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Weed suppression ability and yield performance of rainy season rice varieties under different planting spacing

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ABSTRACT

An experiment was conducted during July to November 2016 at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to find out the effect of planting spacing on weed suppression ability and yield performance of some transplanted *Aman* (rainy season) rice varieties. The experiment was conducted with four newly developed mutant rice varieties viz., Binadhan-7, Binadhan-12, Binadhan-16 and Binadhan-17, and five plant spacing viz. 25cm × 20cm, 25cm × 15cm, 20cm × 20cm, 20cm × 15cm and 15cm × 15cm in a Split-Plot Design (SPD) with three replications. The lowest weed density was found with Binadhan-7 at 15 cm × 15 cm spacing while the lowest weed biomass was found with Binadhan-16 at 15 cm x 15 cm spacing. On the other hand, the highest crop biomass was found with Binadhan-7 at 25 cm x 20 cm spacing. Variety Binadhan-7 and Binadhan-17 gave higher grain yield than the other two varieties. Among the four varieties, Binadhan-7 gave the best performance in relation to grain yield. The highest grain yield of the variety Binadhan-7 was found at 20 cm × 15 cm spacing (5.38 t ha^{-1}) whereas the lowest grain yield was achieved with the Binadhan-12 at 15 cm × 15 cm spacing (2.60 t ha^{-1}). The highest weed suppression was found in Binadhan-17 while the worst performance in respect to the yield ability was noticed in Binadhan-12. The study concludes that Binadhan-7 could be transplanted at 25 cm x 15 cm or 20 cm × 15 cm spacing to obtain substantial weed control and the best grain yield in *Aman* season.

Introduction

Weeds compete with rice plants severely for space, nutrient, light and water. The extent of yield losses due to weed infestation is highly variable and it depends on the type of weed species, time of weed association with crops, weed interference period and the weed management practices used to control the weeds (Mitra *et al*., 2005). The yield losses due to weed competition in transplant *Aman* rice are about 30-40% in Bangladesh (BRRI, 2008). High competitive ability of weeds exerts a serious negative effect on crop production causing significant losses in crop yield. The maximum yield of a crop can be achieved if the field is kept weed free. Generally, two to three hand weeding is required for *aman* rice to achieve the satisfactory yield performance. Hand weeding is environmental friendly but it is cumbersome, uneconomical and becoming more difficult day-by-day due to the scarcity of agricultural labour along with high wages. The decreasing labour availability in agricultural operations is evident in recent years due to migration of landless people towards the urban areas. Different weed control strategies (cultural, manual, mechanical and chemical) are being practiced nowadays for weed management in paddy fields. The adoption of a specific method solely depends on the socio-economic conditions of the farmer, availability of technology, and technical approach of the grower (Ashraf *et al*., 2014). Manual weeding is economical under excess availability of labor at low wages, however, 'crop mimicry' of some weeds at early growth stages make this approach difficult to employ (Awan *et al*., 2015). Therefore, use of herbicides is the most effective, quick, time saving, economical and resource efficient way to control weeds in rice (Ashraf *et al*., 2014; Ahmed *et al*., 2005). However, extensive and promiscuous use of herbicides induces weed resistance, alters weed population dynamics and dominance pattern, weed population shifts, and serious implications to soil micro-biota. Sometimes, phytotoxicity of herbicide is observed which eventually led to lower yield performance (Mandal *et al*., 1995). Herbicides may cause serious agro-ecological and environmental complications that imbalance the plant-soil-environmental relationships (Chauhan, 2012). At this situation, integrated weed management (IWM) is the best way to control weeds in the most secured way (Chauhan and Johnson, 2010). Therefore, all those approaches that suppress weed growth and enhance crop competitive ability must be integrated (Chauhan and Opeña, 2012).

