Effects of Water Salinity on Yield and Yield Components of Three Rice Varieties

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Abstract

This study aims to determine the effects of different levels of water salinity on the growth and yield of three rice varieties. The experiment was conducted on an open field from January to May 2020. The experiment design used 4x3 factorial in Completely Randomized Design (CRD) with three replications. Factor A treatments were four levels of water salinity: 0 (control), 5, 10, and 15 dS/m. Factor B treatments were three rice varieties, of which two were Thai namely Chai Nat 1 (CNT 1) and Pathum Thani 1 (PTT 1) and the other was a salt-tolerance variety from Indonesia; Inpari-35 (IN 35). The results showed that increased water salinity level could decrease all yield and yield components, both assessed from average means and percent reduced values as compared with 0 dS/m (control). The number of fertile tillers, the percentage of filled grain, and the yield per plant are severely affected by the salinity stress from 5 dS/m onward. Thai rice varieties (CNT 1 and PTT 1) showed higher reduction values in all parameters (excepted 1000 seed weight) as compared with Inpari 35. Although both CNT 1 and PTT 1 varieties showed different susceptibility to water salinity levels on different yield components, PTT 1 was more adversely affected at all water salinity stress levels, especially on the number of fertile tillers, filled grain percent, and yield per plant.

Keywords: *salty tolerance, rice growth, rice yield*

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of more than 50% of the world's population (Abdelaziz et al., 2018). More than 90% is grown and consumed by the world's rice in Asia (Islam et al., 2013). Rice accounts for 35-75% of the calories consumed by Asians (Muttayya et al., 2014). About 154 million hectares of arable land or 11% of arable land in the world are annually agricultural crops (Khush, 2005). There are estimated 120,000 different varieties of rice in the world, each with unique advantages and strength. However, most rice cultivars belong to *indica* and *japonica* groups (Ahloowalia et al., 2004; Jain et al., 2004).

At the beginning of the 21st century, there was global water scarcity, environmental pollution, and increased soil and water salinity. As a result, the land available for agriculture is reduced, while increasing human population is recorded (Shrivastava & Kumar, 2015). Even in agricultural areas where farming can still be performed, various environmental stresses, such as high winds, extreme temperatures, soil salinity, drought, and flood, still affect the quantity and quality of crops. Among these problems, soil salinity, which is produced by geo-historical processes or human-made, is one of the most devastating environmental stresses (McGowan, 2017).

Lack of rainfall often results in the absence of water in the rain-fed lowland rice field. Thereby, lowland areas that possess insufficient water will have increased salt particles in the soil surface and thereby can experience the increasing intensity of salinity (Whitehead et al., 2009). This problem is exacerbated by climate change, which leads to salt encroachment in the agricultural area, rise in sea level, and more frequent coastal storms (McCarthy et al., 2001). Furthermore, poor water management practices cause secondary salinization, for example, poor drainage in irrigated areas, (Qureshi et al., 2008). About 800 million hectares of salt-affected areas worldwide are affected, which is equivalent to more than 6% of the world's total (Gerona et al., 2019). Saline soils were defined to have an electrical conductivity (EC) of $\geq$ 4 dS/m (about 40 mmol/L NaCl) as a result of an excess of sodium ions with chloride and sulfate anions (Gerona et al., 2019).

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In the tropical wet and dry or savanna climate found in Thailand, rice can grow twice a year (Seck et al., 2012). Over 80% of rice production in Thailand is conducted under rain-fed conditions in the wet season, less than 20% of the production happens in the irrigated area (Maclean et al., 2002). Rice production was traditionally considered to be limited by the amount of rainfall, even in the rainy season, hence, can be affected by climate change problems. However, rice farming using either rainwater or a modern irrigation system can be affected by the management. Rice varieties that has been improved to tolerate salinity are scarce in Thailand, compared with those enhanced for increasing yield and resistance to diseases and insects (Hossian & Fischer, 1995). In Thailand, salinity stress is one of the problems in some parts of the country especially in the coastal region, semi-arid region, and some northern part of the region (Wassmann et al., 2009). Salinity area is also gradually increased not only in Thailand but also in the world because of climate change (Pholkern et al., 2018). There are many rice varieties grown in Thailand, among them, CNT 1 and PTT 1 rice are famous varieties because of their high yield and the good eating quality. So, these two varieties were tested under various water salinity conditions to obtain the degree of salinity resistance and compared with that of the resistant variety. From forecasting the severity of the salinity problem affecting the world's agricultural sector, obtaining information on the salinity tolerance of popular rice varieties in Thailand will make it possible to further strengthen the improvement or management in rice production. This study focused only on the effects of salinity in yield and yield component in rice received the water salinity, from the tillering to harvesting stage.

