weeds (Mason-Sedun *et al.*, 1986).

Use of weed competitive cultivars is an attractive, low-cost strategy for controlling weed and obtaining higher yield (Andrew *et al.*, 2015). Early maturing rice cultivars and rice hybrids have a smothering effect on weeds due to their improved vigour and early crop canopy cover (Chauhan and Johnson, 2010a). Hybrids exhibit high tillering ability with droopy lower leaves that shade out weeds at early growth, and erect, thick, dark green upper leaves that enhance photosynthetic efficiency at the reproductive stage (WARDA, 1999). Changes in planting geometry and seeding rates may affect weed dynamics and resource use in crops (Khan *et al.*, 2009). The optimum spacing ensures the plant to grow in their both aerial and underground parts through efficient utilization of solar radiation and nutrients (Khan *et al.*, 2005). There is potential for growing hybrids in dry-seeded conditions if seeds can be planted at low seeding rates under wider row spacing. This will help to reduce cost of cultivation because of high cost of hybrid seeds (Chauhan and Opena, 2013).

Therefore, strategies to manage weeds in DSR should emphasize making the crop more competitive by seeding rice optimally and reducing the competitiveness of weeds by using suitable hybrid rice cultivars. Considering the above facts, the present investigation was undertaken to study the effect of non-chemical weed management and planting geometry on weed growth, grain yield and economics in dry DSR.

MATERIALS AND METHODS

A field experiment was carried out during *kharif* seasons of 2015 and 2016 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (25° 18' N, 83° 03' and 128.93 m above the mean sea-level), Uttar Pradesh. The site was well drained sandy clay loam soil, non-saline (EC 0.21 and 0.20 dS/m) with pH 7.49 and 7.52 (1:2.5 soil : water) and contained 0.46% and 0.48% organic carbon, low in available N (180.21 and 182.67 kg/ha), medium in available P (22.12 and 22.85 kg/ha) and medium in available K (216.5 and 218.86 kg/ha) during 2015 and 2016, respectively. The weekly mean maximum temperature, during the period of crop growth of both years ranged from 24.6 to 42.6°C (2015) and 25.4 to 41.0°C (2016). The weekly mean minimum temperature varied 29.8°C–16.2°C (2015) and 29.9°C–11.7°C (2016) while total rainfall received was 881.3 mm (2015) and 1,192.2 mm (2016). The experiment was laid out in a split-plot design consisting of 20 treatment combinations. Two spacing (S_1 , rice seed (30 kg/ha) was sown by tractor drawn zero till seed drill at row spacing of 18.5 cm apart; S_2 , 25 cm × 25 cm rice seed was

sown at the rate of 12 kg/ha by *kudal* manually at a 25 cm × 25 cm row-to-row and plant-to-plant spacing) and 2 cultivars (V_1 , 'Arize 6444'; V_2 , 'PHB 71') were assigned in main plot and 5 non-chemical weed management treatments in subplot, viz. W_1 , weedy; W_2 , 1 hoeing at 12 days after sowing (DAS) *fb* hand weeding at 30 DAS; W_3 , 1 hoeing at 12 DAS *fb* *Sesbania* co-culture and incorporated at 45 DAS (*Sesbania* was sown between inter-row spaces after hoeing at 12 DAS at seed rate of 25 kg/ha and incorporated manually at 45 days after sowing); W_4 , One hoeing at 12 DAS *fb* straw mulching @ 4 t/ha *fb* hand-weeding at 40 DAS; W_5 , 1 hoeing at 12 DAS *fb* straw mulching @ 6 t/ha were taken and was replicated thrice.

The field was ploughed and leveled before start of monsoon, thereafter, rice seeds were sown on 22 June 2015 and 28 June 2016 during first and second year respectively. Irrigation was applied for proper germination after sowing the rice seeds. Uniform dose of nitrogen (150 kg/ha), P_2O_5 (60 kg/ha) and K_2O (60 kg/ha) were applied in all plots through urea (46% N), di-ammonium phosphate (46% P_2O_5 and 18% N) and muriate of potash (60% K_2O) respectively. Half dose of nitrogen, full dose of phosphorous and potassium were applied basal and remaining nitrogen was applied in 2 equal splits at tillering and panicle-initiation stages. One uniform hoeing was done 12 days after sowing with hand hoe in all the plots except weedy. Standard practices were followed to record biometrical observations and yield. Gross return/ha was calculated on the basis of current minimum support price declared by government for prevailing season. The net returns was calculated as:

$$\text{Net returns (₹/ha)} = \text{Gross returns (₹/ha)} - \text{Cost of cultivation (₹/ha)}$$