Weed competitiveness of rice varieties has significant impact on weed management. Thus, the knowledge on weed competitiveness of a rice variety can be an

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effective tool for weed control. Bangladesh Institute of Nuclear Agriculture (BINA) has recently developed some rice varieties through mutational breeding for growing in the rainy season. The weed competitive abilities of these varieties are not well known. Further, plant spacing is another important cultural practice which could be manipulated as a tool for weed suppression. Plant spacing regulates the solar radiation interception, canopy coverage and dry matter accumulation of rice and thus influences on weed suppression (Anwar *et al*., 2011). Wider spacing encourages weed growth because of higher resource allocation for weeds (Guillermo *et al*., 2009) while closer plant spacing restricts weed growth but reduces crop yield by intra-plant completion of crops (Sunyob *et al*., 2012). The adjustment of planting spacing in relation to the variety is important. Therefore, there is a need to optimize planting density for achieving higher weed suppression and maximizing yield of rice. With respect to the above discussion, the present study was, therefore, undertaken with a view to finding out the effect of variety and their plant spacing on weed suppression and yield performance of *Aman* rice.

Materials and Methods

Experimental site and soil

The field trial was conducted during July to November 2016 at the Agronomy Field laboratory of Bangladesh Agricultural University, Mymensingh. The experimental field is located at 24.75 ^oN latitude and 90.50 ^oE longitude at an altitude of 18 m above the mean sea level. The experimental area belongs to the agroecological zone of the Old Brahmaputra Floodplain (AEZ-9). The experimental field was a medium high land having silt loam soil (sand-20%, silt-67% and clay-13%) with particle density of 2.60 (g cc^{-1}), bulk density of 1.35 (g cc^{-1}) and pH value of 6.40. The soil contained 1.67% organic matter, 0.10 % total N, 26.0 ppm available P, 0.14 meq 100 g^{-1} available K, 13.90 ppm S and 0.5 ppm available Zn. The experimental area is under the sub-tropical climate, which is characterized by high temperature, humidity and rainfall with occasional gusty wind in the Kharif season (April – September), and moderately low temperature, humidity and scanty rainfall during the Rabi season (October – March).

Experimental treatment and design

The experiment comprised four rice varieties such as Binadhan-7 (V_1), Binadhan-12 (V_2), Binadhan-16 (V_3) and Binadhan-17 (V_4) and five plant spacing viz. 25 cm × 20 cm (S_1), 25 cm × 15 cm (S_2), 20 cm × 20 cm (S_3), 20 cm × 15 cm (S_4), and 15 cm × 15 cm (S_5), and used a split-plot design with three replications allocating the variety in main plot and plant spacing in sub-plots. The unit plot size was 4 m × 3 m. The space between blocks and plots were 1.0 m and 0.5 m, respectively.

Crop husbandry

Thirty-day old seedlings were transplanted on well puddled land on 6 August 2016 allocating two seedlings per hill. Experimental plots were fertilized with N, P_2O_5, K_2O, S, Zn and B @ 95, 23, 42, 11, 2 and 1 kg ha^{-1} through urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boron fertilizers, respectively. All fertilizers except urea were applied as basal dose. Urea was applied in three equal installments at 15, 25 and 40 days after transplanting (DAT). A pre-emergence herbicide, Pretilachlor (Commit 500 EC) was applied @ 1.0 L ha^{-1} at 4 DAT to check the weed infestation. The crop was harvested at full maturity (when 90% of the grains became golden yellow in colour). Binadhan-7 and Binadhan-16 were harvested on 25 October 2016 while Binadhan-12 and Binadhan-17 were harvested on 6 November 2016.

