https://doi.org/10.55925/btagr.22.5103

Assessment of Seedling Rate per Hill for Irrigated Rice in a Wet Sub-Tropical Condition of Bhutan

Ngawang[e], Chezang Dendup[e], Sonam Tshomo[e]

ABSTRACT

A field experiment was conducted at the research farm of the Agriculture Research and Development Centre (ARDC) Samtenling in Sarpang district of Bhutan in 2020 to assess the effects of transplanting different numbers of seedlings per hill on grain yield and yield components of rice under irrigated conditions. A widely adopted rice variety, Bhur Kambja-1, was used for the study with one to seven seedlings per hill transplanted at 20×20 cm spacing. The experiment was laid out in a randomized complete block design with three replications. The results of the experiment revealed that the number of seedlings per hill had a significant effect on number of tillers per hill and grain yield. In terms of rice grain yield, a significant difference was observed only between three and seven seedlings per hill with a recorded yield of 3.9 and 2.7 t ha^{-1}, respectively. However, no significant effect was established on other yield components, such as the plant height, panicle length, number of grains per panicle, and unfilled grains per panicle. Therefore, this study recommends transplanting three seedlings hill^{-1} for cultivation of Bhur Kambja-1 rice variety in the wet-subtropical condition of Bhutan as three seedlings per hill yielded significantly higher productivity and could potentially reduce the seed rate.

Keywords: *Bhur Kambja-1; Grain yield; Seedlings hill^{-1}; Rice; Yield components*

1. Introduction

Rice (*Oryza sativa*) is the world's most important food for some 4 billion people (IRRI, 2019) and more than 90% of rice is produced and consumed in Asia (Global Rice Science Partnership (GRiSP, 2013). In Bhutan rice is the staple food crop, indispensable to Bhutanese culture, tradition, religion, and livelihoods (Ghimiray et al., 2008) which is often equated to food security (Chhogyel, Ghimiray, Wangdue, & Bajgai, 2015). It is grown in a wide range of altitudes, starting from tropical lowlands (150 m) in the south to elevations as high as 2600 m in the north (Ghimiray et al., 2008).

However, the rice sector in Bhutan is challenged by shrinking rice areas, often losing to urbanization and other infrastructural development activities. Fallowing of the wetland is also

Corresponding email: ngawang@moaf.gov.bt
[e] Agriculture Research and Development Centre- Samtenling, Department of Agriculture, Ministry of Agriculture and Forests

one of the prominent reasons for reduced rice production area. Rice area in Bhutan in 2010 was 22,550 hectares while it dwindled to 14,668 hectares in 2019 (RSD, 2019), accounting for about 35% reduction over the 2010-2019 period. Despite these impediments, rice in southern Bhutan is grown annually for food in small pockets mostly applying farmers' traditional cultivation techniques. One of the prevalent techniques is the use of a thick bunch of seedlings hill^{-1} at planting primarily to save the seedlings from pest damages and also for higher yield under irrigated conditions. It is seen during the field visits that this technique is used in both traditional and improved varieties by the farmers.

According to IRRI (2007), the number of seedlings transplanted hill^{-1} depends on three factors which are the traditional practices of the farmers, quality of seedling, and the price of seed. Hybrid seed, which is costlier, is often transplanted as one seedling hill^{-1} while traditional varieties are sometimes planted with up to six seedlings hill^{-1}. In most countries, the farmers plant two to three seedlings per hill (IRRI, 2007). The use of more seedlings hill^{-1} not only adds to cost but is also a waste of natural resources (Saker & Nahar, 2016). Hence, finding a genotype-based appropriate number of seedlings hill^{-1} or planting density is necessary for optimum rice production under limited production resources. The number of seedlings hill^{-1} is an important factor for higher production as it influences the number of tillers, which ultimately determines the yield, because the tillering ability is an inherent trait that varies among rice varieties (Chowhan, Imdadu, Rani, & M., 2019). Hence, extra seedlings are generally desired based on the tillering capacity of the variety and high-tillering rice varieties are desirable for transplanted or direct-seeded rice (De Datta, 1981). However, the use of extra seedlings is an expensive method of ensuring an increased number of tillers (Liu et al., 2021). Therefore, this study was carried out with the objectives to: (a) determine the effect of the number of seedlings hill^{-1} on yield components and grain yield of Bhur Kambja-1, and (b) to recommend the optimum number of seedlings hill^{-1} to the rice farmers of southern Bhutan.

