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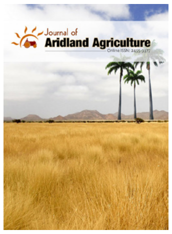

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Effect of planting and nutrient management on the growth, yield and protein content of aromatic fine rice

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from July to November 2015 to find out the effect of planting and nutrient management on the growth, yield and protein content of aromatic fine rice (cv. Binadhan-13). The experimental treatments comprised six planting arrangement *viz.* 25 cm × 20 cm, 25 cm × 15 cm, 25 cm × 10 cm, 20 cm × 20 cm, 20 cm × 15 cm, 20 cm × 10 cm and four nutrient management *viz.* recommended dose of inorganic fertilizer (RDF) N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively; Cow dung @ 10 t ha^{-1}, 25% less than RDF + Cow dung @ 5 t ha^{-1}, 50% less than RDF + Cow dung @ 5 t ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Different crop characters, yield contributing characters, yield and grain quality were significantly influenced by planting arrangement and nutrient management. In the crop growth stage, the maximum number of tillers hill^{-1} (19.03) was recorded from the 25 cm × 15 cm spacing fertilized with 25% less than RDF + cow dung @ 5 t ha^{-1} and the highest total dry matter production (62.70), crop growth rate (19.37) and chlorophyll content (35.77) of leaf were recorded from the 20 cm × 15 cm spacing fertilized with 25% less than RDF + cow dung @ 5 t ha^{-1}. At harvest, the highest grain yield (3.66 t ha^{-1}) and protein content (9.63%) were recorded from the 20 cm × 15 cm spacing fertilized with 25% less than RDF + cow dung @ 5 t ha^{-1}. So, transplantation at 20 cm × 15 cm spacing and fertilization with 25% less than the recommended dose of inorganic fertilizer + cow dung @ 5 t ha^{-1} was found to be promising practice for the cultivation of aromatic fine rice (cv. Binadhan-13).

KEYWORDS: Aromatic rice, Growth, Nutrient management, Planting arrangement, Yield and protein content

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INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most widely cultivated cereal grain which provides the staple food for half of the world's population (Anwari *et al*., 2019; Javed *et al*., 2021). In Bangladesh, agriculture is characterized by rice based cropping systems and rice has been given the highest priority in fulfilling the needs of the ever-increasing population. The area and production of rice in Bangladesh are about 11.52 million hectares and 36.39 million tons, respectively (BBS, 2019). Among the total rice production, *Aman* rice covers about 5.62 million hectares of land with an annual production of 14.06 million tons and aromatic rice constitutes 12.50% of the total transplanted *Aman* rice (Roy *et al*., 2018). Aromatic rice has been attracting rice consumers for its fabulous taste, aroma and deliciousness. So, this rice has greater potential to boost the economic condition of rice growers in developing countries like Bangladesh. But most of the aromatic rice varieties are the traditional photo-period sensitive type, low yielding and grown during *Aman* season with an average yield of 3.04 t ha^{-1} (Kabir *et al*., 2004; Sinha *et al*., 2018). Besides the inherent genetic qualities of aromatic rice varieties, the lack of proper management practices could be responsible for this low yield.

Agronomic management practices such as plant to plant spacing and nutrient management are important means to increase the yield and quality of rice. Higher planting density introduces competition among the plants for light and nutrients. Consequently, the growth slows down and the grain yield decreases (Salahuddin *et al*., 2009; Yasmin *et al*., 2018). On the other hand, planting arrangement plays a significant role in growth, development and yield as proper spacing may help receive maximum leaf Area Index (LAI), light interceptions for better photosynthesis as well as the yield of rice (Paul *et al*., 2017). Yield components, grain and straw yields of rice were increased due to balanced nitrogen fertilization but without organic sources, continuous application of inorganic fertilizer leads to the continuous decline of organic matter content and change of inborn nitrogen status in the soils, which results in lower productivity (Jisan *et al*., 2014; Amanullah & Hidayatullah, 2016; Javed *et al*., 2020). Integrated nutrient management has proved superior to the use of each component separately and has been a widely recommended approach for sustainable crop production (Amanullah & Khalid, 2016; Roy *et al*., 2020a, 2020b). The interactive advantages of combining organic and inorganic nutrients can improve rice growth, yield and quality of rice plants (Sarkar *et al*., 2016; Paul *et al*., 2020). The application of cow dung stimulates the subsequent mineralization of plant nutrients, increases soil microbial growth and activity which improves soil fertility and quality (Islam *et al*., 2007). But, few efforts have been taken to address the synergistic influence of planting arrangement and nutrient management for growing Binadhan-13. Therefore, the present study was undertaken to find out the influence of optimum spacing and nutrient management to obtain satisfactory growth, yield, and quality of aromatic fine rice (cv. Binadhan-13).