2. Objective

To study the effects of water salinity on yield and yield components of three rice varieties.

3. Materials and Methods

3.1 Plant materials and planting

The experiment was conducted on an open field to assess the salinity stress on rice cultivars at the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Phetchaburi Campus, Thailand, from January to May 2020. The 4x3 (salinity levels x rice varieties) Factorial Completely Randomize Design (CRD) with three replications were used in this experiment. Factor A was four levels of water salinity: 0 (control), 5, 10, and 15 dS/m. Factor B was three lowland rice cultivars (*Oryza sativa* L.), namely, Inpari-35 (salt-tolerant variety from Indonesia), Chai Nat 1 (CNT 1), and Pathum Thani 1 (PTT 1) (non-salt tolerant varieties from Thailand). Before the experiment, all three varieties were tested for the germination percent, seed viability, and seed vigor to confirm the viability and quality of seeds. Sandy loam soil was used in this experiment. In the soil analysis, the soil pH was 6.39, organic matter content was 0.93%, electrical conductivity (EC) was 0.92 dS/m, and sodium absorption ratio (SAR) was 0.22 in the trial soil. The lowland rice seeds were prepared by soaking for about 24 hours and incubation at 30°C for 2 days. The germinated seeds were grown in nursery trays, which were filled with fertilized soil. Fourteen-day-old seedlings were transplanted in a plastic pot (32 cm x 30 cm for diameter and height respectively) with 5 plants per pot and were filled with nutrient-rich soil. During the experiment, the pots were kept in the field and were filled with tap water at the frequency of a two-day interval. The seedling started to receive salt stress at 30 days old. The salt stress treatments induced the additional watering of 150 ml salt solution (sodium chloride: NaCl) at 0 (control), 5 (2.92g of NaCl/L of water), 10 (5.84g of NaCl/L of water), and 15 (8.76g of NaCl/L of water) dS/m once per week. The effects of salt stress were evaluated at the harvest (4 months old rice).

3.2 Data collection

Data were collected at the maturity stage of yield and yield components, including plant height, fertile tillers, panicle length, filled grain percent, 1000-seed weight, and seed yield per plant. The plant height was measured from the ground level to the top of the plant, and the fertile tiller was also recorded in each hill at the maturity stage. Counting of filled and unfilled grain from each of the panicle from the harvest plant calculated the percentage of filled grain. 1000 seed weight and yield per plant were measured at 14% moisture content.

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*3.3 Reduction **(%)** of plant character*

The reduction of plant character was calculated with the following equation;

$$\text{Reduction (\%)} = [(A-B)/B] \times 100$$

when A = Measured or evaluated value at salinity stress condition
B = Measured or evaluated value at control condition

3.4 Statistical analysis

Statistical analyses were operated with the R program (R Core Team, 2017). Analysis of variance (ANOVA) with Duncan's Multiple Range Test (DMRT) was executed to compare the mean value for significant differences among treatments.

4. Result and discussion

4.1 Plant height

Plant height is an important parameter among the yield component characters. The results showed that plant height was highly significant (P<0.01) in factor B of rice varieties and factor A of salinity levels, but not significant in the interaction between them (Table 1). Average means of varieties showed the tallest plant height was observed in CNT 1 and followed by Inpari 35 and PTT 1. Plant height showed a decreased trend with increasing salinity levels. Compared with the control treatment, the decreased plant height was started to be observed from 5 dS/m. Saline soil was considered as the soil with more than 4 dS/m salinity (Gerona et al., 2019). This experiment showed that the plant height of these rice varieties was affected by salinity at 5 dS/m, which is in agreement with the study by Zeng et al. (2004) that rice is a salinity-sensitive plant species.

