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Changes in the Growth and Yield of an Extremely Early-Maturing Rice Variety According to Transplanting Density

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Abstract: This study investigated the impact of transplanting density on the growth and yield characteristics of an extremely early-maturing rice variety that has a short vegetative growth period, as the limited growth period results in reduced tiller development and leads to a lower yield. The experiment was conducted in 2019 and 2020 at Chungcheongnam-do Agricultural Research and Extension Services in Republic of Korea, where various transplanting density treatments were tested using the Bbareumi rice variety with a vegetative growth period of less than 50 days. The results showed that the tiller number seedling^{-1} and spikelet number m^{-2} were influenced by the transplanting density and had a significant impact on the milled rice yield. Decreasing the tiller number seedling^{-1} by increasing the transplanting density led to an increase in the spikelet number m^{-2}, which significantly improve the milled rice yield. Furthermore, the study identified the optimal transplanting density for maximizing yield as a transplanting distance of 30 × 12 cm, with 12 seedlings hill^{-1}, which resulted in the highest milled rice yield of 5.64 ton/ha. These findings provide valuable insights for rice farmers and researchers regarding efforts to improve the cultivation practices of extremely early-maturing rice varieties.

Keywords: extremely early-maturing; rice; transplanting distance; seedling number; yield

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1. Introduction

Rice (*Oryza sativa* L.) is a staple food in Korea, but its consumption has been steadily declining as demand increases for various processed foods the main ingredient of which is wheat, such as convenience foods and instant foods [1,2]. The grain self-sufficiency rate of Korea is 20.3% and most agricultural products except for rice are dependent on imports: 99.2% of wheat is imported from other countries [3]. Therefore, increasing wheat production through wheat–rice double cropping is one of the most important goals in Korea, but it has been conducted in limited areas due to climatic conditions and the long growing period of crops [4–6]. Thus, rice varieties with a shorter growing period can be beneficial for increasing wheat–rice double cropping areas [7,8].

In the rice research field, one of the main goals is the development of rice varieties in response to climate change [9]. Previous studies report that extreme weather events such as floods, storms, and droughts are likely to increase in frequency and intensity, causing a reduction in rice yields and threatening food security [10,11]. Thus, there is a need to grow extremely early-maturing rice varieties that can avoid natural disasters and require less irrigation water and fertilizer.

Bbareumi, an extremely early-maturing rice variety, was developed for the purposes of an early harvest and double cropping [8]. Its growing period, from rice transplanting to harvest, is less than 100 days (for commonly cultivated rice varieties, it is approximately 150 days), which is the shortest period among the rice varieties that have been developed in Republic of Korea so far [7]. As a result, it has been selected as a rice variety capable of responding to climate change, as it can reduce irrigation water and fertilizer usage due to its short growing period [8].

The productivity of rice is determined by several factors, including the panicle number, spikelet number, percentage of ripened grain, and 1000-grain weight. Among them, the panicle number is determined first and becomes a factor for determining the other components [12]. However, since the vegetative growing period of Bbareumi is less than 50 days (20–50 days, depending on the transplanting dates), the period for tiller growth is limited [7]. Therefore, it is necessary to develop a cultivation method that can obtain enough panicles. Previous studies have reported that planting density can change the growth and productivity of rice by affecting the amount of sunlight, the nutrient absorption rate, and the photosynthetic rate [6,12–15]. This is because higher planting density can lead to shading and competition for nutrients and water, which can decrease photosynthetic rate and limit nutrients for individual plants. Therefore, it is important to find the optimal planting density for rice cultivation to ensure that the plants receive adequate sunlight, nutrients, and water to maximize their growth and productivity [16,17]. However, most cultivation studies have used rice varieties with a growing period of more than 100 days, and there have been no studies on extremely early-maturing rice varieties. Thus, this study aims to identify the changes in growth and yield according to the transplanting density (transplanting distance and seedling number) of Bbareumi and to develop a cultivation method that can obtain higher grain yields.

2. Materials and Methods

2.1. Experimental Site and Plant Material

This study was conducted from 2019 to 2020 at the rice research field of the Chungcheongnam-do Agricultural Research and Extension Services, located in Yesan, Chungcheongnam-do, Republic of Korea (36°44′ N, 126°49′ E). The rice variety was Bbareumi, which is an extremely early-maturing variety, with a growing period of less than 100 days from transplanting to harvest.

2.2. Experimental Design

The experimental design employed in this study was a split plot design, with transplanting distance as the main plot and the seedling number as the subplot. The experiment was conducted over 2 years, with 4 transplanting distance treatments (30 × 10 cm, 30 × 12 cm, 30 × 14 cm, and 30 × 16 cm) and 3 seedling number hill^{-1} treatments (3, 6, and 9 seedlings) in 2019. In 2020, 3 transplanting distance treatments (30 × 10 cm, 30 × 12 cm, and 30 × 14 cm) and 4 seedling number hill^{-1} treatments (6, 9, 12, and 15 seedlings) were used to confirm the results of the previous year's study. The experiment consisted of 3 replications, with each plot measuring 13.5 m^2 in size. Each plot had a length of 5 m and a width of 2.7 m, with 9 rows and 30 cm row spacing.