MATERIALS AND METHODS

Experimental Site and Experimentation

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (24° 75' N latitude and 90° 50' E longitude and at an altitude of 18 meters above the sea level), Mymensingh from July to November 2015. The experimental site belongs to the Sonatola series of the dark grey floodplain soil type under the Old Brahmaputra Floodplain Agro-Ecological Zone (AEZ-9). The field was a medium high land with a well-drained silty-loam texture having a pH of 6.5. The organic and mineral composition of the soil was generally poor. The organic matter, total nitrogen, available phosphorus (P_2O_5) and potassium of the soil ranged from 0.93%, 0.13%, 16.3 ppm and 0.28%, respectively (Chakraborty *et al*., 2020). The experiment consisted of two factors and was laid out in a randomized complete block design with three replications. There were six spacings *viz*. 25 cm × 20 cm (S_1), 25 cm × 15 cm (S_2), 25 cm × 10 cm (S_3), 20 cm × 20 cm (S_4), 20 cm × 15 cm (S_5), 20 cm × 10 cm (S_6) and four nutrient management *viz*. recommended dose of inorganic fertilizer (RDF) N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1}, respectively (F_1), Cow dung @ 10 t ha^{-1} (F_2), 25% less than RDF + Cow dung @ 5 t ha^{-1} (F_3), 50% less than RDF + Cow dung @ 5 t ha^{-1} (F_4).

Crop Husbandry

Healthy seeds of Binadhan-13 rice were collected from the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh and the sprouted seeds were sown in the nursery beds on 01 July 2015. The main field was prepared by a power tiller with three times ploughing and cross ploughing followed by laddering. Organic and inorganic fertilizers were applied according to experimental treatments. The full dose of triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and cow dung were applied at the final land preparation. Nitrogen fertilizer in the form of urea was applied in three equal splits at 10, 30 and 45 days after transplanting (DAT). Thirty-five days old seedlings were transplanted on 04 August 2015 maintaining different spacings as per experimental specification using 2-3 seedlings hill^{-1}. Intercultural operations were done as and when necessary.

Data Collection on Growth Traits

Five hills were randomly selected soon after transplanting and marked with bamboo sticks in each plot excluding border rows to record the data on plant height and the number of tillers hill^{-1} at every 15 days intervals beginning at 30 DAT to 90 DAT. To determine the total dry matter, two plants were randomly collected excluding border rows and central 1 m^2 area at 30, 45, 60, 75 and 90 DAT. The samples were weighed carefully after oven drying to measure the dry weight of the plant. Crop growth rate (CGR) was calculated from the plant's dry matter using the following formula:

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1}$$

Where,
W_1 = dry matter production at $T_{1\ \text{time}}$
W_2 = dry matter production at $T_{2\ \text{time}}$
A = Ground Area (m^2).

For determination of Soil-Plant-Analysis Development (SPAD) value, chlorophyll meter values (SPAD) were taken using a portable SPAD meter (Model SPAD-502, Minolta crop, Ramsey, NJ) at 45 and 60 days after transplanting. The instrument measures the transmission of red light at 650 nm, at which chlorophyll absorbs light, and the transmission of infrared light at 940 nm, at which no absorption occurs. On the basis of these two transmission values, the instrument calculates a SPAD value that is well correlated with chlorophyll content (Zhu *et al*., 2012).

Data Collection on Yield Components and Yield

The crop was harvested at full maturity. The crop was harvested when 90% of the grain became golden yellow in colour on 10th November, 2015. Five hills (excluding border rows and central 1 m^2 area) were selected randomly from each unit plot and uprooted for recording data on yield contributing components. An area of central 1 m × 1 m was selected from each plot to record the yield of grain and straw. The grains were cleaned and sun-dried to a moisture content of 14%. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

Determination of Protein Content

Paddy samples were collected from each plot. The samples were dried and de-husked manually. Oven-dried rice kernels were ground by a grinding mill using 60 mesh sieves. The prepared samples were then put in polythene bags and kept in a desiccator for subsequent chemical analysis for estimation of protein. Protein content (%) was estimated by the Micro-Kjeldahl method (AOAC, 1984).

Statistical Analysis of Data

Data on different parameters were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done with the help of the computer package MSTAT-C. The mean differences among the treatments were tested with Duncan's Multiple Range Test (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Growth Performance

Plant height

Interaction between planting arrangement and nutrient management had no significant effect on plant height at 30, 45, 60, 75 and 90 DAT (Table 1). Similar results were obtained by Jahan *et al.* (2017b) who reported that interaction between plant spacing and fertilizer management had no significant effect on plant height on different days after transplanting.

Number of Total Tillers Hill^{-1}

Interaction between planting arrangement and nutrient management had no significant effect on tillers number at 30, 45, 60 and 90 DAT except 75 DAT (Table 2) and up to 60 DAT the number of tillers hill^{-1} increased with increasing days after transplanting. At 75 DAT, the maximum number of tillers (19.03) was recorded from 25 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1}. This result might be the result of greater spacing and integrated nutrient management that supplied the nutrients in soluble form by not allowing the entire nutrient into the solution. This might minimize fixation and precipitation which allowed the plant roots to absorb more nutrients and finally produce the highest tillers hill^{-1} (Roy *et al.*, 2017). The minimum number of tillers (11.25) was found in 25 cm × 10 cm spacing combined with only cow dung application at 75 DAT. These findings were in conformity with the reports of Mahato and Adhikari (2017) who reported that the number of tillers per square meter was decreased with the closer spacing as plants compete among themselves for space, nutrients, water, sunlight, air under densely planted condition and less inter-plant competition in wider spacing.