Comparison of plant height percentage of height reduction in each salinity level was presented in Table 1. A higher percentage in reduction (about two times as compared with Inpari 35) was found in CNT 1 at 5 dS/m and PTT 1 at 10 and 15 dS/m. However, at 15 dS/m, CNT 1, PTT 1, and Inpari 35 were observed to have a similar reduction in plant height percentage. Although PTT 1 showed quite a similar reduction in plant height with Inpari 35 at 5 dS/m, PTT 1 had a higher reduction on plant height at 10 and 15 dS/m, as compared with Inpari 35. The difference of responses affected by different salinity levels on plant height in three varieties is likely to be dominated by genetic (Ashraf & Harris, 2004). The observation will help on the decision of a variety for planting in an individual area that the degree of salinity stress is known. Plant height reduction means the decreasing of tissues as well as the potential for photosynthesis (Amirjani, 2010). Also, salinity effects on plant height reduction in rice have been reported in many studies (Rad et al., 2011; Teh et al., 2015).

Table 1 Means of plant height (cm) and plant height reduction (%) (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	**Salinity level (dS/m)**				**Mean**
	0 (NC)	**5 (%NC)**	**10 (%NC)**	**15 (%NC)**	**Varieties**
CNT 1	95.3±0.9	93.0±1.2 (-2.41)	92.6±0.9 (-2.83)	90.0±1.5 (-5.56)	92.8±1.1a
PTT 1	92.6±1.5	91.3±1.2 (-1.40)	88.0±1.5 (-4.97)	86.0±1.5 (-7.13)	89.5±1.4b
IN 35	91.6±1.9	90.3±1.2 (-1.42)	89.0±1.7 (-2.84)	87.0±1.5 (-5.02)	89.5±1.6b
Mean Salinity	93.2±1.4A	91.6±1.2AB	89.9±1.4BC	87.66±1.5C	
P-values (F-test)					
Varieties (V) = 0.0037**, Salinity (S) = 0.0005**, V × S = 0.9377 NS, CV% = 2.7					

Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= Normal condition
CV = coefficient of variation

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** Means significant difference at 0.01 levels of probability, NS means non-significant difference at 0.05 level of probability, different lower case letters (a, b) and upper case letters (A, B, C) mean significant difference at 0.05 level of probability.

4.2 Fertile tiller number

The number of fertile tillers is an important indicator of yield and yield component characters. The results of the number of fertile tillers showed a high significant difference (P<0.01) and affected by factors of the variety and salinity level. No significance between the interaction between variety and salinity level was found (Table 2). The maximum average number of fertile tillers (10.4) was recorded in Inpari 35, followed by PTT 1 (9.2) and CNT 1 (7.3) respectively. The number of fertile tillers per plant on different rice varieties was not significantly different between 5 dS/m and 15 dS/m, but showed significant differences between 0 dS/m and saline conditions (5-15 dS/m). Zeng and Shannon (2000) reported that the number of fertile tillers per plant was significantly reduced at 4.5 dS/m and higher. Although both plant height and number of fertile tillers were affected by the salinity starting at 5 dS/m, the number of fertile tillers seems to be more severely affected than the plant height. This is an important issue since the fertile tiller per plant is a major component for the final yield (Zeng & Shannon, 2000). Na^+ in the soil solution and the resultant reduction of K^+ and Ca^{2+} uptakes cause the inhibition of the proper functioning of cells, instability of cell membrane, and hindrance of enzymatic activity (Quintero et al., 2007). The appearance of rice tillers can be observed at the vegetative stage. However, the number of tillers is one parameter that could affect other yield components developed during the vegetative and reproductive stages, such as the number of productive tillers and panicle length (Rashid et al., 2014).

Percent reduction of fertile tiller number in increasing salinity levels (5 to 15 dS/m) of CNT 1 and Inpari 35 displayed a similar trend when compared with the normal condition. PTT 1 showed a higher reduction (~ 10 percent) of fertile tillers number than CNT 1 and Inpari 35 at 15 dS/m. Beatriz et al. (2001) and Siam (2014) reported similar findings that rice exposed to increased salinity stress had significant adverse effects both on fertile tiller number per plant and panicles per square. PTT 1 is more affected by higher salinity than the other two varieties (CNT 1 and Inpari 35) when grown at the 15 dS/m salinity.