The weed biomass of grasses, sedges and broad leaf weeds were recorded at 90 DAS from the uprooted weeds falling in quadrat (1 m × 1 m) placed at 2 randomly selected spots in each plot. The samples were first sun dried and then dried in oven at 70°C until samples obtained constant weight. Weed biomass data were subjected to square root transformation ($x+0.5$) before statistical analysis. Weed-control efficiency (WCE) was calculated using the weed biomass data in various treatments as suggested by Mani *et al.* (1973).

$$\text{WCE} = \frac{\text{WDMc} - \text{WDMt}}{\text{WDMc}} \times 100$$

where WDM_c, weed biomass (g/m²) in control plot; WDM_t, weed biomass (g/m²) in treated plot.

All observed data were subjected to statistical analysis as per standard procedure (Gomez and Gomez, 1984), to draw a valid conclusion and data were averaged over 2 years.

RESULTS AND DISCUSSION

Relative composition of weed flora

The relative composition of major weed flora among grasses were *Cynodon dactylon* (11.17 and 11.07 %), *Echinochloa colona* (11.13 and 11.16%) and *Echinochloa crus-galli* (8.36 and 8.30%) among sedges; *Cyperus iria* (9.24 and 9.90%), *Cyperus difformis* (8.17 and 8.28%), *Fimbristylis miliacea* (12.83 and 11.48%) and among broad-leaf weeds; *Ammannia baccifera* (11.76 and 11.57%), *Caesulia axillaris* (8.73 and 9.04%); and *Phyllanthus fraternus* (9.70 and 9.93%) among grasses during both the years.

Weed biomass

Square planting recorded significantly lesser weed biomass of grasses, sedges and broad-leaf weeds as compared to the seed drill sown crop (Table 1). This might be due to optimum space available for crop growth which suppressed weed growth. Similar findings were also reported by Nichols *et al.* (2009). Rice cultivar 'Arize 6444' recorded significantly lesser weed biomass of grasses, sedges and

broad leaf weed than 'PHB 71' during 2015 as well as 2016. This might be due to higher weed suppression potential of 'Arize 6444' cultivar. Similar findings were also reported by Tuong *et al.* (2000). Amongst weed management practices, 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS recorded significantly lowest weed biomass of grasses, sedges and broad leaf weeds at 90 DAS. This might be due to removal of weed at critical crop–weed competition period that increased early canopy development of crop and reduced weed growth. Similar findings were also reported by Johnson *et al.* (2004).

Weed-control efficiency

Higher weed-control efficiency was recorded in case of square planting and 'Arize 6444' during both the years. This might be due to higher weed suppression ability and reduced weed biomass in these treatments. Amongst weed management methods, 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS recorded the highest weed-control efficiency followed by 1 hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS during both the years (Table 1).

Table 1. Effect of planting geometry, cultivars and weed management on weed biomass and weed-control efficiency in dry direct seeded rice (average data of 2 years)

Treatment	Grasses	Sedges	Broad leaf weed	Weed-control efficiency (%)
<i>Planting geometry</i>				
18.5 cm (Seed drill sown crop)	14.66 (218.87)	11.03 (124.88)	11.29 (131.66)	37.03
25 cm × 25 cm (Square planting)	13.70 (191.42)	10.22 (107.77)	10.26 (110.26)	40.02
SEm±	0.06	0.04	0.07	
CD (P=0.05)	0.18	0.12	0.20	
<i>Cultivar</i>				
'Arize 6444'	13.91 (197.13)	10.37 (110.64)	10.50 (115.25)	39.19
'PHB 71'	14.45 (213.16)	10.88 (121.68)	11.05 (126.66)	37.86
SEm±	0.06	0.04	0.07	
CD (P=0.05)	0.18	0.12	0.20	
<i>Weed management</i>				
Weedy check	17.44 (304.13)	13.80 (190.10)	14.98 (224.39)	0.00
Hoeing at 12 DAS <i>fb</i> hand weeding at 30 DAS	11.44 (130.67)	7.99 (63.60)	8.88 (78.92)	62.09
Hoeing at 12 DAS <i>fb</i> <i>Sesbania</i> incorporated at 45 DAS	12.97 (168.29)	9.81 (96.23)	9.38 (88.01)	51.09
Hoeing at 12 DAS <i>fb</i> straw mulching 4 t/ha <i>fb</i> hand weeding at 40 DAS	15.17 (230.31)	11.24 (126.00)	10.52 (110.57)	35.11
Hoeing at 12 DAS <i>fb</i> straw mulching 6 t/ha	13.87(192.35)	10.29(105.68)	10.14(102.71)	44.32
SEm±	0.07	0.04	0.06	
CD (P=0.05)	0.19	0.11	0.16	

DAS, Days after sowing; *fb*, followed by.

