

The agro-physiological characteristics of three rice varieties affected by water depth in the coastal agricultural land of Yogyakarta, Indonesia

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Abstract. Nasrudin, Kurniasih B. 2021. *The agro-physiological characteristics of three rice varieties affected by water depth in the coastal agricultural land of Yogyakarta, Indonesia. Biodiversitas 22: 3656-3662.* Coastal agricultural land has many obstacles of abiotic stress for plant cultivation, including waterlogging, strong wind, and high salt concentration. Therefore, the use of adaptive rice varieties, as well as good land management, are expected to be a solution for rice cultivation in the coastal agricultural land. The objective of this study was to examine the agro-physiological characteristics of three rice varieties planted in coastal agricultural land which were affected by water salinity up to more than 10 dS m⁻¹. This study was conducted from February to July 2017 at Tirtohargo, Bantul District, Special Region of Yogyakarta. The experiment was arranged in a split-plot design, with the depths of sunken-bed as a main plot consisted of 25 cm and 50 cm, and variety as a subplot consisted of IR 64, Inpara 4, and Dendang. The experiment results showed that Dendang had the highest growth and yield in coastal agricultural land compared to Inpara 4 and IR64. The highest value is indicated in plant height, leaf area, proline content, and productivity. The depths 50 cm of sunken-bed increased leaf area and proline content, whereas the depths of 25 cm sunken-bed increased productivity. Dendang showed better agro-physiological activity and had the highest productivity. The depths of 50 cm increased several parameters in agro-physiological characteristics, however, the depths of 25 cm increased grain yield. Among the varieties tested, in salinity, the highest growth and yield variables were shown by Dendang, followed by IR 64 and Inpara 4.

Keywords: Abiotic stress, marginal land, paddy, salinity

Abbreviations: Chl: total chlorophyll content; EC: electrical conductivity; LA: leaf area; NRA: nitrate reductase activity; Pc: proline content; PH: plant height; Pn: photosynthesis rate; Pro: productivity; WAP: weeks after planting

INTRODUCTION

Waterlogging and salt stress are abiotic stresses that disrupt the growth and productivity of agricultural crops (Duan et al. 2018). This condition is commonly found in coastal agricultural land which affected by seawater intrusion. Gorji et al. (2015) stated that the soil resources in the world were affected by salt approximately 6% and 21,000 km² which is saline soil in Indonesia. Moreover, the tidal swamp has many obstacles include a high salt concentration in the soil and usually frequent waterlogging (Rad et al. 2012), high evapotranspiration, strong wind, and low precipitation (Bongoua-Devisme et al. 2012; Salt Farm Foundation 2018). Both of impacts caused the roots to become reduced to absorb water and also toxicity caused by high salt concentrations. In addition, it affects many processes of physiological and biochemical mechanisms to become disturbed e.g. nutrient and water uptake (Carillo et al. 2011). Anshori et al. (2018) stated that salinity affects both plant growth and yield through three ways include osmotic stress, ion imbalance, and ionic stress. According to the research of Radanielson et al. (2018) rice planted in saline conditions above 5 dS m⁻¹ caused a decrease of biomass production, photosynthesis rate, and transpiration

rate. Some parameters affected by high salt include plant height, plant dry weight, leaf injury, spikelet number per panicle, and 1,000-grain weight (Ghosh et al. 2016). Whereas Kurniasih et al. (2021a) reported that salinity as high as 2.5 dS m⁻¹ caused growth inhibition in Dendang, Situbagendit, and IR 64 rice varieties.

Waterlogging happened as a result of poor soil quality, slow drainage, high precipitation, and seawater intrusion in coastal agricultural land. Waterlogging in rice plants will cause metabolism disorders and long-term caused death plant. Waterlogging will induce oxygen depletion in plant tissue, affected hypoxic and anoxic stress, and induce the decay of roots and reduce water and nutrients uptake (Wang and Jiang 2007). This condition can reduce the development of aerenchyma that facilitates oxygen transport to inundate plant organs (Basu et al. 2020). Zhou et al. (2020) stated that the submergence in rice plants affects decrease the photosynthesis rate up to 80% compared to the normal condition and caused reduce the sugar content in the root and stem length. It is a consequence of limited O₂ in the water and affects anaerobic respiration (Garcia et al. 2020; Peng et al. 2020), so the plants make stem elongation to catch the solar radiation and CO₂. According to the research of Bruins et

al. (1998) waterlogging affects yield losses between 10-100% and depends on the length of immersion, water temperature, water turbidity, soil fertility, light intensity, and plant age. In many cases waterlogging may come with salinity which can cause complex effects on rice plants (Kurniasih et al. 2021b).