Table 2 Means of fertile tiller number and fertile tiller number reduction (%) (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	**Salinity (dS/m)**				**Mean Varieties**
	0 (NC)	**5** (% NC)	**10** (% NC)	**15** (% NC)	
CNT 1	8.3±0.3	7.3±0.3 (-12.05)	7.0±0.0 (-15.66)	6.66±0.3 (-19.76)	7.3±0.3c
PTT 1	11.0±0.6	9.0±0.6 (-18.18)	9.0±0.6 (-18.18)	7.6±0.7 (-30.91)	9.2±0.6b
IN 35	12.0±0.0	10.3±0.3 (-14.17)	9.6±0.7 (-20.00)	9.6±0.9 (-20.00)	10.4±0.5a
Mean Salinity	10.4±0.3A	8.9±0.4B	8.6±0.4B	8.0±0.6B	
P-values (F-test)					
Varieties (V)	$4.53 \times 10^{-8**}$, Salinity (S)= $3.58 \times 10^{-5**}$, V × S= 0.704 NS, CV%=9.8				

Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= normal condition
CV = coefficient of variation
** Means significant difference at 0.01 levels of probability.
NS means non-significant difference at 0.05 level of probability, different lower case letters (a, b, c) and upper case letters (A, B, C) mean significant difference at 0.05 level of probability.

4.3 Panicle length

The average panicle length affected by salinity level in different rice varieties is shown in Table 3. Both main factors; varieties (factor B) and salinity levels (factor A), significantly affected the average panicle length (P<0.01). The average length of the panicle was higher in both CNT 1 (23.8 cm) and PTT 1 (23.6 cm) than in Inpari 35 (21.5 cm). The highest panicle length was observed in the control treatment (0 dS/m) and had a significant difference between 0 dS/m and saline condition (5-15 dS/m).

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However, no significant difference was shown between 5-15 dS/m, though the panicle length decreased with increased water salinity level. The percentage of reduction in panicle length in each salinity level, as compared with the normal condition (0 dS/m), was higher in Thai rice varieties (CNT 1 and PTT 1) than Inpari 35 around twofold. Interestingly, although the number of effective tillers per plant of Thai rice varieties was similar to 'Inpari 35' across all salinity levels (except at the 15 dS/m in PTT1), the panicle length of Thai rice was approximately two-time shorter than Inpari 35. Panicle length, although not directly considered a yield component in rice, is closely related to the essential yield components such as the number of seeds in panicle, seed density, and rice quality (Wang et al., 2019). The results of the present study are similar to studies by Ali et al. (2004) and Rad et al. (2012) that reported a reduction in rice panicle length under increased salinity level.

Table 3 Means of panicle length (cm) and panicle length reduction (%) (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	**Salinity (dS/m)**				**Mean Varieties**
	0 (NC)	**5** (% NC)	**10** (% NC)	**15** (% NC)	
CNT 1	24.6±0.2	23.8±0.2 (-3.25)	23.5±0.4(-4.47)	23.2±0.3 (-5.69)	23.8±0.3a
PTT 1	24.9±0.5	23.8±0.5 (-4.42)	23.0±0.1 (-7.63)	22.7±0.5 (-8.84)	23.6±0.4a
IN 35	21.9±0.4	21.7±0.4 (-0.91)	21.3±0.3 (-2.74)	21.1±0.5 (-3.65)	21.5±0.4b
Mean Salinity	23.8±0.4A	22.9±0.4B	22.8±0.2B	22.4±0.4B	
P-values (F-test)					
Varieties (V)= 3.46 x 10^{-9**}, Salinity (S)= 0.00129^{**}, V × S= 0.0884 NS, CV%= 2.7					

Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= normal condition
CV = coefficient of variation
** Means significant difference at 0.01 levels of probability, NS means non-significant difference at 0.05 level of probability, different lower case letters (a, b, c) and upper case letters (A, B, C) mean significant difference at 0.05 level of probability.

