Nangarhar University
International Journal of Biosciences
Received: 10 Mar 2022
Accepted after revision: 05 Apr 2022
Published Online: 19 Aug 2022

ORIGINAL ARTICLE Vol 1, Issue 1 (2022) https://nuijb.nu.edu.af

Effects of Different Planting Densities and Planting Spaces on the Growth and Yield Attributes of Rice under Irrigated Condition

Wafa Imran Khan[1, 2], Kakar Kifayatullah [2, 3]*

[1]Agricultural Research Institute of Afghanistan, Ministry of Agriculture, Irrigation, and Livestock, Kabul 1001, Afghanistan; imrankhan_wafa@yahoo.com

[2]Graduate School for International Development and Cooperation, Hiroshima University, Hiroshima 739-8529, Japan

[3]Faculty of Agriculture, Nangarhar University, Nangarhar 2601, Afghanistan

*Correspondence: kifayatullahkakar@gmail.com

ABSTRACT

Background: Rice is a staple food for majority of the world's population. Biotic and abiotic factors can affect its growth, yield and quality attributes. An open field experiment was conducted during the rice-growing period from March to October 2015 to identify the effects of different planting densities and planting spacing on the growth attributes and yield performances of a high tillering capacity Indica rice variety (IR-28).

Materials and Methods: The experiment was conducted under lowland condition in the research farm of Tsukuba International Center, Japan with four different planting densities and three replications in a randomized complete block design. Four different planting densities were selected as high density (15x20cm), standard density (15x30cm), medium density (25x25cm) and low density (30x30cm). Rice growth traits including plant length, tiller number, SPAD value and leaf color; yield and yield components consisting of panicle number per unit land area, spikelet number per panicle, ripening ratio, and 1000 grain weight were compared.

Findings: The greatest grain yield was obtained from high planting density which was 6.5 ton per ha and the lowest (5.8 ton/ha) was from medium planting density. Low planting density increased plant length, tiller number per hill, SPAD value (chlorophyll content), leaf color beside panicle number per hill, spikelet number per panicle and percentage of ripened grain.

Conclusion: This study clearly elucidated the effects of planting density on rice crop and helps farmers in the achievement of optimum yield. Thus, to obtain a satisfactory yield, planting density must be considered based on soil type and production requirement.

Key words: Growth; Yield; Planting Density; Planting Space; Rice

INTRODUCTION

Rice is among the important cereal crops which involved in deity of more than 50% of the world population (Jeon et al., 2010; Kakar et al., 2019a). Its growth, yield and grain quality is affected by several factors including planting densities which limit and decline rice productivity. Dense cultivated crops may face with competition for temperature, solar radiation, moisture and soil fertility which affects their growth, yield and grain quality performance (Bozorgi et al., 2011). Planting density plays a crucial role on growth, yield and grain quality of rice plant through influence of growth parameters such as tillers, panicles and spikelet numbers (Wu, 1998).

Bozorgi et al. (2011) reported that dense rice cultivation increases growth traits, yield, and yield components in contrast to medium or low planting densities. Dense rice cultivation also raises the number of tiller on unit land area (Huang et al., 2013). However, Fukushima et al. (2011) mentioned that high planting density decreased the total number of leaf on the main culms and the number of spikelets per panicle. Baloch et al., (2002) observed that low planting density increased panicle number per hill, ripened grains percentage, 1000-grain weight, and consequently grain yield per hill.

Every plant has its own requirement of optimum planting density (Baloch et al., 2002). Plant characters, growth duration, planting date and method, soil fertility and condition, environmental factors, and agronomical practices are important factors which affect crop optimum planting density (Bozorgi et al., 2011). Wider spaces between crops increased the performance of individual crops and lead them to get enough nutrients and solar radiation for a better photosynthetic process (Asmamaw, 2017). High planting density increased yield, but produces less amount of spikelet per panicle and shorten panicle length (Kakar et al., 2019b; Uddin et al., 2011).

It is well understood that rice tillering capacity is affected by nitrogenous fertilizer and planting density (Fagada, 1971). Therefore, planting density should be in mind when paddy rice is cultivated, as it influence both upper and lower parts of the rice plants (Baloch et al., 2002). Many researchers have described that high planting density optimizes rice grain yield, but little is known regarding Indica rice cultivars especially IR-28. To address the issue, this experiment was conducted to understand the relationship of growth and yield components of IR-28 with different planting densities and planting spaces under the irrigated condition and to find out the optimum planting density for growth and yield of IR-28 rice cultivar.