Tolerant variety use in abiotic stresses is needed to optimize the growth and productivity of agricultural crops. Based on the research of Nasrudin and Kurniasih (2018) reported that the Inpari 29 rice variety was planted in sunken-bed under waterlogging and salt stress conditions with the depth of 25 cm given the best growth and productivity up to 3.2 tons per hectare. It is indicated by the increased chlorophyll content, nitrate reductase activity, plant height, grain weight per plant, and harvest index. Loreti et al. (2016) stated that the rice is remarkably adapted in waterlogging. In waterlogging conditions, rice plants usually use the escape strategy by elongating their leaves, stem, and shoot. Based on Sarangi et al. (2020) research, rice planted in the coastal agricultural land with high salt concentration is better to planted in the wet season using the rice-rabi system. Generally, the tidal swamp has the potential to be used for rice cultivation, but it needs an appropriate effort to plants can withstand and grow optimally. The objective of this study was to examine the agro-physiological response of three rice varieties planted in coastal agricultural land and affected by water depth.

MATERIALS AND METHODS

Study area

The experiment was conducted from February to July 2017 in Tirtohargo, Bantul District, Special Region of Yogyakarta (8°00'26.7" S; 110°17'01.8" E) and Laboratory of Plant Science, Faculty of Agriculture,

Universitas Gadjah Mada, Yogyakarta, Indonesia.

Procedures

The experiment used a split-plot design. The depth of sunken-bed as the main plot consisted of 25 cm and 50 cm. Rice varieties as a sub plot consisted of Dandang, Inpara 4, and IR 64. The treatment was repeated three times. The destructive observation was conducted 6 weeks after planting (WAP). Observation of salt content in the water and soil was measured using an Electrical Conductivity (EC) meter.

The field was prepared by mixing cow manure with a dose of 2 tons per hectare then the soil was processed into sunken-bed 25 cm and sunken-bed 50 cm. The rice seed was sowing on saline bed nursery by 1 x 1 m for each variety and allowed to grow for 30 days after sowing. Transplanting was conducted between 07-09 am by planting four seedlings in each hole by 20 x 20 cm spacing manually. Plant maintenance includes weed control, pest and disease control, and irrigation. The dose of 150 kg hectare⁻¹, 100 kg hectare⁻¹, and 50 kg hectare⁻¹ for each urea, SP-36, and KCl fertilizers in 21 days after planting and the dose of 75 kg hectare⁻¹ and 50 kg hectare⁻¹ for each urea and KCl in 42 days after planting. Harvesting was conducted when the grains were ripe physiologically with a percentage of 90% and was conducted at 7-10 am.

Based on the data of Meteorological, Climatological, and Geophysical Agency, Republic of Indonesia (2017), the average temperature ranged from 26.3-26.6°C, relative humidity 81-86%, and an average of rainfall ranged from 13-325 mm month⁻¹. However, rainfall in May and June was low, each ranged from 23 mm month⁻¹ and 13 mm month⁻¹, respectively. This caused electro conductivity (EC) relatively high due to seawater was pushed into the experiment area.