Total Dry Matter (TDM) Production

Total dry matter production hill^{-1} increased in course of time and reached the maximum at the final sampling date and at

Table 1: Effect of interaction of planting arrangement and nutrient management on plant height of aromatic fine rice (cv. Binadhan-13) at different days after transplanting (DAT)

Planting arrangement × Nutrient management	Plant height (cm)				
	Days after transplanting (DAT)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
$S_1 \times F_1$	68.00	100.92	117.25	134.63	149.42
$S_1 \times F_2$	63.50	92.33	108.33	133.07	146.55
$S_1 \times F_3$	64.25	100.27	117.25	137.67	150.08
$S_1 \times F_4$	64.42	98.75	116.28	135.77	148.00
$S_2 \times F_1$	68.33	98.00	111.82	137.90	144.73
$S_2 \times F_2$	66.30	96.25	114.05	132.33	142.63
$S_2 \times F_3$	67.17	101.90	116.12	137.42	147.42
$S_2 \times F_4$	67.67	100.00	120.00	134.08	143.83
$S_3 \times F_1$	69.33	98.42	115.25	134.17	144.88
$S_3 \times$ F2	62.50	98.25	115.50	134.88	141.55
$S_3 \times F_3$	69.17	99.58	119.08	138.63	145.92
$S_3 \times F_4$	63.42	98.80	113.50	136.83	145.22
$S_4 \times F_1$	67.77	100.58	117.83	95.30	148.58
$S_4 \times F_2$	43.72	97.59	113.58	131.27	143.88
$S_4 \times F_3$	68.50	100.33	116.42	136.92	148.75
$S_4 \times F_4$	66.67	100.58	116.93	133.42	144.67
$S_5 \times F_1$	61.75	99.08	114.72	134.92	144.83
$S_5 \times F_2$	61.42	96.42	115.10	133.75	141.40
$S_5 \times F_3$	66.67	102.17	116.11	97.97	148.50
$S_5 \times F_4$	63.00	98.92	116.25	135.42	146.42
$S_6 \times F_1$	45.47	98.27	114.04	132.65	143.27
$S_6 \times F_2$	62.37	96.72	110.43	128.55	137.43
$S_6 \times F_3$	67.33	102.42	79.67	136.47	145.58
$S_6 \times F_4$	64.83	98.58	111.18	133.33	142.92
CV (%)	9.25	7.44	6.95	5.48	4.38
Level of Significance	NS	NS	NS	NS	NS

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability,* = Significant at 5% level of probability, NS = Not Significant, S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

60, 75 and 90 DAT interactions between planting arrangement and nutrient management had a significant effect on dry matter production (Table 3). At 60 DAT, the highest dry matter production (30.26 g hill^{-1}) was found in 20 cm × 15 cm spacing combined with the recommended dose of inorganic fertilizer and the lowest dry matter production (15.54 g hill^{-1}) was recorded in 25 cm × 10 cm spacing combined with 50% less than RDF + cow dung @ 5 t ha^{-1}. At 75 and 90 DAT, the highest dry matter production (50.70 g hill^{-1} and 62.70 g hill^{-1}, respectively) was obtained from 20 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1} due to proper spacing and optimum uptake of nutrients and the lowest dry matter production (25.25 g hill^{-1} and 32.25 g hill^{-1},

Table 2: Effect of interaction of planting arrangement and nutrient management on number of total tillers hill^{-1} of aromatic fine rice (cv. Binadhan-13) at different days after transplanting (DAT)

Planting arrangement × Nutrient management	No. of tillers hill $^{-1}$				
	Days after transplanting (DAT)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
$S_1 \times F_1$	10.42	14.33	16.92	14.25efg	11.00
$S_1 \times F_2$	9.08	11.75	14.58	11.67hi	10.67
$S_1 \times F_3$	11.57	15.68	18.77	16.25bcd	13.92
$S_1 \times F_4$	10.83	14.47	18.00	15.84b-e	12.50
$S_2 \times F_1$	7.75	13.80	17.08	14.08efg	10.50
$S_2 \times F_2$	6.17	9.00	12.80	11.26i	10.10
$S_2 \times F_3$	8.83	14.10	19.67	19.03a	14.92
$S_2 \times F_4$	8.33	13.23	18.00	15.17cde	12.25
$S_3 \times F_1$	8.98	8.30	15.75	14.08efg	12.70
$S_3 \times$ F2	7.22	10.62	12.43	11.25i	10.08
$S_3 \times F_3$	9.92	13.57	17.25	15.58b-e	12.00
$S_3 \times F_4$	5.23	12.28	15.48	14.15efg	10.67
$S_4 \times F_1$	8.00	12.77	16.15	14.67def	11.62
$S_4 \times F_2$	6.88	11.67	13.53	12.58ghi	11.67
$S_4 \times F_3$	10.58	14.25	18.80	17.33b	15.50
$S_4 \times F_4$	10.67	13.12	17.17	15.62b-e	13.67
$S_5 \times F_1$	7.42	12.92	15.33	14.08efg	12.42
$S_5 \times F_2$	6.33	10.64	13.00	11.92hi	11.17
$S_5 \times F_3$	9.37	14.02	17.80	16.67bc	14.25
$S_5 \times F_4$	8.27	13.33	15.33	14.50def	12.17
$S_6 \times F_1$	8.27	12.17	13.65	13.08fgh	10.05
$S_6 \times F_2$	5.55	8.90	11.73	12.50ghi	9.83
$S_6 \times F_3$	9.68	14.03	17.67	15.42cde	12.00
$S_6 \times F_4$	8.40	12.47	15.45	13.93efg	9.75
CV (%)	4.4	5.9	4.15	7.41	6.35
Level of Significance	NS	NS	NS	*	NS

