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ORIGINAL ARTICLE

Weeding regime and plant spacing influence on weed growth and performance of transplant aman rice variety Binadhan- 7

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Plant spacing and weeding regime are amongst the key factors determining rice growth and yield through maximum utilization of space, plant nutrients, water and sunlight. Therefore, it is essential to identify optimum spacing and proper weeding regime for ensuring the potential yield of a rice cultivar. A field experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh during July- December 2012 to study the influence of spacing and weeding regime on the performance of transplant *aman* rice cv. Binadhan-7. The experiment comprised four plant spacings viz. 25 cm × 15 cm, 20 cm × 15 cm, 15 cm × 15 cm and 15 cm × 10 cm, and five weeding regimes viz. no weeding, one weeding at 15 days after transplanting (DAT), two weeding at 15 and 30 DAT, three weeding at 15, 30 and 45 DAT and weed free. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The highest weed density and dry weight were recorded with the spacing of 20 cm × 15 cm and 25 cm × 15 cm, respectively. But the lowest values were observed in the closest spacing of 15 cm × 10 cm. Plant spacing exerted significant influence on most of the plant characters except plant height and 1000-grain weight. The highest and statistically significant grain yield was obtained from 20 cm × 15 cm spacing (6.05 t ha^{-1}) and 25 cm × 15 cm spacing (6.04 t ha^{-1}) because of highest number of filled grains panicle^{-1} (143.65) and highest number of effective tillers hill^{-1} (10.13). Weeding regime also had significant effect on all the parameters except 1000-grain weight. The highest grain yield (6.29 t ha^{-1}) was obtained from the weed free condition which produced 37.33% higher yield than unweeded condition (4.58 t ha^{-1}). Interaction between plant spacing and weeding regime significantly influenced all the parameters studied except 1000-grain weight. The highest grain yield (6.71 t ha^{-1}) was obtained from the interaction between 20 cm x 15 cm spacing and three weeding regimes at 15, 30, 45 DAT which was similar to the treatment combination of 15 cm × 15 cm spacing and weed free condition. But maintaining season long weed free condition is not practical from economic view point, therefore Binadhan7 should be transplanted at 20 cm × 15 cm spacing following three times weeding at 15, 30 and 45 DAT for higher yield and effective weed control.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the leading cereals of the world (Ashraf et al., 2006), and more than 50% of world population depend on rice for their daily sustenance (Chauhan and Johnson, 2011). World rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.*, 2002), and therefore, it's a great challenge to increase rice

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production for meeting ever increasing rice demand in a sustainable way. Bangladesh has got three distinct rice seasons, namely *Aus* (April to July), *Aman (*August to December*)* and *Boro* (January to May). In 2015, annual rice production of Bangladesh was 34.6 million tons among which a*us* rice covers about 1.05 million hectare with a yield of 2.3 million ton, *aman* rice covers about 5.6 million hectare with a yield of 13.1 million ton and *boro* rice covers about 4.8 million hectare with a yield of 19.2 million ton (BBS 2015). Now-a-days, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh which is one of the most densely populated countries and the increasing rate of population is 1.34%, and her cultivable land is decreasing by about 1% per annum due to urbanization and industrialization (Hussain et al. 2006) resulting in more shortage of food. Therefore, the farmers have to produce maximum rice from minimum land by adopting various sustainable agronomic practices.

Weed is as old as agriculture, and from the very beginning farmers realized that the weed interference with crop production (Ghersa et al. 2000). Weeds are the greatest yield-limiting constraint to rice (Chauhan and Johnson 2011). Weeds compete with rice plants severely for space, nutrients, air, water and light and thus adversely affecting growth and yield of rice. Ramzan (2003) reported that weed could reduce rice yield up to 48, 53 and 74% in transplanted, direct seeded flooded and direct seeded, respectively. In tropic, average rice yield losses from weeds is 35% (Oerke and Dehne 2004). Sunil et al. (2010) stated that season-long weed competition in rice may cause yield reduction up to 80%. Jayadeva et al. (2011), on the other hand, reported complete failure of crops due to weeds in rice. However, yield loss due to weeds depends upon some variables like magnitude of weed infestation, type of weed species and weed interference period with crop (Moody and De Detta 1998). The effect of weed competition can be assessed by observing plant growth and yield reduction (Riya et al. 2017). Weeds do not compete with crops throughout the growing season but there is a critical period when weed completion results in economic yield losses (Anwar et al. 2012). Therefore, that critical period must be kept weed free through manual weeding and/or chemical control. Yeasmin et al. (2008) revealed that for obtaining maximum yield rice field should be weeded out three times at 20, 35 and 50 days after transplanting. Das et al. (2007) recorded that chemical weed control resulted in the highest rice yield followed by three hand weeding. Malek et al. (2016), on the other hand, reported that two weeding resulted in highest rice yield. However, effect of weeding regime on growth and yield performance of rice depends on many factors including growing season, weed pressure, competitiveness of variety, planting density, agronomic management and so on (Juraimi et al. 2013). Therefore, it is very important to identify proper weeding regime for effective and economic weed management.

