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MORPHOLOGICAL AND PHYSIOLOGICAL PERFORMANCE OF BROWN RICE (*ORYZA NIVARA* L.) UNDER SALINITY STRESS

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SUMMARY

Brown rice (*Oryza nivara* L.) is a potential a good source of antioxidants for health. Over the past several years, salinity tolerance has been the main aim of breeders for rice improvement. Salinity adversely affects crop growth and yield, and the use of tolerant cultivars is the only effective way to exploit the potential of saline land. This research aimed to analyze the morphological, physiological, and yield traits of brown rice cultivars under different salinity levels at the Kasa Rumah Sungai Balai Research Center, Rubber Research Center, Galang, Deli Serdang–North Sumatra, Indonesia. The said study was carried out during 2019 in a randomized complete block design (RCBD) and factorial arrangement with two factors, i.e., rice cultivars and salinty levels. Ten brown rice cultivars (Sipenget, Meulaboh, Beras Merah, Sijior, Kelik-3, Mesuji, Inpago-7, Sirap Merah, Fas Memeye, and Si Tappe), and four salinity levels (40, 80, and 120 mM and saline soil) were used and compared in the study. Brown rice cultivars and salinity levels significantly influenced plant height, grain weight, and peroxidase enzyme activity. However, the effects of both factors on leaves per plant and H_2O_2 in rice cultivars were nonsignificant. In rice cultivars, the most active enzyme was superoxide dismutase, which showed an increase of 1.20 units/mg of protein. Results revealed that brown rice cultivars exhibited varied responses to salinity stress levels. The rice cultivars Si Tappe, Kelik-3, Beras Merah, and Meulaboh revealed tolerance to salinity and showed good potential for growth and yield traits. The cultivars Mesuji and Inpago-7 were classified as the most sensitive and suceptible rice genotypes to salinity.

Keywords: Salinity levels, morphological and physiological traits, yield traits, antioxidant enzymes, peroxidase, superoxide dismutase, hydrogen peroxide, brown rice (*Oryza nivara* L.)

Key findings: Brown rice (*Oryza nivara* L.) cultivars have the potential to perform well and produce good seed yield on saline soils.

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INTRODUCTION

Rice is an important staple food crop grown in many regions of the world, particularly in Asia, Latin America, and Africa (Lou *et al*., 2012). It is considered as the second most important cultivated crop in the world with production exceeding 700 million metric tons (MMT; 494.4 MMT milled rice). In 2020, rice production was 496.40 million tons (SOSBAI, 2016). During 2020–2021, rice production reached approximately 503.17 MMT, which might represent an increase of 6.77 million tons (1.36%) in rice production around the globe (USDA, 2021).

In the present era, the public awareness of the importance of healthy food has increased (Shofi *et al*., 2019). Brown rice (*Oryza nivara* L.) can provide a good source of antioxidants for health (Santika and Rozakurniati, 2010). However, the potential development of brown rice is still less prestigious than that of white rice because brown rice has a shorter shelf life (Sadimantara and Suwarjoyowirayatno, 2017). Another major problem faced by brown rice is its high postharvest yield losses that can reach up to 20.5% and relatively high price (Hidju, 2011). Efforts to increase brown rice prodcution can be made to increase the growing area and to bring saline soils under rice cultivarion (Hermanasari *et al*., 2017).

More than 830 million hectares of land are salt-affected worldwide, and Indonesia has approximately 13.2 million hectares of saline land, especially in Sumatra (Hoang *et al*., 2014). In Indonesia, saline soil has a good very potential to be developed and used for the production of crops, especially rice. However, the effects of three important aspects are noted in saline soils: osmotic pressure, nutritional imbalance and toxins. In saline soils, chelels are filled with Na^+, which causes a reduction in the availability of micro elements (Ca^+, Mg^+, and K^+) absorbed by plants. Salinity can also be reduced and managed by P uptake even in the absence of deficiency. Increments in Cl levels are also followed by reductions in the levels of NO_3^- in the canopy.