2. Materials and Method

2.1 Experimental site and design

The study was carried out from June to December of 2020 at the research farm of the ARDC-Samtenling, Sarpang Dzongkhag (26^{o} 54' 17" N latitude and 90^{o} 25' 51" E longitude) which is located in southern Bhutan. The study site falls under wet-humid sub-tropical agroecology with an elevation of 375 meters above sea level (Figure 1). Treatments included seven different numbers of seedlings viz. 1, 2, 3, 4, 5, 6, or 7 hill^{-1} of popular improved variety of rice in the region (Bhur Kambja-1). The experiment was carried out in a randomized complete block design with three replications. Each plot size measured 10 m^2 (5 m × 2 m) and uniform spacing of 20 cm × 20 cm row to plant was maintained for the study. The experimental land was prepared using a tractor and fertilized with urea, single super phosphate (SSP), and muriate of potash (MoP) at the recommended rate of 150, 250, and 50 kg ha^{-1}, respectively. Half dose of nitrogen was applied as basal dose along with full doses of phosphorus and potassium. The remaining half dose of nitrogen was applied in two equal splits at active tillering and panicle initiation stages. Intercultural operations like weeding and irrigation were carried out manually for maintaining the normal growth and development of the crop. And these intercultural operations were uniformly carried out across the seven treatments.