Plant spacing is one of the key factors determining rice productivity and its weed suppressive ability. Plant spacing determines solar radiation interception, canopy coverage and dry matter accumulation of rice and thus influences its weed competitiveness (Anwar *et al.,* 2011). Optimum plant spacing ensures the proper plant growth through efficient utilization of natural resources like solar radiation, soil moisture and nutrients. As reported by Sunyob et al. (2012), closer spacing may result in mutual shading, high intra-specific competition and disease and pest infestation. But at higher plant density, canopy development is very fast which helps suppress weeds effectively and in contrast, at lower plant density, space and resources remain unutilized which encourage weed growth (Guillermo et al. 2009). Therefore, rice plant spacing must be optimized for ensuring higher rice yield and better weed suppression (Anwar et al. 2013). Optimum plant spacing for rice may vary depending upon varietal characters, growing season, planting method and agronomic management. Malek et al. (2016) conducted an experiment in aus season with rice variety BR26 grown under four different spacing and found that 20 cm × 15 cm was the best for yield attributes of rice which ultimately resulted in the highest grain yield. Planting density of 300 seeds m^{-2} for better weed suppression has been suggested by Anwar et al. (2011) for aerobic rice. Sunyob et al. (2012) also observed that 300 seeds m^{-2} successfully suppressed weed growth without sacrificing rice yield. Thus it is evident that plant spacing is very important for obtaining higher yield of rice.

In view of the above discussion, the present study was undertaken to find out how weeding regime and plant spacing influence the weed growth and yield performance of transplant *aman* rice variety Binadhan-7.

METHODOLOGY

Experimental site and soil

The experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University (BAU), Mymensingh during the period from July to December 2012. Geographically the experimental field is located at 24.75° N latitude and 90.50° E longitude at an altitude of 18 m above the mean sea level. The experimental area belongs to the agro-ecological zone of the Old Brahmaputra Floodplain (AEZ-9). The experimental field was a medium high land, and the soil was silty loam in texture with pH value of 6.8, 8.7 meq/100 g of CEC, 0.13 meq/100 g exchangeable K, 1.25% organic matter, 0.11% of total N, 16.69 ppm available P, 14.12 ppm available S and 2.6 ppm Zn (Based on the soil sample analysis done at the Department of Soil Science, BAU, Mymensingh). The experimental area was under 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). During the experimental period, average maximum and minimum temperature, relative humidity, rainfall, evaporation and sunshine hours ranged from 31.8 to 35.2 ºC, 22.6 to 24.8 ºC and 92.5 to 94.9%, 3.4 to 9.2 mm day^{-1}, 2.91 to 4.78 mm day^{-1} and 3.91 to 6.94 hrs day^{-1}, respectively (Source: Weather Yard, BAU, Mymensingh).

Experimental design and treatment

Experimental treatments included four plant spacing of rice viz., 25 cm × 15 cm, 20 cm × 15 cm, 15 cm × 15cm and 15 cm ×10 cm, and five weeding regimes viz., no weeding, one weeding at 30 days after transplanting (DAT), two weeding at 15 and 30 DAT, three weeding at 15, 30 and 45 DAT and weed free throughout the growing season. The experiment was laid out in a randomized complete block design with three replications. The net size of each unit plot was 10 m^2 (4.0 m × 2.5 m). The spaces between blocks and between plots were 1 m and 0.75 m, respectively. Each block was divided into 20 unit plots where the treatment combinations were allocated at random.

Description of the plant material

Binadhan-7, a popular transplant *aman* rice variety of Bangladesh, was used as the plant material in the experiment. Binadhan-7 was developed and released by the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh in 2007 for *aman* season. It is a high yielding (5.5-6.5 t ha^{-1}), moderate duration (110-120 days) and photosensitive variety with medium bold grains (1000 grains weight is about 24.90 g). It can tolerate water logging (up to 60 cm) and salinity (up to 8 ds m^{-1}) (BINA 2007).

Crop husbandry

Seeds of Binadhan-7were collected from the Agronomy Field Laboratory, BAU, Mymensingh. Seeds were incubated for 48 hours after soaking in water for 24 hours. Sprouted seeds were sown on a well prepared nursery bed on 8 July 2012. Water and pest management practices were followed in order to raise healthy seedlings. The experimental land was first opened on 2 August 2012 with a power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering. Weeds and stubbles were removed from the field during land preparation. Experimental plots were fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate @ 150, 110, 70, 60 and 10 kg ha^{-1}, respectively. Total amount of TSP, MoP, gypsum, zinc sulphate and of one-third urea were applied as basal dose during final land preparation. The remaining urea was top dressed in two equal splits at 30 and 45 DAT. Thirty-day old seedlings were uprooted carefully from the nursery bed and transplanted on 8 August 2012 at the rate of three seedlings hill^{-1} maintaining spacing as per experimental treatments. Weeding was done manually as per treatment. No irrigation was given as there was plenty of rainfall during the experimental period. The field was frequently observed to notice any changes in plants, pest and disease attack to the crop and necessary action was taken to ensure normal plant growth. The crop was harvested at full maturity (when 90% of the grains became golden yellow in color) on 27 November 2012.

Data collection

A 50 cm x 50 cm quadrate was randomly placed lengthwise at four spots in each plot for recording of weed data at 15, 30 and 45 DAT. Weeds were clipped to ground level, identified and counted by species, and separately oven dried at 70° C for 72 h. Total weed density and total weed dry weight were recorded and expressed as no. m^{-2} and g m^{-2}, respectively. Degree of infestation of individual weed species {Density of a given weed species/ Total weed density) × 100} was also calculated. Five rice hills were selected randomly from each unit plot and uprooted before harvesting for recording necessary data on growth and yield attributes. After sampling, the whole plot was harvested. The harvested crop of each plot was separately bundled, properly tagged and then threshed by pedal thresher, and the fresh weights 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 plot^{-1} were recorded and converted to t ha^{-1}. Grain yield was adjusted at 14% moisture content.