MATERIALS AND METHODS

Site selection and experimental design

This experiment was conducted at the research field of Tsukuba International Center (TBIC), Ibaraki prefecture, Japan during the rice-growing season from March to October 2015 under irrigated condition. The experiment was one factorial randomized complete block design with four treatments of planting densities and three replications. Four different planting densities were as high (15x20cm; 33.3 hills per m^2), standard (15x30cm; 22.2 hills per m^2), medium (25x25cm; 16 hills per m^2) and low (30x30cm; 11.1 hills per m^2). Total research area was 24 m^2 in which 12 plots were isolated individually based on randomization. Soil characters of the research farm are listed in **Table 1**.

Table 1. Soil characteristics of the experimental farm

Soil characteristics	Portion
pH	5.8
Total Nitrogen	4.70 g kg^{-1}
Total Carbon	49.6 g kg^{-1}
P_2O_5	1042 mg kg^{-1}
K_2O	156 mg kg^{-1}

Plant materials and field preparation

High tillering capacity Indica rice cultivar IR-28 was chosen as the main crop. Seeds were selected using a salt solution of specific gravity 1.13 and then washed with clean water to remove remaining salts. Seeds were disinfected using a fungicide (Benlate-T) for 24 h and then dried for 24 h; disinfected seeds were soaked in fresh water for four days and left at room temperature for one day to sprout. 50 g pre-germinated seeds were sown at nursery trays (60cm x 30cm) on 15th April 2015 using commercial soil. 31 days-old rice seedlings at 3.5 plant ages in leaf number were transplanted by hands on 15th May 2015 at three seedlings per hill and different planting densities were applied based on treatments. Herbicide was used at five days after transplanting to diminished weeds growth and attacks.

Experimental field was plowed and puddle using power tiller and leveled manually. Ahead of plowing 40 kg/ha N, 90 kg/ha P and 50 kg/ha K fertilizers were applied as a basal dressing. The sources of fertilizers were urea (46-0-0), single superphosphate (0-17.5-0) and potassium chloride (0-0-60), respectively. Water was kept at 5-10 cm during growing season. Physical and chemical weeding was conducted at different growing stages using hand weeding and herbicide application. Plants were harvested at the end of October 2015 to measure yield components and total grain yield.

Data collection and measurements

Data of plant growth parameters were recorded on plant length, tiller number, SPAD value, and leaf color at three growing (vegetative, reproductive and ripening) stages. Ten and 60 hills were respectively selected from each plot to evaluate growth and yield parameters using the method described by Hoshikawa, 1997. Plant length was recorded from the surface of soil the till top of the plant; tiller number was simply counted with hands. SPAD value and leaf color were recorded by SPAD (Konica-Minolta 502 Plus, Tokyo, Japan) and leaf color chart (IRRI, Philippines), respectively.

Selected hills were picked out for yield and its components analysis, panicles were cut from rachises. To determine the percentage of ripened grain, separated spikelets were added in fresh water to remove unfilled grain and then filled grains were weighted. 1000 grain weight was measured based on counting and weighing 1000 grains. Grains were dehusked applying a small impeller hulling machine (FC2K, Ohtake Corporation, Japan) to measure brown rice yield. Data were analyzed using one-way ANOVA by SPSS 13.0 software (IBM Corporation).

RESULTS

Growth performance

Significant differences were observed among treatments in term of plant length, number of tillers per hill and unit land area, SPAD value and leaf color ($p < 0.01$). Increased in planting density, decreased plant length, tiller number per hill, SPAD value and leaf color, but increased tiller number per unit land area (**Table 2**). Besides, low planting density enhanced plant length, tiller number per hill, SPAD value and leaf color. Tiller numbers per hill and per unit land area showed opposite values among treatments, increased tiller number per hill reduced tiller number per unit land area and follow the same order in all treatments. SPAD value follows a similar trend as leaf color and had a positive correlation.

Table 2. Effects of different planting densities and planting spacing on growth parameters on rice plant

Treatments	Plant length (cm)	Tiller No. hill^{-1}	Tiller No. m^{-2}	SPAD value	Leaf color
High	99.2 d	9.8 d	325.0 a	30.6 d	3.5 c
Standard	103.7 b	12.7 c	281.5 b	32.1 c	4.1 b
Medium	100.6 c	14.1 b	225.3 d	33.4 b	4.1 b
Low	106.1 a	22.6 a	250.9 c	33.7 a	4.3 a
Significant	**	**	**	**	**

** indicates a significant difference at $p<0.01$ probability level. Different letters in the same column mean significant difference at $p<0.05$ probability level.

Yield components

Paddy grain yield and its components are summarized in **Table 3**. There were significant differences in terms of panicle number per unit land area, spikelet number per panicle, the percentage of repined grain, 1000 grain weight and paddy grain yield. Increased in planting density, raised panicle number per unit land area, ripened grain ratio and paddy grain yield. Moreover, spikelet number per panicle was completely opposite with panicle number per unit land area and exhibited negative correlation. The highest number of spikelets per panicle was observed in low planting density and the lowest was in high planting density. Rice grain yield also followed the same order as paddy yield and was higher at high planting density compare to other treatments (**Fig. 1**).