Soil salinity adversely affects and reduces rice production worldwide (FAO, 2005) because the salt-stress environment triggers many metabolic changes in different pathways. The rice genome shows variation in the degree of salinity tolerance at distinct phases of growth and development and is more resistant at the reproductive and grain filling stages than at the vegetative and germination stages (Dolferus *et al*., 2011). The adverse effects of salinity on plant growth also include soil compactness and hardness, under which crop plants cannot establish an effective root system (Machado and Serralheiro, 2017).

Salinity affects growth traits and seed production, and the use of tolerant rice cultivars is the only way to tackle the said problem effectively and to exploit the potential of saline land. However, the development of saline soils is hampered by some constraints, i.e., the limited number of tolerant rice cultivars that are resistant to salinity and the lack of donors for tolerant genes against salinity (Jalil *et al*., 2016). Each rice cultivar possesses different morphological characters, and some of these traits can be used to differentiate rice, i.e., rice seed length, width and thickness (Hanas *et al*., 2017). Genotypes that have the potential to produce a small number of empty grains can be selected as promising breeding material to produce the desired rice strains (Sunarya, 2018).

Plants apply inclusion and exclusion mechanisms to handle salinity. The inclusion mechanism experienced by crop plants to prevent poisoning by excessive amounts of salt ions include the synthesis of compatible solute compounds, compartmentation of salt into vacuoles, the retranslocation of salt through the phloem, and the excretion of salt through the abortion of old leaves (Marschner, 2012). The exclusion mechanism is the plant's efforts to prevent Na ions from entering the plant tissue and to prevent internal water deficits (Sopandie, 2014).

On the basis of above description, this study was planned with the aim to evaluate and study the morphological and physiological characters of brown rice under salinity stress conditions and identify tolerant brown rice cultivars.

MATERIALS AND METHODS

This research was conducted at the Sungei Putih Research Institute, Galang District, Deli Serdang Regency, and at the Sei Putih Research Institute's Greenhouse, Indonesia (±54 m above sea level and type B climate based on Oldeman classification [7–9 consecutive wet months]). Physiological analysis was performed during April–October 2019 at the Tissue Culture Laboratory, Universitas Sumatera Utara, Indonesia. FAO (2005) standards were used as the evaluation criteria for salinity stress (Table 1).

The experiment was carried out in a randomized complete block design with factorial arrangement to study and compare two factors, i.e., brown rice (*Oryza nivara* L.) cultivars and salinty levels. Ten brown rice cultivars, comprising Sipenget, Meulaboh, Beras Merah, Sijior, Kelik-3, Mesuji, Inpago-7, Sirap Merah, Fas Memeye, and Si Tappe, and four salinity levels, i.e., 40, 80, and 120 mM and saline soil, were used in the study (Table 2). The different stages of research included land preparation, planting, plant maintenance, and the observation of different parameters. The methodology in a previous research by Sulaiman (1980) was modified and followed by planting rice seeds in poly bags containing 10 kg of soil and watered with salt solutions as different salinity treatments. The inundation height of the poly bags was maintained every day such that the salt concentration did not change.

Data recorded

Morphological characters

The morphological and yield traits, i.e., plant height, leaves per plant at 4–8 weeks after planting (WAP), and grain weight (g), were recorded as per standard methodology.

Physiological analysis

Physiological analysis focused on the activities of antioxidant enzymes, i.e., peroxidase (POD), superoxide dismutase (SOD), and hydrogen peroxide (H_2O_2), and was performed on the basis of verified past findings. Protein extraction was performed by following the procedure of Packeer-Mohamad *et al*. (2012). Samples was ground with liquid nitrogen and extracted in 0.2 M phosphate buffer (pH 6.5) containing 0.25% (v/v) Triton X-100 and 3% (w/v) polyvinylpyrrolidone. The homogenate was centrifugated at 12 000 rpm and 4 °C for 15 min. The supernatant was separated for protein quantification and POD activity analysis. Protein content was measured via the Bradford method with BSA as the standard (Bradford, 1976). POD, SOD, and H_2O_2 activities were assayed in accordance with Shannon *et al*. (1996), Beauchamp and Fridovich (1971), and Sergiev *et al*. (1997), respectively.