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability,* = Significant at 5% level of probability, NS = Not Significant, S_1 = 25 cm×20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

Table 3: Effect of interaction of planting arrangement and nutrient management on total dry matter production of aromatic fine rice (cv. Binadhan-13) at different days after transplanting (DAT)

Planting arrangement × Nutrient management	Total dry matter (TDM) production (g hill^{-1})				
	Days after transplanting (DAT)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
$S_1 \times F_1$	4.04	15.41	25.27bc	40.22c-f	53.32b-e
$S_1 \times F_2$	2.96	11.72	21.80b-g	37.46d-g	48.75d-g
$S_1 \times F_3$	3.53	14.64	24.10bcd	47.72ab	59.29ab
$S_1 \times F_4$	2.74	13.82	24.84bcd	43.46bcd	52.63cde
$S_2 \times F_1$	3.41	13.09	24.81bcd	45.57abc	56.07bc
$S_2 \times F_2$	2.05	8.49	21.86b-g	33.71f-i	42.02h
$S_2 \times F_3$	3.58	12.30	23.29b-e	30.05h-k	43.25gh
$S_2 \times F_4$	3.30	12.12	19.97c-i	41.06cde	55.06bcd
$S_3 \times F_1$	3.13	10.77	17.11ghi	34.82e-i	47.12e-h
$S_3 \times F_2$	1.66	9.58	16.55ghi	25.40k	33.64i
$S_3 \times F_3$	3.65	10.98	25.59b	45.73abc	58.73ab
$S_3 \times F_4$	3.05	10.00	15.54i	37.62d-g	50.62c-f
$S_4 \times F_1$	2.77	12.16	19.70d-i	26.96jk	40.96h
$S_4 \times F_2$	2.52	10.35	18.65e-i	25.25k	32.25i
$S_4 \times F_3$	3.53	12.89	22.81b-f	35.72e-h	49.72def
$S_4 \times F_4$	2.80	11.92	24.90bcd	34.83e-i	47.23e-h
$S_5 \times F_1$	2.92	14.89	30.26a	41.02cde	50.32c-f
$S_5 \times F_2$	2.25	8.64	17.16ghi	29.00ijk	41.00h
$S_5 \times F_3$	3.22	11.98	21.65b-h	50.70a	62.70a
$S_5 \times F_4$	2.97	13.98	22.68b-f	36.01e-h	49.01d-g
$S_6 \times F_1$	2.62	8.99	21.58b-h	28.81ijk	41.81h
$S_6 \times F_2$	2.57	6.64	16.37hi	25.40k	32.30i
$S_6 \times F_3$	3.27	10.40	24.96bcd	32.49g-j	45.49fgh
$S_6 \times F_4$	2.64	9.87	17.48f-i	30.68h-k	41.68h
CV (%)	5.24	6.26	6.23	7.78	5.41
Level of Significance	NS	NS	**	**	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability,* = Significant at 5% level of probability, NS = Not Significant, S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

respectively) was recorded at 20 cm × 20 cm spacing combined with the sole application of cow dung. Fageria and Baligar (2011) also reported that dry matter production increased with the advancement of plant age up to flowering. This significantly higher dry matter accumulation might be due to the beneficial effects of the combination of inorganic and animal-originated manures and wider spacing which might have provided photosynthetically active radiation as well as higher nutrient uptake which resulted in the greater source accumulation and efficient translocation of photosynthates into the sink during the growth stages.

Crop Growth Rate (CGR)

Interaction between planting arrangement and nutrient management had a significant effect on the crop growth rate at 45-60, 60-75 and 75-90 DAT (Table 4). At 45-60 DAT, the highest crop growth rate (10.25 g m^{-2} day^{-1}) was obtained from 20 cm × 15 cm spacing combined with the recommended dose of inorganic fertilizer and the lowest crop growth rate (3.70 g m^{-2} day^{-1}) was found in 25 cm × 10 cm spacing combined with 50% less than RDF + cow dung @ 5 t ha^{-1}. At 60-75 DAT, the highest crop growth rate (19.37 g m^{-2} day^{-1}) was obtained

Table 4: Effect of interaction of planting arrangement and nutrient management on crop growth rate (CGR) of aromatic fine rice (cv. Binadhan-13) at different days after transplanting (DAT)