2.3. Cultivation Methods

In order to prevent diseases such as Bakanae disease being transmitted by seeds, the seeds were soaked in 15 °C cold water for 48 h and then disinfected using Tebuconazole + Prochloraz copper chloride [18]. The disinfected seeds were sown in a nursery box and grown in a greenhouse for 3 weeks before being transplanted manually on 4 May. The transplanting distance and the seedling number were determined according to the treatments. After transplanting, the field was flooded immediately and maintained at a depth of 3–5 cm until the grain-filling stage and then dried for harvest. The harvest was conducted when the accumulated temperature reached 1000 °C after heading. Chemical pesticides (Tiadinil 6% + Clothianidin 0.5%) were applied once before transplanting to control pests and diseases, and a base fertilizer containing N-P_2O_5-K_2O was used at a level of 90–45–57 kg/ha.

2.4. Trait Evaluation

Days to heading was evaluated as the number of days from transplanting to 50% of the panicles that were heading. For the panicle length and number, 10 randomly selected plants from each plot were investigated at their maturity stage; the panicle length was measured in centimeters from the panicle neck to the panicle tip and the panicle number was calculated as the number of panicle hill^{-1}. The tiller number seedling $^{-1}$ was calculated by dividing the number of panicle hill^{-1} by the number of seedlings hill^{-1}. For the number of spikelet panicle^{-1} and the percentage of ripened grain, three randomly selected plants from each plot were harvested at maturity, and the plants were manually threshed to separate the grains from the straws. The number of spikelet (filled and unfilled grains) panicle^{-1} was manually counted. The threshed grain samples were air-dried and then submerged in water to distinguish the filled and unfilled spikelets; then, the percentage of ripened grains was estimated by the number of filled grain panicle^{-1} divided by the total number of spikelet (filled and unfilled grains) panicle^{-1}. For the milled rice yield, 50 plants from each plot were harvested, threshed, air-dried, and weighed. Additionally, 500 g of rough rice was de-hulled and then the milled rice was calculated after polishing the brown rice. By measuring the weight of 1000 randomly selected brown rice grains, the 1000-grain weight was evaluated; this calculation was performed in triplicate and the values were averaged. The milled rice yield and 1000-grain weight were corrected for the 15% grain moisture content.

2.5. Statistical Analysis

Statistical analyses, including analysis of variance (ANOVA) and correlation analysis, were performed using SPSS software (Ver. 20.0.0). Phenotypic means of each trait were compared using Duncan's multiple range test. Microsoft Excel 2019 was used to organize the data and to generate tables and figures.

3. Results

3.1. Meteorological Data during the Rice Growing Period

Meteorological data (mean temperature, precipitation, and sunshine hours) from transplanting to the harvest of the Bbareumi rice were divided into 15-day periods and are shown in Figure 1. In 2019, the mean temperature from 1 May to 30 June was slightly lower than in 2020, but from 1 July to 31 July in 2019, it was higher. Total precipitation during the rice-growing period in 2020 was 230 mm higher than in 2019, and heavy precipitation at the end of July was recorded each year. There were 153 h more total sunshine hours in 2019 than in 2020, demonstrating the opposite trend to that observed for precipitation, and the lowest sunshine hours were observed at the end of July each year.

