UDC 633; DOI 10.18551/rjoas.2022-03.10

EFFECT OF PLANT SPACING AND GENOTYPE ON GROWTH, YIELD, AND YIELD-RELATED TRAITS IN RICE (ORYZA SATIVA L.)

Adhikari Madhusudhan*, **Neupane Prajina**, **Rokaya Lokendra Bahadur**, **Poudel Samip Raj**, **Marahatta Santosh**
Agriculture and Forestry University, Rampur, Chitwan, Nepal

Shrestha Jiban
Nepal Agricultural Research Council, National Plant Breeding and Genetics Research Centre, Khumaltar, Lalitpur, Nepal

*E-mail: adhikarinirdosmadhu@gmail.com
ORCID: 0000-0002-7785-9425

ABSTRACT

Plant spacing and genotype have an impact on rice productivity. From June to November 2019, a field experiment was conducted at Rampur, Chitwan, Nepal, to assess the effects of plant spacing and genotype on growth and yield traits of rice. Twelve treatments were laid out in a split-plot design with three replications, consisting of four rice genotypes (OR, Sabitri, Sunaulo Sugandha, and Sugandhit-1) in sub-plots and three plant spacings (20 cm × 15 cm, 20 cm × 20 cm, and 20 cm × 30 cm) in main-plots. Plant height at harvest was found to be similar among all spacings, whereas the tallest plant height (106.21 cm) was found in Sugandhit-1. Leaf area index, at 75 DAT (days after transplanting), was found the highest (3.50) at the spacing of 20 cm × 15 cm and Sabitri (3.56), followed by Sugandhit-1 (3.37). At the spacing of 20 cm × 15 cm, the highest values of no. of effective tillers per m^2 (240.87) and spike sterility percentage (22.92%) were found. Sugandhit-1 had the longest panicle length (29.04 cm), the heaviest panicle weight (5.83 g), and the highest number of grains per panicle (171.38) as compared to other genotypes. Similarly, the spacing of 20 cm × 20 cm resulted in the highest grain yield (5.31 t ha^{-1}) and biological yield (11.05 t ha^{-1}). Sugandhit-1 produced the highest grain yield (5.52 t ha^{-1}) and biological yield (11.15 t ha^{-1}) followed by Sabitri (grain yield; 5.39 t ha^{-1} and biological yield; 10.95 t ha^{-1}). The interaction effect of spacing of 20 cm × 20 cm and genotype namely Sugandhit-1 resulted in the highest grain yield (6.65 t ha^{-1}), which was similar to the interaction effect of spacing 20 cm × 20 cm and genotype namely Sabitri (6.08 t ha^{-1}). As a result, spacing of 20 cm × 20 cm and genotypes such as Sugandhit-1 and Sabitri are found to be best-suited genotypes for maximizing rice production in Chitwan and similar environments.

KEY WORDS

Spacing, effective tillers, panicle, rice, yield attributes, yield.

Rice (*Oryza sativa* L.) is one of the world's most important staple food crops, feeding over 60% of the world's population. Globally, it is grown on 162.055 million hectares, yielding 755.473 million metric tons (Mt) and a productivity of 4.66 t ha^{-1} (FAO, 2020). Rice is the world's third-largest crop in terms of acreage and production, trailing only maize and wheat. In terms of production and cultivated area, rice is Nepal's number one crop. It is grown on 1,458,915 hectares of land, yielding 5,550,878 Mt and 3.80 t ha^{-1} of productivity (MoALD, 2021). Rice production generates 21% and 7% of the Agricultural Gross Domestic Product (AGDP) and Gross Domestic Product (GDP), respectively (MoF, 2020). Rice production in Nepal is typically shown as a lowland field that is conventionally tilled with tractors or bullocks. As a result, the area is puddled and a water depth of 5-10 cm is maintained, followed by the transplantation of seedlings that are 20-25 days old. Farmers face several challenges, including a lack of better varieties, an insufficient supply of chemical fertilizer, a lack of proper farm equipment, and reliance on monsoon rain for crop production (Basyal et al., 2019). Farmers face several challenges, including poor variety selection and inappropriate spacing. Plant growth is ensured by optimal spacing, which maximizes the use of solar energy and nutrients (Bozorgi et al., 2011). Closer spacing resulted in a considerable reduction in both the number of tillers per stand and the number of panicles per m^2 compared to wider spacing (Moro et al., 2016). Up to 2020, NARC-Nepal has released and introduced 87 rice varieties (two hybrids included). Inbred varieties from farm-saved seeds account for over 85% of the rice seed utilized in cultivation (Joshi, Upadhaya, 2020). In Nepal, there is a large rice yield gap; the difference between attainable and potential yield; ranges from 45 to 55% (Joshi, Upadhaya, 2020). Further, the average rice yield is only 3.2 t ha^{-1}, compared to a potential output of 8.0 t ha^{-1} (Marahatta, 2017).

