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Effect of Water Management Practice and Spacing on the Yield Performance of SRI Method of Rice Cultivation

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Authors' contributions

This work was carried out in collaboration between all authors. Author MMH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SI managed the analyses of the study. Authors LA, MAI and NI managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh to study the effect of water management practice and spacing on yield performance of BRRI dhan29. The experiment was laid out in a split-plot design with three replications. The treatments consisted of three factor, Factor A (Depth of Furrow) consists of tow treatments D_1-Shallow furrow (up to 3 cm deep), D_2- Medium furrow (up to 5 cm deep), Factor B (Intensity of Furrow) consists of five treatments F_1-Furrow made after 8 rows, F_2- Furrow made after 6 rows, F_3- Furrow made after 4 rows, F_4- Furrow made after 2 rows, F_5- No furrows (standard SRI irrigation), Factor C (Spacing) consists of two treatments S_2- 25cm x 25cm, S_2- 30cm x 20cm. In case of depth of furrow, the highest grain yield (5.766 t ha^{-1}) was obtained from D_2 treatment and the lowest from D_1 treatment. On the other hand, the highest grain yield (6.287 t ha^{-1}) was obtained

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from F_4 treatment in case of intensity of furrow and the lowest from F_1 treatment. But in the spacing treatment the highest yield (5.552 t ha^{-1}) was obtained from S_1 spacing and the lowest from S_2 treatment. In the combined effect of depth of furrow and intensity of furrow; depth of furrow and spacing; intensity of furrow and spacing the highest grain yield (6.393 t ha^{-1}) was obtained from combined effect of intensity of furrow and spacing and the combination of treatment was F_4xS_1. In case of combined effect of depth of furrow, intensity of furrow and spacing the highest grain yield (6.42 t ha^{-1}) was obtained from $D_2xF_4xS_1$ treatment combination and the lowest grain yield (4.10 t ha^{-1}) was obtained from $D_1xF_5xS_2$ treatment combination.

Keywords: Water management; split-plot design; spacing; depth of furrow; intensity of furrow.

1. INTRODUCTION

Bangladesh is the most vulnerable country due to climate related water challenges [1]. Water stress is a major problem to crop plants, particularly grown in north-western part of Bangladesh. Rice farming is considered as one of the most sustainable and productive cropping system in the world. Different developmental stages of rice are known to respond differently to different irrigation regimes. Rice plant shows a variety of adaptive mechanisms to respond to water deficit conditions. In Bangladesh, majority of food grains come from rice (*Oryza sativa* L.). Rice is the vital food for more than two billion people in Asia and four hundreds millions of people in Africa and Latin America [2]. The people in Bangladesh depend on rice as staple food and have tremendous influence on agrarian economy of the country. About 77.07% of cropped area of Bangladesh is used for rice production, with annual production of 33.54 million tons from 11.52 million hectares of land [3]. Transplant *Boro* rice covers 54.97% of total area and contributes to 41.34% of total rice production in the country [3]. The average yield of rice in Bangladesh is around 2.4 t ha^{-1}, which is very much lower than that of the highest ranking country namely China is 12.9 tha^{-1} [2]. Water is a much precious resource that no life on earth can live without it. Water makes up 70% of our planet. But in spite of this vast availability, our fresh water reserve is finite. Over the years, improper use has led many to waste this precious natural resource, unwire of its dire crippling effects on the world's food supply balance, particularly for rice the staple food of about 3 billion people around the world. Currently demand of rice is expected to continue to grow as population has been increasing by 1% annually until 2025 in Asia and by 0.6-0.9% worldwide until 2050 [4]. SRI practices, which transplant very young seedlings with much wider spacing and reduced plant populations and with active soil aeration, have been reported to increase the yields of irrigated rice by 25–50 %, or more, while reducing water requirements [5, 6]. The challenge for sustainable rice production is to decrease the amount of water used while maintaining or increasing grain yields to meet the demands of an ever-growing population by improving water use efficiency [7]. The system of rice intensification (SRI) which was developed in Madagascar and is now spreading in most Asian countries, and more recently in several African and Latin American countries, could potentially become an approach to increasing rice production with reduced water demand, thus improving both water use efficiency and water productivity [8]. SRI practices include not flooding rice fields during the vegetative stage of crop growth. Previous comparisons therefore were made between SRI with AWD irrigation versus flooded conventional practice. In the present study, similar types of water management were compared between SRI and CTS; therefore, water saving in SRI was only 14 %, which is not as large as has been found by other researchers [9,10]. Averaging in results of SRI crop management with continuous flooding reduces the effect of the other SRI practices. Research found a 28% saving of irrigation water, without reducing grain yield, when using AWD irrigation practice with SRI crop, soil, and nutrient management [11]. In their evaluations, researcher found no yield difference between SRI and the standard management practice of flooded rice; but with SRI, they found there were water savings and significant increases in water productivity [12,9]. Experiment reported that SRI water management reduced NPS pollution loads by 15.8–44.1% compared with conventional management [13]. Cumulative methane emission under SRI and conventional practices was 19.95 and 32.33 kg/ha, respectively, which meant that SRI could significantly reduce methane emission compared with conventional practices [10].