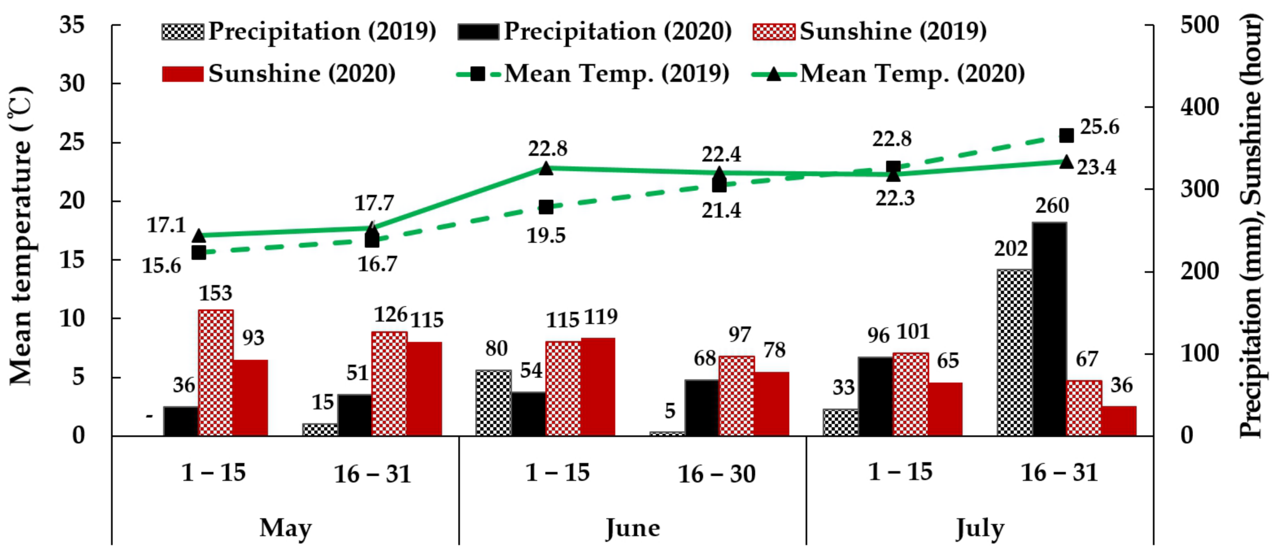

Figure 1. Meteorological data during the rice-growing period. Data of the mean temperature, precipitation, and sunshine hours were obtained from the website of the Korean Meteorological Administration [19].

3.2. Panicle-Related Traits According to Transplanting Density

Panicle-related traits were investigated according to the transplanting density (distance and number of seedlings) and are summarized in Table 1. There was no difference in the total number of days from transplanting to heading according to the transplanting density for the two years, but 2019 was one day shorter than 2020. The panicle length in 2020 was slightly longer than in 2019 at the same transplanting density, and it showed a significant difference in some treatment groups according to the transplanting density for the two years. For the same transplanting distances, as the seedling number increased, the panicle length decreased. The longest panicle length was 19.6 cm in 30 × 14 cm and 6 seedlings in 2020, and the shortest was 17.9 cm in 30 × 10 cm and 9 seedlings in 2019. The panicle number hill^{-1} had a tendency to increase significantly as the transplanting distance and number of seedlings increased. In 2019, the combination of 30 × 16 cm and 9 seedlings showed the highest panicle number hill^{-1} at 17.1; moreover, in 2020, 30 × 14 cm and 15 seedlings had the highest number at 18.7. The panicle number m^{-2} was significantly increased as the transplanting distances decreased and the seedling number increased; 2020 demonstrated approximately 10% more than 2019 for the same transplanting distance and seedling number.

Table 1. Panicle-related traits according to transplanting density.

Year	Transplanting Distance (A)	Seedling Number Hill^{-1} (B)	Days to Heading	Panicle Length (cm)	Panicle Number Hill^{-1}	Panicle Number m^{-2}	Tiller Number Hill^{-1}
2019	30 × 10 cm	3	55	18.5a	10.9b	363b	3.6a
		6	55	18.1b	11.7a	391a	2.0b
		9	55	17.9c	12.2a	406a	1.4c
	30 × 12 cm	3	55	18.6a	12.4c	344c	4.1a
		6	55	18.3a	13.6b	379b	2.3b
		9	55	18.2a	14.6a	405a	1.6c
	30 × 14 cm	3	55	18.7a	14.0b	334b	4.7a
		6	55	18.7a	14.4b	343b	2.4b
		9	55	18.2b	15.2a	363a	1.7c
	30 × 16 cm	3	55	18.6a	14.9c	310c	5.0a
		6	55	18.2a	16.1b	335b	2.7b
		9	55	18.3a	17.1a	357a	1.9c
	Mean	30 × 10	55	18.2a	11.6d	387a	2.3a
		30 × 12	55	18.4a	13.5c	376a	2.7a
		30 × 14	55	18.6a	14.6b	347b	2.9a
		30 × 16	55	18.4a	16.0a	334b	3.2a
	Interaction	A × B	ns	ns	**	**	**

Table 1. *Cont.*

Year	Transplanting Distance (A)	Seedling Number Hill^{-1} (B)	Days to Heading	Panicle Length (cm)	Panicle Number Hill^{-1}	Panicle Number m^{-2}	Tiller Number Hill^{-1}
2020	30 × 10 cm	6	56	18.8a	12.8d	427d	2.1a
		9	56	18.6a	13.4c	448c	1.5b
		12	56	18.2a	14.3b	477b	1.2c
		15	56	18.5a	15.2a	507a	1.0d
	30 × 12 cm	6	56	19.3a	14.6c	406c	2.4a
		9	56	18.8ab	15.8b	439b	1.8b
		12	55	18.6bc	17.1a	476a	1.4c
		15	55	18.4c	17.1a	475a	1.1d
	30 × 14 cm	6	56	19.6a	16.5b	394c	2.8a
		9	56	19.4a	17.2b	409c	1.9b
		12	56	19.0b	18.3a	435b	1.5c
		15	56	18.8b	18.7a	446a	1.2d
	Mean	30 × 10	56	18.5b	13.9c	464a	1.5a
		30 × 12	56	18.8b	16.2b	449a	1.7a
		30 × 14	56	19.2a	17.7a	421b	1.9a
	Interaction	A × B	ns	ns	*	**	**

Means with the same letters in the column for each transplanting distance are not significantly different at the 5% level, as determined by Duncan's multiple range test. * and **: significant at $p < 0.05$ and 0.01, respectively. ns: not significant.