Planting arrangement × Nutrient management	Crop Growth Rate (CGR) (g m^{-2} day^{-1})			
	Days after transplanting (DAT)			
	30-45	45-60	60-75	75-90
$S_1 \times F_1$	7.58	6.58a-g	9.96c-i	8.74abc
$S_1 \times F_2$	5.84	6.72 a-g	10.44c-h	7.53bcd
$S_1 \times F_3$	7.41	6.31 b-g	15.74ab	7.72bcd
$S_1 \times F_4$	7.39	7.34 a-g	12.42b-f	6.11ef
$S_2 \times F_1$	6.45	7.81 a-f	13.84bcd	7.00de
$S_2 \times F_2$	4.30	8.92abc	7.90f-j	5.54fg
$S_2 \times F_3$	5.81	7.33 a-g	4.50j	8.80ab
$S_2 \times F_4$	5.88	5.23 c-g	14.06bc	9.33a
$S_3 \times F_1$	5.10	4.23fg	11.80b-g	8.20a-d
$S_3 \times F_2$	5.28	4.64efg	5.73hij	5.67fg
$S_3 \times F_3$	4.88	9.74ab	13.42b-e	8.67abc
$S_3 \times F_4$	4.63	3.70g	14.72bc	8.67abc
$S_4 \times F_1$	6.26	5.03d-g	4.84ij	9.33a
$S_4 \times F_2$	5.22	5.54c-g	4.50j	4.57g
$S_4 \times F_3$	6.24	6.61 a-g	8.60e-j	9.33a
$S_4 \times F_4$	6.08	8.65 a-d	6.62g-j	8.27a-d
$S_5 \times F_1$	7.98	10.25a	7.17g-j	6.20ef
$S_5 \times F_2$	4.26	5.68 c-g	7.89f-j	8.00a-d
$S_5 \times F_3$	5.84	6.45 a-g	19.37a	8.00a-d
$S_5 \times F_4$	7.34	5.80 c-g	8.89d-j	8.67abc
$S_6 \times F_1$	4.24	8.40 a-e	4.82ij	8.67abc
$S_6 \times F_2$	2.71	6.49 a-g	5.92hij	4.70g
$S_6 \times F_3$	4.75	9.70ab	5.02ij	8.67abc
$S_6 \times F_4$	4.82	5.07 c-g	8.80d-j	7.33cde
CV (%)	6.33	7	5.49	6.95
Level of Significance	NS	**	**	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability,* = Significant at 5% level of probability, NS = Not Significant, S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

from 20 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1} and the lowest crop growth rate (4.50 g m^{-2} day^{-1}) was recorded from 20 cm × 20 cm spacing combined with only cow dung application and 25 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1}. At 75-90 DAT, the highest crop growth rate (9.33 g m^{-2} day^{-1}) was obtained from 20 cm × 20 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1}, 20 cm × 20 cm spacing combined with the recommended dose of inorganic fertilizer and 25 cm × 15 cm spacing with 50% less than RDF + cow dung @ 5 t ha^{-1}, while the lowest crop growth rate (4.57 g m^{-2} day^{-1}) was recorded at 20 cm × 20 cm spacing combined with only cow dung application. This observation was close to the annotations of Roy *et al*. (2020b) who reported that proper spacing with appropriate nutrient management provides the scope for efficient utilization of nutrient, moisture and maximum solar radiation, which leads to faster growth and maximum crop growth rate in rice plant.

Chlorophyll Content (SPAD value) of leaf

Interaction between planting arrangement and nutrient management had a significant effect on chlorophyll content at 45 and 60 DAT (Figure 1). At 45 DAT, the highest chlorophyll content (35.77) was obtained at 20 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1} which is statistically similar with 25 cm × 20 cm spacing with the recommended dose of inorganic fertilizer. The lowest chlorophyll content (26.64) was found in 20 cm × 10 cm spacing with only cow dung application. At 60 DAT, the highest chlorophyll content (31.65) was obtained in 20 cm × 15 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1} and the lowest chlorophyll content (26.34) was found in 20 cm × 20 cm spacing with only cow dung application. Results showed higher SPAD value with wider spacing and higher doses of fertilizer compared to narrower spacing with the lower dose of fertilizer application. This might have occurred due to a sufficient amount of light and nutrients for wider spacing with the higher doses of fertilization which was also observed by Paul *et al*. (2018) and Biswas *et al*. (2016).

