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Effect of seedling management under aerobic soil on the yield and yield Components of Kum Bangpra Rice Variety (*Oryza sativa* L.)

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Abstract The effect of the number of seedlings hill^{-1} on the yield under aerobic soil was investigated which compared to anaerobic soil, and identified the age of the seedlings for the maximum yield under aerobic soil of the Kum Bangpra rice variety. In the first experiment, it was found that there was an effect on the water levels, and number of seedlings hill^{-1} interaction on the number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, number of empty grains panicle^{-1}, and grain yield hill^{-1}. The highest grain yields under aerobic soil were found in using three seedlings hill^{-1} with 41.5 g. hill^{-1} that was not different from one and two seedlings hill^{-1} under anaerobic soil (41.2 g and 41.7 g, respectively). Using three seedlings hill^{-1} under aerobic soil also provided agronomic characteristics that contributed to high productivity as the lower plant height (157 cm), 11 tillers seedlings hill^{-1}, 11 panicles hill^{-1}, 183 spikelets panicle^{-1}, 138 filled grains panicle^{-1}, 82% of filled grain, and 2.55 g of 100 grain-weight. The condition of the aerobic soil showed that it saved water by 26.3%. For the age of the seedlings, it was found that direct seeding and younger seedlings (15 days) were more well-established than the older seedlings, which displayed a clear plant height of 156-160 cm., 12 tillers seedlings hill^{-1}, 11 panicles hill^{-1}, 176 spikelets panicle^{-1}, 158 filled grains panicle^{-1}, 90% of filled grain, 2.43 g of 100 grain-weight, and 38.4 g of grain yield hill^{-1}. Thus, it could be concluded that cultivation of the Kum Bangpra rice variety under aerobic soil by using younger seedlings or direct seeding with three seedlings hill^{-1} could maintain a high yield similar to anaerobic soil.

Keywords: Kum Bangpra, Aerobic rice, Flooded, Non-flooded, Water shortage

Introduction

At present, with the increase in pollution and disease outbreaks, many people have become more interested in healthcare, especially in the selection of healthy food. Consuming rice containing high nutrition is a choice of people who do not want to fall ill. As such, purple rice (*Oryza sativa* L.) is one of the sources containing high anthocyanin (Boonsit *et al*., 2010; Jang and Xu, 2009;

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Pereira-Caro *et al*., 2013; Zaidi *et al*., 2019), which acts as an antioxidant activity that can prevent cell damage by free radicals (Goufo and Trindade, 2014; Ilmi *et al*., 2018; Iqbal *et al.*, 2005). Kum Bangpra is a local rice variety with a purple pericarp colour that has been improved by the bulk selection method (Promsomboon and Promsomboon, 2016). Interestingly, the composite nutrients found in the Kum Bangpra rice variety were higher than that of Riceberry (Thai purple rice variety); such as, GABA, protein, fibre, Omega 3, Gamma oryzanol, including an antioxidant (Promsomboon *et al.,* 2018). This variety is grown in Eastern Thailand; however, in 2019-2020, various areas of Thailand, including the East were faced with severe drought resulting in dramatic yield loss. Thailand is a country located in a tropical zone, which is easily affected by climate fluctuation. In 2019-2020, the amount of precipitation was lower than 15%, and the rainy season was shorter than normal. Consequently, from the drought, the rice yield experienced a loss of about seven billion Baht and half of that value was found in the Northeast (National Agricultural Big Data Centre, 2021). The unpredictable precipitation has been a major problem in rice cultivation in Thailand (Polthanee *et al*., 2014). Moreover, the temperature that could tend to be higher in the future could enhance more severe droughts; therefore, the yield loss would become more serious (Prabnakorn *et al.,* 2018). To cope with the situation and save water in the future, aerobic rice cultivation was adopted for the Kum Bangpra rice variety. However, Kum Bangpra is lowland rice; as a result, growing in aerobic soil would need to be further studied and maintaining the yield under non-flooded conditions could be challenging.