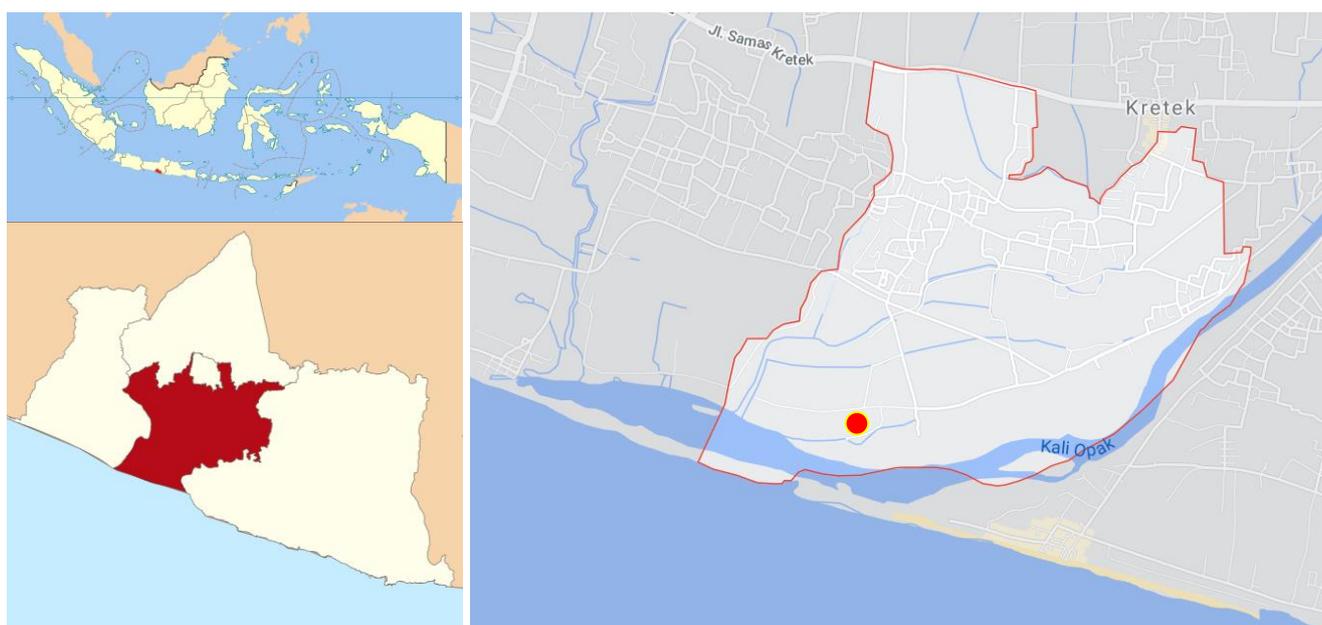


Figure 1. Study site in Tirtohargo, Bantul District, Yogyakarta Province, Indonesia indicating the experiment area (●)

Based on the observed, water of salinity affects plants during vegetative phase to harvest due to tides. The EC value is measured when plant enters the vegetative phase until harvest every 2 weeks. The EC value during the study was obtained between 1.35 dS m⁻¹ up to more than 25 dS m⁻¹. This condition showed that the water contains a high salt concentration and caused negative effects on plants.

The agro-physiological variables

Agronomic variables

Using a measuring instrument, plant height (cm) was measured from the ground surface to the tallest shoot. Leaf area (cm²) was measured by arranging the leaves under the camera using a leaf area meter, then grabbed and measured in the winDIAS 3 versions 3.2.1 application.

Physiology variables

Observation of chlorophyll content (mg L⁻¹) in leaves was measured by extracting each leaves sample taken 1 g from the outer canopy with 100 mL acetone 80%. Then the filtrate was measured using 2 D Milton Roy Spectrophotometer put in the cuvette and absorbance with wavelengths 645 nm and 663 nm. Chlorophyll total calculated using formula (Harborne 1987):

$$\text{Chlorophyll total (mg L}^{-1}\text{)} = (17.3 \times A_{646}) + (7.18 \times A_{663})$$

Observation of photosynthesis rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) was measured using LiCOR Li-6400 portable photosynthesis system version 5 made in USA. Measurement was made by clamping the leaves then the number of photosynthesis rate will appear on the screen.

Nitrate reductase activity ($\mu\text{mol NO}_2\text{-g}^{-2} \text{ hour}^{-1}$) was measured by extracting the 100 g of leaf samples with phosphate buffer solution. Buffer solution, H_2O , and Na_2HPO_4 at pH 7.5 for each 5 mL was put into a dark tube and closed for 24 hours. Then removed the buffer solution and replaced it with 5 mL new solution and added 0.1 mL of 5 M NaNO_3 . Incubation was done for 2 hours and filled each tube with a reagent of 0.2 mL sulfanilamide 1% and naphthylethylendiamide solution 0.02%. The filtrate was mixed with a shaker for 15 minutes until it changes the pink color. The filtrate was measured using 2 D Milton Roy Spectrophotometer with 540 nm wavelength and calculated using formula (Maghfiroh et al. 2020):

$$\text{Nitrate reductase activity } (\mu\text{mol NO}_2\text{-g}^{-2} \text{ hour}^{-1}) = \frac{\text{sample absorbance}}{\text{standard absorbance}} \times 50 \times \frac{1000}{WW} \times \frac{1}{W1} \times \frac{1}{1000}$$