Both variety and spacing are important factors in determining yield traits and, eventually, rice yield. Over the control, greater row spacing increased the number of tillers per plant, the number of spikes per hill, the number of spikelets per spike, the number of seeds per spike, the weight of seed per hill, the 1000 grin weight, and the yield t ha^{-1} (Garba et al., 2013). Issaka et al. (2008), Uddin et al. (2011), and Habib et al. (2013) found that closer spacing of 15 cm × 10 cm, 15 cm × 15 cm, and 20 cm × 15 cm was superior to a wider spacing of 20 cm × 20 cm, 20 cm × 25 cm, and 20 cm × 30 cm in terms of producing more effective tillers per unit area, leaf area index, and sterility percentage. It was found that wider spacing of 20 cm × 20 cm, 20 cm × 25 cm, 20 cm × 30 cm, 25 cm × 25 cm, and 30 cm × 30 cm resulted in considerably more panicles per unit area, longer panicles, higher panicle weight, and higher grain production than the closer spacing of 15 cm × 10 cm, 15 cm × 15 cm, 20 cm × 15 cm (Weewaroth et al., 1979; Adhikari et al., 2013). Optimal domain-specific spacing is required along with the introduction of superior varieties and the promotion of row transplanting for higher grain yields. The goal of this research was to find the best rice genotype and plant spacing.

MATERIALS AND METHODS OF RESEARCH

Experimental location and soil. During the rainy season from June to November 2019, the experiment was conducted at the Agronomy Farm, Agriculture and Forestry University, Rampur, Chitwan. The site is 10 kilometers south of Bharatpur city. The coordinates for this place are 27° 39' north latitude and 84° 21' east longitude. The southern monsoon has a strong influence on the climate in this area, which is subtropical. The dominant soil texture is sandy loam.

Before beginning the field experiment, soil samples were collected using an auger from representative locations at depths of 0-15 cm and 15-30 cm, and composite samples were created and delivered to the Soil and Fertility Testing Laboratory, Hetauda, Makwanpur. The pH of the soil was found to be acidic in the top 15 cm layer but neutral at 15-30 cm depth. In both layers, soil organic matter (0.89 % and 1.56 %) and total nitrogen (0.07 % and 0.09%) were low. Available phosphorus (kg ha^{-1}) was medium (53.51) and high (90.12) at 0-15 cm and 15-30 cm depths whereas available potassium (kg ha^{-1}) was medium (180.42 and 211.34) at both depths of soil respectively.

Climatic conditions during experimentation. Figure 1 shows monthly weather data for the crop-growing season. During the research period, there was a total rainfall of 595.5 mm. The highest rainfall (245.7 mm) and lowest rainfall (97.2 mm) were recorded in July and October, respectively. The maximum temperature ranged from 32.24 °C to 47.17 °C, with the highest maximum temperature (47.17 °C) occurring in June and the lowest maximum temperature (32.24 °C) occurring in November. The minimum temperature ranged from 11.51°C to 26.51°C, with the highest minimum temperature (26.51 °C) occurring in June and the lowest minimum temperature (11.51 °C) occurring in November. The relative humidity ranged from 30.56 % to 78.94 %, with the highest value (78.94 %) in August and the lowest value in June (30.56 %).