The system of rice intensification (SRI) has been adopted in many countries that had less water (Uphoff, 2006). The concept of the SRI utilises early seedlings, improved soil conditions and irrigation methods, including less plant population (McDonald *et al*., 2008; Stoop *et al*., 2002). The population density of the plants per hill was the main cause that affected the competition for resources among the individual plants (Craine and Dybzinski, 2013). Five seedlings hill^{-1} were recommended for using in dry direct-seeded rice with a space of 20 cm×10 cm (Bhowmik *et al*., 2013). Lin (2009) reported that the maximum yield of Basmati-385 was found in two seedlings hill^{-1}, while Bazorgi (2011) reported that the maximum yield of Hashemi was found in three seedlings hill^{-1}. Previous studies of the Kum Bangpra rice variety revealed that transplanting with three seedlings per hill was the most suitable for producing the highest yield (703 kg./rai) under flooded conditions (Promsomboon *et al*., 2019). However, in studying the flooded and non-flooded conditions, it was revealed that an increase in the plant density increased the grain yield in the flooded conditions but were not found in the non-flooded conditions (Hayashi *et al*., 2006). These reports indicated that the differences in the optimum of the seedling hill^{-1} were varied depending on the variety and growing conditions. Moreover, seedling establishment was important for growing rice under aerobic soil. Under the conditions of insufficient water, nutrition was also limited; therefore, the rice cultivars that were not improved for an upland area may not survive, especially in the seedling stage. Seedling age also significantly affected the varied yield production among the cultivar (Rahimpour *et al*., 2013). Under flooded conditions, increasing the seedling age from seven to 21 days was the most appropriate for the yield performance (Asbur, 2018), while some varieties needed 45-day-old seedlings (Reddy *et al*., 2008). Therefore, the number of seedlings per hill and seedling age at the transplanting time of the Kum Bangpra rice variety under aerobic soil were clarified in this study.

Materials and methods

The field experiments were conducted at the Plant Science Research Field, Department of Plant Production Technology, Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan-Ok Bangpra Campus, Chon Buri province, Thailand. The soil was the Satuk series (Suk) with fine sandy loam. This study was conducted by two experiments. The first was the effect of the number of seedlings hill^{-1} under the aerobic and anaerobic soils of the Kum Bangpra rice variety, and the second was the effect of the seedling age and direct seeding on the yield of the Kum Bangpra rice variety under the aerobic soil.

Experiment I

The conditions of the water were divided for the aerobic and anaerobic soils. The aerobic soil was a non-flooded condition (well-drained and non-saturated soil) that irrigation was applied through sprinklers when the plants required water (Phule *et al*., 2019), while anaerobic soil was a flooded condition with a water depth of 30 cm until 30 days before harvesting. The conditions of the water and the number of seedlings hill^{-1} were arranged into a split plot design with three replications. The water was the main plot, and the number of seedlings hill^{-1} was the subplot. The total consisted of 18 plots with a plot size of 5mx5m. The number of seedlings hill^{-1} comprised one, two, and three seedlings/seed hill^{-1}. Direct seed was used in aerobic soil, while the seedlings were used in anaerobic soil, which was conducted on 25 June 2020. 20 kg/rai of ammonium phosphate fertiliser (16-20-0) and 10 kg/rai of urea fertiliser (46-0-0) were applied at 30 and 45 days after transplanting, respectively. Nets were used to cover the rice plants throughout the growing season to protect them from pests and diseases. Weeds were also controlled by hand in the anaerobic soil and by a brushcutter in the aerobic soil.

The daily mean temperature, humidity, and rainfall were recorded in all seasons. The amount of water irrigation throughout the growing season was recorded. After transplanting, the plant height and tiller seedlings hill^{-1} were recorded at two months, three months, and at physiological maturity to measure the growth and development. At 50% flowering, the plants were collected. At maturity, the number of panicles hill^{-1} were collected. Two panicles were randomised to count the number of spikelet panicles^{-1}, number of filled grain panicles^{-1}, and number of empty grain panicles^{-1}, and then calculated to the percentage of the filled grain. The shoots and grain were separately collected to be dried in an oven at a temperature of 60 °C for 72 hrs. The shoots dry weight hill^{-1}, grain dry weight hill^{-1}, including grain weight rai^{-1} and harvest index (HI) were measured. The grain yields were randomised in 1 m^2 from each plot to estimate the yield per rai^{-1}.

Data were analyzed by analysis of variance (ANOVA) by the Statistix V.8 programme according to the experimental design. The mean was compared by the least significant difference (LSD) at $P<0.05$.

Experiment II

Seedling age was composed of direct seeding, 15-, 20-, 30-, and 45-day-old seedlings. Five seedling age managements were arranged in a completely randomised design (CRD) with three replications. The sowing dates were set according to the seedling age in order to synchronise the experiment, which were 9 June 2020, 4 June 2020, 25 May 2020, and 5 May 2020, for the 15-, 20-, 30-, and 45-day-old seedlings, respectively, while direct seeding was classified in 0 day. All of them were grown simultaneously in aerobic field conditions with spacing of 25x25 cm. The experimental plots consisted of 15 plants, and each plot size was 5x5 m. Fertiliser applications, data collection, and data analysis were done similarly to Experiment I.