Yield Components and Yield

Interaction of planting arrangement and nutrient management had no significant effect on plant height, number of non-effective tillers $hill^{-1}$, sterile spikelets $panicle^{-1}$ and 1000-grain weight (Table 5). There was significant variation in the number of total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield, straw yield and harvest index due to the interaction between planting arrangement and nutrient management. The highest number of total tillers $hill^{-1}$ (13.42) and effective tillers $hill^{-1}$ (11.58) was observed in 25 cm × 20 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1}. This might be due to the capturing of more solar radiation and optimum nutrient management. The lowest number of total tillers $hill^{-1}$ (6.67) and effective tillers $hill^{-1}$ (5.92) was recorded from 25 cm × 10 cm spacing combined with 25% less than RDF + cow dung @ 5 t ha^{-1}. Plants with wider spacing could exploit more solar radiation for photosynthesis which results in the accumulation of more carbohydrate and finally produced maximum number of effective tillers $hill^{-1}$ (Jahan *et al*., 2017a). The highest number of grains $panicle^{-1}$ (145.68) was observed in 20 cm × 15 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1} and the lowest number of grains $panicle^{-1}$ (122.72) was recorded in 20 cm × 10 cm spacing with only cow dung application. The highest grain yield (3.66 t ha^{-1}) was recorded in 20 cm × 15 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1} due to the fact that the highest number of grains per panicle (145.68) and 1000 grain weight (13.55) were obtained from same treatment combination. The lowest grain yield (2.04 t ha^{-1}) was recorded in 20 cm × 10 cm spacing with only cow

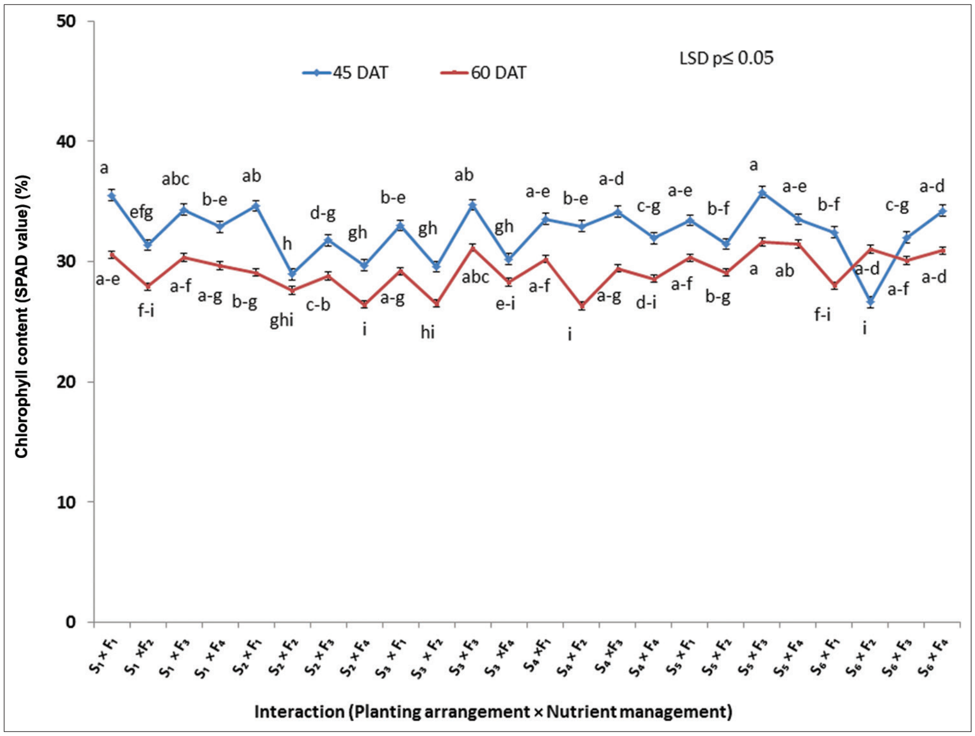

Figure 1: Effect of interaction between planting arrangement and nutrient management on Chlorophyll content (SPAD value) of leaf of aromatic fine rice (cv. Binadhan-13) at different days after transplanting (DAT)

S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

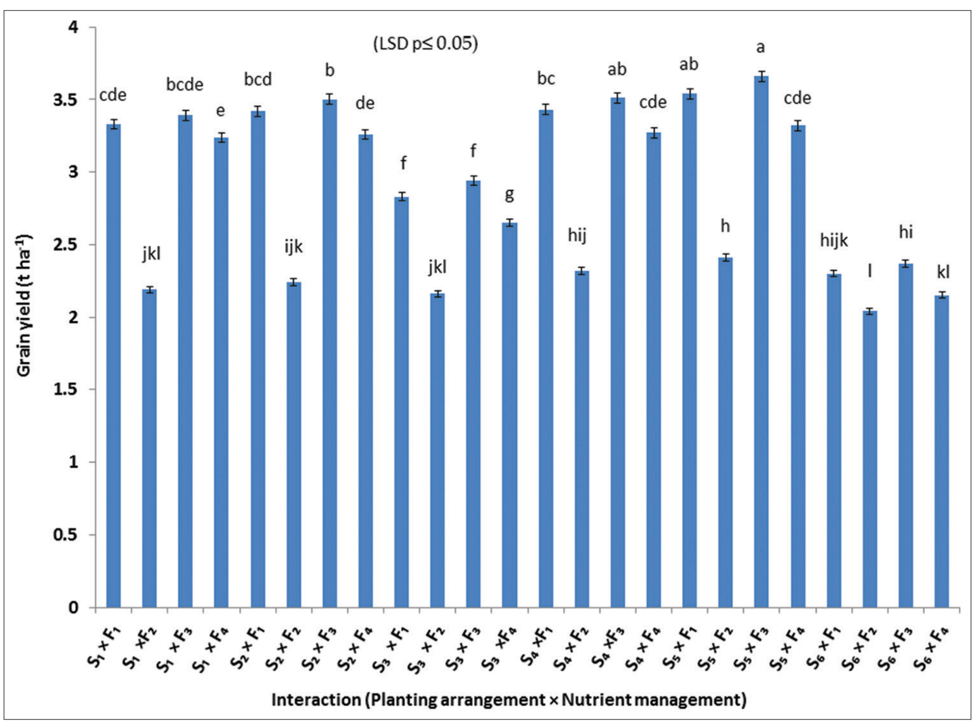

Figure 2: Effect of interaction between planting arrangement and nutrient management on grain yield of aromatic fine rice (cv. Binadhan-13)