Data analysis

Microsoft excel software version 2010 was used for the analysis of variance (ANOVA) (Steel *et al*., 1997). The effect of different salinity levels on the morphological, physiological, and yield traits of brown rice cultivars was tested through ANOVA and Duncan's multiple range test at the 5% level of probability.

RESULTS

Brown rice cultivars and salinity levels significantly influenced morphological, physiological and seed yield traits, i.e., plant height, leaves per plant at 4–8 WAP, grain weight, and POD enzyme activity.

The cultivar Sijior had higher plant height than all other rice cultivars. Control plots produced rice plants that were taller than the salinity-stressed plots, wherein plants exhibited an average reduction of 10 cm. Several brown rice cultivars showed a varied response every week of observation, and the same was observed in the cultivars Meulaboh, Inpago-7, Fas Memeye, and Sijior (Table 3).

ANOVA showed that the salinity stress treatments had nonsignificant effects on 10 cultivars for number of leaves at 4 WAP, whereas the cultivars had a significant effect on the number of leaves at 6 WAP. The interaction of salinity levels and cultivars did not have a significant effect on the number of leaves at 4–8 WAP (Table 4).

Under abiotic stress caused by salinity, the brown rice cultivars Si Tappe, Beras Merah, Kelik-3, and Meulaboh produced approximately two times heavier grain weight than the other genotypes. Cultivars Inpago-7 and Mesuji were unable to produce panicles because the plants dried up and died in the later stages (Table 5).

The activity of the POD enzyme was significantly different due to varied response of the cultivars. However, the highest average was found in cultivar Meulaboh. The lowest average of POD enzyme was found in cultivar Fas Memeye (0.08 units/mg of protein) and did not significantly differ from that in cultivar Kelik-3 (0.20 units/mg of protein) (Table 6).

SOD enzyme activity was not significantly influenced by the different rice cultivars. The highest average value was found in the cultivar Sipenget, whereas the lowest mean value was found in the cultivar Kelik-3 (Table 7). The effect of salinity on SOD activity in the cultivars was not significantly different, and the value obtained in the control plots was lower than the value obtained for the genotypes grown in saline soil. Saline soil treatment could increase SOD enzyme activity by 57.84%. The interaction of cultivars and salinity levels also had a nonsignificant effect on SOD activity. The highest percent increase in SOD activity was observed in cultivar Sipenget and was 69.56% higher than that in the other genotypes. However, the brown rice cultivar Meulaboh showed a reduction (66.93%) in SOD activity as compared with control plot plants and saline soil plants.

Rice cultivars had a significant effect on H_2O_2 value. Numerically the highest average value was found in cultivar Fas Memeye, whereas the lowest average value was noticed in rice cultivar Meulaboh (Table 8). Salinity levels also resulted in nonsignificant differences for H_2O_2, whereas the H_2O_2 value in the control plots plants was higher than those grown in saline soil.

Table 1. Evaluation criteria for salinity stress (FAO, 2005).

Score	Description	Type
1	Normal growth, only old leaves show white tips, whereas young leaves show no symptoms on young leaves	Very tolerant
3	Near normal growth, but only leaf tips burn, few older leaves become whitish partially	Tolerant
5	Growth severely retarded, most old leaves severely injured, few young leaves elongating	Moderately tolerant
7	Complete cessation of growth, most leaves dried, only few young leaves still green	Sensitive
9	Almost all plants dead or drying	Very sensitive

Table 2. Details of the randomized complete block design.