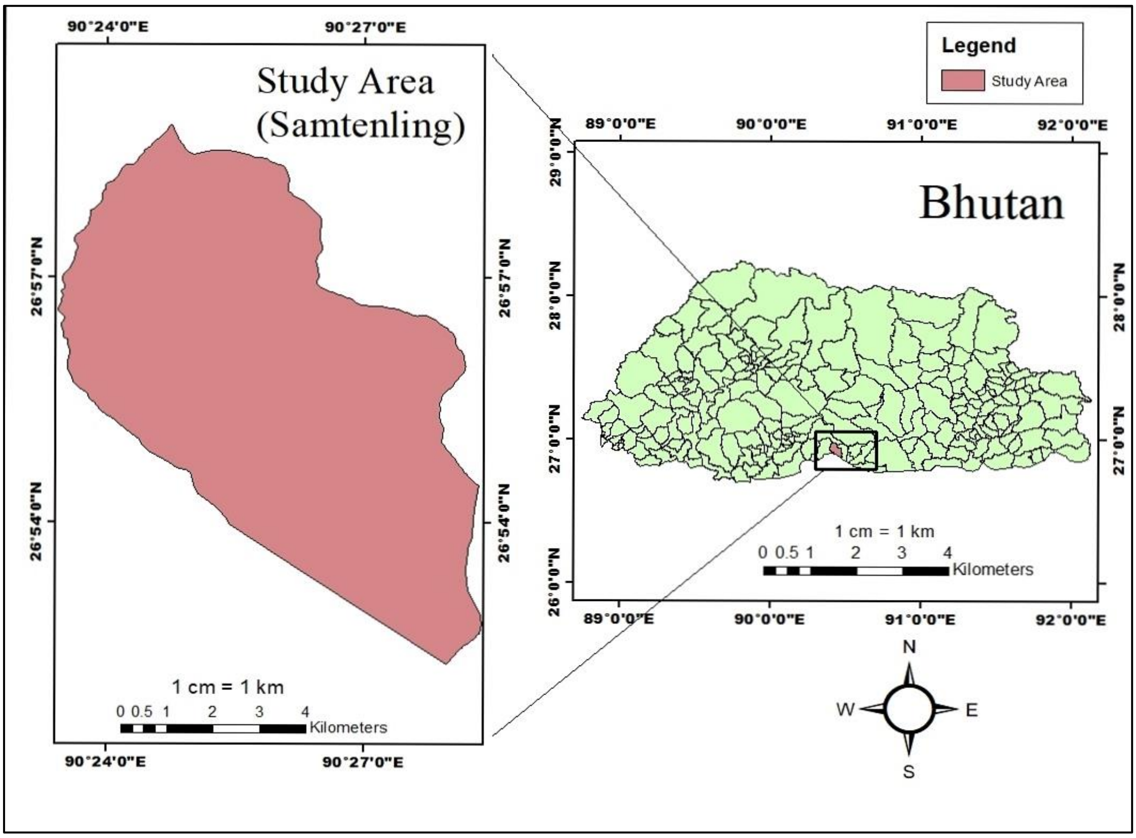

Figure 1. Location of the experimental site in Bhutan

2.2 Data compilation and analysis

Data from the experiment were gathered following the Standard Evaluation System for Rice developed by the International Rice Research Institute (IRRI, 2002) and every care had been taken to minimize errors. The experimental plots were monitored at regular intervals and data for plant height were gathered immediately after flowering, while agronomic parameters such as number of productive tillers, number of filled grains $panicle^{-1}$, and number of unfilled grains panicle^{-1}, panicle length, and yields were collected during the harvesting stage as per the methods described by (IRRI, 2002).

The crop was harvested at full maturity and five hills per treatment were randomly selected to gather the required data. All data was collection was performed after discarding two rows of plants from each side of the experimental unit to avoid biases through border effect. The counting of the number of productive tillers, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} were done manually and panicle length was measured using a scale. The grain yield was determined from the harvested area of 5.04 m^2 adjusting moisture content to 14 % using the standard formula.

$$Grain\ yield\ (t/ha) \quad = \frac{Adjusted\ moisture\ x\ Plot\ yield\ (kg)\ \ x\ 10000}{Plot\ size\ x\ 1000}$$

Where $Adjusted\ moisture \quad = \frac{100 - MC}{100 - 86}, and\ MC = grain\ moisture\ content\ at\ harvest$

The compilation of data was carried out using Microsoft Excel spreadsheet while analysis of variance (ANOVA) was conducted using statistical software Statistical Tool for Agriculture Research (STAR version 2.0.1) and Statistical Package for the Social Sciences (SPSS version 22). Multiple comparisons among the means were conducted using Tukey's HSD Test. All effects were declared significant at P-value ≤ 0.05 unless otherwise stated.

3. Results and Discussion

3.1 Plant height

Rice seedlings transplanted with one to seven seedlings hill^{-1} did not show any significant differences in plant height *(P*-value=0.489). The plant heights varied from 98.8 to 103.5 cm, without showing any significant relation to the different seedling rates (Table 1). Though there were no significant differences, transplanting two to three seedlings hill^{-1} resulted in the numerically tallest plants in this experiment.

Our finding agrees with those of Mahamud, Haque, and Hasanuzzaman (2013) and Faruk, Rahman, and Hasan (2009) who also reported having taller plants when three rice seedlings were transplanted per hill. Plant height is an important trait in rice and has greater bearings on the grain yield and harvest index (IRRI, 2006). The tallest plant height recorded in this study for three seedlings hill^{-1} is similar to the findings of Faruk et al. (2009), who reported the tallest plant height from two seedlings hill^{-1} density in BRRI Dhan-33 variety of rice. The Bhutanese farmers use rice straw as cattle feed, and therefore it is important to assess the optimum seedling rate that will give good grain yield without compromising the straw potential of crop varieties. In an earlier study, the rice variety, Bajo Maap, gave good grain as well as straw yields when transplanted with three to four seedlings hill^{-1} in Wangdi valley of Bhutan (Ghaley, Høgh-Jensen, & Christiansen, 2010).