Recently, System of Rice Intensification (SRI) has attracted attention because of its apparent success in increasing rice yield. Field trials were conducted during the *Boro* seasons of 2002-03 and 2003-04 in Nandigram and Kahalu upazilas, Bogra district, Bangladesh, to evaluate the SRI practice and make a comparative study between SRI and farmers practice in rice cultivation. SRI is claiming to be a superior technology [14], which can increase the yield to a fantastic level [15]. SRI was originated in Madagascar and was first synthesized by Henri de Laulanie [16], a French Jesuit priest. SRI raises productivity not by relying on external inputs, e.g., new seeds and fertilizer, but by changing the way farmers manage their rice plants, soil, water and nutrients [17]. The success of SRI method of rice cultivation depends on the synergistic development of both tiller and root system. The main elements of SRI are to transplant young seedlings that preserve the full genetic potential for producing more viable tillers and root growth, to give the plants wide spacing with single seedling that can reduce competition between hills and keep the soil well-aerated that can allow maximum uptake of nutrients [18]. In SRI method there are some components that are to be maintained properly for obtaining the maximum return from the method. For example, under this system less than 15 day old infant seedlings are transplanted within 30 minutes of uprooting with single seedling hill^{-1} and having spacing not less than 25 cm x 25 cm even up to 50 cm x 50 cm in square method of planting. Rice plants can better realize their potential for tiller and root growth and for subsequent grain filling when spaced more widely rather than more densely. Yield depends on the number and size of fertile tillers cm^{-1} rather than per plant, but total plant performance can be enhanced with optimum spacing rather than crowding. The seedlings are transplanted so that their roots remain in `L' shape instead of traditional `J' shape. The field should be kept moist, no standing water would be allowed until reproductive stage. It is a system of plant, soil, water, and nutrient management for irrigated rice, developed in Madagascar which has been yielding 5-8 t ha^{-1} even more on farmers fields where previous yield average was around 3 t ha^{-1}.

2. MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh (24.75° N latitude and 90.50°E longitude at an elevation of 18 m above the sea level). The soil of the experimental field was characterized by non- calcareous dark grey floodplain soils with 1.29% organic matter content. The experimental field was a medium high land with flat and well drained condition. The pH value of the soil ranged from 5.9-6.5.

The experiment was carried out in a split-plot design having nine treatments with three replications and the size of each plot was 4m x 2.5m. The treatments consisted of three factor, Factor A (Depth of Furrow) consists of two treatments D_1-Shallow furrow (up to 3 cm deep), D_2- Medium furrow (up to 5 cm deep), Factor B (Intensity of Furrow) consists of five treatments F_1-Furrow made after 8 rows, F_2- Furrow made after 6 rows, F_3- Furrow made after 4 rows, F_4- Furrow made after 2 rows, F_5- No furrows (standard SRI irrigation), Factor C (Spacing) consists of two treatments S_1- 25cm x 25cm, S_2- 30cm x 20cm.

