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Growth and Yield of Inpari 29 Rice Varieties on Raised-bed and Different Depths of Sunken-bed in Saline Field

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ABSTRACT

Increased productivity of rice is required to meet the increasing food demand. Utilization of marginal lands, such as saline land is one of the solutions applicable to increase rice production. The objective of this research was to determine the growth and yield of Inpari 29 rice variety planted on raised-bed and different depths of sunken-bed in saline field. This research used the Split Plot Design with two treatments. The depth as the main plot consisted of two depth levels: a depth of 50 cm and a depth of 25 cm; and the planting area field as the subplot consisted of two levels: raised-bed and sunken-bed. The treatment was repeated three times. The rice planted in sunken-bed showed higher growth than in raised-bed as indicated by the high content of chlorophyll a, chlorophyll b, total chlorophyll, nitrate reductase activity and plant height. The rice planted in the sunken-bed yielded higher than in raised-bed as indicated by higher harvest index and the weight of grain per clump. Rice planted in 25 cm depth showed higher nitrate reductase activity and grain weight per clump than in 50 cm depth.

Keywords: Depth, raised-bed, rice, saline field, and sunken-bed

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important food commodities in Indonesia as the most widely-consumed food by the people. Rice production in 2016 was 79.35 million tons from 15.16 million Ha land area or 52.36 Ku.Ha[-1] productivity (Kementerian Pertanian, 2017). Indonesia is a country with population majority that consumes rice as the staple food. The amount was equal to 114.6 kg.capita[-1].year[-1] in 2016 with an increasing population growth rate of 1.49% year[-1] (Ministry of Agriculture, 2016). In order to meet such food demand, a technology that can increase rice productivity is consequently required.

Marginal land such as tidal land can be used as a strategy to increase rice productivity. Sudaryono (2017) stated that the tidal area in Indonesia can be estimated as 20.12 million Ha consisting of 2.07 million Ha of potential field, 6.72 million Ha of acid sulphate field, 10.89 million ha of peat-soil field, and 0.44 million ha of saline field. However, the land use still has to cope with various problems such as water and soil issues.

Agricultural land in Baros Village consists of fields with limiting factors such as salinity and waterlogging due to seawater overflow. Salinity is one of the major stresses in rice cultivation (Aref, 2013). It leads to water quality with high level electrical conductivity (Zeng and Shannon, 2000) and low soil fertility (Rad *et al*., 2011). According to Rusd (2011), when the EC value of water or soil reaches over 4 dS.m^{-1}, it will affect the plant growth. Salinity has various impacts on rice cultivation depending on the phase of growth, severity, and duration of stress (Radanielson *et al*., 2017). The effect of salinity in the soil for rice cultivation includes reduction of growth and development (Cha-um and Kirdmanee, 2010). Percentage of rice yield loss based on EC was <10%, 10–20%, 20–50%, and >50% when EC was <4 dS.m^{-1}, 4–6 dS.m^{-1}, 6–10 dS.m^{-1}, and >10 dS.m^{-1}, respectively (FAO, 2005).

Water is an absolute need for plant to allow various

metabolic activities. However, excessive water is the limiting factor in rice cultivation process. According to Sakagami et al. (2013) plants that are waterlogged for too long, will face disruption in photosynthesis. It will also bring yield loss by 10–100% depending on the duration of inundation, water temperature and turbidity, soil fertility, light intensity, and the plant age (Bruins et al., 2012).

Waterlogging will cause metabolic disturbances to the rice plants which consequently bring impacts on the plant growth, decreasing yield, and mortality (Rachmawati and Retnaningrum, 2013). It also leads to low levels of O_2 and solar radiation in the air resulting in disrupted growth and mortality (Sarkar et al., 2006). When the water recedes, the plant returns to adapt to the environment by obtaining optimal O_2 and light intensity (Ella et al., 2003). Morphologically and physiologically, most rice cultivars lengthen their stem in response to waterlogging. The elongation of the stem allows rice plants to continue the anaerobic metabolic processes and CO_2 fixation (Sarkar et al., 2006; Kawano et al., 2008). Based on the research by Rachmawati and Retnaningrum (2003), waterlogging of rice plant by 8 cm of depth within a certain period of time increases plant height, plant biomass, and canopy root ratio. A study by Kawano et al. (2008) showed that 1-m depth of waterlogging for 7 days increased the stem length, leaf area, and plant biomass.