Statistical analysis

Data recorded for different parameters were compiled and tabulated for statistical analysis. "Analysis of Variance" was done as per randomized complete block design with the help of computer package MSTAT-C. Significant differences among means were adjudged by Duncun's Multiple Range test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Plant height and tillering ability of rice

Plant spacing showed significant effect on plant height at 30 and 60 DAT, but not at 45 and 75 DAT (Table 1). Plant height was found highest at the closest spacing at both sampling dates because of higher competition for sunlight in closer spacing. This finding is not in agreement with that of Anwar et al. (2011) who reported that rice plant height decreased with increasing seeding density. Plant height was significantly affected by the weeding regime at all the sampling dates (Table 1). The tallest plant (79.80 cm) was obtained from three weeding at 15, 30 and 45 DAT and the shortest one (67.37 cm) was found in no weeding treatment. Chowdhury et al. (1994) reported that the tallest plant was produced by weed free condition and the shortest one was found in no weeding treatment, which is in agreement with the present findings. Anwar et al. (2010) reported 12-19% reduction in plant height due to weed competition. Results revealed that plant height was greater in all weeded plots than in control plot indicating weeding at any growth stages of rice has positive effect on growth and development of rice. On the other hand, competition for nutrients and other resources between weeds and rice plants was severe in unweeded plots which resulted in reduced plant height. Similar results were also reported by Bari (2004) and Bhowmick (2005) who reported that weeding within 20 to 60 DAT resulted in superior plant growth and development in rice. Plant height was significantly influenced by the interaction between spacing and weeding regime only at 75 DAT (Table 2). The tallest plant (83.73 cm) was obtained from the interaction between 15 cm × 15 cm spacing and one weeding at 30 DAT and the shortest one (64.41 cm) was found in the interaction between 25 cm × 15 cm and no weeding treatment (Table 2).

Table 1. Effect of plant spacing and weeding regime on the plant height and tillering ability of transplant *aman* rice cv. Binadhan 7

	Plant height (cm)				No. of tillers/hill^{-1}			
Spacing	30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
S_1	30.43d	47.68	65.09b	75.10	3.54c	8.17c	10.67c	11.50c
S_2	31.73c	47.25	66.08b	76.75	4.27b	9.52b	11.56b	12.28b
S_3	32.48b	48.60	68.67a	76.33	4.69b	10.38ab	12.96a	12.85b
S_4	33.80a	50.60	71.01a	78.06	5.07a	11.71a	12.56a	13.00a
Level of significance	**	NS	**	NS	**	**	**	**
Weeding regime	30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
W_0	29.88d	45.25e	61.29c	67.37c	3.27c	7.58d	9.08d	10.49c
W_1	30.86c	47.86d	69.28ab	78.48b	4.19bc	9.20c	11.92c	12.69b
W_2	32.49b	48.27c	68.84b	78.36ab	4.50b	10.20b	12.29bc	12.28b
W_3	32.82b	49.71b	69.45a	79.80a	4.79b	11.31a	12.71b	13.05ab
W_4	34.50a	51.56a	69.71a	78.79ab	5.22a	11.45a	13.71a	13.52a
CV (%)	5.75	5.23	6.24	5.23	5.63	7.48	7.25	4.25
Level of significance	**	**	**	**	**	**	**	**

S_1= 25 cm × 15 cm, S_2= 20 cm × 15 cm, S_3= 15 cm × 15 cm, S_4= 15 cm × 10 cm; W_0= No weeding, W_1= One weeding at 30 DAT, W_2= Two weeding at 15 and 30 DAT, W_3=Three weeding at 15, 30 and 45 DAT, W_4= Weed free throughout
** Indicate significant at 1% level of probability; NS Indicates not significant; CV means co-efficient of variance.

Table 2. Interaction effect of plant spacing and weeding regime on plant height and tillering ability of transplant *aman* rice cv. Binadhan 7

Interaction	Plant height				No. of tillers/hill			
	30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
S_1W_0	28.25	40.23	58.41	64.41d	2.53i	6.12g	7.23	9.32
S_1W_1	28.33	45.50	63.80	70.41bcd	3.20h	8.06ef	11.66	12.30
S_1W_2	30.84	45.60	62.87	77.33abc	3.50h	8.39c-f	12.56	12.14
S_1W_3	31.84	52.53	69.13	81.47a	4.04g	8.96cde	10.33	11.23
S_1W_4	32.89	54.54	71.27	81.87a	4.41efg	9.31cd	11.55	12.53
S_2W_0	30.20	42.75	61.12	65.46d	3.19h	7.42f	9.43	10.00
S_2W_1	30.87	44.48	71.52	80.71a	4.55ef	8.24def	11.48	12.19
S_2W_2	31.33	46.07	63.72	74.45abc	4.36efg	8.78cde	10.57	11.52
S_2W_3	32.30	49.12	67.80	80.67a	4.45efg	11.60ab	12.54	12.88
S_2W_4	33.93	53.82	66.27	82.47a	4.82cde	11.57ab	13.79	14.82
S_3W_0	29.71	46.47	61.93	69.83cd	3.37h	7.25f	9.48	10.73
S_3W_1	31.54	52.00	70.27	83.73a	4.34fg	9.09cde	12.46	13.41
S_3W_2	32.55	52.33	75.51	81.80a	5.03bcd	11.28b	12.89	14.05
S_3W_3	32.08	46.92	69.24	77.04abc	5.23bc	12.00ab	14.64	14.29
S_3W_4	36.53	45.25	66.40	69.24cd	5.49b	12.25ab	15.36	11.76
S_4W_0	31.37	51.54	63.70	69.78cd	3.98g	9.51c	10.16	11.92
S_4W_1	32.71	49.47	71.54	79.07ab	4.68def	11.39b	12.08	12.87
S_4W_2	35.23	49.07	73.26	79.87a	5.10bcd	12.33ab	13.12	11.42
S_4W_3	35.07	50.27	71.64	80.01a	5.44b	12.66a	13.33	13.79
S_4W_4	34.63	52.64	74.91	81.57a	6.17a	12.64a	14.13	14.98
CV (%)	5.75	5.23	6.24	5.23	5.63	7.48	7.25	4.25
Level of significance	NS	NS	NS	**	*	**	NS	NS