BRRI dhan29 was used as plant material. The 11 days old seedlings were uprooted from the seedbed and transplanted on field. Recommended dose of fertilizer (Cowdung 15 tha^{-1}, Urea 270 Kgha^{-1}, TSP 130 Kgha^{-1}, MoP 180 Kgha^{-1}, Gypsum 70 Kgha^{-1} and Zinc Sulphat 10 Kgha^{-1}) was applied in due time. Data on yield attributes was determined from randomly selected five hills of each plot and grain and straw yields were recorded from the inner rows leaving border lines at harvest stage. Crops of each plot were separately harvested, bundled, tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using pedal thresher. The grains were cleaned and sun dried to a moisture content of 14% (IRRI). Straw was also sun dried properly. Finally grain and straw yields were determined and converted to ton ha^{-1}.

3. RESULTS

3.1 Effect of Depth of Furrow

Depth of furrow significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (13.45), effective tiller hill^{-1} (12.08), filled grains panicle^{-1} (116.90) and grain yield (5.766 t ha^{-1}) was obtained from D_2 treatment and the lowest number of total tiller hill^{-1} (12.85), effective tiller hill^{-1} (11.61), filled grains panicle^{-1} (112.90) and grain yield (5.037 t ha^{-1}) was obtained from D_1 treatment (Table 1).

3.2 Effect of Intensity of Furrow

Intensity of furrow significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (14.17), effective tiller hill^{-1} (12.78), filled grains panicle^{-1} (127.60) and grain yield (6.287 t ha^{-1}) was obtained from F_4 treatment and the lowest number of total tiller hill^{-1} (12.01) was obtained from F_5 treatment, effective tiller hill^{-1} (10.64) was obtained from F_5 treatment, filled grains panicle^{-1} (102.90) was obtained from F_5 treatment and grain yield (4.66 t ha^{-1}) was obtained from F_5 treatment (Table 2).

3.3 Combined Effect of Depth of Furrow and Intensity of Furrow

The combined effect of depth of furrow and intensity of furrow significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (14.17) was obtained from D_2xF_4 treatment combination which was statistically similar with D_1xF_4 treatment combination. The lowest number of total tiller hill^{-1} (11.39) was obtained from D_1xF_5 treatment combination. The highest number of effective tiller hill^{-1} (12.91) was obtained from D_2xF_4 treatment combination. The lowest (10.50) from D_1xF_4 treatment combination which was statistically similar with D_2xF_5 treatment combination. The highest filled grain panicle^{-1} (128.5) was obtained from D_2xF_4 treatment combination which was statistically similar with D_1xF_4 treatment combination. The lowest filled grain panicle^{-1} (101.8) was obtained from D_1xF_5 treatment combination which was statistically similar with D_2xF_5 and D_1xF_1 treatment combination. The highest grain yield (6.35 t ha^{-1}) was obtained from D_2xF_4 treatment combination which was statistically similar with D_2xF_3 and D_1xF_4 treatment combination. The lowest grain yield (4.26 t ha^{-1}) was obtained from D_1xF_5 treatment combination which was statistically similar with D_1xF_1 treatment combination (Table 3).

3.4 Effect of Spacing

Spacing between plant to plant and row to row significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (14.13), effective tiller hill^{-1} (12.67), filled grains panicle^{-1} (120.90) and grain yield (5.552 t ha^{-1}) was obtained from S_1 spacing and the lowest number of total tiller hill^{-1} (12.17), effective tiller hill^{-1} (11.02), filled grains panicle^{-1} (109.00) and grain yield (5.251 t ha^{-1}) was obtained from S_2 spacing (Table 4).

3.5 Combined Effect of Depth of Furrow and Spacing

The combined effect of depth of furrow and spacing significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (14.45), effective tiller hill^{-1} (12.92), filled grains panicle^{-1} (123.2) and grain yield (5.894 t ha^{-1}) was obtained from D_2xS_1 treatment combination and the lowest number of total tiller hill^{-1} (11.89), effective tiller hill^{-1} (10.80), filled grains panicle^{-1} (107.3) and grain yield (4.863 t ha^{-1}) was obtained from D_1xS_2 treatment combination (Table 5).

3.6 Combined Effect of Intensity of Furrow and Spacing

The intensity of furrow and spacing combinedly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (15.05), effective tiller hill^{-1} (13.78), filled grains panicle^{-1} (130.3) and grain yield (6.393 t ha^{-1}) were obtained from F_4xS_1 treatment combination. The lowest number of total tiller hill^{-1} (10.94), effective tiller hill^{-1} (9.780), filled grain panicle^{-1} (95.19) and grain yield (4.500 t ha^{-1}) were obtained from F_5xS_2 treatment combination (Table 6).