Salinity levels	S0 (Control)	S1 (NaCl 40 mM)	S2 (NaCl 80 mM)	S3 (NaCL 120 mM)	S4 (Saline soil)
Rice cultivars					
K1 : Sipenget	S0K1	S1K1	S2K1	S3K1	S4K1
K2 : Meulaboh	S0K2	S1K2	S2K2	S3K2	S4K2
K3 : Beras Merah	S0K3	S1K3	S2K3	S3K3	S4K3
K4 : Sijior	S0K4	S1K4	S2K4	S3K4	S4K4
K5 : Ketik 3	S0K5	S1K5	S2K5	S3K5	S4K5
K6 : Mesuji	S0K6	S1K6	S2K6	S3K6	S4K6
K7 : Inpago-7	S0K7	S1K7	S2K7	S3K7	S4K7
K8 : Sidrap Merah	S0K8	S1K8	S2K8	S3K8	S4K8
K9 : Fas Memeye	S0K9	S1K9	S2K9	S3K9	S4K9
K10 : Si Tappe	S0K10	S1K10	S2K10	S3K10	S4K10

Table 3. Effect of salinity on the plant height of local brown rice genotypes.

Time	Rice cultivars	Salinity levels					Means (cm)
		S0 (Control)	S1 (40 mM)	S2 (80 mM)	S3 (120 mM)	S4 (Saline soil)	
4 WAP	K1 (Sipenget)	46.33	43.67	41.33	39.67	39,67	41.33 ce
	K2 (Meulaboh)	46.77	38.33	37.00	36.67	43.67	40.47 de
	K3 (Beras Merah)	57.33	47.00	46.00	43.67	45.67	47.93 ab
	K4 (Sijior)	55.33	49.33	47.67	47.33	58.33	51.40 a
	K5 (Kelik-3)	57.00	53.67	45.67	50.33	45.33	50.40 a
	K6 (Mesuji)	44.33	41.33	43.67	35.67	37.00	39.40 e
	K7 (Inpago-7)	43.00	43.33	43.67	35.67	37.00	40.53 de
	K8 (Sirap Merah)	54.00	44.00	49.67	49.33	35.00	46.40 ad
	K9 (Fas Memeye)	51.00	47.33	50.00	46.67	38.00	46.60 ac
	K10 (Si Tappe)	46.67	46.00	43.33	46.33	34.00	43.33 be
	Means (cm)	50.17 a	45.40 b	44.90 b	43.97 b	39.47 c	
6 WAP	K1 (Sipenget)	57.67	69.67	68.67	63.00	46.00	61.00 df
	K2 (Meulaboh)	62.00	61.33	59.00	58.00	65.67	61.20 df
	K3 (Beras Merah)	91.67	77.67	69.67	70.33	70.67	76.00 ab
	K4 (Sijior)	90.33	78.00	75.00	74.67	92.00	82.00 a
	K5 (Kelik-3)	79.33	76.33	65.00	72.67	74.67	73.60 bc
	K6 (Mesuji)	66.67	62.33	65.67	62.00	44.00	60.13 ef
	K7 (Inpago-7)	65.00	60.33	52.67	44.33	62.67	57.00 f
	K8 (Sirap Merah)	72.33	62.00	73.33	78.67	57.33	68.73 bd
	K9 (Fas Memeye)	76.00	76.33	73.33	63.67	78.33	73.53 bc
	K10 (Si Tappe)	62.33	68.67	68.33	68.33	62.33	66.00 ce
	Means (cm)	72.33	69.27	67.07	65.57	65.37	
8 WAP	K1 (Sipenget)	123.00	113.67	106.67	101.00	89.67	106.80 bc
	K2 (Meulaboh)	82.67	92.67	88.33	89.67	90.00	88.67 d
	K3 (Beras Merah)	126.33	121.00	110.00	110.67	107.33	115.07 b
	K4 (Sijior)	137.67	129.33	117.67	117.33	133.67	127.13 a
	K5 (Kelik-3)	121.67	115.00	98.67	111.33	111.67	111.67 b
	K6 (Mesuji)	113.00	98.00	108.00	100.67	77.33	99.40 cd
	K7 (Inpago-7)	94.33	95.67	76.67	76.33	100.00	88.60 d
	K8 (Sirap Merah)	116.33	105.33	111.67	116.67	89.00	107.80 bc
	K9 (Fas Memeye)	122.67	108.67	112.33	97.67	117.67	111.80 b
	K10 (Si Tappe)	120.00	108.67	107.33	101.00	88.33	105.07 bc
	Means (cm)	115.74 a	108.80 b	103.73 bc	102.23 bc	100.47 c	

Table 4. Effect of salinity on leaves per plant of local brown rice genotypes.