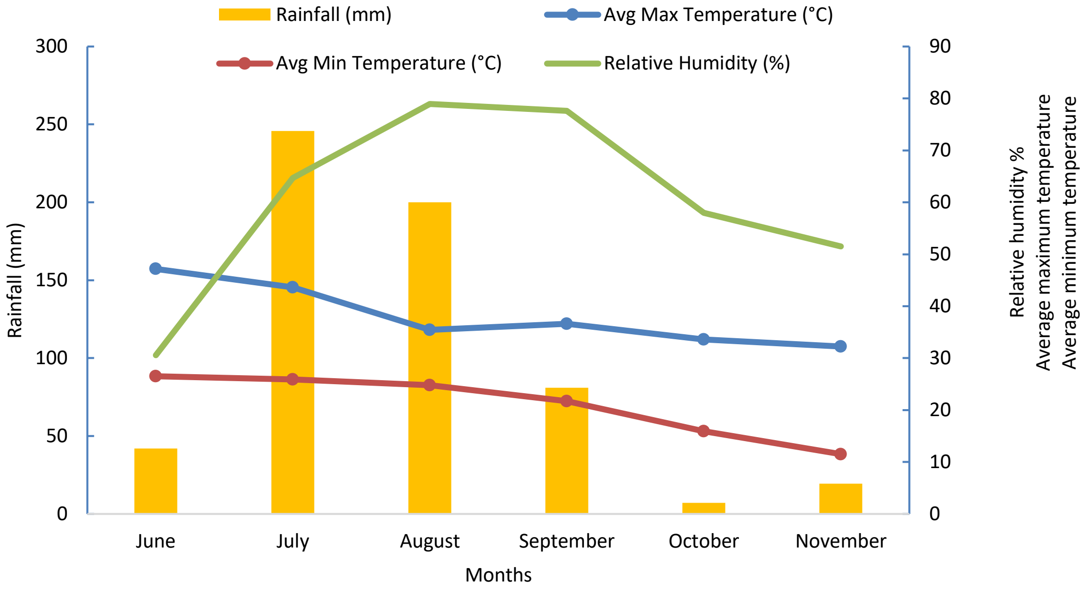

Figure 1 – Monthly average weather data during crop growing period of the study at Rampur, Chitwan, Nepal

Experiment design and fertilizer management. Twelve treatments were laid out in a split-plot design with three replications, consisting of four rice genotypes (OR, Sabitri, Sunaulo Sugandha, and Sugandhit-1) in sub-plots and three plant spacings (20 cm × 15 cm, 20 cm × 20 cm, and 20 cm × 30 cm) in main-plots. These rice genotypes were received from National Rice Research Program, Hardinath, Dhanusha, Nepal. The plot size was 3 m × 3 m (9 m^2) with an experimental area of 324 m^2. The recommended dose of chemical fertilizers @ 100: 30: 30 kg N, P_2O_5 and K_2O were applied through Urea (46%), DAP (46% P_2O_5 and 18% N) and MOP (60% K_2O). Nitrogen was applied in three split doses as basal ½ N, ¼ N at the tiller initiation stage and ¼ N at the panicle initiation stage.

Cultivation Practices. Dry nursery beds were used to grow rice seedlings. With two seedlings per hill, 27-day-old seedlings were transplanted in a well-prepared puddled field. To maintain the appropriate plant population, gap filling was done after 7 days after rice transplantation. Weed management in the field included one pre-emergence herbicide spray and one hand weeding at 10 and 45 days after transplanting (DAT). Irrigation was used during the seedling, tillering, panicle initiation, and flowering stages of the plant. The sample crop plant was manually gathered from net plot areas of 4.86 m^2 (20 cm ×15 cm), 4.68 m^2 (20 cm × 20 cm), and 4.32 m^2 (20 cm × 30 cm) and sun-dried for three days in the field. The grains were cleaned and weighted after threshing with a pedal-operated thresher.

Measurements and methods. Data on plant height at 30 DAT, 45 DAT and at harvest, leaf area index (LAI) at 30 DAT, 45 DAT, 60 DAT and 75 DAT, number of tillers per m^2 at 30 DAT, 45 DAT, 60 DAT, 75 DAT and at harvest were taken. The destructive row sampling technique was done for leaf area index and was measured manually. Mother, primary, secondary and tertiary tillers were counted as the number of tillers per m^2 whereas tillers with panicles were counted as effective tillers per m^2. Leaf area was estimated using below formula (Eq. 1):

$$\text{Leaf area index} = \frac{\text{Leaf area, cm}^2}{\text{Land area, cm}^2} \times 0.75 \quad (1)$$