To optimize the growth and production, a proper method of rice cultivation is required. One of them was by making the growth media into raised and sunken-bed. Raised-beds are part of the field that has physical, chemical and biological properties as a dry agricultural field. The soil in raised-bed is aerobic so that the cultivated plants should not need much water. Sunken-beds are part of the field with physical, chemical and biological properties that are the same as wet agricultural field with anaerobic soil atmosphere (Sasmita, 2006). The making of raised and sunken-bed are aimed to minimize crop failures due to environmental stresses such as floods, salinity, seawater overflows, and others. Raised-beds by 50–60 cm of height with worm ducts around the sunken-bed are used to wash the poison compounds and to avoid overflow of seawater that will inundate the rice plants (Susilawati and Nursyamsi, 2014).

The Center for Research on Sukamandi Rice has released Inpari 29 rice variety with properties suitable for lowland irrigation to 400 m altitude of height above sea level, especially in flood-prone areas with the total inundation of the vegetative phase of more than 14 days. This variety has a planting age of ± 110 days after seedling, 103 cm of height, the average yield of 6.5 tons.ha^{-1}, and potential yield of 9.5 tons.ha^{-1} (BB Padi, 2012). Land arrangement by modifying the planting field has not been widely studied. Therefore, the use of sunken-bed (aquatic) and raised-bed (terrestrial) in different depths and heights are expected to be location-specific accurate technology for rice cultivation in the tidal field. The objective of this research was to determine the growth and yield of Inpari 29 rice variety planted on raised and sunken-bed with different depths in saline field.

MATERIALS AND METHODS

This research was carried out from February to July 2017 at Baros Sub-Village, Tirto Hargo Village, Kretek District, Bantul Regency, which is located 4 m above sea level. It includes a marginal tidal field with overflow type A. Small tide occurrs twice a day: in the morning and evening, with a water level of ± 30 cm in sunken-bed of 50 cm of depth. Big tides submerged plants in the sunken and raised-bed. It occurred four times, on March 31, and April 1, 29 and 30, 2017.

Based on the data by BMKG 2017, the average monthly temperature of the command area ranged from 26.3–26.6°C with 81–86% of humidity and monthly rainfall between 13-325 mm.month^{-1}. According to Mareja (2015) suitable climate for rice cultivation was between 22–27°C with 50–90% of humidity and 200 mm.month^{-1} monthly rainfall. Based on the climate data above, such conditions were suitable for rice cultivation. However, monthly rainfall in May and June was quite low, each of which was 23 mm.month^{-1} and 13 mm.month^{-1}, respectively. This caused the high electrical conductivity of water due to seawater which was pushed into the research area through river flow more than brackish water.

Experiments used split-plot design and carried out by two treatments. The depth as the main plot consisted of two levels: a depth of 50 cm (A1) and a depth of 25 cm (A2). The planting area field as the sub-plot consisted of two levels: raised-bed (G) and sunken-bed (L). Raised-bed is a planting area field with limited water and sunken-bed is a planting area field with adequate water availability. Raised-bed is beside the sunken-bed. The treatment was repeated three times. Destructive observation was carried out on week 3, week 6, and the harvest time. The research used Inpari 29 variety which was resistance

to submergence.

Soil processing included plowing and making excavations into two fields: raised and sunken-bed of 25 cm and 50 cm depth. Experiment of sunken-bed was 1×3 m for each. Together with plowing, manure was given at a dose of 2 tons.Ha^{-1}. Sowing was carried out on saline bed nursery by 1×1 m for each variety and allowed to grow for 30 days after seedling. Transplanting was done by planting four plants in each hole by 20×20 cm spacing manually. Plant maintenance included the weeding, pest and disease control, irrigation, and fertilization by applying urea, SP-36, and KCl in a dose of 150, 100 and 50 kg.ha^{-1} in 21 days after planting and 75 kg.Ha^{-1} urea and 50 kg.ha^{-1} KCl in 42 days after planting. Harvest was carried out 86–88 days after planting.