Biomass accumulation and nutrient addition by *sesbania* incorporation

Sesbania added on an average 1,400 kg/ha (on dry weight basis) biomass to soil incorporated at 45 DAS and 28.14 kg N/ha, 1.848 kg P/ha, 30.044 kg K/ha were added in the soil.

Yield attributes and yield

The yield attributes, viz. number of panicles/m², panicle length (cm), panicle weight (g), number of grains/panicle, were higher in square planting geometry as compared to seed drill sown crop (Table 2). This might be due to efficient utilization of nutrients and available resources due to lesser weed competition which increased number of panicles/m². The plants grown with wider spacing might have optimum rhizospheric area to draw nutrition and capture solar radiation. Similar findings were also reported by Sonboir *et al.* (2017). Number of unfilled spikelets/plant was higher in seed drill sown crop as compared to square planting. This might be due to lower resources availability, higher weed competition and higher intra and inter-plant competition.

Rice cultivar 'Arize 6444' recorded significantly higher values of yield attributing characters, viz. number of panicles/m², panicle length (cm), panicle weight (g), number of grains/panicle as compared to 'PHB 71' during both the years. These findings are also in conformity with Raj *et al.* (2017). However, number of unfilled spikelets/plant was higher in 'PHB 71' as compared to 'Arize 6444'. This might be due to less competitive nature of 'PHB 71' than 'Arize 6444'.

Maximum panicles/m² were observed in 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS which was at par with hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS and 1 hoeing at 12 DAS *fb* straw mulching @ 6 t/ha during both the years. However, panicle length, panicle weight and number of grains/panicle were higher in 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS and were at par with hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS during both the years. Hand weeding and *Sesbania* co-culture at critical crop growth period reduced weed growth and increased performance of yield attributes. Similar findings were also reported by Chongtham *et al.* (2016) and Maity and Mukherjee (2008). However, number of unfilled

Table 2. Effect of planting geometry, rice cultivars and weed management on yield attributes in dry direct seeded rice (average data of 2 years)

Treatment	Panicles/ m ²	Panicle length (cm)	Panicle weight (g)	No. of grains/ panicle	No. of unfilled spikelets/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (₹/ha)
<i>Planting geometry</i>									
18.5 cm (Seed drill sown crop)	294.36	22.95	3.17	139.25	30.69	23.00	3.89	5.01	35,117.0
25 cm × 25 cm (Square planting)	317.16	24.77	3.91	149.80	27.36	23.35	4.19	5.45	41,605.5
SEm±	4.64	0.38	0.07	2.01	0.44	0.23	0.05	0.08	997.4
CD (P=0.05)	14.30	1.17	0.23	6.21	1.34	NS	0.15	0.24	3,073.29
<i>Cultivar</i>									
'Arize 6444'	317.19	25.15	3.85	149.47	27.97	23.24	4.24	5.44	42,256.7
'PHB 71'	294.32	22.57	3.23	139.58	30.08	23.11	3.83	5.02	34,465.9
SEm±	4.64	0.38	0.07	2.01	0.44	0.23	0.05	0.08	997.4
CD (P=0.05)	14.30	1.17	0.23	6.21	1.34	NS	0.15	0.24	3,073.29
<i>Weed management</i>									
Weedy	173.75	20.00	2.63	105.94	37.23	22.36	2.16	2.87	11,278.7
Hoeing at 12 DAS <i>fb</i> hand weeding at 30 DAS	356.03	26.63	4.34	162.98	23.01	23.92	4.85	6.19	57,018.9
Hoeing at 12 DAS <i>fb</i> <i>Sesbania</i> incorporated at 45 DAS	347.50	26.09	3.98	157.47	25.43	23.50	4.68	6.01	56,425.2
Hoeing at 12 DAS <i>fb</i> straw mulching 4 t/ha <i>fb</i> hand weeding at 40 DAS	313.84	22.22	3.19	145.15	32.23	22.96	4.05	5.35	31,958.60
Hoeing at 12 DAS <i>fb</i> straw mulching 6 t/ha	337.66	24.36	3.57	151.10	27.22	23.14	4.46	5.72	35,125.1
SEm±	4.29	0.39	0.09	1.85	0.48	0.26	0.04	0.09	837.83
CD (P=0.05)	12.11	1.10	0.24	5.22	1.36	NS	0.12	0.25	2,367.04

DAS, Days after sowing; *fb* followed by; Price: Rice grain, 1,550 ₹/q (Department of Agriculture and cooperation, Directorate of Economics and Statistics); rice straw, 300 ₹/q; NS, non-significant.

spikelets/plant was higher in weedy check during both the years.