Time	Rice cultivars	Salinity levels					Means (#)
		S0 (Control)	S1 (40 mM)	S2 (80 mM)	S3 (120 mM)	S4 (Saline soil)	
4 WAP	K1 (Sipenget)	4.00	4.33	3.67	4.00	4.00	4.00
	K2 (Meulaboh)	5.33	4.33	4.67	4.33	5.33	4.80
	K3 (Beras Merah)	4.67	4.33	4.67	4.33	4.67	4.53
	K4 (Sijior)	4.67	4.33	4.00	4.00	5.00	4.40
	K5 (Kelik-3)	5.33	5.00	4.33	4.33	4.67	4.73
	K6 (Mesuji)	5.33	4.67	5.33	4.33	3.33	4.60
	K7 (Inpago-7)	4.33	4.33	4.33	4.00	4.00	4.20
	K8 (Sirap Merah)	4.67	3.67	4.00	3.33	4.67	4,07
	K9 (Fas Memeye)	4.67	3.67	4.00	3.33	4.67	4,07
	K10 (Si Tappe)	4.33	4.33	4.33	5.00	3.67	4.33
	Means (#)	4.73	4.27	4.37	4.23	4.27	
6 WAP	K1 (Sipenget)	4,67	5.33	5.00	4.33	5.00	4.87 ab
	K2 (Meulaboh)	4.33	3.67	4.00	4.33	5.33	4.33 c
	K3 (Beras Merah)	4.00	4.33	4.33	5.67	5.33	4.73 ab
	K4 (Sijior)	5.33	4.67	5.00	5.33	6.67	5.40 a
	K5 (Kelik-3)	4.33	4.67	4.67	5.00	5.67	4.87 ab
	K6 (Mesuji)	4.00	4.67	4.67	4.33	4.67	4.47 bc
	K7 (Inpago-7)	3.67	4.33	4.00	4.33	5.00	4.27 c
	K8 (Sirap Merah)	6.00	5.00	5.33	4.33	4.67	5.07 ab
	K9 (Fas Memeye)	4.67	6.00	4.00	4.67	5.33	4.93 ab
	K10 (Si Tappe)	5.00	4.00	5.67	5.33	4.67	4.93 ab
	Means (#)	4.60	4.67	4.67	4.77	5.23	
8 WAP	K1 (Sipenget)	5.00	5.67	5.00	5.33	5.00	5.20
	K2 (Meulaboh)	4.67	5.33	4.33	5.00	5.33	4.93
	K3 (Beras Merah)	4.33	5.00	5.33	5.00	5.33	5.00
	K4 (Sijior)	5.33	5.33	5.00	5.00	5.00	5.13
	K5 (Kelik-3)	5.67	4.33	3.67	6.00	5.33	5.00
	K6 (Mesuji)	4.00	4.67	4.33	5.00	5.00	4.60
	K7 (Inpago-7)	5.00	5.67	5.00	4.67	5.67	5.20
	K8 (Sirap Merah)	5.67	4.67	5.33	6.00	5.33	5.40
	K9 (Fas Memeye)	5.00	5.00	4.67	5.33	5.00	5.00
	K10 (Si Tappe)	6.33	5.00	5.00	5.00	5.33	5.33
	Means (#)	5.10	5.07	4.77	5.23	5.23	

Table 5. Effect of salinity on the grain weight of local brown rice cultivars.

Rice cultivars	Grain weight (g)
K1 (Sipenget)	13.33 g
K2 (Meulaboh)	50.33 d
K3 (Beras Merah)	58.00 b
K4 (Sijior)	6.00 h
K5 (Kelik-3)	54.00 c
K8 (Sirap Merah)	28.00 f
K9 (Fas Memeye)	30.00 e
K10 (Si Tappe)	61.00 a

Table 6. Effect of salinity on POD activity.