In order to understand the variation in the tiller number seedling^{-1} according to the transplanting distance and the number of seedlings, the tiller number seedling^{-1} was calculated by dividing the panicle number hill^{-1} by the seedling number hill^{-1}. The tiller number seedling^{-1} increased significantly as the transplanting distances increased and the seedling number decreased. The highest tiller number seedling^{-1} was 5.0 for the combination of 30 × 16 cm and 3 seedlings in 2019.

3.3. Changes in Rice-Grain-Related Traits According to Transplanting Density

Rice spikelet-related characteristics were investigated according to the transplanting distance and the number of seedlings and are summarized in Table 2. The spikelet number panicle^{-1} increased as the transplanting distance increased and the seedling number decreased. However, the spikelet number m^{-2} showed a tendency to increase significantly as the transplanting distance decreased and the seedling number increased; in 2020, values were approximately 10% higher than in 2019 for the same transplanting distance and seedling number. The highest spikelet number m^{-2} was 31,158 m^{-2} for the combination of 30 × 12 cm and 9 seedlings in 2019; meanwhile, it was 36,278 m^{-2} for 30 × 12 cm and 12 seedlings in 2020. There was no significant difference in the percentage of ripened grain according to the seedling number at the same transplanting distance. However, in 2020, the percentage of ripened grain decreased by approximately 5% or more compared to 2019 at the same transplanting distance. Most treatment groups showed no significant difference in terms of the 1000-grain weight according to the transplanting distance and seedling number.

Table 2. The changes in rice-grain-related traits according to transplanting density.

Year	Transplanting Distance (A)	Seedling Number Hill^{-1} (B)	Spikelet Number Panicle^{-1}	Spikelet Number m^{-2}	Ripened Grain (%)	1000-Grain Weight (g)
2019	30 × 10 cm	3	81.0a	29,431b	85.5a	20.3a
		6	77.3b	30,238ab	86.3a	20.2a
		9	76.3b	30,961a	85.2a	20.3a
	30 × 12 cm	3	82.7a	28,402b	84.7a	20.1b
		6	77.3b	29,283b	85.7a	20.2b
		9	77.0b	31,158a	85.7a	20.4a
	30 × 14 cm	3	85.7a	28,613b	83.3a	20.1b
		6	83.2ab	28,523b	84.3a	20.1b
		9	80.4cb	29,172a	84.7a	20.3a
	30 × 16 cm	3	91.9a	28,449a	80.2a	20.0a
		6	85.7b	28,735a	81.2a	20.1a
		9	79.3c	28,318a	80.5a	20.1a
	Mean	30 × 10	78.2b	30,210a	85.7a	20.3a
		30 × 12	79.0b	29,614ab	85.3ab	20.3a
		30 × 14	84.6a	29,307bc	83.8b	20.2a
		30 × 16	85.6a	28,501c	80.6c	20.0b
	Interaction	A × B	**	*	ns	ns
2020	30 × 10 cm	6	81.5a	34,774c	75.3b	20.1a
		9	79.7a	35,701b	76.5b	20.2a
		12	77.3b	36,087a	80.7a	20.2a
		15	71.3c	35,940a	80.3a	20.3a
	30 × 12 cm	6	86.0a	34,858c	76.5a	20.2a
		9	81.8b	35,871b	77.9a	20.1a
		12	76.7c	36,278a	78.9a	20.3a
		15	75.2c	35,783b	77.3a	20.2a
	30 × 14 cm	6	87.4a	34,389a	75.8a	20.2a
		9	84.5a	34,551a	75.5a	20.1a
		12	80.5b	34,998a	74.3a	20.1a
		15	78.0b	34,790a	76.1a	20.2a
	Mean	30 × 10	77.5b	35,868a	78.2a	20.2a
		30 × 12	79.9ab	35,732a	77.7a	20.2a
		30 × 14	82.6a	34,682b	75.4b	20.2a
	Interaction	A × B	**	ns	ns	ns

Means with the same letters in the column for each transplanting distance are not significantly different at the 5% level, as determined by Duncan's multiple range test. * and **: significant at $p < 0.05$ and 0.01, respectively. ns: not significant.

3.4. Relationship between the Tiller number Seedling^{-1} and Yield-Related Traits

In order to identify the effect of the tiller number seedling^{-1} on panicle and spikelet traits, a correlation analysis was performed and is summarized in Figure 2. The analysis revealed that the tiller number seedling^{-1} was positively correlated with panicle length and spikelet number panicle^{-1} but negatively correlated with the panicle number m^{-2} and spikelet number m^{-2} during the two years. The tiller number seedling^{-1} showed the highest positive correlations with the spikelet number panicle^{-1} at r^2 = 0.668 ** in 2019 and with r^2 = 0.852 ** in 2020.