S_1= 25 cm × 15 cm, S_2= 20 cm × 15 cm, S_3= 15 cm × 15 cm, S_4= 15 cm × 10 cm; W_0= No weeding, W_1= One weeding at 30 DAT, W_2= Two weeding at 15 and 30 DAT, W_3=Three weeding at 15, 30 and 45 DAT, W_4= Weed free throughout
** Indicate significant at 1% level of probability; NS indicates not significant; CV means co-efficient of variance.

Spacing exerted a significant influence on the tillering ability of rice at all sampling dates (Table 1). The highest number of total tillers hill^{-1} (13.00) was recorded with 15 cm × 10 cm spacing, and the lowest one (11.50) with 25 cm × 15 cm spacing. With the increase in spacing, number of hills m^{-2} was decreased which might be resulted in decreased number of total tillers m^{-2}. The number of total tillers hill^{-1} was significantly differed among the different weeding regimes at all sampling dates (Table 1). The highest number of total tillers hill^{-1} (13.52) was found in weed-free treatment and the lowest one (10.49) was observed in no weeding treatment. Results indicate that proper weed management increased the number of total tillers hill^{-1}. No weeding treatment produced the lowest number of total tillers hill^{-1} irrespective of spacing at all the growth stages. Results revealed that total tillers hill^{-1} was greater in weeded plots than in unweeded (control) plot indicating weeding at any growth stages of rice has positive effect on growth and development of rice plant. On the other hand, competition for nutrients and water in between weeds and rice plants was severe resulting in the reduced number of total tillers hill^{-1} in no weeding treatment. Similar result was also reported by Ahmed et al. (1986) who reported that one weeding is not sufficient to control the weeds effectively but if one weeding is to be done, it is better to do between 20 and 40 DAT. The interaction showed significant effect on number of total tillers hill^{-1} only at 30 and 45 DAT (Table 2). The closest spacing coupled with weed free or three weeding treatments resulted in maximum tillering because of less crop-crop and crop-weed competition for resources.

Yield attributes of rice

Plant spacing significantly influenced the number of effective tillers hill^{-1}(Table 3). The highest number of effective tillers hill^{-1} (10.13) was produced under 25 cm × 15 cm spacing, and the lowest one (5.38) was found in 15 cm × 10 cm spacing. Number of effective tillers hill^{-1} was significantly influenced by the weeding regime also (Table 3). The highest number of effective tillers hill^{-1} (10.48) was obtained from weed free treatment and the lowest one (4.36) in no weeding treatment. Results further revealed that the number of effective tillers hill^{-1} was greater in all weeded plots than in control (unweeded) plots which confirms that weeding has positive effect on growth and development as well as yield attributes of rice. The interaction of spacing and weeding regime showed significant effect on number of effective tillers hill^{-1} (Table 4). The highest number of effective tillers hill^{-1} (11.93) was obtained from the interaction between 25 cm × 15 cm spacing with weed free all the time and the lowest number of effective tillers hill^{-1} (3.18) was obtained from 15 cm × 15 cm spacing with no weeding regime. Number of non-effective tillers hill^{-1} was significantly affected by spacing and weeding regime (Table 3). The highest number of non-effective tillers hill^{-1} (2.84) was produced by 15 cm × 10 cm spacing which was statistically identical with 15 cm × 15cm and lowest one (1.69) was recorded from 20 cm × 15 cm spacing. The highest number of non-effective tillers hill^{-1} (2.77) was produced by no weeding which was statistically identical to one weeding at 30 DAT and the lowest one (1.86) was obtained from two weeding at 15, 30 DAT. The effect of interaction between spacing and weeding regime showed insignificant effect on the number of non-effective tillers hill^{-1} (Table 4). Similar results were also reported by Jaya Jaya Suria et al. (2013) who confirmed that weed management markedly increased effective tiller number and reduced non-effective tiller number in rice.