Rice cultivars	Salinity	
	S1 (Control)	S4 (Saline Soil)
	(unit/mg protein)	
K1 (Sipenget)	0.22 def	0.79 a
K2 (Meulaboh)	0.61 ae	0.80 a
K3 (Beras Merah)	0.37 ce	0.23 df
K4 (Sijior)	0.14 ef	0.43 bd
K5 (Kelik-3)	0.30 df	0.09 f
K8 (Sirap Merah)	0.13 ef	0.65 ab
K9 (Fas Memeye)	0.12 ef	0.04 f
K10 (Si Tappe)	0.06 f	0.80 a

Table 7. Effect of salinity on SOD activity.

Rice cultivars	Salinity		Average
	S1 (Control)	S4 (Saline soil)	
	(unit/mg protein)		
K1 (Sipenget)	0.70	2.30	1.50
K2 (Meulaboh)	1.24	0.41	0.83
K3 (Beras Merah)	0.43	1.63	1.03
K4 (Sijior)	0.07	0.51	0.29
K5 (Kelik-3)	0.12	0.19	0.16
K8 (Sirap Merah)	0.23	0.58	0.41
K9 (Fas Memeye)	0.27	1.29	0.78
K10 (Si Tappe)	0.15	0.68	0.42
Average	0.40	0.95	

Note: Numbers followed by the same notation in the same column group show no significant difference at the 5% level in accordance with Duncan's multiple range test.

Table 8. Effect of salinity on H_2O_2 activity.

Rice cultivars	Salinity		Average
	S1 (Control)	S4 (Saline soil)	
	(µmol/g)		
K1 (Sipenget)	0.38	0.38	0.38
K2 (Meulaboh)	0.29	0.22	0.25
K3 (Beras Merah)	0.30	0.36	0.33
K4 (Sijior)	0.29	0.27	0.28
K5 (Kelik-3)	0.34	0.35	0.34
K8 (Sirap Merah)	0.38	0.34	0.36
K9 (Fas Memeye)	0.52	0.37	0.45
K10 (Si Tappe)	0.31	0.23	0.27
Average	0.35	0.31	

DISCUSSION

Salinity has a very significant effect on the morphology of brown rice cultivars in the vegetative phase. The results of this work showed that the cultivars in the control plots had a better average plant height than all the salinity-treated plots at 4 and 8 WAP. This result showed that NaCl stress could reduce rice plant height. However, the average number of leaves was not significantly affected by salinity treatments. Barus (2016) reported that salinity stress in rice can reduce vegetative growth (number of tillers, panicles and leaves, leaf length and width, plant height, and plant biomass) and seed yield traits (panicle length, 1000-grain weight, and grain yield) while increasing the percentage of unhulled grain, harvest index, and the number and weight of dry grain. Ismail and Horie (2017) found that evaluating genotypes for advancement through breeding at an early growth stage via high-through put phenotyping saves time and resources compared with traditional phenotyping strategies.

In general, at high salinity levels, especially under saline treatment (S4), plant height decreased significantly. Munns and Tester (2015) showed that in salt-affected soils, crops must compete with salts in the soils for water and cope with ion toxification, nutritional disorders, and poor soil physical conditions to survive. Therefore, their productivity is affected.

The rice cultivars Si Tappe, Sijior, Beras Merah, and Sidrap Merah had the best average grain weight. This result implied that four out of 10 planted cultivars had good potential and tolerance for salinity. Small deficiencies during vegetative growth can reduce the rate of leaf widening and leaf area index (LAI) in the next stage of development (Wibowo, 2011). Severe water shortage can lead to stomatal closure, which reduces CO_2 uptake and dry mass production. The continuous deficiency of moisture can also cause a reduction in the rate of photosynthesis. The cultivars Mesuji and Inpago-7 have been clasified as the most sensitive and suceptible genotypes given that their plants dried up and later died. Protein is another major organic substance in the endosperm of rice grain that accounts for 5% to 12% of the total dry weight of the grain (Chen *et al*., 2012). Proteins are considered as the determinants of rice sensory quality (Calingacion *et al*., 2014). Rice grain proteins are reported to be altered under different salinity levels (Wani *et al*., 2012).