4.4 Filled grain percent

Filled grain percent is an important contributory factor to yield component characters in rice. The results showed a significant difference in filled grain percentage that affected by variety, salinity level, and interaction between them (Table 4). Filled grain percentage was another characteristic that is affected by increased water salinity. However, the effects on seed filling are clear, both either from genetic differences among Thai rice varieties or different salinity levels. The decrease in filled grain percentage from the normal condition (0 dS/m) was found in ascending order at salinity levels 5 dS/m to 15 dS/m. The mean average was highest in Inpari 35 (68.16%), followed by CNT 1 (54.33%) and PTT 1 (48.83%) respectively. In the interaction between varieties and salinity, maximum filled grain percent was observed in the control and the minimum was recorded in 15 dS/m of water salinity level in the tested varieties. However, there was a percentage reduction, as compared with the control treatment (0 dS/m), of each rice variety, depending on the degree of salinity. A higher percent reduction was found at 5 dS/m, and a similar reduction was observed at 10 and 15 dS/m in all rice varieties. Nevertheless, a higher percent reduction was observed in two Thai rice varieties when compared with Inpari 35 about 8 fold at 5 dS/m. The reduction in grain filling percentage was approximately 4-5 fold over Inpari 35 was calculated at 10 and 15 dS/m, respectively.

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Table 4 Means of filled grain percent and filled grain reduction (%) (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	Salinity (dS/m)				Mean
	0 (**NC**)	**5** (% **NC**)	**10** (% **NC**)	**15** (% **NC**)	**Varieties**
CNT 1	76.66±0.4a	57.0±4.0de (-25.58)	48.6±4.9f (-36.55)	35.0±2.6h (-54.31)	54.33±3.0B
PTT 1	74.66±0.9a	55.0±0.6e (-26.33)	41.3±0.9g (-44.68)	24.3±0.9i (-67.45)	48.83±0.8C
IN 35	73.0±0.6ab	70.6±0.3ab (-3.29)	66.6±0.9bc (-8.77)	62.3±1.2cd (-14.66)	68.16±0.7A
Mean Salinity	74.8±0.6E	60.9±1.7F	52.2±2.2G	48.6±1.6H	
P-values (F-test)					
Varieties (V)= $6.98\text{x}10^{-12**}$, Salinity (S)= $2.14\text{x}10^{-15**}$, V×S =$9.97\text{x}10^{-8**}$, CV%=6.3					

Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= normal condition
CV = coefficient of variation
** means significant difference at 0.01 levels of probability, different lower case letters (a, b, c,…), and upper case letter (A, B, C) or (E, F, G, H) mean significant difference at 0.05 level.

Karami et al. (2010) also reported that the effects of salinity on rice are decreased plant height, the number of fertile tillers, filled grain per panicle, and seed weight. Sterility and reduction in seed sets were primarily affected by the salinity stress. Many mechanisms of plants were reported affected by the salinity stress, such as reduced translocation of soluble carbohydrates to primary and secondary spikelets. Moreover, the accumulation of more sodium and less potassium in all floral parts in rice also was found. This physiological inhibition of the specific activity of starch synthesis during the development of rice grains can be a factor in reduced seed set at salinity stress (Aref & Rad, 2012). Besides, It has been reported that the decrease in the plant inflorescences, possibly due to decreased pollen viability, was strongly influenced by the ionic toxicity under salinity (Islam, 2018).

4.5 1000-seed weights

The results of the salinity effects on 1000-seed weight were similar to filled grain percentage; where a significant difference was shown to be affected by variety and salinity level (Table 5). A higher average 1000-seed weight was found in Inpari 35, followed by CNT 1 and PTT 1 respectively. The seed weight decreased as the salinity increased. The highest 1000-seed weight was found in the control and the lowest was observed in 15 dS/m salinity level. In most reports, seed weight was found to be stable (highly heritable within cultivar) under various stressful conditions, compared with other yield components such as plant height, active tillering, and seed per panicle (Roy & shill, 2020).

However, the reduction in seed weight in this study is also in agreement with many pieces of research that 1000-seed weight decreased with increased salinity level (Abdullah, 2001; Ali, 2004). Asch and Wopereis (2001) reported that salinity in the reproductive stage could decrease 1000-seed weight. Therefore, the problem of salinity is a major problem and can damage rice production by affecting the yield components.