S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

Table 5: Effect of interaction between planting arrangement and nutrient management on crop characters, yield and yield contributing characteristics of aromatic fine rice (cv. Binadhan-13)

Planting arrangement × Nutrient management	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non- effective tillers hill^{-1}	No. of grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000-grain weight (g)	Straw yield (t ha^{-1})	Harvest index (%)
$S_1 \times F_1$	157.17	10.83 a-d	8.92a-e	1.92	141.10bcd	12.78	13.38	6.02g	35.61bc
$S_1 \times F_2$	151.59	10.00bcd	8.25 b-f	1.75	135.80fgh	13.10	13.49	5.86hi	27.18e
$S_1 \times F_3$	156.17	13.42a	11.58a	1.83	140.32b-e	14.42	13.45	6.25f	35.16bc
$S_1 \times F_4$	155.33	12.08ab	10.25abc	1.83	143.83ab	13.30	13.44	5.96gh	35.22bc
$S_2 \times F_1$	155.50	9.42b-f	8.25b-f	1.17	140.65b-e	13.40	13.40	6.37f	34.93c
$S_2 \times F_2$	152.58	8.25c-f	6.33ef	1.92	135.43gh	14.01	13.40	6.23f	26.45e
$S_2 \times F_3$	157.00	12.08ab	10.92ab	1.17	140.15b-f	12.31	13.27	6.62de	34.58c
$S_2 \times F_4$	155.25	10.50 a-d	9.33a-d	1.17	139.10c-g	13.32	13.35	6.34f	33.96c
$S_3 \times F_1$	154.25	11.17 a-d	9.42a-d	1.75	139.60b-g	13.47	13.46	7.48b	27.45e
$S_3 \times F_2$	151.00	9.17b-f	8.08b-f	1.08	136.17e-h	12.95	13.37	7.19c	23.10f
$S_3 \times F_3$	159.00	6.67f	5.92f	0.75	140.22b-f	14.05	13.35	7.73a	27.55e
$S_3 \times F_4$	154.75	6.83ef	6.17ef	0.67	139.10c-g	13.23	13.44	7.43b	26.30e
$S_4 \times F_1$	155.67	9.00b-f	7.75c-f	1.25	136.85d-h	13.47	13.48	6.29f	35.29bc
$S_4 \times F_2$	152.42	11.08 a-d	9.42a-d	1.67	143.23abc	14.13	13.28	6.26f	27.04e
$S_4 \times F_3$	156.75	10.58 a-d	9.67a-d	0.92	140.85bcd	15.87	13.52	6.55e	34.89c
$S_4 \times F_4$	156.58	9.83 b-e	8.25b-f	1.58	133.05h	13.33	13.35	6.25f	34.35c
$S_5 \times F_1$	156.75	9.50b-f	8.58b-f	0.92	142.02abc	14.17	13.38	5.78ij	37.98a
$S_5 \times F_2$	154.25	8.50c-f	7.25def	1.25	132.62h	14.60	13.43	5.51k	30.43d
$S_5 \times F_3$	156.67	11.42abc	9.83a-d	1.58	145.68a	13.85	13.55	5.84hi	38.53a
$S_5 \times F_4$	154.42	9.58b-f	8.17b-f	1.42	141.55abc	13.43	13.54	5.65j	37.01ab
$S_6 \times F_1$	155.75	8.08def	7.17def	0.92	123.55i	14.15	13.39	7.18c	24.27f
$S_6 \times F_2$	154.75	8.08def	7.00def	1.08	122.72i	13.58	13.32	6.71d	23.31f
$S_6 \times F_3$	157.58	9.50b-f	7.67c-f	1.83	125.87i	13.38	13.40	7.34b	24.41f
$S_6 \times F_4$	157.58	9.42b-f	8.50b-f	0.92	122.78i	13.85	13.30	7.05c	23.37f
CV (%)	6.58	6.45	8.45	12.34	3.62	5.64	5.99	1.29	3.60
Level of Significance	NS	*	*	NS	**	NS	NS	**	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability,* = Significant at 5% level of probability, NS = Not Significant, S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer+Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