Data recording

Data on weed density were collected from each plot at vegetative growth stage of rice plant (45 DAT) using a 0.25 m x 0.25 m quadrate (Cruz et al, 1986). The quadrate was randomly placed lengthwise at three spots in each plot. Weeds were uprooted, washed, identified, counted, clipped to ground level and packed species wise and separately oven dried at 70 ^{o}C for 72 hours to record weed biomass. Weed density and biomass were expressed as no. m^{-2} and g m^{-2}, respectively. Weed control rating was done at 45 DAT based on visual observation using European Weed Research Society (EWRS) developed 1 to 9 scale, where, 1= total control, 9= no effect on weeds (Delchev and Barakova, 2018). Five rice hills were randomly selected from each unit plot and uprooted before harvesting for recording necessary data on growth and yield attributes. After sampling, harvesting was done from central 3.0 m x 2.0 m area of each plot to record the grain and straw yield. The harvested crop from each plot were separately bundled, properly tagged and then threshed by pedal thresher and the fresh weight of grain and straw were recorded plot-wise. The grains were cleaned and sun dried, and straws were also sun dried properly. Finally, grain and straw yields were recorded in t ha^{-1}. Grain yield was adjusted at 14% moisture content.

Statistical analysis of data

Data were compiled and tabulated for statistical analysis and then subjected to "Analysis of variance" test as per split-plot design following computer package "Statistix 10". Significant differences among means were adjudged by Tukey's HSD test at p = 0.05 using the same statistical package programme.

Results

Floristic composition of infesting weeds

Eight weed species belonging to five families were found in the experimental field. Among these weed species, three were from the family Gramineae, two from the family Cyperaceae and one each was under family Pontederiaceae, Onagraceae and Oxaledaceae (Table 1). Out of the eight weed species, two weed species, *Leersia hexandra* Swartz and *Echinochloa crusgali* (L.) occupied 74 percent of the total volume of infesting weed population, and therefore, these two grass weeds could be considered as the most dominating weeds in the experimental field.

Table 1. Infesting weed species in the experimental field at 45 days after transplanting

Sl.	Scientific name	Family	Morphological type	Life cycle	Infestation (%)
1.	*Leersia hexandra* Swartz.	Gramineae	Grass	Perennial	48.1
2.	*Echinochloa crusgali* L.	Gramineae	Grass	Annual	26.1
3.	*Paspalum scrobiculatum* L.	Gramineae	Grass	Perennial	6.5
4.	*Monochoria vaginalis* (Burn.F.)	Pontederiaceae	Broadleaved	Perennial	5.5
5.	*Fimbristylis miliaceae* L.	Cyperaceae	Sedge	Annual	4.7
6.	*Oxalis europaea* L.	Oxaledaceae	Broadleaved	Annual	4.5
7.	*Ludwigia hyssopifolia* (G. Don)	Onagraceae	Broadleaved	Annual	2.8
8.	*Scirpus juncoides* Roxb.	Cyperaceae	Sedge	Perennial	1.8

Weed density and biomass

Planting spacing and the interaction of variety and planting spacing had significant effect on weed density and biomass but variety had no significant effect on weed density. On the other hand rice variety and plant spacing had significant effect on weed and crop biomass production. The spacing 20 cm × 20 cm showed the highest weed density which was statistically similar with 25 cm × 20 cm spacing while the closest spacing (15 cm × 15 cm) had the lowest weed density (Table 3). The interactions of variety and planting spacing showed significant effect on weed biomass production. Table 2 shows that variety Binadhan-12 and Binadhan-17 had higher weed biomass (130.65 and 131.87 g m^{-2}) than other two varieties (88.03 and 78.27 g m^{-2} for Binadhan-7 and Binadhan-16). The planting spacing 20 cm × 20 cm showed the highest weed biomass (162.18 g m^{-2}) which was followed by 25 cm x 20 cm spacing (140.46 g m^{-2}). The closest spacing (15 cm × 15 cm) showed that lowest (63.08 g m^{-2}) weed biomass (Table 3). Variety Binadhan-17 at 20 cm × 20 cm spacing showed the highest density (150.7 m^{-2}) and biomass (254 g m^{-2}). Variety Binadhan-12 planted at 20 cm × 20 cm spacing showed the second highest weed density (133 m^{-2}) but the same variety at a spacing of 25 cm × 20 cm gave the second highest weed biomass (166 g m^{-2}).