3.2 Panicle length

Panicle length is an important characteristic in rice because together with spikelet number and density, and seed setting rate determines the grain number per panicle which elucidates the productivity or yield in a given situation. The longest panicle was recorded in one seedling hill^{-1} corresponding to 22.5 cm while the shortest was found in the treatment which had three seedlings hill^{-1} (20.8 cm) through the values did not differ significantly (Table 1). A similar finding was also reported by Mahamud et al. (2013) and (Chowhan et al., 2019) who recorded the longest panicle from one seedling hill^{-1}. In contrast, Ninad, Bahadur, Hasan, Alam, and Rana (2017) reported the longest panicle length from four seedlings hill^{-1} while they found the shortest panicle length under one seedling hill^{-1} and this could be possibly related to varietal traits. Yao et al. (2015) reported that the panicle length is a quantitative trait controlled by multiple genes which are greatly affected by the environment. However, non-significant differences among treatments could be related to Bhur Kambja-1 and the effect on other varieties may differ.

3.3 No. of tillers hill^{-1}

Tillering ability is one of the yield-determining parameters in a rice crop and it makes agronomic denotation to evaluate the ability in Bhur Kambja-1. The number of tillers hill^{-1} was significantly affected by seedling rates *(P*-value=0.017). Transplanting of rice at three seedlings hill^{-1} showed the highest number of productive tillers (11). Treatments with one, two and four seedlings hill^{-1} resulted in the lowest number of productive tillers of eight each, whereas the use of five, six and seven seedlings hill^{-1} produced nine tillers hill^{-1} (Table 1).

The significant variation in terms of the tillering ability of Bhur Kambja-1 under different numbers of seedlings at transplantation corroborates the findings of Dejen (2018), Mahamud et al. (2013), Promsomboon et al. (2019), Imran, Inamullah, Naeem, and Khan (2015), and Islam and Salam (2017) who reported significant differences in the number of tillers under different number of seedlings hill^{-1}. Tillering capacity may be attributed to the variety and is also affected by cultivation methods such as fertilizer application (Nuruzzaman, Yamamoto, Nitta, Yoshida, & Miyazaki, 2000). However, Faruk et al. (2009) reported the highest number of tillers from four seedlings hill^{-1} while Saker and Nahar (2016) reported insignificant differences in tillering due to differences in the number of seedling hill^{-1}, and so the literature needs to be consulted with reference to varieties and crop management practices, not just the number of tillers per hill. In general, high-tillering varieties have a higher number of panicles and thus higher yield in comparison to that of the low-tillering varieties.

3.4 Number of filled grains panicle-1

The result revealed no significant differences in the case of the number of filled grains panicle^{-1}. All the treatments responded with a similar number of filled grains with the highest being 136 filled grains recorded in one seedling hill^{-1} at transplantation (Table 1). The lowest number of grains was observed for six seedlings hill^{-1} with only 121 filled grains. This study saw a non-uniform pattern in the number of grains across the treatments with different numbers of seedlings.

Chowhan et al. (2019) reported the maximum number of grains from one seedling hill^{-1} and their finding is in agreement with our observations. However, the findings of this study are not consistent with the results of Dejen (2018) and Hasanuzzaman, Rahman, Roy, Ahmed, and Zobaer (2009) who found a decreasing trend in the number of grains per panicle with increasing number of seedlings hill^{-1}. This result also disagrees with the finding of Ninad et al. (2017) who reported an increased number of grains panicle^{-1} with an increase in the number of seedlings hill^{-1} in rice variety BRRI Dhan-48. Further, the number of grains panicle^{-1} accounts for higher grain yield (Zhang, Li, Ashraf, Liu, & Li, 2019) while it is determined by panicle architecture like panicle length and length of panicle branch-lets (Kovi, Bai, Mao, & Xing, 2011). Further, the seed setting rate often determines the number of grains panicle^{-1} which is largely affected by external environment (Zhang et al., 2019). Therefore, the effect of seedlings number in a hill in terms of the number of grains panicle^{-1} could be location- and genotype-specific under the influence of different environmental conditions. Further, the study showed unfilled grains panicle^{-1} ranging from 16 to 23 numbers among the treatments. Higher numbers of unfilled grains were observed in six and seven seedlings hill^{-1} with 23 and 21 unfilled grains, respectively. Thus, as stated by Kobata, Yoshida, Masiko, and Honda (2013) and Fu et al. (2021), halving plant density during flowering increased spikelet fertility by 1.3 to 1.5 times, and therefore use of the right number of seedlings hill^{-1} is more economic.