Spacing significantly affected number of grains panicle^{-1} and sterile spikelets panicle^{-1} (Table 3). The highest number of grains panicle^{-1} was (143.65) recorded with 20 cm × 15 cm spacing. The lowest number of grains panicle^{-1} (92.91) obtained from 15 cm × 10 cm spacing. The highest number of sterile spikelets was (18.32) obtained from 25 cm × 15cm spacing, and the lowest one (11.48) was obtained from 15 cm ×15 cm spacing which was identical to 20 cm × 15 cm spacing. Weeding regime exerted significant influence on number of grains panicle^{-1} (Table 3). However, number of grains panicle^{-1} was found the highest (140.50) from weed free treatment and the lowest one (100.63) was found in unweeded condition. Number of grains panicle^{-1} was 39.62% higher in weed-free treatment than in unweeded treatment. Reduced grains panicle^{-1} under no weeding condition might be due to competition for resources between weeds and rice plants. This result is in agreement with the results of Islam (2003) who reported that un-weeded plot had lower number of grains panicle^{-1} compared to weeded plot in rice. Number of sterile spikelets panicle^{-1} was significantly affected by the weeding regime. The highest number of sterile spikelets (23.40) was produced by no weeding treatment and lowest one (8.54) was produced by two weeding at 15 and 30 DAT (Table 3). The interaction effect of spacing and weeding regime on the number of grains panicle^{-1} and sterile spikelets panicle^{-1} was significant (Table 4). The highest grains panicle^{-1} (167.02) was found in the interaction between 20 cm × 15 cm spacing and weed free condition, and the lowest one (77.23) was found in the interaction between 15 cm × 10 cm spacing and no weeding condition. The highest sterile spikelets (30.13) was recorded with 15 cm × 10 cm spacing under no weeding condition, and the interaction between 15 cm × 15 cm and weed free condition produced the lowest value (5.60). Thousand grains weight was not significantly influenced by spacing, weeding regime and their interaction (Tables 3 and 4). Sunyob et al. (2012) reported that closest spacing improved most of the yield contributing characters of rice which ultimately resulted in increased grain yield.

Table 3. Effect of plant spacing & weeding regime on the yield contributing characters and yield of transplant *aman* rice cv. Binadhan 7

Spacing	No. of effective tillers	No. of non-effective tillers	No. of filled grains per panicle	No. of unfilled grains per panicle	1000 grain weight (g)	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	HI (%)
S_1	10.13a	2.57a	139.46b	18.32a	22.18	6.04a	6.29b	48.98a
S_2	9.36b	1.69b	143.65a	12.62c	21.88	6.05a	6.53a	48.02b
S_3	7.38c	2.67a	105.13c	11.48c	21.46	5.73b	5.93c	49.02a
S_4	5.38d	2.84a	92.91d	15.04b	21.02	4.77c	5.80c	44.85c
Level of sig.	**	**	**	**	NS	**	**	**
Weeding regime								
W0	4.36d	2.77a	100.63d	23.40a	21.15	4.58e	5.62d	44.64c
W1	6.82c	2.61a	117.05c	14.47b	21.71	5.45d	5.98c	47.63b
W2	10.16ab	1.86b	118.90c	8.54d	21.49	6.00b	6.36ab	48.59a
W3	8.51b	2.61a	124.34b	13.25bc	21.98	5.90c	6.17bc	48.77a
W4	10.48a	2.35ab	140.50a	12.17c	21.84	6.29a	6.55a	48.95a
CV (%)	6.22	5.47	7.48	7.25	4.25	4.96	8.25	5.61
Level of significance	**	**	**	**	NS	**	**	**

S_1= 25 cm × 15 cm, S_2= 20 cm × 15 cm, S_3= 15 cm × 15 cm, S_4= 15 cm × 10 cm; W_0= No weeding, W_1= One weeding at 30 DAT, W_2= Two weeding at 15 and 30 DAT, W_3=Three weeding at 15, 30 and 45 DAT, W_4= Weed free throughout
** Indicate significant at 1% level of probability; NS indicates not significant; CV means co-efficient of variance.

Rice yield

Plant spacing significantly influenced grain yield of Binadhan-7(Table 3). The highest and statistically significant grain yield was obtained from 20 cm × 15 cm spacing (6.05 t ha^{-1}) and 25 cm × 15 cm spacing (6.04 t ha^{-1}) because of highest number of filled grains panicle^{-1} (143.65) and highest number of effective tillers hill^{-1} (10.13). The lowest grain yield (4.77 t ha^{-1}) was produced by 15 cm × 10 cm spacing because of lowest number of effective tillers hill^{-1} (4.77), lowest filled grains panicle-1 (92.91), and highest number of non effective tillers hill^{-1} (2.84). The result showed that grain yield decreased with the decreasing of spacing from 20 cm × 15 cm. Patra (2001) and Sunyob et al. (2012) also reported that rice grain yield under closer spacing was significantly higher than that under wider spacing mainly due to higher number of panicles m^{-2}. Weeding regime also significantly affected the grain yield (Table 3). Among the weeding regimes, weed free regime produced the highest grain yield (6.29 t ha^{-1}), while the lowest grain yield (4.58 t ha^{-1}) was obtained from no weeding regime. In weed-free regime, grain yield was increased by more than 37% compared to no weeding regime. The second highest grain yield (6.00 t ha^{-1}) was obtained from two weeding at 15 and 30 DAT. Yield variations in rice due to weeding regime were also observed by many researchers (Hossain et al. 2002; Islam et al. 2003; Rahman et al. 2005; Anwar et al. 2012). Grain yield was significantly influenced by the interaction between spacing and weeding regime (Table 4). It was observed that the highest grain yield (6.71 t ha^{-1}) was obtained from 20 cm × 15 cm spacing combined with three weeding at 15, 30 and 45 DAT which was identical with the treatment combination of 15 cm × 15 cm spacing and weed free regime. The lowest grain yield (3.40 t ha^{-1}) was obtained from the interaction between 15 cm × 10 cm spacing and no weeding regime.