Effective tillers per square meter, panicle length, panicle weight, 1000-grain weight, number of filled grains per panicle, number of chaffy grains per panicle and sterility percentage were recorded using below formula (Eq. 2):

$$\text{Sterility percentage} = \frac{\text{Number of chaffy grains per 20 panicle}}{\text{Total grains per 20 panicle}} \times 100 \quad (2)$$

Biomass yield, straw yield and grain yield were taken during harvesting from the net plot area. The harvested crop was left in the field; dried, threshed, sun-dried, cleaned and final weight was recorded. Grain moisture content was recorded using a multi-crop moisture meter. Grain yield per hectare was calculated using the following formula at 14% moisture content (Eq. 3).

$$\text{Grain yield}\left(\frac{\text{kg}}{\text{ha}}\right)\text{at 14\% moisture} = \frac{(100 - \text{M}) \times \text{Net plot yield (kg)} \times 10000\ \text{m}^2}{(100 - 14) \times \text{Net plot area, m}^2} \quad (3)$$

Where: M is the grain moisture content in percentage; Net plot area 4.86 m^2 – 20 cm × 15 cm spacing; 4.68 m^2 – 20 cm × 20 cm spacing; 4.32 m^2 – 20 cm × 30 cm spacing.

Similarly, the harvest index (HI) was calculated using the given formula (Eq. 4):

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Grain yield} + \text{straw yield}} \quad (4)$$

Statistical Analysis. For graphs and tables, MS-Excel 2019 was utilized, R Studio version 4.1.1 was used for data analysis, and DMRT at the 5% probability level was employed for mean separation. The analysis of variance (ANOVA) procedure described by Gomez and Gomez (1984) for split plot design studies was used to statistically examine all of the data collected. The Fisher's least significant difference (LSD) procedure was also used to separate the treatment means for the significant difference at the 0.05 probability level (Obi, 1986).

RESULTS AND DISCUSSION

Growth characteristics. Plant height at harvest was not affected by spacing, although it was greatly affected by genotype (Table 1). Plant height was slightly higher (97.78 cm) at the spacing of 20 cm × 20 cm (97.78 cm) and the lowest at the spacing of 20 cm × 15 cm (96.15 cm). Sugandhit-1 (106.21 cm) had a significantly higher plant height than Sabitri and Sunaulo Sugandha, which were at par and the lowest plant height was observed in the OR genotype (84.23 cm). Moro *et al.* (2016) also found that plant height was unaffected by spacings of 15 cm × 15 cm, 20 cm × 15 cm, 20 cm × 20 cm, 20 cm × 20 cm, 20 cm × 25 cm, 30 cm × 10 cm, and 30 cm × 15 cm. Similar findings were also found by Rajbhandari (2007). The results consistent with the findings of Bisne *et al*. (2006), Nizamani *et al*. (2014) and Suleiman *et al*. (2014), who observed plant heights differed significantly among the varieties.

The effect of spacing and genotype on the leaf area index is presented in Table 1. Both spacing and genotype had a significant influence on the leaf area index. A higher leaf area index was observed at the spacing of 20 cm × 15 cm (3.50) than at 20 cm × 20 cm (3.15) and 20 cm × 30 cm (2.92) which were at par. Among rice genotypes, Sabitri (3.56) and Sugandhit-1 (3.37) gave higher leaf area indexes which were at par and lower leaf area indexes found in OR (3.01) and Sunaulo Sugandha (2.82) which were also at par statistically. According to Paramesh *et al.* (2013), the leaf area index was much greater with a spacing of 20 cm ×10 cm, followed by 20 cm × 20 cm, and the lowest with a spacing of 30 cm × 30 cm.