3.7 Combined Effect of Depth of Furrow, Intensity of Furrow and Spacing

The combined effect of depth of furrow, intensity of furrow and spacing significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. The highest number of total tiller hill^{-1} (15.11) was obtained from $D_2xF_4xS_1$ treatment combination and the lowest number of total tiller hill^{-1} (10.44) was obtained from $D_1xF_5xS_2$ treatment combination. The highest number of effective tiller hill^{-1} (13.83) was obtained from $D_2xF_4xS_1$ treatment combination and the lowest number of effective tiller hill^{-1} (10.44) was obtained from $D_1xF_5xS_2$ treatment combination

Table 1. Effect of depth of furrow on yield and yield contributing characters of rice production

Depth of furrow	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
D_1	84.27	12.85 b	11.61 b	1.240b	22.55 b	112.90	17.56 b	23.20	5.037	7.175 b	12.21 b	41.25 b
D_2	84.27	13.45 a	12.08 a	1.373a	23.20 a	116.90	19.05 a	22.91	5.766	7.650 a	13.42 a	43.04 a
$LSD_{0.05}$	3.39	0.544	0.423	0.099	0.448	7.15	1.37	0.726	0.035	0.405	0.368	0.407
Level of significance	NS	*	*	*	*	NS	*	NS	**	*	**	**
CV (%)	3.63	3.72	3.21	6.85	1.77	5.61	6.74	2.84	0.59	4.92	2.59	0.87

*** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant*

D_1 = Shallow furrow (up to 3 cm depth), D_2 = Medium deep furrow (up to 5 cm depth)

Table 2. Effect of intensity of furrow on yield and yield contributing characters of rice production

Intensity of furrow	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1	84.04 b	12.72 d	11.61 c	1.111 d	22.52	110.1 c	18.90 a	22.67 b	4.94 d	7.32 c	12.27 d	40.22 c
F_2	81.93 c	13.19 c	12.02 b	1.175 c	22.66	115.4 bc	18.67 a	22.92 b	5.30 c	7.725 b	13.03 c	40.62 c
F_3	84.60 b	13.68 b	12.18 b	1.497 a	23.24	118.7 b	17.63 b	22.67 b	5.804 b	7.891 b	13.69 b	42.32 b
F_4	86.85 a	14.17 a	12.78 a	1.382 b	23.47	127.6 a	17.13 b	23.94 a	6.287 a	8.243 a	14.53 a	43.33 ab
F_5	83.93 b	12.01 e	10.64 d	1.366 b	22.48	102.9 d	19.19 a	23.08 b	4.66 e	5.88 d	10.55 e	44.25 a
$LSD_{0.05}$	1.72	0.394	0.378	0.045	1.08	6.75	0.891	0.663	0.199	0.252	0.378	1.11
Level of significance	**	**	**	**	NS	**	**	**	**	**	**	**
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, NS = Not significant*

F_1 = Furrow made after 8 years of rice, F_2 = Furrow made after 6 years of rice, F_3 = Furrow made after 4 years of rice, F_4 = Furrow made after 2 years of rice, F_5 = Standard SRI irrigation (No furrow)

Table 3. Combined effects of depth of furrow and intensity of furrow on yield and yield contributing characters of rice production