dung application (Figure 2). Higher rice yield might be due to the beneficial effect of the combination of animal-originated manure and inorganic fertilizer which offers a steady release of nutrients compared to only inorganic fertilizer. The findings of the present study were in close agreement with the observations of Laila *et al.* (2020) and Pal *et al.* (2016) who reported that the combined application of organic and inorganic nutrients and proper spacing allows plant roots to compete with loss mechanisms for absorption of more nutrient elements which contributes in better yield. The maximum straw yield (7.73 t ha^{-1}) was found in 25 cm × 10 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1} and the lowest straw yield (5.51 t ha^{-1}) was obtained in 20 cm × 15 cm spacing with only cow dung application. Shaha *et al.* (2014) and Rahman *et al.* (2019) reported balanced nutrient management and proper spacing influences vegetative growth in terms of plant height and number of total tillers hill^{-1} which are responsible for the highest straw yield of rice plant. The maximum harvest index (38.53%) was found in 20 cm × 15 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1} which was at par with 20 cm × 15 cm spacing with the recommended dose of inorganic fertilizer and the lowest harvest index (23.10%) was obtained in 25 cm × 10 cm spacing with only cow dung application.

Grain Protein Content

The application of inorganic fertilizer with organic manure increased grain protein content ability of fine aromatic rice was reported elsewhere (Sarkar *et al.*, 2014; Biswas *et al.*, 2016; Pal *et al.*, 2016; Roy *et al.*, 2017). Protein content was not significantly influenced by the interaction between planting arrangement and nutrient management as it is a qualitative character of plant. The maximum protein content (9.63%) was found in 20 cm × 15 cm spacing with 25% less than RDF + cow dung @ 5 t ha^{-1} and the lowest protein content (6.65%) was obtained from 25 cm × 10 cm spacing with only cow dung application and 20 cm × 10 cm spacing with only cow dung application (Figure 3). The maximum protein content might be due to the availability and uptake of adequate nitrogen from the soil. Nitrogen application significantly increased the grain protein content of rice (Sarkar *et al.*, 2014; Ray *et al.*, 2015).

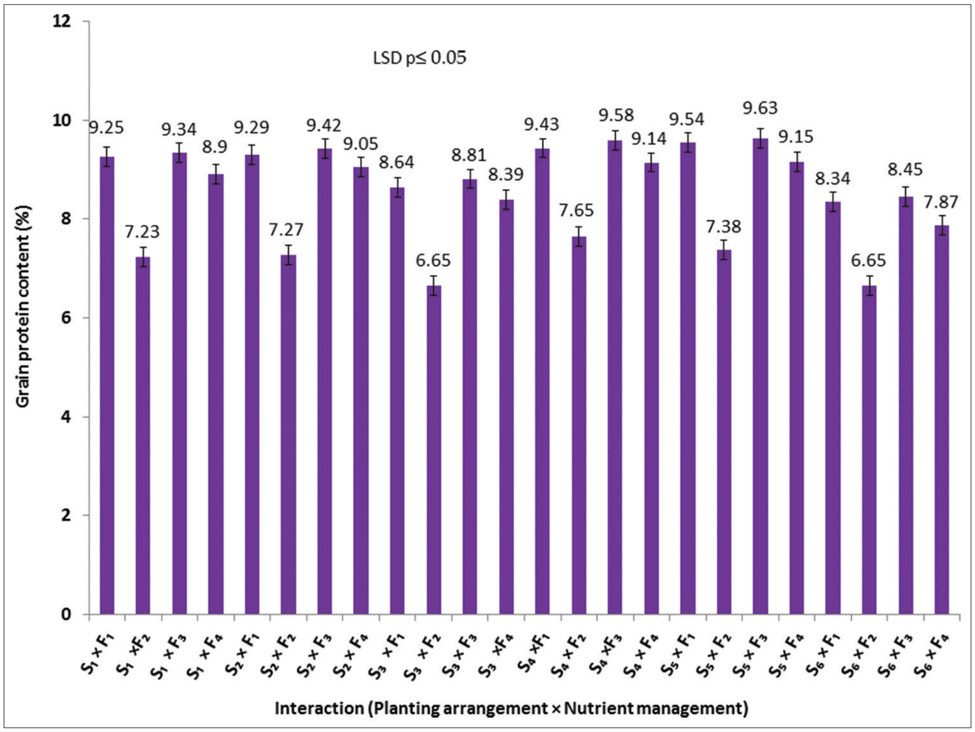

Figure 3: Effect of interaction between planting arrangement and nutrient management on grain protein content of aromatic fine rice (cv. Binadhan-13)

S_1 = 25 cm × 20 cm, S_2 = 25 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 20 cm × 20 cm, S_5 = 20 cm × 15 cm, S_6 = 20 cm × 10 cm, F_1 = Recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn at the rate of 75-42-75-17-2 kg ha^{-1} respectively, F_2 = Cow dung @ 10 t ha^{-1}; F_3 = 25% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}, F_4 = 50% less than recommended dose of inorganic fertilizer + Cow dung @ 5 t ha^{-1}

CONCLUSION

From the present study, it can be concluded that transplanting with 20 cm × 15 cm spacing combined with 25% less than the recommended dose of inorganic fertilizer N-P_2O_5-K_2O-S-Zn @ 75-42-75-17-2 kg ha^{-1} + cow dung @ 5 t ha^{-1} performed best considering yield and grain protein content.

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