Results

The average temperature throughout the season was 27.9±3.1 ℃ and 87.4±8.4 %RH. The water irrigation in the aerobic soil with 160 mm^3/rai was lower than the anerobic soil (480 mm^3/rai), while the accumulated rainfall throughout the seasons totalled 736 mm (Figure 1), Therefore, the water supply throughout the season of the aerobic and anerobic soils were 896 and 1,216 mm, respectively. The condition of the aerobic soil saved water by 26.3%.

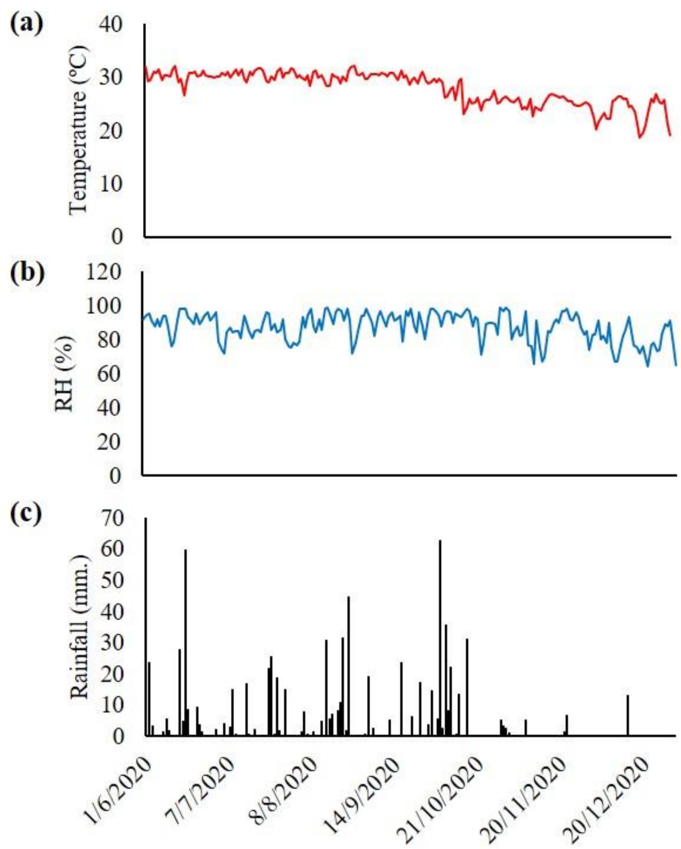

Figure 1. Daily mean temperature (℃) (a), relative humidity (%) (b), and rainfall (mm.) (c) throughout the growing season

Experiment I: Effect of the seedlings hill^{-1} under the aerobic and anaerobic soils of the Kum Bangpra rice variety

Plant height

Plant height was significantly different between the water conditions (Figure 2a). The aerobic soil showed a shorter plant height than the anaerobic soil in all stages, especially with regard to physiological maturity. However, the effects of the seedlings hill^{-1} on plant height were found in some stages of growth. The effects of the seedlings hill^{-1} under the aerobic soil were found slightly at three months, while under the anaerobic soil were found at two months until harvesting. At physiological maturity, the plant height of the rice growing under the aerobic soil was not different at 160 cm, while under the anaerobic soil, the highest was found in three seedlings hill^{-1} (234 cm.) followed by one and two seedlings hill^{-1} (217 cm and 222 cm, respectively).