Table 5 Means of 1000-seed weight (g) and seed weight reduction (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	Salinity (dS/m)				Mean
	0 (**NC**)	**5** (% **NC**)	**10** (% **NC**)	**15** (% **NC**)	**Varieties**
CNT 1	25.5±0.1	25.3±0.2 (-0.78)	25.4±0.1(-0.39)	25.1±0.1 (-1.57)	25.3±0.1b
PTT 1	24.8±0.1	24.7±0.1 (-0.40)	24.5±0.1 (-1.21)	24.4±0.2 (-1.61)	24.6±0.1c
IN 35	26.0±0.1	25.8±0.1 (-0.77)	25.6±0.2 (-1.54)	25.5±0.1 (-1.92)	25.8±0.1a
Mean Salinity	25.5±0.1A	25.3±0.1AB	25.2±0.1BC	25.0±0.1C	
P-values (F-test)					
Varieties (V)= $3.1 \text{ x } 10^{-11**}$, Salinity (S)= 0.00266^{**}, V × S= 0.90633 NS, CV%= 1.8					

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Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= normal condition
CV = coefficient of variation
** means significant difference at 0.01 levels of probability, NS means non-significant difference at 0.05 level of probability, different lower case letters (a, b, c) and upper case letters (A, B, C) mean significant difference at 0.05 level.

4.6 Yield per plant (g)

Yield per plant was significantly affected by varieties (factor B), salinity level (factor A), and interaction between them (Table 6). The highest was recorded in Inpari 35 (9.7) followed by CNT 1 (7.6), and the lowest yield was observed in PTT 1 (6.2). In salinity factor, yield also decreased with an increase in salinity levels as compared with the normal condition, where the lowest yield was observed in 15 dS/m. Concerning the interaction between factor A and factor B, the maximum yield was recorded in Inpari 35 under the control condition, and the minimum yield was found on PTT 1 at 15 dS/m.

The reduction of yield in Thai rice varieties (CNT 1 and PTT 1) was more than 50 percent at 15 dS/m as compared with the normal conditions (0 dS/m). However, a significant difference reduction in percentage in yield was detected in CNT 1 and PTT 1 both at 5 and 10 dS/m. A higher reduction in rice yield was recorded in PTT 1 at all salinity levels, compared with CNT 1 and Inpari 35. At 10 dS/m salinity, more than 50 percent of yield reduction was reported in PTT 1. Similarly, Grattan et al. (2002) also reported that a yield loss of 50% with an electric conductivity (EC) of around 7.4 dS/m. Increasing salinity level in soil could reduce rice yield (Hossain, 2006). However, the degree of susceptibility for the salinity stress may be inconsistent between rice varieties (Hasanuzzaman et al., 2009). Therefore, the management to increase rice yield cannot consider solely the salinity level of the farming area but also the response of each rice cultivar under the salinity stress in each salinity level.

Table 6 Means of yield per plant (g) and yield reduction (%) (±standard error) (at maturity stage) in three rice varieties grown under different salinity levels

Varieties	**Salinity (dS/m)**				**Mean**
	0 (NC)	**5** (% NC)	**10** (% NC)	**15** (% NC)	**Varieties**
CNT 1	9.8±0.3bc	8.9±0.5cd (-9.18)	6.9±0.4f (-29.59)	4.5±0.3g (-54.08)	7.6±0.4B
PTT 1	9.5±0.3bc	7.5±0.2ef (-21.05)	4.5±0.3g (-52.63)	3.0±0.3h (-68.42)	6.2±0.3C
IN 35	11.0±0.5a	10.1±0.0b (-8.18)	9.4±0.1bc (-14.55)	8.2±0.2de (-25.45)	9.7±0.2A
Mean Salinity	10.1±0.4E	8.9±0.3F	7.0±0.2F	5.3±0.3G	
P-values (F-test)					
Varieties (V)= 2.17 x 10^{-14**}, Salinity (S)= 4.75 x 10^{-16**}, V × S=0.0002**, CV%=6.7					

Note: CNT 1 = Chai Nat 1, PTT 1 = Pathum Thani 1, IN 35= Inpari 35, NC= normal condition
CV = coefficient of variation
** Means significant difference at 0.01 levels of probability.
Different lower case letters (a, b, c,…), and upper case letters (A, B, C) or (E, F, G,) mean significant difference at 0.05 level.