Tiller number was significantly affected by both spacing and genotype at all days after transplanting (DAT) (Table 1). At 30 DAT, a higher tiller number per m^2 was found at 20 cm × 15 cm (92.08) than at 20 cm × 20 cm (80.27) and 20 cm × 30 cm (74.43). As spacing decreases, the number of tillers per m^2 increases, which ultimately increases the final count of tillers. The higher number of tillers per m^2 was observed at 20 cm × 15 cm at 45 DAT (154.75) and 60 DAT (212.08) than at 20 cm × 20 cm and the lowest was found at 20 cm × 30 cm. At 75 DAT, a higher tiller number was found at both 20 cm × 15 cm (255.63) and 20 cm × 20 cm (239.69) than at 20 cm × 30 cm (213.85). However, it is obvious that the number of tillers per hill was significantly higher at spacing of 20 cm × 30 cm than all the spacing. As the distance between plants stand decreases, competition for light, nutrients and space sets in resulting in lower tiller production per hill. The highest number of total tillers per m^2 was obtained at spacings of 20 cm × 10 cm than 25 × 15 cm, 20 cm × 15 cm and 15 cm × 10 cm (Bhowmik *et al*., 2012). OR produced the highest number of tillers per m^2 followed by Sabitri at 30, 45, 60 and 75 DAT (Table 1). This finding follows those of Rahman *et al.* (2010), and Mali and Choudhary (2011), who found significant differences in tiller counts among evaluated rice varieties.

Table 1 – Plant height, leaf area index and number of tillers per m^2 of rice as influenced by spacing and genotype at Rampur, Chitwan, Nepal, 2019

Treatments	Plant height at harvest (cm)	Leaf area index (LAI) at 75 DAT	Number of tillers per m^2			
			30 DAT	45 DAT	60 DAT	75 DAT
Spacing						
20 cm × 15 cm	96.15	3.50^{a}	92.08^{a} (2.76)	154.75^{a} (4.64)	212.08^{a} (6.36)	255.63^{a} (7.66)
20 cm × 20 cm	97.78	3.15^{b}	80.27^{b} (3.21)	142.26^{ab} (5.69)	199.93^{ab} (7.99)	239.69^{a} (9.58)
20 cm × 30 cm	97.11	2.92^{b}	74.43^{b} (4.46)	135.39^{b} (8.12)	186.05^{b} (11.16)	213.85^{b} (12.83)
LSD (0.05)	7.84	0.27	8.07	13.93	18.43	21.47
F test	Ns	*	**	*	*	*
Sem (±)	0.47	0.17	5.19	5.66	7.51	12.17
CV%	7.13	7.57	8.65	8.52	8.15	8.01
Genotype						
OR	84.23^{c}	3.01^{b}	101.35	163.03^{a}	214.49^{a}	257.36^{a}
Sabitri	100.22^{b}	3.56^{a}	86.54	148.67^{b}	202.65^{ab}	248.27^{a}
Sunaulo Sugandha	97.41^{b}	2.82^{b}	73.33	135.14^{c}	191.10^{b}	224.83^{b}
Sugandhit-1	106.21^{a}	3.37^{a}	67.82	129.69^{c}	189.17^{b}	215.10^{b}
LSD (0.05)	5.59	0.21	10.17	9.90	13.98	21.05
F test	***	***	***	***	**	**
Sem (±)	4.64	0.16	7.47	7.45	5.85	9.86
CV %	5.82	6.92	12.48	6.93	7.08	9.00
Grand Mean	97.01	3.19	82.26	144.13	199.35	236.39

*Means with the same letter in the column are not significantly different at P = 0.05 by DMRT. Ns = Not significant, * =significant at P <0.05, ** =significant at P <0.01, *** =significant at P <0.001. Data in parentheses indicates number of tillers per hill.*

The variation in growth, yield and yield-related traits were observed among rice genotypes by Shrestha *et al.* (2021a) and Shrestha *et al.* (2021b). Similarly, Shrestha *et al.* (2020a) found the variability in Chinese hybrid rice for growth and yield traits. Variation in growth and grain yield among rice genotypes was found by Shrestha *et al.* (2020b).

Yield-attributing characteristics. The number of effective tillers produced per m^2 at harvest under different spacings and genotypes is presented in Table 2. Effective tiller was significantly influenced by both spacing and genotype. The highest effective tillers per m^2 were observed at spacings of 20 cm × 15 cm (240.87) and 20 cm × 20 cm (224.23) than at 20 cm × 30 cm (198.67). However, effective tillers per hill were found to be significantly higher at spacing of 20 cm × 30 cm than all other spacings. Higher effective tiller per m^2 at the spacing of 20 cm × 15 cm might be due to more plant stand per square meter, better nutrient and space availability and reduced competition among the plants. Similarly, the highest effective tillers per m^2 were found in genotypes namely OR (243.08) and Sabitri (232.13) which were at par and lower in Sugandhit-1 (199.04) and Sunaulo Sugandha (210.77) which was at par. The higher effective tiller per m^2 in OR and Sabitri might be due to their high tillering genotype character. The maximum number of effective tillers per m^2 was observed at the spacing of 20 cm × 20 cm than at 15 cm × 15 cm and 15 cm × 20 cm by Bhowmik *et al.* (2012).