Parameters observed included leaf area (cm^2), measured by placing leaves under the camera in the leaf area meter, then grabbed and measured in the winDIAS 3 version 3.2.1 application. Observation of leaf area was carried out when plants were 3 and 6 weeks after planting. Photosynthesis rate (μmol CO2.m^{-2}.s^{-1}) was measured by clamping the leaves using a LiCOR Li-6400 portable photosynthesis system and photosynthesis will appear on the screen of the device. Photosynthetic rate was carried out when plants were 6 weeks after planting. Contents of chlorophyll a, chlorophyll b, total chlorophyll (mg.g^{-1} fresh weight of leaf) was measured by extracting fresh leaves which were added with 80% of acetone, then the resulting filtrate was measured using a 2 D Milton Roy Spectrophotometer at a wavelength of 663 nm and 645 nm. Nitrate reductase activity (μmol NO$_2^-$.g^{-1}.hour^{-1}) was measured by extracting leaves which were added with phosphate buffer and NaNO$_3$ solution, then the filtrate produced was measured using a 2 D Milton Roy Spectrophotometer at a wavelength of 540 nm. Proline content (μmol.g^{-1} fresh weight of leaf) was calculated by extracting leaves which were added with 3% of sulfosalicylic acid, ninhydrin acid, and 100% of glacial acetic acid, then the resulting filtrate was measured using a Spectro 2 D Milton Roy Spectrophotometer at a wavelength of 520 nm. Observation of chlorophyll content, nitrate reductase activity, and proline content was carried out when plants were 7 weeks after planting. Concentration of leaf Na$^+$ and K$^+$ (mmol.g^{-1} dry weight of sample leaf) was measured by extracting leaves added with HNO$_3^-$ solution, then the filtrate obtained was measured using the PFP7 Flame Photometer. Observation of leaf Na$^+$ and K$^+$ concentrations was done when plants were 3 weeks after planting, 6 weeks after planting, and at harvest time. Plant height (cm) was measured using a meter from the base of the stem to the highest end of the leaf and the number of tillers that grew; observing both parameters was done when plants were 8 weeks after planting. Canopy dry weight (g.clump^{-1}), root dry weight (g.clump^{-1}), and biomass (g.clump^{-1}) used digital scales when harvested. Number of panicles per clump, panicle length (cm), percentage of filled grain (%), weight of 1,000 grain (g), grain weight per clump (g.clump^{-1}), grain weight per plot (g.plot^{-1}), and harvest index were observed after plants were harvested.

Variance analysis (ANOVA) was used to analyze data. When a significant effect was obtained, the analysis was continued by using the Duncan's multiple range test at 5% error level. Processing statistical data analysis was carried out using SAS 9.1.3 Portable software.

RESULTS AND DISCUSSION

Soil and water conditions in research area

The soil analysis was carried out in STIPER Agriculture Institute Yogyakarta (2017). It showed that before and after harvesting, the soil was indicated in neutral pH which ranged between 6.57 and 6.88. Soil moisture contents of 0.5 mm deep before planting was 11.35%, and after harvest in the raised-bed and sunken-bed of 25 cm and 50 cm depth were 6.03%, 9.54%, and 9.01%, respectively. The total N contents in the soil before planting was 0.19%, and after harvest in raised-bed and sunken-bed of 25 cm and 50 cm depth were 0.13%, 0.16%, and 0.15% respectively. The content of Na$^+$ in the soil before planting was 0.13 me.100 g^{-1}, and after harvest in sunken-beds of the 25 cm and 50 cm of depths were 0.11 me.100 g^{-1}, 0.12 me.100 g^{-1}, and 0.11 me.100 g^{-1}, respectively. The content of K$^+$ in the soil before planting was 0.21 me.100 g^{-1}, and after harvest in raised-bed and sunken-bed of 25 and 50 cm of depth were 0.20 me.100 g^{-1}, 0.19 me.100 g^{-1}, and 0.18 me.100 g^{-1}, respectively. The content of Ca$_2^+$ in the soil before planting was 8.17 me.100 g^{-1}, and after harvest in raised-bed and sunken-bed with 25 cm and 50 cm of depth were 11.26 me.100 g^{-1}, 9.47 me.100 g^{-1}, and 6.55 me.100 g^{-1}. The content of Mg$_2^+$ in the soil before planting was 1.04 me.100 g^{-1}, in the soil after harvest in raised-bed and sunken-bed with 25 cm and 50 cm of depth, were 0.91 me.100 g^{-1}, 1.31 me.100 g^{-1}, and 0.78 me.100 g^{-1}, respectively.

The EC value of irrigation water in the command area ranged from 1.07–25 dS.m^{-1} (Figure 1). According
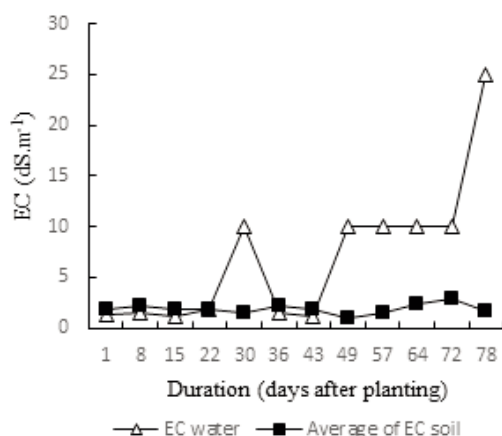
Figure 1. The electrical conductivity of water and soil in the command area
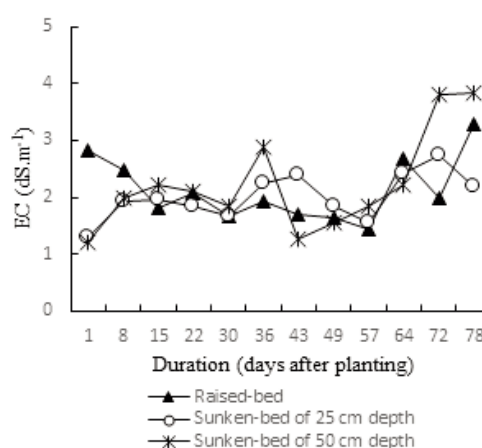