Table 2. Effect of variety on weed density, weed biomass, crop biomass and visual score of weed control in transplant *aman* rice at 45 days after transplanting

Variety	Weed density (no. m^{-2})	Weed biomass (g m^{-2})	Crop biomass (g m^{-2})	Visual score for weed control
Binadhan-7	69.73	88.03b	484.00a	6.6a
Binadhan-12	88.67	130.65a	398.01b	5.7ab
Binadhan-16	65.73	78.27b	498.85a	4.8b
Binadhan-17	90.93	131.87a	388.18b	5.1b
CV (%)	33.07	21.28	13.69	23.69
$LSD_{(0.05)}$	NS	20.38	54.09	1.178

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant

Visual scoring for weed control

Weed infestation was estimated by visual observation and the result revealed that degree of weed infestation varied significantly among the varieties and due to different plant spacing but not due to the interaction between variety and plan spacing (Table 4). The highest weed control score was found with variety Binadhan-7 and the lowest with Binadhan-16 among the four varieties (Table 2). In respect to plant spacing, the highest visual score for weed control was found with 20 cm × 15 cm and lowest with 15 cm × 15 cm spacing (Table 3). The weed control scores found in other spacing's were statistically similar with that for 20 cm × 15 cm (Table 3).

Table 3. Effect of spacing on weed density, weed biomass, crop biomass and visual score of weed control in transplant *aman* rice at 45 days after transplanting

Treatment	Weed density (no. m^{-2})	Weed biomass (g m^{-2})	Crop biomass (g m^{-2})	Visual score for weed control
25 cm × 20 cm	98.83a	140.46b	453.69	6.0a
25 cm × 15 cm	65.67b	83.41c	460.17	5.8ab
20 cm × 20 cm	107.67a	162.18a	438.65	5.7ab
20 cm × 15 cm	62.33b	86.91c	426.42	5.5ab
15 cm × 15 cm	59.33b	63.08d	432.37	4.9b
CV (%)	26.81	20.09	13.56	20.42
$LSD_{(0.05)}$	17.56	17.91	NS	1.31

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant

Crop biomass production

The biomass of rice plant (crop biomass) obtained at 45 DAT was significantly affected by interaction between variety and plant spacing. The crop biomass differed significantly due to variety but not due to plant spacing. The highest crop biomass was found with Binadhan-16 (499 g m^{-2}) which was statistically similar with Binadhan-7 (484 g m^{-2}). The crop biomasses obtained in these two varieties were significantly higher than the other two varieties (Table 2).

Table 4. Effect of interaction between variety and spacing on weed density, weed biomass, crop biomass and visual scoring on weed control in transplant *aman* rice at 45 days after transplanting