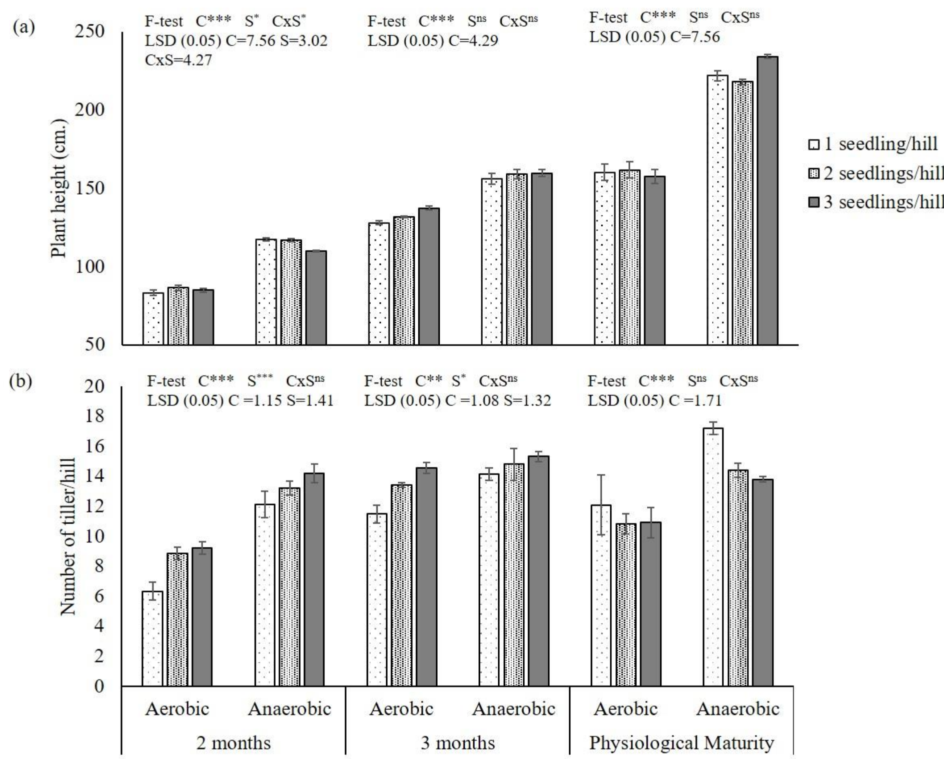

Figure 2. Plant height (a) and number of tillers/hill (b) of the Kum Bangpra rice variety grown under the aerobic and anaerobic conditions at two months, three months, and physiological maturity. The ANOVA of each month is shown at the top of the figure. *, **, and *** refer to the significant difference at $P<0.05$, 0.01, and 0.001, respectively. Ns = non-significant difference

Number of tillers hill^{-1}

The number of tillers hill^{-1} of rice under the aerobic soil was lower than the anaerobic soil where three seedlings hill^{-1} tended to provide the highest number (Figure 2b). At physiological maturity, the number of tillers hill^{-1} was reduced from three months, both under the aerobic and anaerobic soils. The highest number of tillers hill^{-1} under the anaerobic soil was found in one seedling hill^{-1} (17 tillers hill^{-1}) followed by two and three seedlings hill^{-1} (14 tillers hill^{-1}), while there was no significant differences among the seedlings hill^{-1} under aerobic soil (11 tillers hill^{-1}).

Days to 50% flowering

The significant difference of the days to 50% flowering was found between the water conditions of the soil but was not found between the seedlings hill^{-1}. Under the aerobic soil, it was 136 days, which was slightly later than the anaerobic soil (132 days) (Table 1).

Table 1. Days to 50% flowering of the Kum Bangpra rice variety grown under aerobic and anaerobic soils with different seedlings hill-1

Seedling Hill^{-1}	**Condition**		**Mean**
	Aerobic	Anaerobic	
1 Seedling/hill	136.3	131.7	134.0
2 Seedlings/hill	137.0	131.3	134.2
3 Seedlings/hill	135.0	132.7	133.8
Mean	136.1	131.9	
	F-test	LSD	
Condition (C)	**	1.72	
Seedling number (S)	ns	-	
C x S	ns	-	

Number of panicles hill^{-1}

The highest number of the panicles hill^{-1} under the anaerobic soil was found in one seedling hill^{-1} (16 panicles hill^{-1}) then was decreased to 13 panicles hill^{-1} when the number of the seedlings hill^{-1} was increased. However, these were still higher than under the aerobic soil (11 panicles hill^{-1}), which there was no significant difference between the number of the seedlings hill^{-1} (Figure 3a).

Number of spikelets panicle^{-1}

The different water conditions did not affect the number of spikelets panicle^{-1}, but variation was found between the number of seedlings hill^{-1} (Figure 3b). The highest mean of the number of spikelets number panicle^{-1} was found at three seedlings hill^{-1} (179), followed by one seedling hill^{-1} (165) which was not different from two seedlings hill^{-1} (160). Under the anaerobic condition, the highest number of spikelets panicle^{-1} were at one and three seedlings hill^{-1} (183), while under the aerobic condition, the highest were at two and three seedlings hill^{-1} (169).