Treatment combination	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
D_1xF_1	84.28	12.34	11.28	1.055 g	22.32	106.8	18.11 b	23.00	4.46 e	7.17 d	11.64	38.37 e
D_1xF_2	81.65	13.06	11.75	1.305 e	22.39	113.5	17.70 b	22.83	4.80 d	7.66 bc	12.46	38.55 e
D_1xF_3	85.55	13.50	11.89	1.610 b	23.06	115.9	16.41 c	23.17	5.43 c	7.74 bc	13.18	41.16d
D_1xF_4	85.69	14.00	12.65	1.345 de	22.95	126.8	15.91 c	23.83	6.22a	7.90 b	14.12	44.07ab
D_1xF_5	84.15	11.39	10.50	0.885 h	22.03	101.8	19.65a	23.17	4.26 e	5.39 f	9.660	44.10ab
D_2xF_1	83.79	13.11	11.94	1.167 f	22.71	113.4	19.68a	22.33	5.42 c	7.48 cd	12.90	42.07 cd
D_2xF_2	82.20	13.33	12.28	1.045 g	22.94	117.3	19.63a	23.00	5.80 b	7.79 bc	13.60	42.69abcd
D_2xF_3	83.64	13.85	12.48	1.385 cd	23.42	121.6	18.85ab	22.17	6.17a	8.03 b	14.21	43.48abc
D_2xF_4	88.00	14.34	12.91	1.420 c	23.98	128.5	18.35ab	24.05	6.35a	8.58a	14.93	42.58 bcd
D_2xF_5	83.72	12.63	10.78	1.847 a	22.93	103.9	18.72ab	23.00	5.07d	6.36 e	11.44	44.39a
$LSD_{0.05}$	2.44	0.557	0.535	0.064	1.53	9.54	1.26	0.938	0.282	0.357	0.535	1.57
Level of significance	NS	NS	NS	**	NS	NS	**	NS	**	**	NS	**
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, NS = Not significant*

Table 4. Effect of spacing on yield and yield contributing characters of rice production

Spacing	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	84.28	14.13a	12.67 a	1.464 a	23.34 a	120.9 a	17.70 b	22.96	5.552 a	7.774 a	13.32 a	41.65 b
S_2	84.26	12.17b	11.02 b	1.148 b	22.40 b	109.0 b	18.90 a	23.15	5.251 b	7.051 b	12.30 b	42.65 a
$LSD_{0.05}$	1.09	0.249	0.239	0.029	0.684	4.26	0.564	0.419	0.126	0.160	0.239	0.703
Level of significance	NS	**	**	**	**	**	**	NS	**	**	**	**
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, NS = Not significant*

S_1 = 25 cm x 25 cm, S_2 = 30 cm x 30 cm

Table 5. Combined effects of depth of furrow and spacing on yield and yield contributing characters of rice production

Treatment combination	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$D_{1x}S_1$	84.99 a	13.82	12.43	1.39 b	23.11	118.6	16.71	23.13	5.210	7.557	12.77	40.77
$D_{1x}S_2$	83.54 b	11.89	10.80	1.08 d	21.99	107.3	18.41	23.27	4.863	6.794	11.66	41.73
$D_{2x}S_1$	83.56 b	14.45	12.92	1.535 a	23.57	123.2	18.70	22.79	5.894	7.992	13.88	42.52
$D_{2x}S_2$	84.98 a	12.45	11.24	1.211 c	22.82	110.7	19.40	23.03	5.638	7.309	12.95	43.56
$LSD_{0.05}$	1.54	0.352	0.338	0.040	0.968	6.03	0.797	0.593	0.178	0.225	0.338	0.993
Level of significance	**	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, NS = Not significant, D_1 = Shallow furrow (up to 3 cm depth), D_2 = Medium deep furrow (up to 5 cm depth), S_1 = 25 cm x 25 cm, S_2 = 30 cm x 30 cm*

Table 6. Combined effects of intensity of furrow and spacing on yield and yield contributing characters of rice production

Treatment combination	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1x S_1	83.36 bcd	13.66	12.28	1.387d	23.07	118.1	18.28	22.83	5.002	7.672	12.67	39.34
F_1x S_2	84.71 bc	11.78	10.94	0.835g	21.96	102.0	19.51	22.50	4.890	6.980	11.87	41.09
F_2x S_1	83.05 bcd	14.27	12.82	1.460c	23.29	122.0	18.30	22.50	5.480	8.035	13.52	40.42
F_2x S_2	80.81 d	12.11	11.22	0.890g	22.04	108.8	19.03	23.33	5.125	7.415	12.55	40.81
F_3x S_1	84.41 bc	14.61	12.98	1.640a	23.34	123.5	16.85	22.33	6.050	8.247	14.30	42.32
F_3x S_2	84.79 bc	12.75	11.39	1.355d	23.14	114.0	18.41	23.00	5.558	7.535	13.09	42.32
F_4x S_1	88.33a	15.05	13.78	1.265e	24.21	130.3	16.37	24.13	6.393	8.785	15.18	42.08
F_4x S_2	85.36 b	13.28	11.78	1.500c	22.73	124.9	17.89	23.75	6.180	7.700	13.88	44.57
F_5x S_1	82.23 cd	13.07	11.50	1.570b	22.81	110.5	18.70	23.00	4.835	6.133	10.97	44.06
F_5x S_2	85.64 b	10.94	9.780	1.162f	22.16	95.19	19.67	23.17	4.500	5.627	10.13	44.44
$LSD_{0.05}$	2.44	0.557	0.535	0.064	1.53	9.54	1.26	0.938	0.282	0.357	0.535	1.57
Level of significance	**	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, NS = Not significant*