Table 3. Effects of different planting densities and planting spacing on yield and yield components

Treatments	Panicle No. m^{-2}	Spikelet No. panicle^{-1}	Ripened grain ratio (%)	1000 grain weight (g)	Paddy grain yield (ton ha^{-1})
High	317.2 a	82.6 c	85.6 a	29.0 b	6.5 a
Standard	250.3 b	105.8 b	76.2 c	29.5 a	6.0 b
Medium	215.3 c	117.5 a	84.4 b	28.7 c	5.8 c
Low	207.3 d	117.9 a	85.0 ab	28.6 c	5.9 bc
Significant	**	**	**	**	**

** means a significant difference at $p<0.01$ probability level. Different letters in the same column mean significant difference at $p<0.05$ probability level.

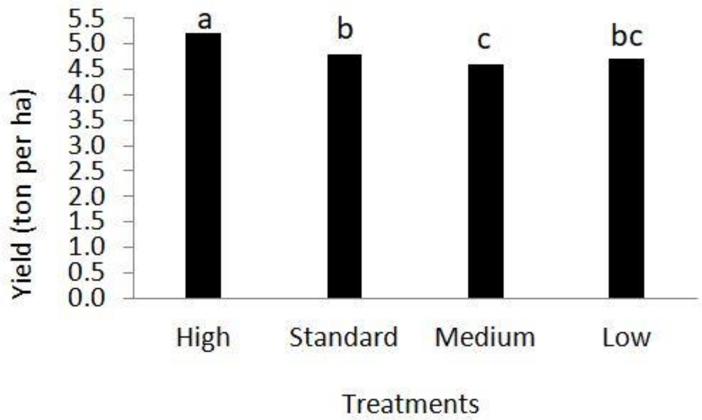

Fig. 1. Rice grain yield in different treatments of planting densities, different letters indicate significant difference at $p < 0.05$ probability level.

DISCUSSION

Among morphological characteristics in rice plant, the most affected characteristic by planting density in this experiment was tiller number per hill and per unit land area which is also reported by Akita (1992) that tiller is affecting by planting density. Low planting density increased tiller number per hill after transplanting till harvesting in contrast with other treatments, more space between crops in low planting density may provide a great condition for their better growth. In high planting density, the space between crops was less which leads the way for competition among them. Therefore, the value of leaf color was decreased and showed that less nitrogen is available for crops as reported by Lin et al. (2009).

Effects of planting density apparently direct on growth and yield performance of rice plant. Akita (1992) reported that yield is calculated from four components which are panicle number per hill, spikelet number per panicle, the percentage of ripened grain and 1000 grain weight. In high planting density; tiller number per hill was lower but tiller number per unit land area was higher, resulted to produce more panicle per unit land area. It is true because the number of plants per unit land area was higher in high planting density treatment. Panicle number per unit land area and paddy yield have a positive correlation; as panicle number is increased, grain yield also increased (Asmamaw, 2017; Sheieh, 1997).

Reduced in planting density caused to increase spikelet number per panicle, highest spikelet number per panicle was observed in low planting density which was 117.9. Increased in spikelet number per panicle in low planting density is due to more space between crops in this density which lead the way for proper nutrient supply and easy solar light penetration to the lower parts of the crops as was also reported by Uddin et al., (2010 and 2011). In this experiment, grain ripening ration had negligible difference among treatments and was ranged from 76.2 to 85.6 percent. The weight of 1000 grain is not correlated with planting density (Akita, 1992; Kakar et al., 2019c). In our experiment, the weight of 1000 grain also was not affected by planting densities; the same results were found by Asmamaw, (2017). The results revealed that paddy yield and number of panicle per unit land area had a positive correlation. High yield was obtained at high planting density as we as high panicle number per unit land area; identical results were cited by Mobasser et al., (2007) and Chandrankar et al., (1981).

CONCLUSION

To obtain significant yield and decrease input cast, planting density must be a focal point when rice plant is cultivated. Every cultivar within a species has its own requirement of nutrients and cultivation system including planting density. Planting density had significant effects on plant length, number of tiller per panicle and unit land area, SPAD value, leaf color, number of spikelet per panicle, ripened grain ration, 1000 grain weight, and paddy and rice grain yields. The yield of rice plant was more attributed with number of panicle per unit land area. The yield was not significant among treatment, but little seedlings were used in low planting density. Therefore, we would like to recommend low planting density for IR-28 rice cultivar.