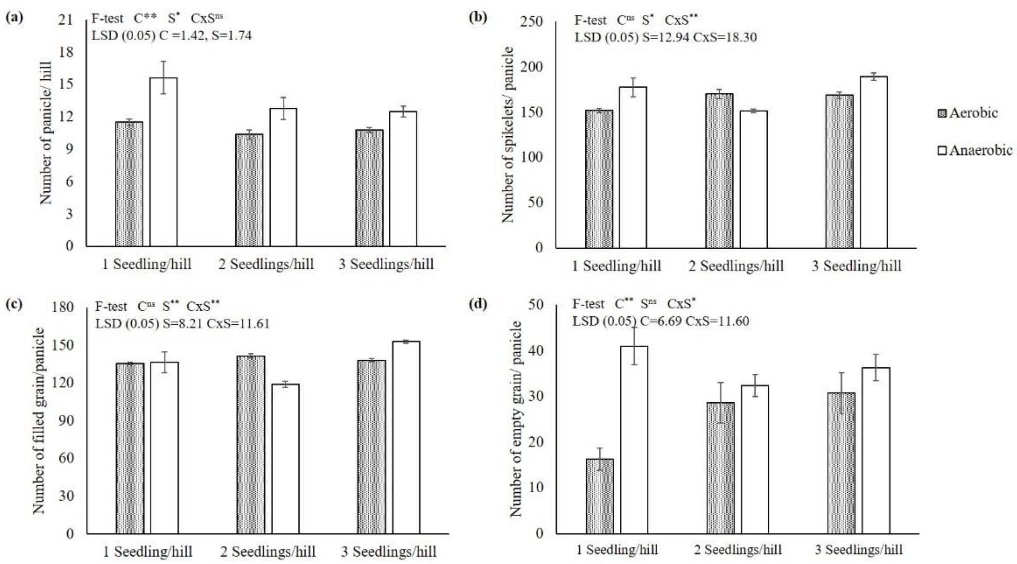

Figure 3. Number of panicle/hill (a), number of spikelets/panicle (b), number of filled grains/panicle (c), and number of empty grains/panicle (d) of Kum Bangpra rice variety grown under the aerobic and anaerobic conditions. *, **, and *** refer to the significant difference at P<0.05, 0.01, and 0.001, respectively. Ns = non-significant difference

Number of filled grains panicle^{-1}

The water conditions did not affect the number of filled grains panicle^{-1}, while the variation depended on the number of seedlings hill^{-1} (Figure 3c). The highest number of filled grains panicle^{-1} of rice under the aerobic soil was found in two seedlings hill^{-1} (142), while under the anaerobic soil, it was found in three seedlings hill^{-1} (153).

Number of empty grains panicle^{-1}

Rice growing under the anaerobic soil tended to provide a higher number of empty grains panicle^{-1} than the aerobic soil, especially in one seedling hill^{-1}, which were 41 grains number panicle^{-1}, while under the aerobic soil, there was only 16 grains panicle^{-1}. However, there were no differences found between the two and three seedlings hill^{-1} (32) (Figure 3d).

Percentage of filled grain

The level of the water significantly affected the percentage of filled grain (Figure 4a). Under the aerobic soil, this was 85%, while for the anaerobic soil, it was 79%. The highest filled grain percentage under the aerobic soil was the one seedling hill^{-1} (89%), while the others were 83%.

100 grain-weight

Significant differences of the 100 grain-weight were not found between the water conditions but was slightly different among the number of seedlings hill^{-1} (Figure 4b). The highest was found at three seedlings hill^{-1} (2.55 g), followed by two seedlings hill^{-1} (2.51 g), and the lowest was at one seedling hill^{-1} (2.31 g).

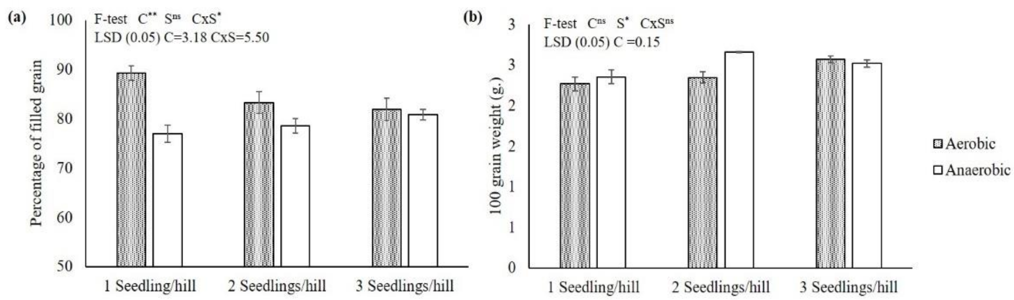

Figure 4. Percentage of filled grain and 100 grain weight of Kum Bangpra rice variety grown under the aerobic and anaerobic conditions. *, **, and *** refer to the significant difference at P<0.05, 0.01, and 0.001, respectively. Ns = non-significant difference

Shoot dry weight hill^{-1}

There was a significant difference between the aerobic and anaerobic soils, but there were no differences found between the number of seedlings hill^{-1} (Figure 5a). The shoot dry weight of the Kum Bangpra rice variety grown under the anaerobic soil was much higher (107 g) than the aerobic soil (49 g).

Grain dry weight hill^{-1}

It was found that increasing the number of seedlings hill^{-1} under the aerobic soil increased the grain yield hill^{-1}, and the highest was found in three seedlings hill^{-1} with 41.5 g, while under the anaerobic soil, increasing the number of seedlings hill^{-1} decreased the grain yield hill^{-1}. The lowest grain yield under the anaerobic soil was found in the three seedlings hill^{-1} (37 g), while the highest was in one seedling hill^{-1} (41.2 g) (Figure 5b).