Where: WW (wet weight, mg); W1 (incubation time, hours); standard absorbance (0.0142)

Proline content ($\mu\text{mol g}^{-1}$ fresh leaves) was measured using Bates et al. (1973) method. 0.5 g fresh leaf were crushed and mixed with 10 mL sulfosalicylic acid 3% and filtered. The filtrate was mixed with 2 mL glacial acetic acid and 2 mL ninhydrin then put into a tube and heated to 100 °C for an hour. The solution was extracted with 4 mL toluene until it changes the red color. The red color showed proline contains in the solution in the top layer then measured by using 2 D Milton Roy Spectrophotometer

with 520 nm wavelength and calculated using the formula:

$$\text{Proline content } (\mu\text{mol g}^{-1} \text{ fresh leaves}) = (64.3649 \times \text{absorbance reading}) + (-5.2987 \times 0.347)$$

Yield observed variables

Rice productivity (ton per hectare) was measured by weighing grain yield per plot (the size of experimental unit per plot is 3 x 1 m), afterward conversion to grain yield per hectare.

Data analysis

The data were analyzed using Analysis of variance (ANOVA). If the data significantly differ between the treatment, then Duncan's Multiple Range Test continued at 5%. The correlation analysis using Pearson correlation to determine the relationship between parameters. The processing statistical data using the Statistical Tools for Agricultural Research ver 2.0.1 and Microsoft Excel.

RESULTS AND DISCUSSION

General characteristics of three rice varieties were used in this experiment and analysis of variance result

This study used three rice varieties consisting IR 64, Inpara 4, and Dendang. All were lowland rice varieties. On normal conditions, IR64 has a yield potential up to 6.0 tons ha⁻¹, Inpara 4 has a yield potential up to 7.63 tons ha⁻¹, and Dendang has a yield potential up to 5.0 tons ha⁻¹ (BB Padi 2010). IR64 has characteristic tolerance to biotic stress but it can widely adapt. Mackill and Khush (2018) stated that IR64 is a high-yield rice variety and it has characteristics of early maturity, average plant height of approximately 100 cm, high quality, and fluffier rice texture. Inpara 4 has characteristics as a rice variety that can survive water immersion after 10-14 days, is suitable for rice development in swampland, average plant height of approximately 94 cm and can produce a yield up to 7.0 tons ha⁻¹ dried grain in *lebak* swamp Paiman et al. (2020). Arini et al. (2019) reported that the Dendang have characteristic tolerance to salinity, average plant height approximately 100 cm, and fluffier texture.

Based on the experiment results, analysis of variance (Table 1) showed interaction between the treatment of the depths of sunken-bed and variety on leaf area, nitrate reductase activity, proline content, and productivity. Meanwhile, the single factor of the depths of sunken-bed effects on proline content. The single factor of variety affects plant height, leaf area, nitrate reductase activity, and productivity.

Variety and water depth in the coastal agriculture land promote better growth rice plant

Table 2 showed that there was different plant height on each variety. Dendang was the highest rice plant compared to IR64 and Inpara 4. However, the depths of sunken-bed did not affect to plant height. Abiotic stress in swampland is affected by waterlogging and high salt concentration. Waterlogging affects deficit O₂ in the soil, caused inhibits

root growth, and decreased nutrition uptake to shoots (Mandal et al. 2019). This condition was exacerbated by high salt concentration in the water and soil. High salt caused stomatal closure and inhibit the development of shoot elongation (Reddy et al. 2017). Irakoze et al. (2020) said that salt stress will decrease photosynthesis, productive tillers, and grain yield. Based on the characteristics, Dendang had the same plant height with IR64 but higher than that of Inpara 4. Both Dendang and Inpara 4 have adaptive mechanisms to waterlogging by making the aerenchyma to support the transportation of O₂ from leaves to root and through shoot, elongation was able the photosynthesis and other metabolism processes (Soleh et al. 2019). Nevertheless, this study showed that the photosynthesis rate and total chlorophyll content were not significantly different, it assumed both of three varieties tested in this study may survive in waterlogging and salt concentration (~2.0 dS m⁻¹).