Like grain yield, straw yield of BINA Dhan-7 also was significantly affected by plant spacing and weeding regime (Table 3). The highest straw yield (6.53 t ha^{-1}) was obtained from 20 cm × 15 cm spacing and the lowest one (5.80 t ha^{-1}) was observed in 15 cm × 10 cm spacing. Weed-free condition produced the highest straw yield (6.55 t ha^{-1}), while the lowest straw yield (5.62 t ha^{-1}) was obtained from no weeding regime

(Table 3). Effect of interaction between plant spacing and weeding regime on straw yield was also significant (Table 4). The highest straw yield (6.88 t ha^{-1}) was found in the interaction between 20 cm × 15 cm spacing and weed free regime, which was identical to 25 cm × 15 cm spacing and two weeding at 15 and 30 DAT. The lowest straw yield (5.22 t ha^{-1}), on the other hand, was obtained from the interaction between 15 cm × 15 cm spacing and no weeding regime.

Table 4. Interaction effect of plant spacing and weeding regime on the crop characters, yield components and yield of transplant *aman* rice cv. Binadhan 7

Interaction	No. of effective tillers	No. of non-effective tillers	No. of filled grains per panicle	No. of unfilled grains per panicle	1000 grain weight (g)	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	HI (%)
S_1W_0	6.24h	1.54	118.50g	19.26d	21.07	5.27hi	5.73e	47.92cde
S_1W_1	9.98cd	2.34	145.13de	16.01e	22.48	5.79f	5.80de	49.94abc
S_1W_2	11.44ab	3.00	127.52f	7.20ij	22.07	6.38bc	6.85a	48.24b-e
S_1W_3	11.03abc	2.29	150.36cd	22.31c	22.53	6.22cd	6.42abc	49.24abc
S_1W_4	11.93a	3.67	155.77bc	26.82b	22.74	6.54ab	6.67ab	49.54abc
S_2W_0	5.50hi	2.52	117.34g	19.57d	21.07	5.11i	5.90de	46.41ef
S_2W_1	9.32de	0.78	143.19e	15.60e	22.13	5.89ef	6.62ab	47.06def
S_2W_2	10.84abc	1.67	132.51f	8.38g-j	21.18	6.14d	6.64ab	48.05cde
S_2W_3	10.49bc	1.31	158.18b	10.65fg	22.41	6.71a	6.61ab	50.40a
S_2W_4	10.68bc	2.15	167.02a	8.91ghi	22.59	6.40bc	6.88a	48.18b-e
S_3W_0	3.18j	4.39	89.46j	24.64bc	21.74	4.55k	5.22f	46.57ef
S_3W_1	5.25hi	4.10	91.61j	10.92fg	21.18	5.50g	5.68e	49.21abc
S_3W_2	10.34bcd	0.76	117.88g	8.30g-j	21.49	6.08de	6.21bcd	49.48abc
S_3W_3	7.47g	3.09	98.02i	7.92g-j	21.92	5.81f	5.87de	49.73abc
S_3W_4	10.68bc	1.00	128.66f	5.60j	20.98	6.69a	6.66ab	50.11ab
S_4W_0	2.53j	2.63	77.23k	30.13a	20.73	3.40l	5.63e	37.65h
S_4W_1	2.72j	3.24	88.27j	15.34e	21.05	4.61k	5.82de	44.31g
S_4W_2	8.01fg	2.01	97.69i	10.29fgh	21.22	5.42gh	5.75de	48.61a-d
S_4W_3	5.03i	3.76	90.80j	12.13f	21.08	4.86j	5.78de	45.70fg
S_4W_4	8.63ef	2.57	110.54h	7.32hij	21.05	5.54g	6.01cde	47.97cde
CV (%)	6.22	5.47	7.48	7.25	4.25	4.96	8.25	5.61
Level of significance	**	NS	**	**	NS	**	**	**

S_1= 25 cm × 15 cm, S_2= 20 cm × 15 cm, S_3= 15 cm × 15 cm, S_4= 15 cm × 10 cm; W_0= No weeding, W_1= One weeding at 30 DAT, W_2= Two weeding at 15 and 30 DAT, W_3=Three weeding at 15, 30 and 45 DAT, W_4= Weed free throughout
** Indicate significant at 1% level of probability; NS indicates not significant; CV means co-efficient of variance.

Table 5. Floristic composition of weed community

SL.No.	Common name	Scientific name	Family	Infestation (%)
1	Panikachu	*Monochoria hastata*	Pontederiaceae	39.54
2	Mutha	*Cyperus rotundus*	Cyperaceae	2.56
3	Angta	*Panicum repens*	Gramineae	10.89
4	Shama	*Echinochloa crusgalli*	Gramineae	13.77
5	Shusnishak	*Marsilea crenata*	Marsileaceae	2.04
6	Arail	*Lersia hexandra*	Gramineae	2.89
7	Joina	*Fimbristylis milliaceae*	Cyperaceae	1.70
8	Chesra	*Scirpus mucronatus*	Cyperaceae	23.21
9	Panilong	*Ludwigia prostrata*	Onagraceae	3.40

N.B. Weed species have been arranged according to their degree of infestation.