5. Conclusion

It can be concluded that water salinity stress at 5 dS/m could decrease all studied traits in rice; the plant height, the number fertile tiller, panicle length, 1000-seed weight, and percentage of filled grain. However, higher damages by water salinity demonstrated in reduction percentage when compared with the normal condition (0 dS/m) in each variety were observed on the number of fertile tillers, filled grain percentage, and yield per plant. Compared with the Inpari 35 at various salinity levels, CNT 1 and PTT 1 showed higher reductions in panicle length, filled grain percentage, and yield per plant. Among Thai rice

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varieties, PTT 1 showed more susceptibility under salinity stress than CNT 1, considered the reduction percentage value as compared with the value at 0 dS/m of individual varieties. This experiment should find out the next research to verify these research findings.

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7. References

Abdelaziz, M. N., Xuan, T. D., Mekawy, A. M. M., Wang, H., & Khanh, T. D. (2018). Relationship of salinity tolerance to Na^+ exclusion, proline accumulation, and antioxidant enzyme activity in rice seedlings. *Agriculture*, *8*(11), 166.

Abdullah, Z. K. M. A., Khan, M. A., & Flowers, T. J. (2001). Causes of sterility in seed set of rice under salinity stress. *Journal of Agronomy and Crop Science*, *187*(1), 25-32.

Ahloowalia, B., Maluszynski, M., & Nichterlein, K. (2004). Global impact of mutation-derived varieties. *Euphytica*, *135*(2), 187-204.

Ali, Y. & Awan, A. R. (2004). Influence of salinity at seedling stage and on yield and yield components of different rice lines. *International Journal of Biology and Biotechnology (Pakistan)*, 37(1), 131-139.

Amirjani, M. R. (2010). Effect of NaCl on some physiological parameters of rice. *European Journal of Biological Sciences*, *3*(1), 6-16.

Aref, F. & Rad, H. E. (2012). Physiological characterization of rice under salinity stress during vegetative and reproductive stages. *Indian Journal of Science and Technology*, *5*(4), 2578-2586.

Asch, F. & Wopereis, M. C. (2001). Responses of field-grown irrigated rice cultivars to varying levels of floodwater salinity in a semi-arid environment. *Field Crops Research*, *70*(2), 127-137.

Ashraf, M. P. J. C. & Harris, P. J. C. (2004). Potential biochemical indicators of salinity tolerance in plants. *Plant science*, *166*(1), 3-16.

Gerona, M. E. B., Deocampo, M. P., Egdane, J. A., Ismail, A. M., & Dionisio-Sese, M. L. (2019). Physiological responses of contrasting rice genotypes to salt stress at reproductive stage. *Rice Science*, *26*(4), 207-219.

Grattan, S., Zeng, L., Shannon, M., & Roberts, S. (2002). Rice is more sensitive to salinity than previously thought. *California agriculture*, *56*(6), 189-198.

Hasanuzzaman, M., Fujita, M., Islam, M. N., Ahamed, K. U., & Nahar, K. (2009). Performance of four irrigated rice varieties under different levels of salinity stress. *International Journal of Integrative Biology*, *6*(2), 85-90.

Hossain, M. & Fischer, K. S. (1995). Rice research for food security and sustainable agricultural development in Asia: achievements and future challenges. *GeoJournal*, *35*(3), 286-298.

Hossain, M. M. (2006). *Effect of salinity level on growth and yield of advanced mutant rice in Boro season* (Doctoral dissertation, MS Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh).

Islam, M., Ali, M., Guswami, P., Ullah, S. M., Hossain, M., Miah, M., & Prodhan, S. H. (2013). Assessment of genetic diversity among moderately drought tolerant landraces of rice using RAPD markers. *Journal of BioScience & Biotechnology*, *2*(3): 207-213.

Islam, M. M., Faruqe, M. H., Rana, M. S., Akter, M., & Karim, M. A. (2018). Screening of rice (*Oryza sativa* L.) genotypes at reproductive stage for their tolerance to salinity. *The Agriculturists*, *16*(1), 65-77.

Jain, S., Jain, R. K., & McCouch, S. R. (2004). Genetic analysis of Indian aromatic and quality rice (*Oryza sativa* L.) germplasm using panels of fluorescently-labeled microsatellite markers. *Theoretical and Applied Genetics*, *109*(5), 965-977.