The effect of spacing and genotype on panicle length is presented in Table 2. Spacing had no significant effect on panicle length but was significantly influenced by genotypes. However, a non-significant, mean panicle length was found to be slightly longer at spacing 20 cm × 30 cm than all other spacing. Closer spacing reduces the assimilation and translocation of assimilates to the economic region of the panicle, resulting in a shorter panicle. Salahuddin et al. (2009) found that panicle length had a similar result. A significantly longer panicle length was found in Sugandhit-1 (29.04 cm) than in other genotypes. This might be due to the better genotypic characters of Sugandhit-1.

Table 2 shows the effect of spacing and genotype on individual panicle weight. Spacing had no significant influence but genotype had a significant effect on panicle weight. However, a non-significant, slightly higher panicle weight was found at the spacing of 20 cm × 30 cm (5.10 g) than at other spacings. The general observation was that the panicle weight increased with wider spacing. Statistically, a higher panicle weight was observed in Sugandhit-1 (5.83 g) than in other genotypes. It is due to genotype character for better translocation of photosynthesis assimilates to the grain.

The mean 1000-grain weight of improved rice genotypes was found to be 23.41 g (Table 2). Statistically non-significant but slightly higher 1000-grain weight was found at spacing 20 cm × 15 cm (23.77 g) than other spacings. Genotypes had a significant effect on 1000-grain weight. A higher 1000-grain weight was found in the genotype Sunaulo Sugandha (25.30 g) than in other genotypes. This is due to its genetic characters.

The mean number of filled grains per panicle was found to be142.84 (Table 2). Spacing had no significant influence but genotype had a significant influence on the number of filled grains per panicle. The higher number of filled grains per panicle was found in Sugandhit-1 (171.38) than all other genotypes. It might be due to its superior genetic potential.

Spike sterility percentage was significantly influenced by spacing but not by genotype (Table 2). Statistically, higher spike sterility was found at the spacing of 20 cm × 15 cm (22.92%). The lowest sterility percentage was found at 20 cm × 20 cm (16.60%) and 20 cm × 30 cm (17.61%) which were at par. Higher sterility at closer spacing is due to competition among the plant stands for space, nutrients and light for better photosynthesis and biomass accumulation and their translocation to the grains, resulting in chaffy and poorly filled grains. This finding is in line with the findings of Haque *et al.* (2015). There was no difference in spike sterility in genotype. Higher sterility percentage (19.59%) was observed at closer spacing of 20 cm × 15 cm than at spacing of 20 cm × 20 cm (Rajbhandari, 2007). A higher sterility percentage lowered the final grain yield.

Table 2 – Yield attributes of rice as influenced by spacing and genotype at Rampur, Chitwan, Nepal, 2019

Treatments	Yield attributes					
	No. of effective tillers at harvest per m^2	Panicle length (cm)	Panicle weight (g)	1000-grain Weight (g)	Number of filled grains per panicle	Spike Sterility (%)
Spacing						
20 cm × 15 cm	240.87^a (7.22)	26.36	4.34	23.77	136.79	22.92^b
20 cm × 20 cm	224.23^a (8.96)	26.15	4.48	22.88	150.30	16.69^a
20 cm × 30 cm	198.67^b (11.92)	27.15	5.10	23.58	141.42	17.61^a
LSD (0.05)	20.84	1.68	0.69	1.38	22.38	2.91
F test	*	Ns	Ns	Ns	Ns	*
Sem (±)	12.27	0.30	0.23	0.27	3.96	1.94
CV%	8.31	5.60	13.29	5.21	13.82	13.48
Genotype						
OR	243.08^a	24.97^b	4.11^b	23.36^b	131.19^{bc}	18.38
Sabitri	232.13^a	25.46^b	4.67^b	22.34^c	149.57^{ab}	18.49
Sunaulo Sugandha	210.77^b	26.75^{ab}	3.94^b	25.30^a	119.21^c	20.00
Sugandhit-1	199.04^b	29.04^a	5.83^a	22.63^{bc}	171.38^a	19.43
LSD (0.05)	19.57	2.59	0.80	0.89	27.64	2.61
F test	***	*	*	***	**	Ns
Sem (±)	9.99	0.90	0.43	0.66	11.37	0.38
CV%	8.93	9.85	17.40	3.85	19.54	13.81
Grand Mean	221.26	26.56	4.64	23.41	142.84	19.07