Plant spacing, weeding regime and their interaction had significant effect on harvest index of BINA Dhan-7 (Tables 3 and 4). Table shows that the highest harvest index (49.02%) was calculated from 15 cm × 15 cm spacing and it was identical to 25 cm × 15 cm spacing. The lowest harvest index (44.85%) was found in 15 cm × 10 cm spacing. Among the weeding regimes, the highest harvest index (48.95%) was found in weed free regime and it was identical to two weeding at 15, 30 DAT and three weeding at 15, 30, 45 DAT. The lowest harvest index (44.64%) was obtained from no weeding regime. The results imply that harvest index increased gradually with increased weeding intensity. The interaction between 20 cm × 15 cm spacing and three weeding regime at 15, 30, 45 DAT produced the highest harvest index (50.40 %), while the lowest one (44.31%) was obtained from the interaction between 15 cm × 10 cm spacing and one weeding at 30 DAT regime.

Plant spacing has got tremendous influence on weed density and therefore seeding density or planting spacing has been suggested to include as a vital tool for the integrated weed management of rice by many researchers (Anwar et al. 2013, 2014; Juraimi et al. 2013).

Floristic composition of weed

Nine weed species belonging to five families namely, Pontederiaceae, Cyperaceae, Gramineae, Marsileaceae and Onagraceae were found to infest the crop field (Table 5). Among the weed species 3 were grasses, 3 were sedges and other 3 were broadleaved weeds. According to degree of infestation five top most weed species were *Monochoria hastata* (39.54%), *Scirpus mucronatus* (23.21%), *Echinochloa crusgalli* (13.77%), *Panicum repens* (10.89%), *and Ludwigia prostrata* (3.40%). The community was mostly dominated by broadleaf weeds (45%), while sedges and grasses contributed equally. Anwar et al. (2012) also recorded dominance of broadleaf weeds in their experimental rice field. But Suynob et al. (2012) observed that grasses were dominant in their rice fields. The variation in weed community might be due to differences in weed seed bank composition among experimental sites.

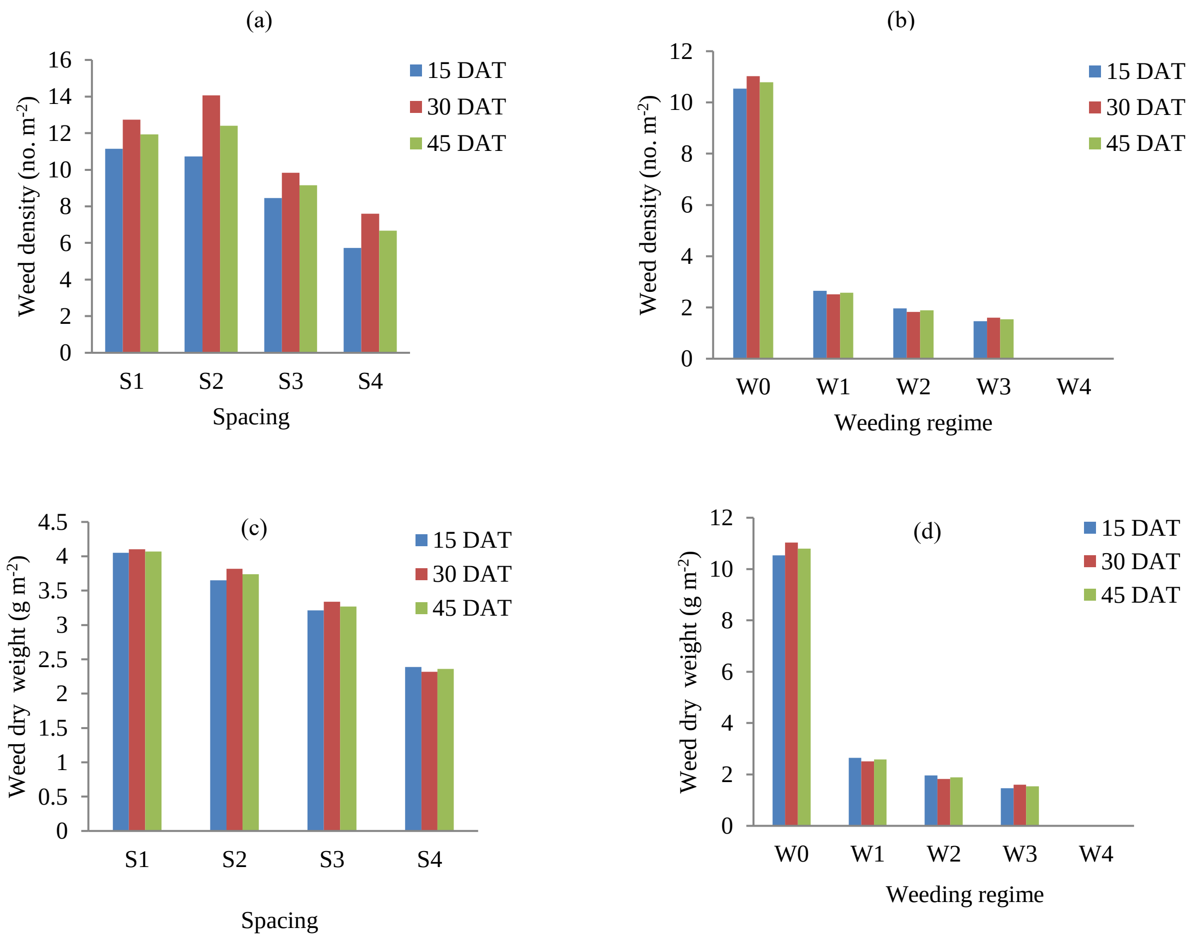

Figure 1. Effect of plant spacing (a) and weeding regime (b) on weed density in transplant *Aman* rice cv. Binadhan 7