3.5 Grain Yield

In terms of rice grain yield, the significant difference (*P*-value=0.013) was recorded only between three and seven seedlings hill^{-1} with 3.9 and 2.7 t ha^{-1}, respectively (Table 1). In other words, transplanting with one to seven seedlings hill^{-1} produces no significant yield differences except for the three seedlings hill^{-1} treatment.

The lower grain yield in seven seedlings hill^{-1} may be attributed to lower number of tillers (9) and higher number of unfilled grains (21) (Table 1) in comparison to the three seedlings hill^{-1} treatment. This is also true for other treatments concerning the number of unfilled grains (17 to 23), but the numbers of tillers hill^{-1} showed an inconsistent pattern. The maximum grain yield of rice using three seedlings hill^{-1} was also obtained by Bhowmik, Sarkar, and Zaman (2012) and Dejen (2018). The highest grain yield might be due to optimum density suitable for Bhur Kambja-1 to tiller adequately. A higher number of tillers, especially fertile tillers, was found as the determinant of higher yield in rice (Dejen, 2018; Yumnam et al., 2021). Pruneddu and Spanu (2001) revealed that higher grain yield in hybrid rice was due to a higher number of effective tillers and a higher number of filled grains. However, it must be restated that our findings only represent Bhur Kambja-1 in wet sub-tropics and cannot be generalized to other varieties and locations.

Table 1. Effects of different numbers of seedlings hill^{-1} at transplanting on yield and yield component of Bhur Kamjha-1 rice variety

Treatment	Plant height (cm)	Panicle length (cm)	No. of Tillers hill^{-1}	No. of grains panicle^{-1}	No. of unfilled grains panicle-1	Yield tha^{-1}
One seedling hill^{-1}	101.9	22.5	8b	136	18	3.3ab
Two seedling hill^{-1}	103.5	21.6	8b	122	17	3.1ab
Three seedling hill^{-1}	101.4	20.8	11a	130	16	3.9a
Four seedling hill^{-1}	102.7	21.5	8b	132	18	3.4ab
Five seedling hill^{-1}	102	21.6	9ab	123	18	3.3ab
Six seedling hill^{-1}	98.8	20.9	9ab	121	23	3.2ab
Seven seedling hill^{-1}	102.2	20.9	9ab	128	21	2.7b
P-value	0.489	0.06	0.017	0.388	0.09	0.013
CV (%)	2.69	2.85	8.77	6.85	16.4	9

Means with the same letter(s) in the same column are not significant at $P \leq 0.05$

4. Conclusion

Information on seedling rates for all released varieties under the given set of environments is highly useful in exploiting their yield potential. To this end, this is the first study to document the optimum seedling rate hill^{-1} for a popular rice variety, Bhur Kambja-1 in a field experiment conducted at ARDC Samtenling in Sarpang. The study found that the use of three or four seedlings hill^{-1} produced the highest number of productive tillers hill^{-1}, the lowest number of unfilled grains panicle$^{-1,}$ and the highest when planted during the main season under the wet-subtropical condition of Southern Bhutan. This research also shows that the number of seedlings hill^{-1} did not have significant effects on other yield attributes, such as plant height and the number of filled grains panicle^{-1}. The findings of this study are in agreement with the research conducted earlier, both in Bhutan as well as in other parts of Asia. Thus, this study recommends the use of three seedlings hill^{-1} for Bhur Khamja-1 rice variety as this seedling rate not only gives the highest grain yield but also could reduce the seed quantity as compared with the more than three seedling hill^{-1}.