Harvest index (HI)

The shoot dry weight and grain weight hill^{-1} were calculated to the HI (Figure 5c). The rice grown under the aerobic soil provided a higher average HI (0.41) than the anaerobic soil (0.28), especially the three seedlings hill^{-1}. For this treatment, the HI of the rice grown under the aerobic soil was higher than the anaerobic by almost double.

Grain yield rai^{-1}

The highest grain yield rai^{-1} was found at three seedlings hill^{-1} under the aerobic soil, and one and two seedlings hill^{-1} under the anaerobic soil with 1,060 kg (Figure 5d).

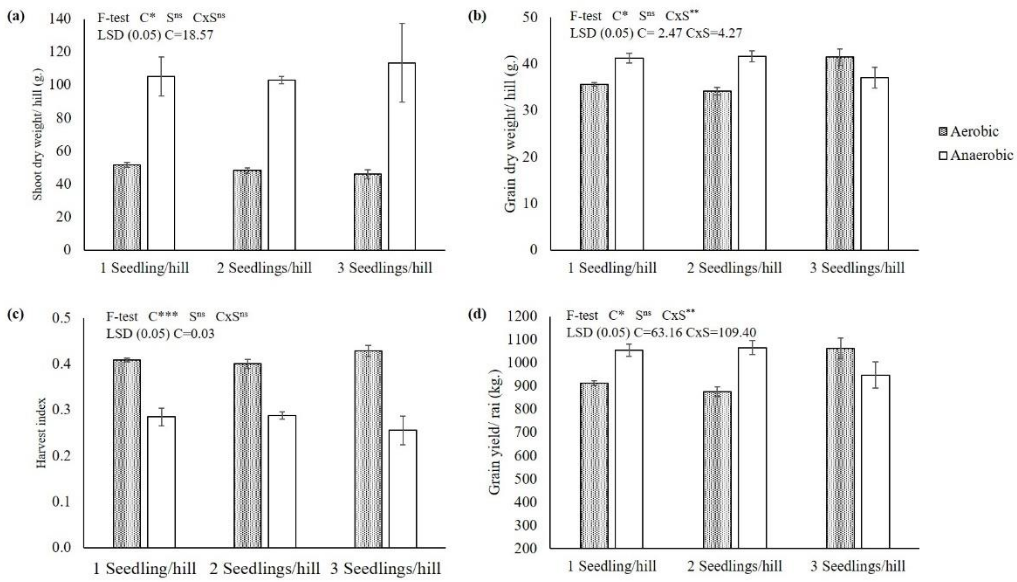

Figure 5. Shoot dry weight/hill, grain yield/hill, harvest index, and grain yield/ rai of Kum Bangpra rice variety grown under the aerobic and anaerobic conditions. *, **, and *** refer to the significant difference at P<0.05, 0.01, and 0.001, respectively. Ns = non-significant difference

Experiment II: Effect of the seedling age and direct seeding on the yield of the Kum Bangpra rice variety under the aerobic soil

The different seedling age significantly affected the plant height (P<0.01), number of tillers hill^{-1} (P<0.05), and number of panicle hill^{-1} (P<0.001) but was not found in the days to 50% flowering, number of spikelets panicles^{-1}, number of filled grain panicles^{-1}, number of empty grain panicles^{-1} and 100 grain weight (Table 2). The plant height at direct seeding, 15- and 20-day-old seedlings (156-160 cm.) were higher than the 30- and 40-day-old seedlings (150 cm). The days to 50% flowering displayed no significant difference among the seedling ages, which varied between 137-140 days. For the tillers hill^{-1}, the direct seeding and 15-day-old seedlings provided a higher number of tillers (12 tillers hill^{-1}) than the 20-, 30-, and 45-day-old seedlings (9 tillers hill^{-1}), which was similar to the number of panicle hill^{-1}. The highest number of panicle hill^{-1} was found in direct seeding and 15-day-old seedlings

(11 panicle hill^{-1}), while the others were 8.3-9.7 panicle hill^{-1}. For the dry matter, significant differences were found in the grain dry weight hill^{-1} (P<0.001), shoot dry weight hill^{-1} (P<0.01), and grain yield rai^{-1} (P<0.001) (Table 3). The direct seeding and 15-day-old seedlings showed the highest yield hill^{-1} (38.4 g), followed by at 20 days (35.6 g), and the lowest were found at 30 and 40 days (32.2 g). For the shoot dry weight, the direct seeding and 15-day-old seedlings showed the highest shoot dry weight (85 g), while the others were varied from 68-76 g. The direct seeding and 15-day-old seedlings also showed the highest grain yield rai^{-1} (982.5 kg. rai^{-1}), followed by 20 days (911.8 kg.rai^{-1}), while the lowest was found at 30 and 45 days (824 kg.rai^{-1}). The grain yields were tested for the correlation with nine agronomic traits, which found that the number of panicle hill^{-1} was highly significant and correlated with the grain yield (R=0.86***), followed by the shoot dry weight hill^{-1} (R=0.80***), plant height (R=0.72**), and number of tillers hill^{-1} (R=070**). In contrast, this was not found in the number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, number of empty grains panicle^{-1}, 100 grain weight, and HI (Table 4).