Interaction	Weed density (no. m^{-2})	Weed biomass (g m^{-2})	Crop biomass (g m^{-2})	Visual score for weed control
$V_1 \times S_1$	96.00b-d	130.23de	626.81a	6.33
$V_1 \times S_2$	56.00e-g	34.07ij	505.81bcd	4.33
$V_1 \times S_3$	88.00c-f	142.13bcde	388.64efgh	5.00
$V_1 \times S_4$	60.67d-g	90.33fgh	452.16bcdef	3.33
$V_1 \times S_5$	48.00g	43.37ij	446.57bcdefg	6.33
$V_2 \times S_1$	100.67bc	172.19b	343.57gh	6.66
$V_2 \times S_2$	76.00c-g	110.09efg	347.29gh	6.33
$V_2 \times S_3$	133.33ab	165.68bcd	500.76bcd	7.33
$V_2 \times S_4$	58.67d-g	70.33hi	351.91fgh	5.00
$V_2 \times S_5$	74.67c-g	134.97cde	446.53bcdefg	7.33
$V_3 \times S_1$	86.67b-e	90.75fgh	468.21bcde	5.33
$V_3 \times S_2$	57.33d-g	62.15hi	548.13ab	6.00
$V_3 \times S_3$	58.67d-g	86.17gh	525.35abc	6.66
$V_3 \times S_4$	75.33c-g	139.75bcde	496.29bcd	4.00
$V_3 \times S_5$	50.67fg	12.56j	456.24bcde	4.33
$V_4 \times S_1$	112.00a-c	168.68bc	376.17efgh	7.00
$V_4 \times S_2$	73.33c-g	127.32ef	439.44cdefgh	6.33
$V_4 \times S_3$	150.67a	254.72a	339.87h	6.33
$V_4 \times S_4$	54.67e-g	47.23ij	405.31defgh	5.00
$V_4 \times S_5$	64.00d-g	61.40hi	380.12efgh	5.33
CV (%)	13.62	20.09	13.56	27.61
$LSD_{(0.05)}$	2.19	35.82	104.03	NS

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant (V_1 = Binadhan-7 , V_2 = Binadhan-12, V_3 = Binadhan-16, V_4 = Binadhan-17; S_1 = 25cm × 20cm, S_2 = 25cm × 15cm, S_3 = 20cm × 20cm, S_4 = 20cm × 15cm S_5 = 15cm × 15cm)

The variety Binadhan-7 transplanted at 25 cm × 20 cm gave the highest crop biomass (627 g m^{-2}) which was similar with Binadhan-16 transplanted at 25 cm × 15 cm (548 g m^{-2}) and 20 × 20 cm (525 g m^{-2}). The lowest crop biomass was found with Bindhan-17 transplanted at 20 cm × 20 cm (Table 4). The result explicitly reveals that Binadhan-7 and Binadhan-16 produced higher crop biomass than the other two varieties. The result shows that the biomass production for Binadhan-7 was the highest at 25 × 20 cm while the highest values for Binadhan-16 were at 25 × 15 cm and 20 × 20 cm spacing (Table 4).

Growth and yield related attributes of rice

Plant height did not vary significantly due to variety, planting spacing and their interaction. On the other hand, number of total and effective tillers varied significantly due to variety and planting spacing but not by their interaction (Table 5). Binadhan-7 produced the highest number of total (11 $hill^{-1}$) and effective tillers (10 $hill^{-1}$) which was statistically similar with Binadhan-16 but significantly higher than other two varieties (Table 5). The crop planted at 25 cm × 20 cm produced the highest number of total and effective tillers $hill^{-1}$ while at 15 cm × 15 cm produced the lowest number of total and effective tillers $hill^{-1}$. Binadhan-12 produced the highest number of grains $panicle^{-1}$ (330 $panicle^{-1}$) while Binadhan-16 produced the lowest (169 $panicle^{-1}$). The thousand-grain weight was highest with Binadhan-16 (23.72 g) and lowest with Binadhan-12 (12.56 g). Number of grains $panicle^{-1}$ did not differ significantly due to planting spacing while thousand-grain weight differed significantly. The highest value of thousand-grain weight was obtained with 25 cm × 20 cm (19.14 g) while all other spacing produced significantly lower grain weight (Table 6).