References

Bhowmik, S. K., Sarkar, M. A. R., & Zaman, F. (2012). Effect of spacing and number of seedlings per hill on the performance of aus rice cv. NERICA 1 under dry direct seeded rice (DDSR) system of cultivation. *Journal of the Bangladesh Agricultural University, 10*(452-2016-35674), 191-195. doi:10.22004/ag.econ.209319

Chhogyel, N., Ghimiray, M., Wangdue, K., & Bajgai, Y. (2015). Enhancing Bhutanese Rice in the Domestic Market through increased Production and Favorable Pricing Regime. *Journal of Bhutan Studies*(32), 26-44.

Chowhan, S., Imdadu, H. M., Rani, G. S., Islam, , & M., B. A. M. (2019). Effect of variety and seedling number on the growth and yield of Boro Rice in Bangladesh. Journal of Experimental Agriculture International. *41*(6), 1-15. doi:https://doi.org/10.9734/jeai/2019/v41i630436

De Datta, S. K. (1981). *Principles and practices of rice production*. Los Baños (Philippines): International Rice Research Institute (IRRI).

Dejen, T. (2018). Effect of Plant Spacing and Number of Seedlings per Hill toTransplanted Rice (Oryza Sativa X Oryza Glaberrima) under Irrigation in Middle Awash, Ethiopia. *Journal of Applied Life Sciences International*, 1-9. doi: 10.9734/JALSI/2018/42081

Faruk, M. O., Rahman, M. A., & Hasan, M. A. (2009). Effect of seedling age and number of seedling per hill on the yield and yield contributing characters of BRRI Dhan 33. *International journal of sustainable crop production, 4*(1), 58-61.

Fu, Y.-q., Zhong, X.-h., Zeng, J.-h., Liang, K.-m., Pan, J.-f., Xin, Y.-f., . . . Chen, R.-b. (2021). Improving grain yield, nitrogen use efficiency and radiation use efficiency by dense planting, with delayed and reduced nitrogen application, in double cropping rice in South China. *Journal of Integrative Agriculture, 20*(2), 565-580. doi:https://doi.org/10.1016/S2095-3119(20)63380-9

Ghaley, B. B., Høgh-Jensen, H., & Christiansen, J. L. (2010). Recovery of nitrogen fertilizer by traditional and improved rice cultivars in the Bhutan Highlands. *Plant and soil, 332*(1), 233-246. doi:https://doi.org/10.1007/s11104-010-0288-3

Ghimiray, M., Dorji, K. D., Katwal, T. B., Penjore, U., Dorji, S., Pem, S., . . . Pradhan, K. (2008). *Rice in Bhutan - A Source Book*. Thimphu: Council for RNR Research of Bhutan (CoRRB). Ministry of Agriculture, Bhutan.

GRiSP. (2013). *Rice almanac* (4 ed.). Los Baños (Philippines): Global Rice Science Partnership (GRiSP), International Rice Research Institute (IRRI).

Hasanuzzaman, M., Rahman, M. L., Roy, T. S., Ahmed, J. U., & Zobaer, A. S. M. (2009). Plant characters, yield components and yield of late transplanted Aman rice as affected by plant spacing and number of seedling per hill. *Advances in biological research*, *3*(5-6), 201-207.

Imran, A. A. K., Inamullah, F. A. S., Naeem, L. Z. M., & Khan, M. N. (2015). Phenological traits of rice as influenced by seedling age and number of seedling per hill under temperate region. *J Biol Agri Healthcare*, *5*, 145-149.

IRRI. (2002). *Standard Evaluation System for Rice (SES)*. Los Baños (Philippines): International Rice Research Institute (IRRI).