The leaf is the main organ that had many functions in plants to produce photosynthesis assimilation. Abiotic stress significantly decreased leaf area and only resistant variety that can survive under abiotic conditions. Waterlogging may be decreased of leaf area index, photosynthesis rate, and total biomass (Shao et al. 2013). Table 3 showed that there was leaf area of Dendang variety that can survive in waterlogging which salt contain under the depths of 50 cm compared to IR64 and Inpara 4. Inpara 4 can survive under the depths of 50 cm but under the depths of 25 cm may decrease leaf area. Ding et al. (2020) reported that waterlogging significantly decreased leaf area and also become mainly related to reducing the photosynthesis rate (Tian et al. 2011). IR64 was able to wide adaptation even though in this study IR64 had a narrow leaf area under both of the depths of sunken-bed 25 and 50 cm compared Dendang and Inpara 4 under the depths of sunken-bed of 50 cm. Meanwhile, salt contained in the water also had a role in inhibiting the leaf area growth through ionic and osmotic stresses. Radanielson et al. (2018) reported that several variables such as biomass, leaf area, and grain were positively correlated affected by salinity. The water depth salinity affects leaf area development due to ions Na⁺ and Cl⁻ were absorbed into the leaves, and the deeper water salinity causes plants to grow better than shallow water for metabolism processes. Tamang and Fukao (2015) reported that submergence under high salt conditions inhibits the transpiration process, thereby reducing the root-to-shoot transport of water and minerals. Nevertheless, ions Na⁺ and Cl⁻ were easily stored in the leaves due to submergence conditions, affecting the development of leaf area. This study showed that the wider leaves may increase the photosynthesis rate. Based on the correlation analysis (Table 6), the leaf area positively correlated with photosynthesis rate (R² = 0.55).

Physiological response of three rice varieties underwater depth in the coastal agricultural land

Nitrate reductase is one of the enzymes that catalyzes nitrate reduction to nitrite using an electron donor in the form of NADH/NADPH. It has played a role in the nitrate assimilation pathway (Karwat et al. 2019), its also enzyme

catalytic that described response of plants to the environment. Table 4 showed that Inpara 4 planted on 25 cm of sunken-bed and IR64 planted on 50 cm of sunken-bed have higher nitrate reductase activity (NRA) compared to IR64 planted on 25 cm of sunken-bed and Dendang planted on 50 cm of sunken-bed. This experiment indicated that Inpara 4 is a tolerance variety to waterlogging and IR64 can wide adaptation included in waterlogging conditions.

Table 1. The result of two-way analysis of variance of the depths of sunken-bed, variety, and their interaction for the variables listed

Variables	The depths of sunken-bed	Variety	The depths of sunken-bed x variety
Plant height	4.83 ^{ns}	7.86 [*]	0.29 ^{ns}
Photosynthesis rate	1.62 ^{ns}	0.75 ^{ns}	0.45 ^{ns}
Total chlorophyll content	2.70 ^{ns}	1.49 ^{ns}	1.57 ^{ns}
Leaf area	10.89 ^{ns}	7.32 [*]	5.23 [*]
Nitrate reductase activity	0.07 ^{ns}	8.85 ^{**}	38.40 ^{**}
Proline content	6.00 [*]	1.49 ^{ns}	5.37 [*]
Productivity	13.03 ^{ns}	24.64 ^{**}	32.24 ^{**}

Note: *P < 0.05; **P < 0.01; ns: not significant, numbers represent P value at 5%

Table 2. The depth of sunken-bed effect on plant height, photosynthesis rate, total chlorophyll content in three varieties

Treatment	Plant height (cm)	Photosynthesis rate (μmol CO ₂ m ⁻² s ⁻¹)	Total chlorophyll content (mg g ⁻¹ fresh leaves)
Varieties			
IR64	88.85 ^b	29.40	41.12
Inpara 4	85.76 ^b	31.13	52.34
Dendang	97.58 ^a	34.33	48.74
The depth of sunken-bed			
25 cm	87.17	26.54	45.17
50 cm	94.28	36.70	49.63
Interaction	(-)	(-)	(-)

Note: The value in the same column followed by the same letter were significantly different according to Duncan’s multiple range test 5%; the notation (-) indicated that there was no interaction between each factor