The stress physiology of plants plays an important role in maintaining relative moisture content in the leaves. Stress-tolerant cultivars exhibit greater leaf cuticle thickness under drought conditions and retain relatively high moisture content in their leaves for their survival. Pigliucci (2005) revealed that the same cultivars, if grown at different locations, certainly perform differently under varied environmental conditions. Moreover, the efforts exerted by plants to maintain survival are not the same. The capability of a genotype to display different phenotypic performances due to different environmental influences is called phenotypic plasticity. Salama *et al.* (2014) reported that POD enzyme activity is higher in salinity-tolerant green bean genotypes than in those that are sensitive to NaCl. Pinto *et al*. (2015) reported that genotypes with resistance to salinity stress have relatively high levels of enzymatic antioxidants.

POD activity significantly differed in the genotypes grown under control and saline conditions and was higher under saline conditions than under the control. The salt-tolerant rice cultivar Pokkali has higher enzyme-scavenging activity for reactive oxygen species (ROS), such as catalase, and enhanced levels of antioxidants, including ascorbate and glutathione, than the salt-sensitive rice cultivar Pusa Basmati during salinity stress. The concerted action of enzymatic and nonenzymatic ROS-scavenging machineries is vital for overcoming salinity-induced oxidative stress in rice (Vaidyanathan *et al*., 2003). Dionisio-Sese and Tobita (1998) reported that salt-tolerant rice cultivars display protective mechanisms against increased radical production during salinity stress by maintaining the specific activity of antioxidant enzymes.

The lower average value of SOD enzyme activity in control red rice plants than that in plants under saline conditions confirmed that SOD activity increased under stress. The same mechanisim was also observed for the activity of the POD enzyme, which generally increased when plants face saline stress. Manurung *et al*. (2018) mentioned that plant physiology is the capability of plants to grow, complete their life cycle, and produce better results under salt stress. Plants that are choked by salinity and produce reactive molecules, such as singlet oxygen (O_2), H_2O_2, O_2, and OH radicals, that can damage cells and enzyme activity. One other way for plants to protect cells from this stress effect is by producing antioxidant enzymes, namely, SOD and POD. The higher the value of SOD and POD enzymes, the more resistant the plant will be to abiotic stress.

The increase in ROS levels has been reported to cause significant injury and eventual death in plants (Chawla *et al*., 2013). Surprisingly, in this case, control plants had the highest H_2O_2 values, which exceeded the H_2O_2 in plants in saline soil. This result could be due to high SOD value. ROS in saline-stressed plants is assumed to be broken down by antioxidant enzymes, specifically, SOD. Razzaq *et al*. (2020) reported that salinity can cause several changes in the vital constituents of rice grains. However, due to the polygenic nature of salt stress tolerance, the large number of metabolic changes in grain chemistry, including enzyme complexes, carbohydrates and reducing sugars, storage proteins, vitamins, and amino acid modifications, efforts to identify the effects of salinity on these scientific domains are still required to shed light on the response of the grains to salinity and the quality of grain produced under salt stress environments.

POD enzymes in local brown rice cultivars, such as Kelik-3, Beras Merah, and Fas Memeye, decreased under stress. However, these genotypes had better grain weight compared than other brown rice cultivars likely because in the local cultivars of brown rice, the most active enzyme is SOD, which showed an increase of 1.20 units/mg of protein. Pinto *et al.* (2015) indicated that studies on plant mechanism activity can reveal several PODs involved in different physiological processes, such as plant defense mechanisms against pathogens, hormone regulation, lignin biosynthesis, lignin precursor oxidation, and responses to abiotic stress.

CONCLUSIONS

Brown rice cultivars revealed varied responses to salinity stress. Salinity influenced and decereased plant height and POD activity but exerted nonsignificant effects on the average number of leaves and H_2O_2. The most active enzyme was SOD, which showed an increase of 1.20 units/mg of protein in brown rice cultivars. The brown rice cultivars Si Tappe, Kelik-3, Beras Merah, and Meulaboh revealed tolerance to salinity and have the potential to be developed into promising genotypes with good yield. The rice cultivars Mesuji and Inpago-7 were classified as very sensitive and susceptible types.

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