IRRI. (2006). Rice Knowledge Bank. Retrieved from http://www.knowledgebank.irri.org/ricebreedingcourse/Grain_quality.htm

IRRI. (2007). Rice Knowledge Bank: Planting the rice. Retrieved from http://www.knowledgebank.irri.org/ericeproduction/II.6_Seedling_and_plant_rate.htm

IRRI. (2019). *Annual Report 2019. Race for Impact*. Los Baños (Philippines): International Rice Research Institute (IRRI).

Islam, T., & Salam, M. A. (2017). Effect of number of seedlings hill-1 on the yield and yield contributing characters of short duration Aman rice cultivars. *Progressive Agriculture, 28*(4), 279-286. doi:https://doi.org/10.3329/pa.v28i4.36367

Kobata, T., Yoshida, H., Masiko, U., & Honda, T. (2013). Spikelet Sterility is Associated with a Lack of Assimilate in High-Spikelet-Number Rice. *Agronomy Journal*, *105*(6), 1821-1831. doi: https://doi.org/10.2134/agronj2013.0115

Kovi, M. R., Bai, X., Mao, D., & Xing, Y. (2011). Impact of seasonal changes on spikelets per panicle, panicle length and plant height in rice (Oryza sativa L.). *Euphytica, 179*(2), 319-331. doi:https://doi.org/10.1007/s10681-010-0332-7.

Liu, J., He, L., Luo, H., Wu, T., Zhang, T., Wen, R., . . . Tang, X. (2021). Different seedling managements and fertilizer rates at tillering stage influences the yield formation and aroma content in fragrant rice. *Chilean journal of agricultural research, 81*(2), 128-137. doi:http://dx.doi.org/10.4067/S0718-58392021000200128

Mahamud, J. A., Haque, M. M., & Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. *International Journal of Sustainable Agriculture, 5*(1), 16-24.

Ninad, T. A., Bahadur, M. M., Hasan, M. A., Alam, M. M., & Rana, M. S. (2017). Effect of Spacing and Seedling Per Hill on the Performance of Aus Rice var. BRRI dhan48. *Bangladesh Agronomy Journal, 20*(2), 17-26. doi:https://doi.org/10.3329/baj.v20i2.37084

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshida, T., & Miyazaki, A. (2000). Varietal differences in tillering ability of fourteen japonica and indica rice varieties. *Soil Science and Plant Nutrition, 46*(2), 381-391.

Promsomboon, P., Sennoi, R., Puthmee, T., Marubodee, R., Ruanpan, W., & Promsomboon, S. (2019). Effect of seedlings numbers per hill on the growth and yield of Kum Bangpra RiceVariety (Oryza sativa L.). *International Journal of Agricultural Technology, 15*(1), 103-112.

Pruneddu, G., & Spanu, A. (2001). Varietal comparison of rice in Sardinia. *Informatore Agrario, 57*(5), 47-49.

RSD. (2019). *RNR Census of Bhutan*. Thimphu: Renewable Natural Resources Statistics Division (RSD), Ministry of Agriculture and Forests, Royal Government of Bhutan.

Saker, B. C., & Nahar, N. (2016). Effect of number of seedlings per hill and spacing on growth and yield of transplanted Aman rice (Var. Ranisalute). *Khulna University Studies, 14*, 27-38.

Yao, X. Y., Li, Q., Liu, J., Jiang, S. K., Yang, S. L., Wang, J. Y., & Xu, Z. J. (2015). Dissection of QTLs for plant height and panicle length traits in rice under different environment. *Sci Agric Sin, 48*(3), 407-414. doi:https://doi.org/10.3864/j.issn.0578-1752.2015.03.01

Yumnam, L., Sorokhaibam, S., Laishram, B., Hajarimayum, S. S., Yambem, S., & Newmai, Z. K. (2021). Effect of planting date and spacing on growth and yield of black aromatic rice (*Oryza sativa* L.) cultivar chakhao poireiton. *The Pharma Innovation Journal 2021, 10*(3), 382-387.

Zhang, J., Li, M., Ashraf, U., Liu, S., & Li, R. (2019). Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017. *Front. in Plant Sci., 10*, 1-12. doi:https://doi.org/10.3389/fpls.2019.00543