Grain and straw yields

The grain and straw yields were significantly higher in square planting than seed drill sown crop (Table 2). The higher yield in wider plant spacing might be due to lower weed competition and higher number of effective tillers/m² and number of filled grains/panicle. Square planting had uniform plant population with precise cropping geometry that helped in better tillering and more number of filled grains/panicle. Grain and straw yields were significantly higher in 'Arize 6444' cultivar than 'PHB 71'. This might be due to better performance of growth and yield attributing characters of 'Arize 6444' and was found more competitive against weeds than 'PHB 71'. Similar findings were also reported by Raj *et al.* (2017).

Among weed management treatments 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS recorded the maximum grain and straw yields, significantly superior to rest of the weed management treatments except 1 hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS during both the years. Hoeing followed by hand weeding at critical crop growth period might have increased performance of yield attributes and yield of rice crop. *Sesbania* incorporation resulted in addition of 28.14 kg N/ha to soil. Concurrent growing of *Sesbania* also smothered weed growth due to shading effect and decreased transmission of light through canopy (Baumann *et al.*, 2000). Lower weed competition and higher values of yield attributes were recorded in these weed management treatments which ultimately increased grain and straw yields.

Interaction effect on grain yield

Interaction effect (Table 3) of planting geometry and weed management treatments revealed that square planting

and 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS recorded the maximum grain yield which was significantly superior to rest of the treatment combinations except seed drill sown crop and 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS, and square planting and 1 hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS during both the years. Optimum planting geometry helped to capture more space by crop and maximized crop growth by availability of all resources and lower weed competition. *Sesbania* coculture and incorporation not only reduced weed growth but also increased yield by supplying nutrient specially nitrogen to crop plant. Similar findings were also reported by Pathak *et al.* (2011).

Interaction effect (Table 3) of cultivars and non-chemical weed management treatments revealed that the maximum grain yield was recorded with rice cultivar 'Arize 6444' and 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS interactions, and remained at par with 'Arize 6444' and 1 hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS. This might be due to mechanical weeding at critical growth period followed by *Sesbania* incorporation at 45 DAS reduced weed growth and increased rapid canopy development of 'Arize 6444' which increased grain yield in respective treatment combinations.

Net return

Square planting recorded maximum net return of 41,605.5 (Table 2). In case of cultivars, 'Arize 6444' recorded maximum net returns. This could mainly be owing to lesser cost of cultivation, and higher grain and straw yields under this treatment which led to maximum net returns. Higher net returns was obtained with hoeing at 12 DAS *fb* hand weeding at 30 DAS were statistically at par with that obtained with hoeing at 12 DAS *fb* *Sesbania* incorporated at 45 DAS, i.e. 56,425.2. The higher net return under this treatment was mainly owing to reduced weed

Table 3. Interaction effect of planting geometry and cultivar with non-chemical weed-management on grain yield of dry direct-seeded rice

Treatment/Weed management	Planting geometry		Cultivars	
	S ¹ , 18.5 cm (Seed drill sown crop)	S ² , 25 cm × 25 cm (Square planting)	V ₁ , 'Arize 6444'	V ₂ , 'PHB 71'
W ₁ , Weedy	1.84	2.47	2.27	2.05
W ₂ , Hoeing at 12 DAS <i>fb</i> hand-weeding at 30 DAS	4.74	4.95	5.13	4.56
W ₃ , Hoeing at 12 DAS <i>fb</i> <i>Sesbania</i> incorporated at 45 DAS	4.59	4.78	4.96	4.40
W ₄ , Hoeing at 12 DAS <i>fb</i> straw mulching @ 4 t/ha <i>fb</i> hand-weeding at 40 DAS	3.94	4.16	4.15	3.95
W ₅ , Hoeing at 12 DAS <i>fb</i> straw mulching @ 6 t/ha	4.35	4.57	4.71	4.20
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
W at same levels of S/V	0.059	0.167	0.059	0.167
S/V at same or different levels of W	0.073	0.215	0.073	0.215

management cost and more grain yield.

It can be concluded that rice cultivar 'Arize 6444', square planting and either weed management by 1 hoeing at 12 DAS *fb* hand weeding at 30 DAS or 1 hoeing at 12 DAS *fb* *Sesbania* co-culture and incorporated at 45 DAS may be recommended to obtain effective and economical weed control, higher yield and net returns in dry direct seeded condition for Varanasi region of Uttar Pradesh.

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