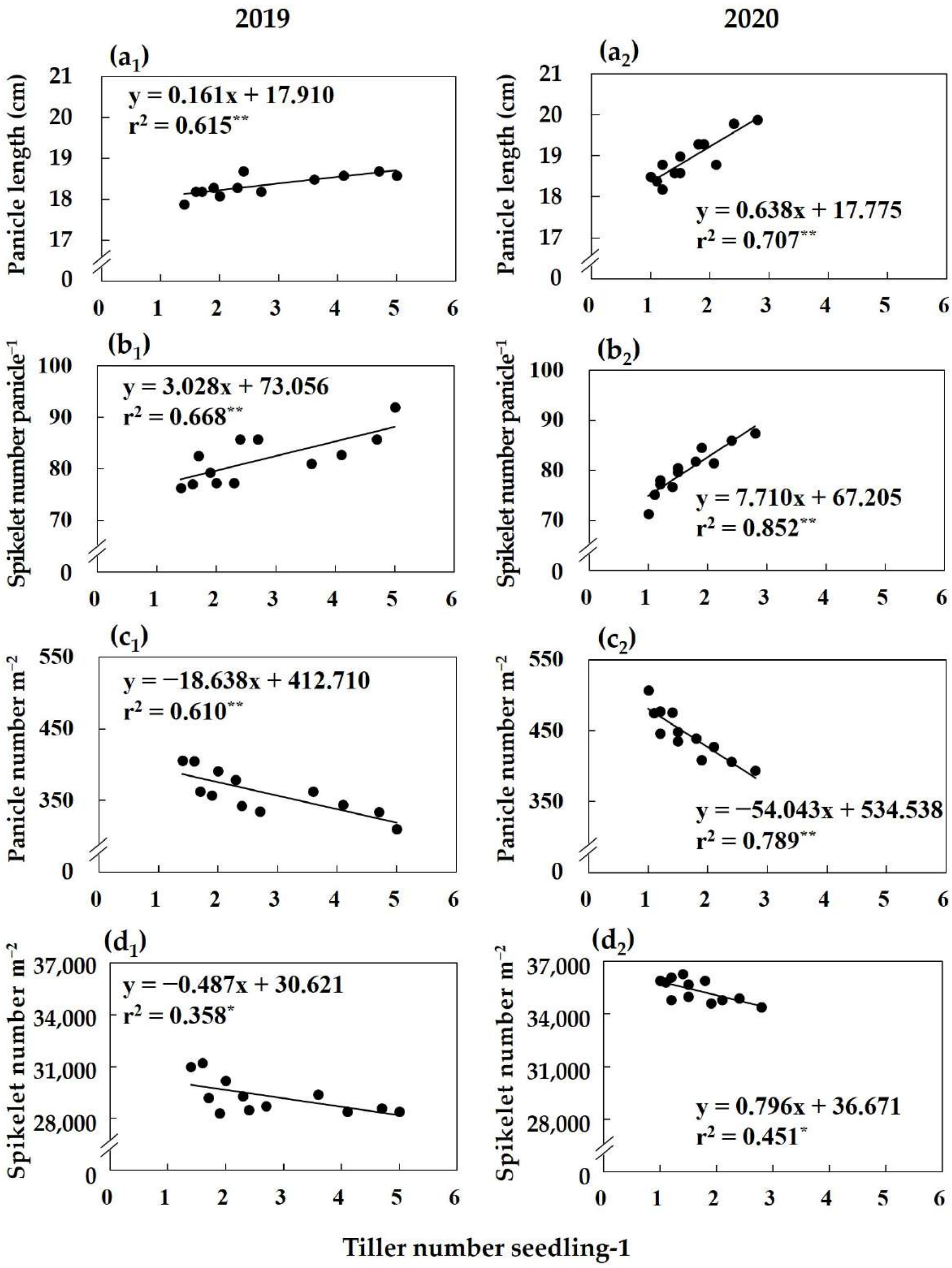

Figure 2. Relationship between the tiller number seedling^{-1} and (**a$_1$**,**a$_2$**) panicle length; (**b$_1$**,**b$_2$**) spikelet number panicle^{-1}; (**c$_1$**,**c$_2$**) panicle number m^{-2}; and (**d$_1$**,**d$_2$**) spikelet number m^{-2}. The tiller number seedling^{-1} is calculated as the panicle number hill^{-1} divided by the seedling number hill^{-1}. Each data point is the mean of the replicates. * and **: significant at $p < 0.05$ and 0.01, respectively.

3.5. Milled Rice Yield According to the Transplanting Density (Transplanting Distance, Seedling Number)

In this study, the milled rice yield was significantly different according to the seedling number (Figure 3). In 2019, the highest milled rice yield was 532 kg/10a for the combination of 30 × 12 cm and 9 seedlings, followed by 521 kg/10a in 30 × 10 cm and 9 seedlings. In 2020, the highest milled rice yield was 564 kg/10a for the combination of 30 × 12 cm and 12 seedlings, followed by 559 kg/10a for 30 × 10 cm and 12 seedlings. For the transplanting distance of 30 × 10 cm and 30 × 12 cm, the milled rice yield increased as the seedling number increased to 9 in 2019 and increased to 12 in 2020. The transplanting distances of 30 × 14 cm and 30 × 16 cm showed slightly lower milled rice yields than those of 30 × 10 cm and 30 × 12 cm for the same seedling number.