*Means with the same letter in the column are not significantly different at P = 0.05 by DMRT. Ns=Not significant, * = significant at P <0.05, ** =significant at P <0.01, *** =significant at P<0.001. Data in parentheses indicates effective tillers per hill.*

Grain yield, biological yield, straw yield and harvest index. The effect of spacing and genotype is presented in Table 3. Both spacing and genotype had a significant effect on grain yield. Higher grain yield was observed at spacing of 20 cm × 20 cm (5.31 tha^{-1}) followed by 20 cm × 30 cm (5.04 t ha^{-1}) and the lowest at 20 cm × 15 cm (4.58 t ha^{-1}). This is due to a significantly higher number of effective tillers at harvest at spacing of 20 cm × 20 cm which was at par with 20 cm × 15 cm and the lowest spike sterility than all other spacings. Also, though a non-significant, slightly higher number of filled grains per panicle were also found at the spacing of 20 cm × 20 cm than at other spacings. Haque *et al.* (2015) also found that grain and biological yield increased with wide spacing. A similar observation was also made by Moro et al. (2016) where the wider spacings of 25 cm × 20 cm and 20 cm × 20 cm, produced 8.06 and 7.56 t ha^{-1} more grain than the closer spacings of 30 cm × 10 cm and 15 cm × 15 cm. According to Baloch *et al.* (2002), plant density at spacing of 20 cm × 20 cm was more effective and yielded a significantly greater grain yield per plot than spacing of 25 cm × 25 cm making it the most appropriate spacing for maximizing yields.

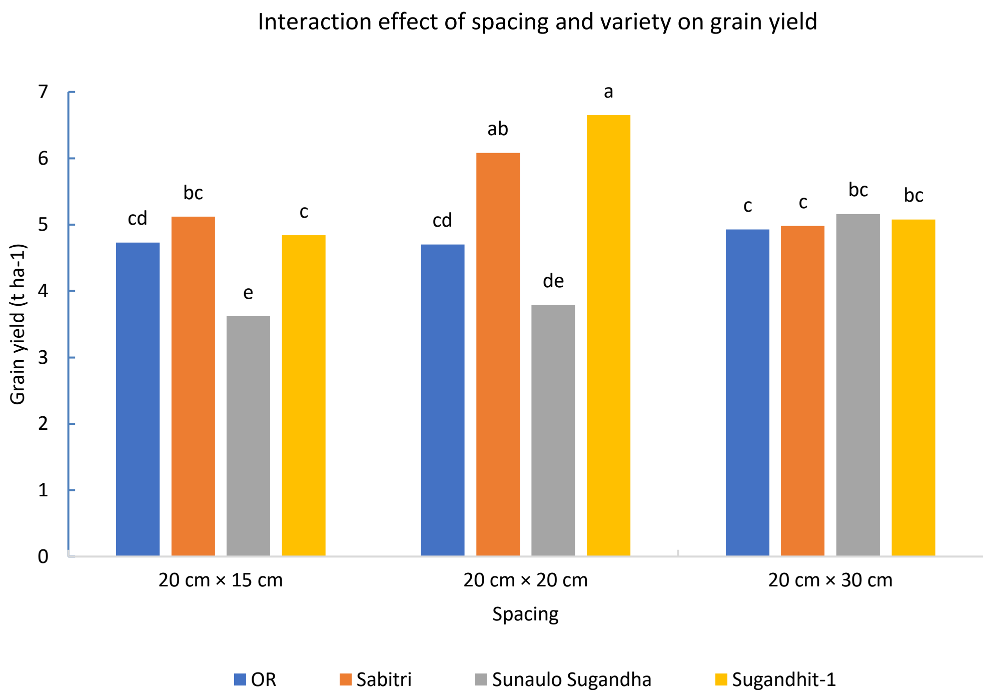

Figure 2 – Interaction effect of spacing and genotype on grain yield (t ha^{-1}) of rice at Rampur, Chitwan, Nepal, 2019