Grain yield of rice

Variety, planting spacing and their interaction were significant for rice grain yield. Table 7 showed that the variety Binadhan-7 planted at 20 cm × 15 cm produced the highest grain yield (5.38 t ha^{-1}) which was at par with the same variety at 25 cm × 15 cm spacing (4.90 t ha^{-1}). On the other hand, Binadhan-17 produced grain yield of 4.94 t ha^{-1} at 15 cm x 15 cm, 4.69 t ha^{-1} at 25 cm × 15 cm and 4.69 t ha^{-1} at 20 cm × 15 cm spacing. The lowest yield (2.68 t ha^{-1}) was found with Binadhan-16 at 20 cm × 15 cm spacing. Considering varietal effect, the highest grain yield was found with variety Binadhan-17 (4.51 t ha^{-1}) which was statistically similar with Binadhan-7 (4.38 t ha^{-1}) and the lowest yield was recorded from Binadhan-16 (2.95 t ha^{-1}) as shown in table 5. Over the range of plant spacing's, the highest grain yield was found with crop planted at 20 cm × 15 cm (4.06 t ha^{-1}) while the lowest grain yield (3.41 t ha^{-1}) was observed in the spacing 25 cm × 20 cm (Table 6).

Discussion

Floristic composition of infesting weed

The weed species found in this experimental field are more or less common in most T. aman rice fields. The three-weed species *Leersia hexandra* Swartz, *Echinochloa crusgall* (L.) and *Paspalum scrobiculatum* L belonging to the gramineae family occupied about 80% of the total infesting weed population. Similar to the present study, Hasanuzzaman *et al*. (2008) found that about 75% infesting weeds belonged to Gramineae family in transplanted rice. On the other hand, Anwar *et al*. (2012) reported dominance of broadleaf weeds in their experimental rice field. They reported that broadleaved weeds are commonly found in transplanted *Aman* rice field which depresses crop yield significantly if not timely controlled (Hia *et al*., 2017). Khan *et al*. (2017) reported that nine weed species belonging to five families namely, Pontederiaceae, Cyperaceae, Gramineae, Marsileaceae and Onagraceae were found to infest the crop field. They reported that the five top most weed species were *Monochoria hastate* (39.54%), *Scirpus mucronatus* (23.21%), *Echinochloa crusgalli* (13.77%), *Panicum repens* (10.89%), *and Ludwigia prostrata* (3.40%). They also reported that the weed community was mostly dominated by broadleaf weeds (45%), while sedges and grasses contributed equally in their experimental field. Thus, research reports suggest that the weed species vary with the land type and other factors in *Aman* season.

Table 5. Effect of variety on growth characters, yield related attributes and yield of transplanted *aman* rice

Variety	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of filled grains panicle^{-1}	Thousand- grain weight (g)	Grain yield (t ha^{-1})
Binadhan-7	99.47	11.06a	10.12a	197.20b	20.048b	4.38a
Binadhan-12	101.11	7.38b	6.77c	329.60a	12.564d	2.99b
Binadhan-16	96.75	9.74a	8.70ab	168.80b	23.729a	2.95b
Binadhan-17	98.10	8.02b	7.56bc	191.33b	18.965c	4.51a
CV (%)	4.36	19.09	23.01	22.32	2.03	12.11
$LSD_{(0.05)}$	NS	1.54	1.70	44.26	0.34	0.40

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant

Table 6. Effect of planting spacing on growth characters, yield related attributes and yield of transplanted *aman* rice

Treatment	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of filled grain panicle^{-1}	Thousand grain weight (g)	Grain yield (t ha^{-1})
25cm × 20cm	99.72	10.21a	9.45a	223.00	19.147a	3.41b
25cm × 15cm	99.65	9.15ab	8.40b	230.58	18.762b	4.02a
20cm × 20cm	98.82	9.55ab	8.66ab	219.42	18.798b	3.58b
20cm × 15cm	98.81	8.63bc	8.05b	215.50	18.795b	4.06a
15cm × 15cm	97.26	7.73c	6.88c	220.17	18.632b	3.47b
CV (%)	2.62	19.09	13.72	14.07	1.22	11.64
$LSD_{(0.05)}$	NS	1.08	0.94	NS	0.19	0.35

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant

Table 7. Effect of interaction between variety and planting spacing on growth characters, yield related attributes and yield of transplanted *aman* rice