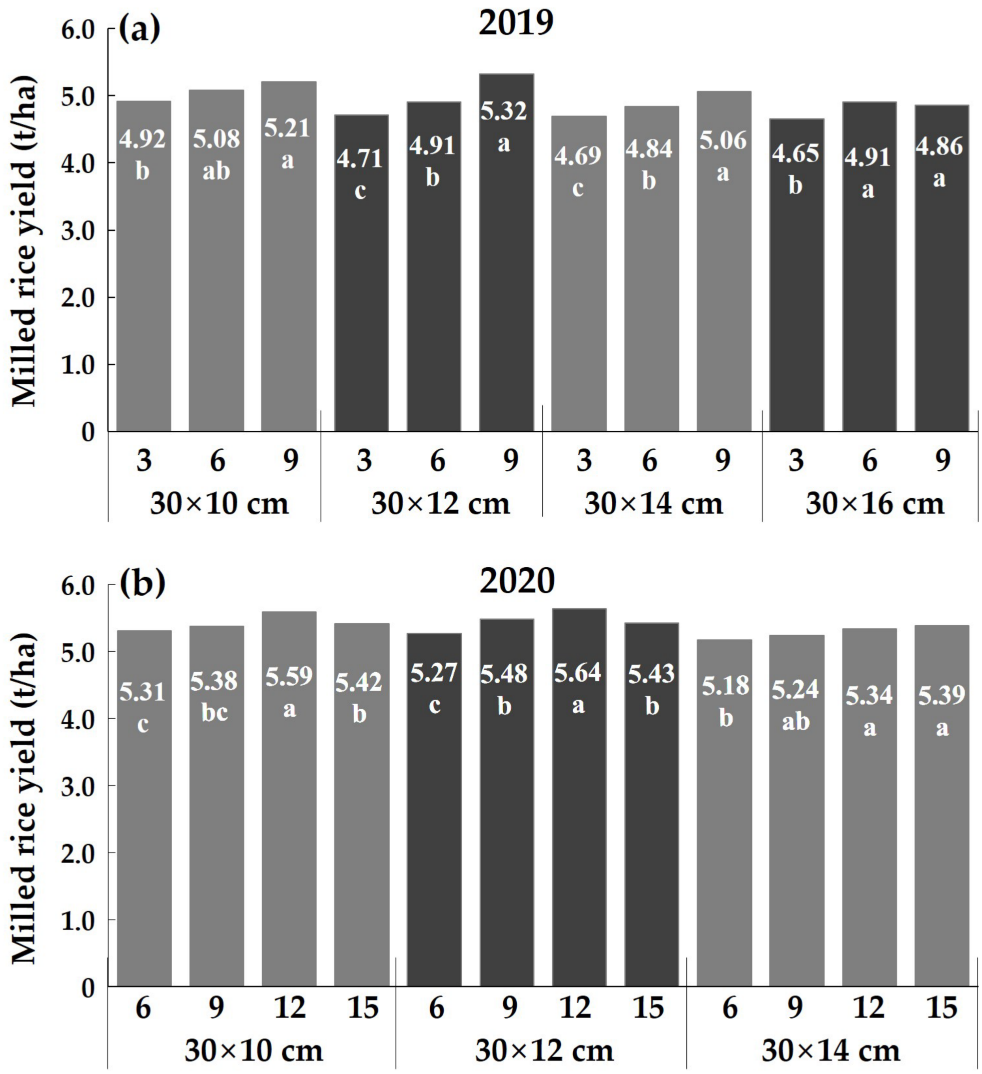

Figure 3. Milled rice yield according to the transplanting density (transplanting distance, seedling number): (**a**) milled rice yield of 2019: the transplanting distance of 4 treatments (30 × 10 cm, 30 × 12 cm, 30 × 14 cm, and 30 × 16 cm) and the seedling number of 3 treatments (3, 6, and 9); (**b**) milled rice yield of 2020: the transplanting distance of 3 treatments (30 × 10 cm, 30 × 12 cm, and 30 × 14 cm) and the seedling number of 4 treatments (6, 9, 12, and 15). Each data point is the mean of the replicates. Means with the same letters in the transplanting distance are not significantly different at the 5% level, as determined by Duncan's multiple range test.

3.6. Relationship between Milled Rice Yield and Yield Components

As shown in Tables 1 and 2, growth and yield varied according to the transplanting density. As the transplanting density increased (the transplanting distance decreased and the seedling number increased), the tiller number seedling^{-1} decreased but the panicle number m^{-2} and spikelet number m^{-2} increased. Moreover, the highest milled rice yield was observed for the combination of 30 × 12 cm and 9 seedlings in 2019 and 30 × 12 cm and 12 seedlings in 2020, at 532 kg/10a and 564 kg/10a, respectively. To determine which traits had the greatest impact on yield, correlation analysis between the milled rice yield and the yield components was conducted and is summarized in Figure 4. The results showed that all yield components, except for the percentage of ripened grain in 2020, were significantly correlated with the milled rice yield over the two-year period. Notably, the milled rice yield demonstrated a strong linear relationship with both the spikelet number m^{-2} (with r^2 values of 0.826 ** and 0.817 ** in 2019 and 2020, respectively) and the panicle number m^{-2} (with r^2 values of 0.810 ** and 0.605 ** in 2019 and 2020, respectively).