Table 3 – Grain yield, straw yield, biological yield and harvest index of rice as influenced by spacing and genotype at Rampur, Chitwan, Nepal 2019

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
Spacing				
20 cm × 15 cm	4.58^{b}	5.90	9.29^{b}	0.44
20 cm × 20 cm	5.31^{a}	7.02	11.05^{a}	0.42
20 cm × 30 cm	5.04^{ab}	6.34	10.17^{ab}	0.45
LSD (0.05)	0.50	1.56	1.29	0.058
F test	*	Ns	*	Ns
Sem (±)	0.21	3.26	0.50	0.006
CV (a)%	8.86	21.52	11.24	11.66
Genotype				
OR	4.79^{b}	5.38^{b}	9.70^{ab}	0.47
Sabitri	5.39^{a}	7.09^{a}	10.95^{a}	0.439
Sunaulo Sugandha	4.19^{c}	5.36^{b}	8.88^{b}	0.437
Sugandhit-1	5.52^{a}	7.85^{a}	11.15^{a}	0.41
LSD (0.05)	0.55	1.48	1.62	0.04
F test	***	**	*	Ns
Sem (±)	0.30	6.25	0.53	0.012
CV (b)%	11.32	23.26	16.11	10.21
Grand Mean	4.97	6.42	10.17	0.43

*Means with the same letter in the column are not significantly different at P = 0.05 by DMRT. Ns=Not significant, * = significant at P <0.05, ** =significant at P <0.01, *** =significant at P<0.001.*

Similarly, a significantly higher grain yield was found in genotypes Sugandhit-1 (5.52 t ha^{-1}) and Sabitri (5.39 t ha^{-1}) which were at par with genotype OR (4.79 t ha^{-1}) and the lowest yield in Sunaulo Sugandha (4.19 t ha^{-1}). The higher grain yield in Sugandhit-1 is due to significantly longer panicle length, panicle weight, number of filled grains per panicle than all other genotypes. Also, the higher grain yield in Sabitri is due to a significantly higher number of effective tillers at harvest, the similar number of filled grains per panicle with Sugandhit-1 and a slightly lower sterility percentage than other genotypes. Saeed et al. (2012) found significant differences in grain yield among the rice genotypes. Higher grain yields were the result of the cumulative effects of enhanced growth and yield traits.

Similarly, a significant effect of the interaction between spacing and genotype on grain yield was observed. Genotype Sugandhit-1 with the spacing of 20 cm × 20 cm produced higher grain yield followed by Sabitri with spacing of 20 cm × 20 cm and the lowest grain yield was found in Sunaulo Sugandha at spacing of 20 cm × 15 cm (Figure 2).

The straw yield was found to be non-significant as influenced by spacing but was significant as influenced by genotype. The straw yield was found to be higher in Sugandhit-1 (7.85 t ha^{-1}) and Sabitri (7.09 t ha^{-1}) than OR and Sunaulo Sugandha. The biological yield was found to be significant as influenced by spacing and genotype. A higher biological yield was observed at the spacing of 20 cm × 20 cm (11.05 t ha^{-1}) than other spacings. Genotype Sugandhit-1 produced a higher biological yield (11.15 t ha^{-1}) which was at par with Sabitri (10.95 t ha^{-1}) than the other genotypes. The harvest index indicates the efficiency of assimilating partitions to parts of the economic yield of rice plants (panicle). Both spacing and genotype had no significant effect on the harvest index. Rajbhandari (2007) reported that spacing had no significant effect on the harvest index.

CONCLUSION

Plant spacing and genotypes had profound effects on growth, yield and yield-related traits in rice. Among the plant spacings, 20 cm × 15 cm produced the highest grain yield and biological yield. Similarly, the genotype Sugandhit-1 produced the highest grain yield which was at par with that of Sabitri. Therefore, the use of plant spacing of 20 cm × 20 cm and the genotypes Sugandhit-1 and Sabitri is beneficial to achieve higher rice production in Chitwan and similar agro-environments.

ACKNOWLEDGEMENTS

The authors would like to acknowledge DOREX (Directorate of Research and Extension), Agriculture and Forestry University, Rampur Chitwan, Nepal for funding.

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