Table 2. Average of the plant height, number of tillers/hill, number of panicle/hill, number of spikelets/panicle, number of filled grains/panicles, number of empty grains/panicle and 100 grain weight with ±SE of the Kum Bangpra rice variety grown with five different seedling ages

Seedling Age	Days to 50% Flowering	Plant Height (cm)	Tiller no./Hill	Panicle no./Hill	Spikelet no./Panicle	Filled Grains no./Panicle	Empty Grains no./Panicle
Direct seedling	136.7±0.3	159.7±2.7	12.0±0.6	11.3±0.3	174.9±2.6	157.9±0.9	17.0±2.5
15 days old	137.3±0.9	156.0±0.6	11.3±0.9	11.0±0.6	177.2±1.4	158.6±0.8	18.6±2.2
20 days old	140.7±1.5	157.3±1.2	9.7±0.3	9.7±0.3	170.9±3.2	155.8±2.2	15.1±1.1
30 days old	137.7±1.2	150.7±0.9	9.7±0.3	9.0±0.0	173.3±7.5	155.5±3.9	17.8±3.9
45 days old	138.0±0.6	150.0±1.2	8.3±0.9	8.3±0.3	165.4±1.2	151.3±1.1	14.1±0.6
Mean	138.1	154.7	10.2	9.9	172.3	155.8	16.5
F-test	ns	**	*	***	ns	ns	ns
CV(%)	1.23	1.7	11	6.4	4	2.4	24.8
LSD	-	4.7	2	1.2	-	-	-

*,**, and *** refer to the significant difference at P<0.05, 0.01, and 0.001, respectively; ns = non-significant difference

Table 3. Average of 100 grain-weight, grain dry weight hill^{-1}, shoot dry weight hill^{-1}, harvest index, and grain yield rai^{-1} with ±SE of the Kum Bangpra rice variety grown with five different seedling ages

Seeding Age	100 Grains Weight (g)	Grain Dry Weight Hill^{-1} (g)	Shoot Dry Weight Hill^{-1} (g)	Harvest Index	Grain Yield Rai^{-1} (kg)
Direct seeding	2.431±0.1	38.59±0.4	84.26±2.6	0.31±0.02	987.8±9.3
15 days old	2.478±0.2	38.2±0.5	85.21±4.4	0.31±0.02	978.0±14.1
20 days old	2.565±0.1	35.62±0.4	76.93±0.9	0.32±0.01	911.8±10.7
30 days old	2.312±0.1	32.74±0.9	73.49±1.5	0.31±0.01	838.1±22.9
45 days old	2.297±0.1	31.66±0.8	68.53±2.3	0.32±0.01	810.4±20.4
Mean	2.416	35.36	77.68	0.31	905.2
F-test	ns	***	**	ns	***
CV (%)	8	3.13	5.81	4.67	3.1
LSD	-	2.01	8.22	-	51.5

** and *** refer to the significant difference at P<0.01 and 0.001;
ns = non-significant difference.

Table 4. Correlation between the yield and growth parameters of different Kum Bangpra seedling age grown under the aerobic condition

Growth Parameter	Correlation Coefficient	P-value
Plant height	0.72	<0.01
Tiller no./hill	0.70	<0.01
Panicle no./hill	0.86	<0.001
Spikelet no./panicle	0.40	not significant at P<0.05
Filled grain no./panicle	0.46	not significant at P<0.05
Empty grain no./panicle	0.19	not significant at P<0.05
100 grain weight	0.34	not significant at P<0.05
Shoot dry weight	0.80	<0.001
Harvest index	0.15	not significant at P<0.05

Discussion

In the first experiment, the interesting appearance of the Kum Bangpra rice variety growing under aerobic soil was a shorter plant height than in the anaerobic soil. This characteristic enhanced the stem strength and reduce the risk of logging, especially at flowering; moreover, grain filling coincidentally occurred with heavy rain. Next, this provided the tillers per hill, where tillers hill^{-1} of all conditions continuously increased. This also decreased when reaching physiological maturity, except at one seedling hill^{-1} under the anaerobic soil that provided the highest number (17 tillers hill^{-1}). However, the percentage of the reduction under the aerobic soil was less than the anaerobic soil. Shading over the leaves or tillers increased the death tillers and decreased the shoot and grain production (Caton *et al*., 2017), which was consistent in this study. Overcrowded tillers were the main reason for senescence and death tillers under the anaerobic soil, especially for the two and three seedlings hill^{-1}, while there was a slight effect on the aerobic soil. These results were according to the HI that was lower in the anaerobic soil because of the overcrowded tillers, and the tall plants had begun to sink instead of the source. This resulted in an imbalance between the source and sink size; additionally, there was insufficient nutrition to fill in the panicle. The major difference between the source and sink size was the main cause for the inefficiency of the nutrient partitioning (Asli *et al*., 2011).