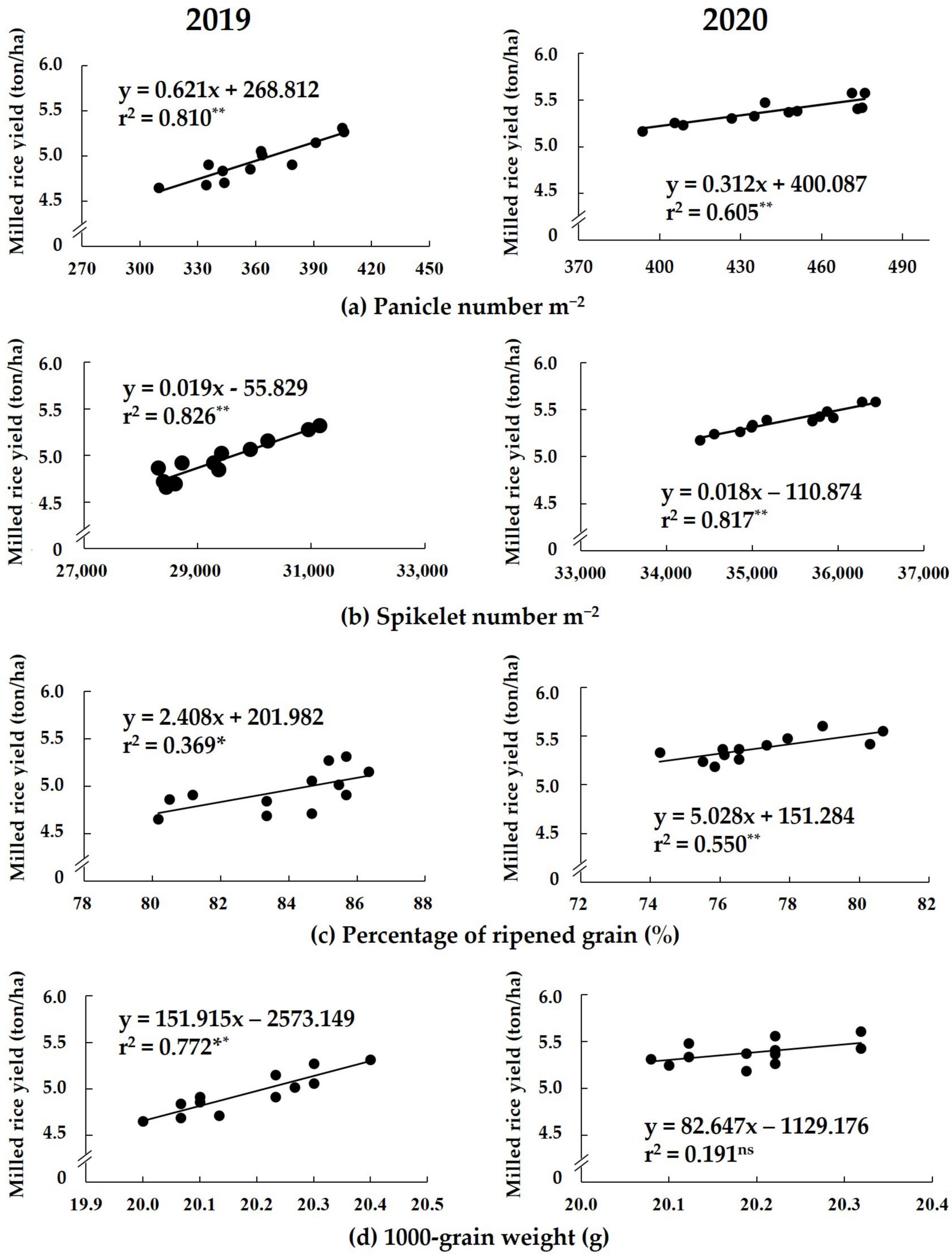

Figure 4. Relationship between the milled rice yield and yield components: (**a**) panicle number m^{-2}; (**b**) spikelet number m^{-2}; (**c**) percentage of ripened grain; (**d**) 1000-grain weight. Each data point is the mean of replicates in 2019 and 2020. The regression analysis was performed using two years of data. * and **: significant at $p < 0.05$ and 0.01, respectively. ns: not significant.