Table 7. Combined effects of depth of furrow, intensity of furrow and spacing on yield and yield contributing characters of rice production

Treatment combination	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$D_1xF_1xS_1$	85.14bcdefg	13.11	12.00	1.11 i	22.97	113.6	17.26	23.00	4.53fg	7.57	12.11	37.38
$D_1xF_1xS_2$	83.42cdefgh	11.56	10.56	1.00 j	21.68	99.89	18.96	23.00	4.40gh	6.77	11.17	39.36
$D_1xF_2xS_1$	81.44gh	14.22	12.50	1.72 c	23.03	120.4	17.04	22.33	4.83efg	8.02	12.85	37.61
$D_1xF_2xS_2$	81.87 fgh	11.89	11.00	0.890 k	21.75	106.6	18.37	23.33	4.77fg	7.30	12.07	39.49
$D_1xF_3xS_1$	88.47ab	14.44	12.56	1.89 b	23.12	121.3	15.41	23.00	5.90b	8.12	14.02	42.08
$D_1xF_3xS_2$	82.63efgh	12.56	11.22	1.33 fg	23.00	110.4	17.41	23.33	4.96def	7.37	12.34	40.24
$D_1xF_4xS_1$	87.00abc	14.99	13.74	1.25 gh	23.97	127.9	14.67	24.00	6.36a	8.40	14.77	43.00
$D_1xF_4xS_2$	84.39cdefg	13.00	11.55	1.44 e	21.94	125.7	17.15	23.67	6.08ab	7.40	13.48	45.14
$D_1xF_5xS_1$	82.89defgh	12.33	11.33	1.00 j	22.47	109.5	19.15	23.33	4.42gh	5.66	10.09	43.80
$D_1xF_5xS_2$	85.41bcdefg	10.44	9.670	0.770 l	21.59	94.04	20.15	23.00	4.10h	5.13	9.233	44.40
$D_2xF_1xS_1$	81.58gh	14.22	12.56	1.66 c	23.17	122.6	19.30	22.67	5.47c	7.77	13.23	41.31
$D_2xF_1xS_2$	86.01abcde	12.00	11.33	0.670 m	22.25	104.2	20.07	22.00	5.38cd	7.19	12.57	42.82
$D_2xF_2xS_1$	84.66bcdefg	14.33	13.13	1.20 hi	23.55	123.6	19.56	22.67	6.13ab	8.05	14.18	43.24
$D_2xF_2xS_2$	79.74 h	12.33	11.44	0.890 k	22.33	111.1	19.70	23.33	5.48c	7.53	13.02	42.13
$D_2xF_3xS_1$	80.34 h	14.78	13.39	1.39 ef	23.56	125.6	18.30	21.67	6.20ab	8.37	14.57	42.56
$D_2xF_3xS_2$	86.94abcd	12.93	11.56	1.38 ef	23.28	117.6	19.41	22.67	6.15ab	7.70	13.85	44.40
$D_2xF_4xS_1$	89.67a	15.11	13.83	1.28 gh	24.45	132.8	18.07	24.27	6.42a	9.17	15.59	41.17
$D_2xF_4xS_2$	86.33abcde	13.56	12.00	1.56 d	23.51	124.2	18.63	23.83	6.28ab	8.00	14.28	43.99
$D_2xF_5xS_1$	81.57 gh	13.81	11.67	2.14a	23.14	111.5	18.26	22.67	5.25cde	6.60	11.85	44.31
$D_2xF_5xS_2$	85.87abcdef	11.44	9.890	1.55 d	22.72	96.33	19.18	23.33	4.90ef	6.12	11.02	44.48
$LSD_{0.05}$	3.45	0.789	0.757	0.091	2.16	13.50	1.78	1.33	0.398	0.505	0.757	2.22
Level of significance	**	NS	NS	**	NS	NS	NS	NS	**	NS	NS	NS
CV (%)	2.48	3.62	3.86	4.19	5.72	7.09	5.89	3.48	4.46	4.11	3.57	3.18

*** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant* which was statistically similar with $D_2xF_5xS_2$ treatment combination. The highest number of filled grain panicle^{-1} (132.8) was obtained from $D_2xF_4xS_1$ treatment combination and the lowest number of filled grain panicle^{-1} (94.04) was obtained from $D_1xF_5xS_2$ treatment combination. The highest grain yield (6.42 t ha^{-1}) was obtained from $D_2xF_4xS_1$ treatment combination which was statistically similar with $D_1xF_4xS_1$. The lowest grain yield (4.10 tha^{-1}) was obtained from $D_1xF_5xS_2$ treatment combination which was statistically similar with $D_1xF_1xS_2$ and $D_1xF_5xS_1$ treatment combination (Table 7).

4. DISCUSSION

In this study, we used the furrow irrigation system with the depth of the irrigation furrow of up to 3 cm and up to 5 cm, respectively. This technique is especially promising for areas of water shortage and also may serve as an effective means for water conservation in areas with competing water demands for agriculture, industry, and urban uses. For example, research indicated that water saving under saturated soil was on average 23% with yield reduction of only 6% [19]. Experiment reported that using a new water-saving Ground Cover Rice Production System (GCRPS) with lowland rice cultivated without a standing water layer during the entire growth period and plot irrigation when soil water tension was below 15 kPa [20]. On the other hand, research found that the grain yields of rice were slightly greater in paddy than on raised beds with continuous FI, but pointed out that all cultivars grown with the FI system had more tillers, leaf area, and dry weight at an thesis, suggesting a greater yield potential [21].

Researcher observed that plant height and number of tillers were significantly higher when crops were transplanted at 30 cm x 30 cm than at 10 cm x 10 cm and 20 cm x 20 cm [22], on the contrary, other experiment reported that plant spacing at 40 cm x 40 cm only produced higher number of tillers, number of leaves, shorter days to 50% heading and 1000 grain weight whereas plant spacing at 30 cm x 30 cm recorded longest panicles, more number of panicles and paddy yield but with no significant differences in plant height for the two different spacing [23]. This is in conformity with earlier observations of Bishnu [24], Mondal and Putch [25], who reported that lower seeding density resulted in the formation of more productive tillers, superior performance for all morpho-physiological and yield components, resulting in higher grain yields over higher seedling density.

5. CONCLUSION

Singly depth of furrow, intensity of furrow and spacing significantly influenced the total number of tillers hill^{-1}, number of effective tiller hill^{-1}, number of filled grains panicle^{-1} and grain yield. Combined effect of depth of furrow and intensity of furrow; depth of furrow and spacing; intensity of furrow and spacing; and depth of furrow, intensity of furrow and spacing has also significantly influenced the yield contributing characters. In case of depth of furrow, the highest grain yield (5.766 t ha^{-1}) was obtained from D_2 treatment and the lowest from D_1 treatment. On the other hand, the highest grain yield (6.287 t ha^{-1}) was obtained from F_4 treatment in case of intensity of furrow and the lowest from F_1 treatment. But in the spacing treatment the highest yield (5.552 t ha^{-1}) was obtained from S_1 spacing and the lowest from S_2 treatment. In the combined effect of depth of furrow and intensity of furrow; depth of furrow and spacing; intensity of furrow and spacing the highest grain yield (6.393 t ha^{-1}) was obtained from combined effect of intensity of furrow and spacing and the combination of treatment was F_4xS_1. In case of combined effect of depth of furrow, intensity of furrow and spacing the highest grain yield (6.42 t ha^{-1}) was obtained from $D_2xF_4xS_1$ treatment combination and the lowest grain yield (4.10 t ha^{-1}) was obtained from $D_1xF_5xS_2$ treatment combination. On the conclusion, we can say that the treatment combination $D_2xF_4xS_1$ was significantly influenced the grain yield of BRRI dhan29.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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