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KaramiA, A. (2010). Quantitative and qualitative responses of rice genotypes (*Oryza sativa*) to salinity levels of drained water. In *19th World Congress of Soil Science*. 1 – 6 August 2010, Brisbane, Australia

Khush, G. S. (2005). What it will take to feed 5.0 billion rice consumers in 2030. *Plant molecular biology*, *59*(1), 1-6.

Maclean, J. L., Dawe, D. C., Hettel, G. P., & Hardy, B. (2002). *Rice almanac: Source book for the most important economic activity on earth*: Int. Rice Res. Inst.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2): Cambridge University Press.

McGowan, J. (2017). Uncovering the roles of African surveyors and draftsmen in mapping the gold coast. *Decolonizing the Map: Cartography from Colony to Nation*, 205.

Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the new york Academy of Sciences*, *1324*(1), 7-14.

Pholkern, K., Saraphirom, P., & Srisuk, K. (2018). Potential impact of climate change on groundwater resources in the Central Huai Luang Basin, Northeast Thailand. *Science of the Total Environment*, *633*, 1518-1535.

Quintero, J. M., Fournier, J. M., & Benlloch, M. (2007). Na^+ accumulation in shoot is related to water transport in K^+-starved sunflower plants but not in plants with a normal K^+ status. *Journal of plant physiology*, *164*(1), 60-67.

Qureshi, A. S., McCornick, P. G., Qadir, M., & Aslam, Z. (2008). Managing salinity and waterlogging in the Indus Basin of Pakistan. *Agricultural Water Management*, *95*(1), 1-10.

R Core Team. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Viena, Austria. URL https://www.R-project.org/

Rad, H. E., Aref, F., Khaledian, M., Rezaei, M., Amiri, E., & Falakdehy, O. Y. (2011). The effects of salinity at different growth stage on rice yield. In *ICID 21st International Congress on Irrigation and Drainage, New Delhi, India* (pp. 155-165).

Rad, H. E., Aref, F., & Rezaei, M. (2012). Response of rice to different salinity levels during different growth stages. *Research Journal of Applied Sciences, Engineering and Technology*, *4*(17), 3040-3047.

Rashid, K. A. S. H. I. F., Kahliq, I., Farooq, M. O., & Ahsan, M. Z. (2014). Correlation and cluster analysis of some yield and yield related traits in rice (*Oryza sativa*). *Journal of Recent Advances in Agriculture*, *2*(8), 290-295.

Roy, S. C. & Shil, P. (2020). Assessment of genetic heritability in rice breeding lines based on morphological traits and caryopsis ultrastructure. *Scientific Reports*, *10*(1), 1-17.

Seck, P. A., Diagne, A., Mohanty, S., & Wopereis, M. C. (2012). Crops that feed the world 7: Rice. *Food security*, *4*(1), 7-24.

Shrivastava, P. & Kumar, R. (2015). Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi journal of biological sciences*, *22*(2), 123-131.

Teh, C. Y., Mahmood, M., Shaharuddin, N. A., & Ho, C. L. (2015). *In vitro* rice shoot apices as simple model to study the effect of NaCl and the potential of exogenous proline and glutathione in mitigating salinity stress. *Plant Growth Regulation*, *75*(3), 771-781.

Wang, X., Liu, G., Wang, Z., Chen, S., Xiao, Y., & Yu, C. (2019). Identification and application of major quantitative trait loci for panicle length in rice (*Oryza sativa*) through single-segment substitution lines. *Plant Breeding*, *138*(3), 299-308.

Wassmann, R., Jagadish, S. V. K., Sumfleth, K., Pathak, H., Howell, G., Ismail, A., ... & Heuer, S. (2009). Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. *Advances in agronomy*, *102*, 91-133.

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Whitehead, P. G., Wilby, R. L., Battarbee, R. W., Kernan, M., & Wade, A. J. (2009). A review of the potential impacts of climate change on surface water quality. *Hydrological sciences journal*, *54*(1), 101-123.

Zeng, L. & Shannon, M. C. (2000). Salinity effects on seedling growth and yield components of rice. *Crop Science*, *40*(4), 996-1003.

Zeng, L., Kwon, T. R., Liu, X., Wilson, C., Grieve, C. M., & Gregorio, G. B. (2004). Genetic diversity analyzed by microsatellite markers among rice (*Oryza sativa* L.) genotypes with different adaptations to saline soils. *Plant Science*, *166*(5), 1275-1285.

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