4. Discussion

In this study, most of the growth and yield characteristics varied according to the transplanting density. Previous reports have shown that the transplanting density can significantly influence rice growth and productivity by affecting key factors such as sunlight availability, nutrient uptake, and photosynthetic efficiency [20–22]. Rice plants grown at higher densities can shade each other, reducing the amount of sunlight that reaches the lower leaves and resulting in a decrease in the photosynthetic rate. Moreover, they may compete for nutrients and water in the soil, limiting the availability of these resources for individual plants. Therefore, determining the optimal transplanting density of extremely early-maturing rice varieties is a critical area of research, as such studies have not yet been conducted.

In addition, the panicle number hill^{-1} was approximately 10% higher in 2020 than in 2019 under the same transplanting density, as shown in Tables 1 and 2. A previous study reported that the tiller numbers of Bbareumi were significantly affected by the mean temperature in the early stages of growth due to the short vegetative growing period [7]. We found that the mean temperature from transplanting to heading in 2020 was higher than that in 2019, which was advantageous for tiller growth (Table 1). Unlike the panicle number, the percentage of ripened grains in 2019 was higher than that in 2020 since the environmental conditions during the grain filling stage in 2020 were poor, with much more precipitation and less sunlight, which were the main factors that decreased the percentage of rice grains (Figure 1).

Although there were differences in rice growth over the span of the two years due to meteorological factors and the different treatments applied, the changes in growth of Bbareumi according to the transplanting density showed the same trend. As the transplanting distance decreased, the panicle number hill^{-1} decreased but the panicle number m^{-2} increased. This is consistent with previous studies and suggests that the panicle number is more affected by the density m^{-2} than the hill density^{-1} [13,14,22–24]. To identify the variation in the tiller number seedling^{-1} according to the transplanting density, the panicle number hill^{-1} was divided by the seedling number to calculate the tiller seedling number^{-1}. The tiller number seedling^{-1} increased significantly as the transplanting distance increased, and it tended to increase as the seedling number decreased in the same transplanting distance (Table 2). This is mainly because there was little competition between seedlings, which created an advantageous environment for the rice to grow [12,24,25]. Additionally, the tiller number seedling^{-1} was significantly positively correlated with the panicle length and spikelet number, which is consistent with a previous study [26].

The milled rice yield is determined by several factors, including panicle and spikelet numbers, the percentage of ripened grain, and the 1000-grain weight, with the spikelet number m^{-2} being a major determinant [27]. This study found that the tiller number seedling^{-1} was negatively correlated with spikelet m^{-2}, while spikelet m^{-2} showed a significant positive correlation with the milled rice yield. Therefore, decreasing the tiller number seedling^{-1} by increasing the transplanting density (reducing the transplanting distance and increasing the seedling number) led to an increase in the spikelet number m^{-2} and ultimately improved milled rice yields. These findings are consistent with previous studies [17,28,29].

The optimal transplanting density for maximizing the yield of extremely early-maturing rice was investigated in this study, with a focus on yield-related traits such as the spikelet number m^{-2}. Previous studies have shown that the spikelet number m^{-2} and yield are maximized at a certain transplanting density, and the yield does not increase when the transplanting density exceeds this limit [30]. Therefore, it is important to determine the ideal seedling number hill^{-1}. The results from these experiments showed that the milled rice yield consistently increased up to 9 seedlings hill^{-1} in both 2019 and 2020. However, in 2020, the yield began to decrease slightly at 15 seedlings, indicating that 12 seedlings hill^{-1} may be considered the optimal number for a maximum yield. The highest milled rice yield observed in this study was 5.64 ton/ha, which was achieved at a transplanting distance of 30 $\times$ 12 cm with 12 seedlings. These findings have important implications for rice cultivation practices, as they suggest that increasing the number of seedlings hill^{-1} beyond a certain point does not lead to a significant increase in yields, and may even result in decreased yields. By identifying the optimal transplanting density for maximizing yield, farmers can ensure that they are using resources efficiently and producing the highest possible yield of rice.

Our results suggest that different transplanting distances and seedling numbers affect rice growth and yields, and that an appropriate combination can effectively increase the yield of extremely early-maturing rice.

5. Conclusions

In conclusion, this study investigated the effects of transplanting density on the growth and yield characteristics of an extremely early-maturing rice variety. The results showed that the tiller number seedling^{-1} and spikelet number m^{-2} were significantly influenced by the transplanting density and affected the milled rice yield. These findings suggest that decreasing the tiller number seedling^{-1} by increasing the transplanting density led to an increase in the spikelet number m^{-2} and ultimately improved the milled rice yield. Furthermore, this study identified the optimal transplanting density for maximizing yields as a transplanting distance of 30 × 12 cm with 12 seedlings hill^{-1}, which resulted in the highest milled rice yield of 5.64 ton/ha. The outcomes of this study have significant implications for rice cultivation practices, as they emphasize the crucial role of transplanting density in increasing the production of extremely early-maturing rice varieties. This study is the first of its kind to examine the effect of transplanting density on the yield of an extremely early-maturing rice variety, providing valuable data that can benefit both rice farmers and researchers. These findings make an important contribution to the development of more effective and sustainable cultivation practices, with the potential to advance the production of rice and meet the increasing demand for this staple crop.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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