S_1= 25 cm × 15 cm, S_2= 20 cm × 15 cm, S_3= 15 cm × 15 cm, S_4= 15 cm × 10 cm; W_0= No weeding, W_1= One weeding at 30 DAT, W_2= Two weeding at 15 and 30 DAT, W_3=Three weeding at 15, 30 and 45 DAT, W_4= Weed free throughout

Weed density and dry weight

Weed density was significantly affected by plant spacing of Binadhan-7 at 15, 30 and 45 DAT. The highest weed plant population was (12.40 m^{-2}) produced in 20 cm × 15 cm spacing and it was identical to 25 cm × 15 cm spacing. The lowest weed density (6.67 m^{-2}) was produced in 15 cm × 10 cm spacing. Weeding regime also had a significant effect on the weed density at 15, 30 and 45 DAT. The highest weed density (31.47 m^{-2}) was recorded under no weeding (W_0) treatment and the lowest one under three weeding treatment. The highest weed density was (39.00 m^{-2}) obtained from the interaction between 20 cm × 15 cm spacing and no weeding regime and it was identical to the interaction of 25 cm × 15 cm spacing and no weeding regime (Fig 1a,b). Spacing significantly affected weed dry weight of at 15, 30 and 45 DAT. The highest dry weight (4.07 g m^{-2}) was recorded from 25 cm × 15 cm spacing and the lowest one (2.36 g m^{-2}) was recorded from 15 cm × 10 cm spacing. Weeding regime also showed a significant effect on the dry weight of weeds at 15, 30 and 45 DAT. The highest dry weight (10.79 g m^{-2}) was recorded from no weeding regime and the lowest one was recorded from three weeding regime. The interaction between spacing and weeding regime also showed a significant effect on the dry weight of weeds at all sampling dates. The highest dry weight (12.54 g m^{-2}) was recorded from no weeding treatment irrespective of planting spacing (Fig 1 c, d). It is evident from Fig 2 a, b that grain yield of rice is strongly and negatively correlated with weed density and dry matter. Weed density could explain grain yield by 92% while weed dry matter by 89%. This findings reconfirms the devastating effect of weeds in reducing rice yield and therefore proper weed management is very crucial for obtaining potential yield of rice.

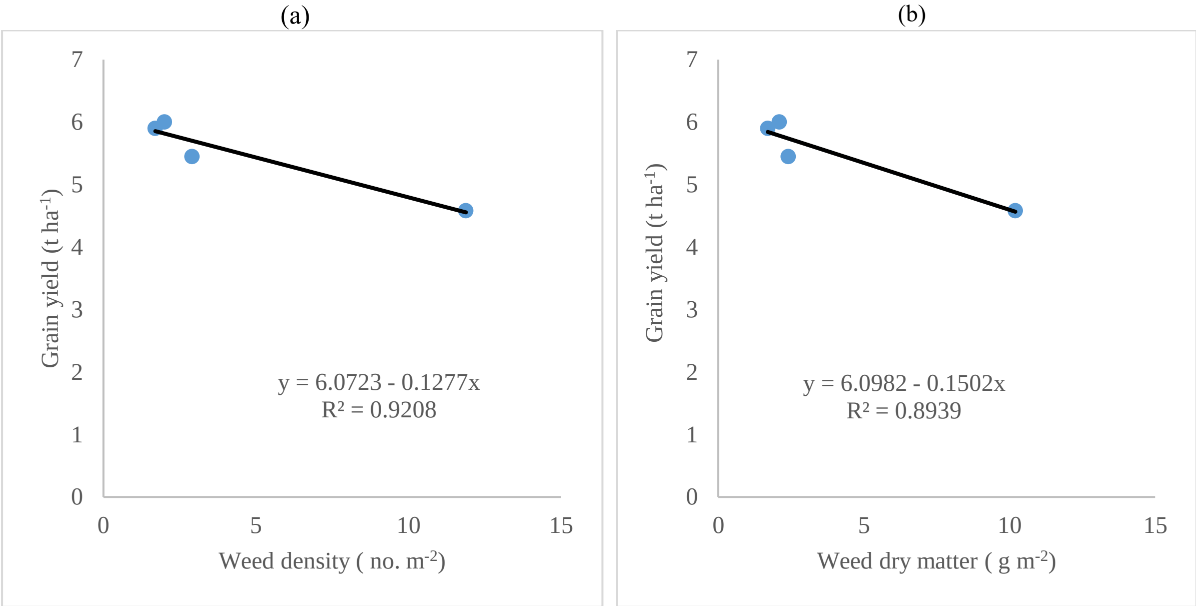

Figure 2. Correlation between weed density and grain yield (a) and weed dry matter and grain yield (b) of Binadhan 7

Both weed density and dry weight decreased with decreasing spacing. Wider plant spacing provides a congenial environment for weeds to germinate and grow, and may enhance the survival and fecundity of weeds. Similar results were also observed by many researchers (Phuong et al. 2005; Anwar et al. 2011). Mahajan et al. (2010) opined that closer spacing can keep the weed flora under check through smothering effect. Guillermo et al. (2009), on the other hand, revealed that higher plant densities might have a competitive advantage over weeds due to fast canopy development resulted in reduced weed growth.

CONCLSION

Findings of the present study suggest that closer plant spacing might have some positive effect on weed suppression and therefore, rice farmers facing difficulties in managing weeds should use closer spacing to suppress weeds and grow rice with least weed management. Therefore, three weeding at 15, 30 and 45 DAT with 20 cm × 15 cm spacing would be the best practice for better weed management and higher yield of rice.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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