At three seedlings hill^{-1}, the aerobic soil offered 11 tillers hill^{-1}; however, the total number of the tillers hill^{-1} could provide all the panicles, while the anaerobic soil offered 14 tillers hill^{-1} but provided the panicles to equal 12.5 resulting in no difference of the panicle hill^{-1} between the aerobic and anaerobic soils. Although proving the number of spikelets panicle^{-1} and filled grains panicle^{-1} of the aerobic soil were lower than the anaerobic soil, it was compensated with the 100 grain-weight (2.57 g) and percentage of the filled grain (85), which were higher than the anaerobic soil, while the empty grains panicle^{-1} was lower (30). These were the reasons why the grain yield hill^{-1} in the aerobic soil (41.5 g) was higher than the anaerobic soil (37 g). The grain yield of the Kum Bangpra rice variety of previous studies under flooded conditions was 39.5 g. hill^{-1} (Promsomboon *et al*., 2019), which was lower than in this study (aerobic soil). These results illustrated that growing the Kum Bangpra rice variety under aerobic soil could provide a yield higher than traditional flooding.

In the second experiment, the dominant characteristic was performed in direct seeding (0 day) and 15-day-old seedlings. These seedling ages showed the plant height of 156-160 cm, 11-12 tillers hill^{-1}, 11 panicle hill^{-1}, shoot dry weight of 84-85 g, and grain yield hill^{-1} 38.2-38.6 g, which were higher than the other seedling ages. These results concurred with Ali (2013), where younger seedlings were transplanted, and 15-day-old seedlings provided a greater tiller number, growth, and yield compared with the old seedlings. The establishment and nutrition uptake of the younger seedling were better than the older seedling in both the flooded and non-flooded conditions (Mishra and Salokhe, 2008). Tight correlations between the grain yield and plant height (r=0.72), tillers hill^{-1} (r=0.70), and shoot dry weight (r=0.80) indicated that if the seedling age was well-established, this could produce more vegetative organs resulting in higher grain yields.

The large number of seedlings in the nursery bed resulted in the competition for water, light, and nutrition, especially the older seedlings that resulted in reducing the seedling vigour. Under the same age, seedlings that were grown in fields without pest interference could grow and produce tiller numbers better than seedlings grown in a seedbed. Moreover, under the aerobic conditions with unsaturated and well-drained soil, using older seedlings that were spindly and weakened without water support resulted in taking a long period of time for establishment in the field. Older seedling ages were more suitable for the flooded conditions, while younger seedlings or direct seeding were recommended for the non-flooded conditions. This result concurred with Khakwani (2005), who revealed that using younger seedlings under shallow water was an appropriate way for growing rice under high temperatures.

In addition, all the characteristics provided under the aerobic soil that were obtained from using three seedlings hill^{-1} in the first experiment and young seedlings (0 and 15 days) in the second were similar. These characteristics consisted of the plant height (157 and 156-160 cm), tillers hill^{-1} (11 and 12), number of the panicle hill^{-1} (11 and 11), number of spikelets panicle^{-1} (183 and 176), number of filled grains panicle^{-1} (138 and 158), percentage of the filled grain (82 and 90), 100 grain-weight (2.55 and 2.43), and grain yield hill^{-1} (41.5 and 38.4 g). These results confirmed that growing the Kum Bangpra rice variety under the aerobic soil by using three seedlings hill^{-1} with direct seeding or 15-day-old seedlings could maintain the yield like the anaerobic soil.

In conclusion, the Kum Bangpra rice variety responded differently to the soil water management and seedlings hill^{-1}. Because of the high capacity of tillering of the Kum Bangpra rice variety, one seedling hill^{-1} was suitable for growing under the anaerobic soil to reduce the effect of overcrowded tillers, which produced the highest yield, while three seedlings hill^{-1} was the most appropriate for growing under the aerobic soil. The young seedlings (15 days) or direct seeding were well-established than the old seedlings, which was clearly displayed by the plant height, tillers hill^{-1}, grain yield, and shoot dry weight. Young seedlings (15 days) or direct seeding with three seedlings hill^{-1} provided the highest yield under the aerobic soil and also maintained the yield similar to traditional flooding.

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