Interaction	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of filled grains panicle^{-1}	Thousand -grain weight (g)	Grain yield (t/ha)
$V_1 \times S_1$	99.04	11.46	10.80	213.33	20.88c	4.00cdef
$V_1 \times S_2$	102.42	12.00	10.86	187.33	19.72de	4.90ab
$V_1 \times S_3$	97.63	12.00	11.00	185.00	19.36e	4.24bcde
$V_1 \times S_4$	100.96	10.00	9.40	190.33	19.44de	5.38a
$V_1 \times S_5$	97.29	9.86	8.53	210.00	20.84c	3.38fghi
$V_2 \times S_1$	103.38	9.13	8.46	314.33	12.26j	2.90hij
$V_2 \times S_2$	99.29	6.40	6.00	325.33	12.32j	3.15ghij
$V_2 \times S_3$	102.79	7.80	6.86	323.33	12.72i	2.82hij
$V_2 \times S_4$	100.33	7.33	7.00	348.67	13.16h	3.49efgh
$V_2 \times S_5$	99.75	6.26	5.33	336.33	12.36ij	2.60j
$V_3 \times S_1$	96.88	10.73	9.73	191.00	23.56b	2.94hij
$V_3 \times S_2$	96.58	10.46	9.20	186.67	23.72ab	3.26fghij
$V_3 \times S_3$	98.46	10.46	9.40	172.33	23.83ab	2.90hij
$V_3 \times S_4$	96.58	9.06	8.00	146.33	24.03a	2.68ij
$V_3 \times S_5$	95.25	8.00	7.20	147.67	23.48b	2.95hij
$V_4 \times S_1$	99.63	9.53	8.80	173.33	19.88d	3.80defg
$V_4 \times S_2$	100.33	7.73	7.53	223.00	19.28e	4.75abc
$V_4 \times S_3$	96.42	7.93	7.40	197.00	19.28e	4.36bcd
$V_4 \times S_4$	97.37	8.13	7.80	176.67	18.54f	4.69abc
$V_4 \times S_5$	96.75	6.80	6.26	186.67	17.84g	4.94ab
CV (%)	2.62	79.30	26.81	14.07	1.22	11.64
$LSD_{(0.05)}$	NS	NS	NS	NS	0.48	0.75

Figures in a column having common letters do not differ significantly at 5% level of significance, CV(%) = Coefficient of variation, NS = Not significant (V_1 = Binadhan-7 , V_2 = Binadhan-12, V_3 = Binadhan-16, V_4 = Binadhan-17; S_1 = 25cm × 20cm, S_2 = 25cm × 15cm, S_3 = 20cm × 20cm, S_4 = 20cm × 15cm S_5 = 15cm × 15cm)

Weed density and biomass

Weed density and biomass was the highest with 20 cm x 20 cm spacing and the lowest was found with 15 cm × 15 cm. It was also noted that 20 cm x 20 cm spacing showed the higher weed density and biomass than those for 25 cm x 20 cm spacing. The present study shows that the weed density and biomass decreased with decrease in plant spacing and vice versa. It is also evident that the crop planted at square arrangement (20 cm x 20 cm) are subjected to more weed pressure than those planted at rectangular arrangement (25 cm x 20 cm). The crop develops canopy rapidly under higher population densities at narrower spacing and suppresses weeds more effectively while weed growth encouraged in widely spaced plants (Guillermo *et al*., 2009). Thus, higher planting density should be maintained for better weed competitiveness for rice (Anwar *et al*., 2011).