Table 3. Leaf area of three varieties in the depths of sunken-bed

Treatment	Varieties	The depth of sunken-bed		Average
		25 cm	50 cm	
Leaf area (cm ²)	IR64	224.77 ^{bc}	236.48 ^{bc}	230.32
	Inpara 4	167.93 ^c	275.88 ^b	221.90
	Dendang	222.21 ^{bc}	390.57 ^a	306.39
	Average	204.77	300.97	252.87 (+)

Note: The value in the same row or column followed by the same letter were significantly different according to Duncan’s multiple range test 5%; the notation (+) indicated that there was an interaction between each factor

Table 4. Nitrate reductase activity and proline content of three varieties in the depths of sunken-bed

	Treatment	The depth of sunken-bed		Average
		25 cm	50 cm	
Nitrate reductase activity ($\mu\text{mol NO}_2^- \text{g}^{-2} \text{hour}^{-1}$)	Varieties			
	IR64	0.109 ^c	0.777 ^a	0.278
	Inpara 4	0.815 ^a	0.329 ^{bc}	0.572
	Dendang	0.411 ^b	0.146 ^c	0.443
	Average	0.445	0.417	0.431 (+)
Proline content ($\mu\text{mol g}^{-1}$)	Varieties			
	IR64	2.29 ^{ab}	1.25 ^b	6.16
	Inpara 4	0.90 ^b	2.82 ^{ab}	1.95
	Dendang	1.59 ^b	4.40 ^a	2.23
	Average	1.52	5.37	3.45 (+)

Note: The value in the same row or column followed by the same letter were significantly different according to Duncan's multiple range test 5%; the notation (+) indicated that there was an interaction between each factor

Despite Dendang planted on 25 cm of sunken-bed, it can survive and had higher NRA due to its tolerance to salinity. Water availability and environmental conditions affected the activity of enzyme nitrate reductase. Yu et al. (2014) stated that waterlogging and salinity will inhibit N, P, K, Ca uptake, however, Na uptake was increased. Salt stress became a limiting factor for plant growth and inhibit nitrogen assimilation processes (Reda et al. 2011). Salinity affects a significant decrease of nitrate reductase activity in leaves of *Prosopis alba* (Meloni et al. 2004), Canola (Bybordi and Ebrahimian 2011). A significant decrease of NRA under salt stress due to a reduction of nitrate uptake. Increase of NRA followed by total chlorophyll content due to nitrate has an important role in amino acid synthesis and vegetative plant growth. NRA positively correlates with chlorophyll content (Table 6) $R^2 = 0.20$. Dewi et al. (2020) stated that the improved soil fertility directly affected to increase of chlorophyll content through nitrate reductase activity.

Plants have adaptive mechanisms to abiotic stress, there was accumulated amino acid for keeping the turgor. Hendrati et al. (2016) stated that plants have strategies to defend themselves to keep growing, including avoidance, osmotic adjustment, and salt excretion. Based on this experiment, results showed that Dendang planted on 50 cm of sunken-bed had the higher proline content compared to Dendang planted on 25 cm of sunken-bed. Dendang had similar proline content to both of Inpara 4 planted on 50 cm of sunken-bed and IR64 planted on 25 cm of sunken-bed but different to IR64 planted on 50 cm of sunken-bed and Inpara 4 planted on 25 cm of sunken-bed. This indicated that Dendang and Inpara 4 while planted on 50 cm of sunken-bed experienced salt stress and waterlogging therefore they accumulated the highest proline content. Plants will accumulate very high proline content up to 80% under stress conditions and on the susceptible variety to salt stress plants will accumulate higher proline content in leaf (Kaur and Asthir 2015) due to the proline synthesis affected expression of genes encoding enzymes (Iqbal et al. 2014). Further, tolerance variety accumulated proline

higher than the sensitive variety to the response of salinity stress (Mansour and Ali 2017). In the current study, Dendang had a higher proline content and indicated that it was categorized as a tolerant rice variety under salt and waterlogging stress, whereas IR64 was a sensitive rice variety (Zhao et al. 2014). Theoretically, Dendang rice variety was a tolerance variety to salinity and potential to produce a higher proline content. Novianti et al. (2020) reported in their study that the Amas rice variety planted in swampland has higher proline content ($1.28 \mu\text{g g}^{-1}$) compared to 8 other varieties. Miftahudin et al. (2020) reported that IR64 and Situbagendit have a higher proline content than Hawara Bunar and Inpago 10 under drought stress. Rice planted in drought conditions also increased the proline content as an osmotic adjustment strategy to defend cell membranes from water deficit in the surrounding environment (Salsinha et al. 2020).