Acknowledgements

The authors would like to express sincere appreciation and gratitude to the Japan International Cooperation Agency (JICA) and the Tsukuba International Center (TBIC) staff for their technical and financial support to this research. Dr. Tetsu Watanabe, Dr. Shinzo Koizumi, Mr. Yoshiaki Umemiya, Mr. Mitsuo Numata, Dr. Mitate Yamada, and Mr. Toshio Fujii are highly acknowledged for their active and constant cooperation during this research.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

Akita, K., Tanaka, N. (1992). Effect of planting density and planting patterns of young seedlings transplanting on the growth and yield of rice plant. Japan Journal of Crop Science, 61, 80-86.

Asmamaw, B. A. (2017). Effects of planting density on growth, yield and yield attributes of rice (Oryza sativa L.). African Journal of Agricultural Researches, 35, 2713-2721.

Baloch, A. W., Soomro, A. M., Javed, M. A., Ahmed, M. (2002). Optimum plant density for high yield in rice (Oryza sativa L.). Asian Journal of Plant Science, 1, 25-27.

Bozorgi, H. R., Faraji, A., Danesh, R. K., Keshavarz, A., Azarpour, E., Tarighi, F. (2011). Effect of plant density on yield and yield components of rice. World Applied Science Journal, 12, 2053-2057.

Chandrankar, B. L., Khan, R. A. (1981). Optimum spacing for early medium and late duration tall indica rice cultivars. Oryza, 18, 108-109.

Fadaga, S. O. and De Datta, S. K. (1971). Leaf area index, tillering capacity, and grain yield of tropical rice as affected by plant density and nitrogen level. Agronomy, 63, 503-506.

Fukushima, A., Shiratsuchi, H., Yamaguchi, H., Fukuda, A. (2011). Effects of nitrogen application and planting density on morphological traits, dry matter production and yield of large grain type rice variety bekoaoba and strategies for super high yielding rice in the Tohoko region of Japan. Plant Production Science, 14, 56-63.

Hoshikawa, K. (1989). In: The Growing Rice Plant, an anatomical monograph: Panicle, Flower and Grain. First Ed. Nobunkyo, Tokyo, Japan, 280-281.

Huang, M., Yang, C., Ji, Q., Jinang, L., Tan, J., Li, Y. (2013). Tillering responses of rice to plant density and nitrogen rate in a subtropical environment of southern China. Field Crops Research, 149, 187-192.

Jeon, W. T., Seong, K. Y., Lee, J. K., Oh, I. S., Lee, Y. H., Ok, Y. S. (2010). Effects of green manure and carbonized rice husk on soil properties and rice growth. Korean Journal of Soil Science and Fertilizer, 43, 484-489.

Kakar, K., Xuan, T. D., Haqani, M. I., Rayee, R., Wafa, I. K., Abdiani, S., Tran, H. D. (2019a). Current situation and sustainable development of rice cultivation and production in Afghanistan. Agriculture, 9(3), 49-56.

Kakar, K., Nitta, Y., Asagi, N., Komatsuzaki, M., Shiotsu, F., Kokubo, T., Xuan, T. D. (2019b). Morphological analysis on comparison of organic and chemical fertilizers on grain quality of rice at different planting densities. Plant Production Science, 22(4), 510-518.

Kakar, K., Xuan, T. D., Abdiani, S., Wafa, I. K., Noori, Z., Attai, S... Tran, H. D. (2019c). Morphological observation and correlation of growth and yield characteristics with grain quality and antioxidant activities in exotic rice varieties of Afghanistan. Agriculture, 9(8), 167-178.

Lin, X. Q., Zhu, D. F., Chen, H. Z., Cheng, S. H., Uphoff, N. (2009). Effect of plant density and nitrogen fertilizer rates on grain yield and nitrogen uptake of hybrid rice (Oryza sativa L.). Journal of Agriculture, Biotechnology and Sustainable Development, 1, 44-53.

Mobasser, H. R., Delarestaghi, M. M., Khorgami, A., Tari, B. D., Pourkalhor, H. (2007). Effect of planting density on agronomical characteristics of rice (Oryza sativa L.) varieties in North of Iran. Pakistan Journal of Biological Science, 18, 3205-3209.

Sheieh, Y. J. (1977). Effect of planting density on community photosynthesis and on yielding components of rice plants. Botanical Bulletin of Academia Sinica, 18, 153-168.

Uddin, J., Hasan, M., Ahmed, S., Hasan, M. (2010). Effect of spacing on morphology and yield response of different aroma rice cultivars under costal high land ecosystem. Indian Journal of Agricultural Research, 44, 251-258.

Uddin, J., Ahmed, S., Harun, O. R., Hasan, M., Asaduzzaman. (2011). Effect of spacing on the yield and yield attributes of transplanted aroma rice cultivars in medium lowland ecosystem of Bangladesh. Journal of Agricultural Research, 49, 465-476.

Wu, G., Wilson, L. T., McClung, A. M. (1998). Contribution of rice tillering to dry matter accumulation and yield. Agronomy, 90, 317-323.