The plots planted at 20 cm × 20 cm had higher weed density (8.2%) and biomass (13.4%) than those planted at 25 cm × 20 cm. The area per hill was higher at 25 cm × 20 cm spacing but the weed density and biomass was higher at 20 cm × 20 cm. The higher weed pressure at 20 cm × 20 cm over 25 cm × 20 cm could be attributed to the differences in planting geometry between two spacing. The spacing 25 cm × 20 cm is a rectangular pattern while 20 cm × 20 cm is a square pattern. The square pattern allows more light interception to the soil that encourages more weed growth compared with the rectangular pattern (Lu *et al*., 2020). It was also found that between the two square patterns, wider spacing (20 cm x 20 cm) had more weed density and biomass while closer spacing (15 cm × 15 cm). Similar result was also observed by different researcher who reported that weed pressure reduced at closer spacing (Ali *et al.,* 2008, Anwar *et al*., 2011, Ashraf *et al.,* 2014, Shinggu *et al.,* 2009). It is obvious that the closer spacing increases weed suppression but it hampers intercultural operations and increases competition among the plants for nutrients and light that leads to the production of weaker plants and consequently reduces yield. The wider plant spacing provides a congenial environment for weeds to germinate and grow and may enhance the survival and fecundity of weeds (Phuong *et al*., 2005; Anwar *et al.,* 2011) while closer spacing keeps the weed flora under check through smothering effect (Mahajan *et al*., 2010).

Crop biomass and grain yield

The highest grain yield was found at the plant spacing 20 cm × 15 cm for Binadhan-7 which was similar with 25 cm × 15 cm for same variety. Statistically similar yield was produced from Binadhan-17 at 25 cm × 15 cm, 20 cm × 15 cm and 15 cm × 15 cm spacings. Thus, the result indicates that 25 cm × 15 and 20 cm × 15 cm is better for obtaining grain yield than 20 cm x 20 cm crop. Thus, present study confirms that plant spacing directly affects the normal physiological activities as well as yield of rice (Oad *et al*., 2001). The optimum spacing and weed free condition provides the minimum intra- and inter-plant competition for natural resources among the plants and consequently resulted in maximum number of effective tillers hill^{-1} and grains panicle^{-1} responsible for the highest grain yield. Probably the closer spacing made the field over populated that maximized the intra-species competition among the crop plants. Malek *et al*. (2016) found the highest yield with 20 cm × 15 cm spacing in aus rice BRRI dhan26. Bozorgi *et al.* (2011) studied three levels of plant spacings i.e., 15 × 15, 20 × 20, and 25 × 25 cm and found the highest grain yield at 15 cm × 15 cm. However, the present study showed that narrow plant spacing in rice significantly reduced weed pressure and weed dry biomass but failed to increase yield. Nonetheless, Sultana *et al*. (2012) and Alam *et al*. (2012) found the highest rice yield at 25 cm x 15 cm spacing which supports the result of the present study. Hossain *et al.* (2003) obtained highest grain yield of rice with 25 × 15 cm spacing and reported that this yield was reduced by 52% with 25 x 25 cm, 29% with 20 cm x 20 cm and 19% with 15 cm x 15 cm spacing. In the present study, higher rice yield was obtained at 25 cm x 15 cm and 20 cm × 15 cm than at 20 cm × 20 cm irrespective of the variety. The higher grain yield at 25 cm × 15 cm and 20 cm x 15 cm compared to at 20 cm × 20 cm spacing could attributed to the fact that the crop at 20 cm × 20 cm spacing was much prone to higher weed pressure and that consequently reduced the yield.

Conclusion

The rice varieties showed their differential weed suppression ability and the weed suppression increased as the crop was planted at closer spacing. On the other hand, the yield of rice decreased at a closer spacing. Among the four varieties, Binadhan-7 and Binadhan-16 showed more weed suppression than Binadhan-12 and Binadhan-17. However, Binadhan-7 gave the highest yield among the four varieties. Nonetheless, the highest yield of rice was obtained from transplanting of variety Binadhan-7 at 20 cm × 15 cm (5.38 t ha^{-1}) and 25 cm × 15 cm spacing (4.90 t ha^{-1}). Considering the weed suppressive ability and yield performance, Binadhan-7 could be planted at 25 cm × 15 cm or 20 cm × 15 cm spacing for realizing maximum yield of rice in *Aman* season.

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