Depth of the sunken bed affected grain yield of three varieties

Plants struggle with the escape mechanism under stress to further the damage through delaying the generative phase. In this case, water availability which salt contains became a benefit to plants for accumulating the assimilate. However, a high watering availability caused a decrease in accumulating the assimilate due to O_2 deficit effects inhibiting the roots' respiration process. When the plants entering the generative phase, the water condition contains high salt concentration. Based on the observation, in soil water containing salt concentration 5 to 20 dS m^{-1} , only tolerant variety can survive in this condition. Rad et al. (2012) reported that increasing saline water up to 8 dS m^{-1} caused a decrease in rice yield components. Further, in another reported saline watering up to 4.5 dS m^{-1} did not affect rice yield components (Fraga et al. 2010).

Table 5 showed that Dendang planted on 25 cm the depths of sunken-bed had the highest productivity compared to other treatments. Thorat et al. (2018) reported that low EC value ($\sim 3.5 \text{ dS m}^{-1}$) caused yield losses of 10%, whereas when high EC value (7.2 dS m^{-1}) caused yield losses of 50%. Islam et al. (2007) stated that increased water salinity levels caused a decrease in the reproductive phase. Mondal et al. (2013) stated that the tolerance variety such as Pokkali had a low yield loss due to salinity (6.49%).

Table 5. Productivity of three varieties in the depths of sunken-bed

	Treatment	The depth of sunken-bed		Average
		25 cm	50 cm	
Productivity (ton per hectare)	Varieties			
	IR64	1.04 ^b	1.22 ^b	1.13
	Inpara 4	0.65 ^c	0.71 ^c	0.68
	Dendang	1.66 ^a	0.70 ^c	1.18
	Average	1.12	0.87	0.99 (+)

Note: The value in the same row or column followed by the same letter were significantly different according to Duncan's multiple range test 5%; the notation (+) indicated that there was an interaction between each factor

Table 6. The correlation matrix between variables of rice plant affected by water depth and salt stress in the coastal agricultural land

Treatment	NRA	Pn	Pc	Chl	LA	PH	Pro
NRA	1*						
Pn	-0.09 ^{ns}	1*					
Pc	0.31*	0.14 ^{ns}	1*				
Chl	0.20 ^{ns}	-0.19 ^{ns}	0.003 ^{ns}	1*			
LA	-0.38*	0.55**	-0.02 ^{ns}	0.17 ^{ns}	1*		
PH	-0.44*	0.32*	0.09 ^{ns}	0.22 ^{ns}	0.65**	1*	
Pro	0.04 ^{ns}	-0.16 ^{ns}	0.15 ^{ns}	-0.27*	-0.26*	0.20 ^{ns}	1*

Note: NRA (nitrate reductase activity); Pn (photosynthesis rate); Pc (proline content); Chl (total chlorophyll content); LA (leaf area); PH (plant height); Pro (productivity)

The submergence under high salt conditions declines rice productivity due to increase of Na⁺ and Cl⁻ to production and transport assimilate. Tolerant variety had the best performance of agro-physiological characteristics and the highest rice productivity compared to susceptible variety underwater salinity. Application of sunken-bed in the coastal agricultural land enabled plants to have enough water, particularly while entering the generative phase. However, submerge conditions in the sunken-bed caused a decrease in several rice yield components. The experiment results showed that in the coastal agricultural land Dendang had the best performance compared to Inpara 4 and IR64, as indicated from the highest value in plant height, leaf area, proline content, and productivity. The depths of 50 cm of sunken-bed increased leaf area and proline content, whereas the depths of 25 cm sunken-bed increased productivity. Dendang showed better agro-physiological activity and had the highest productivity compared to other varieties tested. The depths of 50 cm increased several parameters in agro-physiological characteristics, however, the depths of 25 cm increased grain yield parameters. Among the varieties studied in salinity, the highest growth and yield variable were shown by Dendang, followed by IR 64 and Inpara 4.

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