Figure 2. The electrical conductivity of raised-bed soil and sunken-bed soil with 25 cm and 50 cm of depths

Table 1. Leaf area of 3 and 6 weeks after planting ($cm^2.clump^{-1}$), photosynthesis rate of 6 weeks after planting (μmol $CO_2 .m^{-2}.s^{-1}$), and chlorophyll content in the leaf of 7 weeks after planting ($mg.g^{-1}$ fresh weight of leaf) plant of Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatment	Leaf area (cm^2)		Photosynthesis rate (μmol $CO^2.m^{-2}.s^{-1}$)	Chlorophyll content in the leaf ($mg.g^{-1}$ fresh weight of leaf)		
	3 wap	6 wap		Chlorophyll a	Chlorophyll b	Chlorohyll total
Depth						
50 cm	192.80 a	450.92 a	9.22 a	19.58 a	19.12 a	38.69 a
25 cm	219.65 a	567.26 a	10.82 a	20.27 a	19.81 a	40.07 a
Planting Area						
Raised-bed	187.89 p	480.61 p	9.13 p	15.58 q	11.79 q	27.36 q
Sunken-bed	224.56 p	537.57 p	10.91 p	24.28 p	27.14 p	51.41 p
Interaction	-	-	-	-	-	-
CV (%)	10.05	20.23	14.41	14.87*	28.98*	21.98*

Note: (-) no interaction; wap (weeks after planting); (*) the data was transformed; the number followed by the same letter in the same column has no significant different in the Duncan's Multiple Range Test at 5% error level

to the Soil Research Center (2009), based on the assessment criteria, EC> 4 $dS.m^{-1}$ was considered very high. The EC value of raised-bed and sunken-bed with 25 cm and 50 cm depth were 2.22, 2.02, and 2.36 $dS.m^{-1}$, respectively (Figure 2). Based on the EC value, referring to the classification of dissolved saline in the soil, the EC value of the soil was classified rather saline.

Leaf area, chlorophyll content in the leaf and photosynthesis rate

Leaf is the main component of plants functioning as a place for photosynthesis. It is increasingly widespread and has the ability to hold more and more light (Syamsuddin *et al*., 2011). Table 1 shows that the leaf area and photosynthetic rate of the rice plant were not significantly different between planting area and depth treatments. It was assumed that the plant had the same adaptability in both treatments which had no different soil and water electro

conductivity (Figure 1) so that the leaf area and photosynthesis rate of plants were not different.

Chlorophyll is mostly found in leaves. It is the green leaves that play a role of the photosynthesis process (Hussain *et al*., 2017.) Table 1 shows that the rice planted in sunken-bed contained higher chlorophyll a, chlorophyll b, and total chlorophyll than in raised-bed. The high content of chlorophyll in rice grown in sunken-bed due to the adequate availability of water, soil N content, and soil Mg_2^+ content. Rice planted in raised-bed has limited water. Limited water affects cell turgor, thus reducing cell development, inhibiting protein synthesis, chlorophyll and cell walls (Ai and Banyo, 2011). Chlorophyll synthesis was affected by several factors including light, sugar or carbohydrates, water, temperature, plant genetic factors, and some elements such as N and Mg_2^+. Gohagu *et al*. (2016) detailed that N had the role in the production of chlorophyll and the element Mg_2^+ was the core of chlorophyll.

Table 2. Leaf Na^+ and K^+ concentration (mmol.g^{-1} dry weight of sample leaf) in Inpari 29 rice variety at 3 weeks after planting, 6 weeks after planting, and when harvested grown on raised-beds and different depths of sunken-beds

Treatment	Leaf Na^+ concentration(mmol.g^{-1} dry weight of sample leaf)			Leaf K^+ concentration (mmol.g^{-1} dry weight of sample leaf)		
	3 wap	6 wap	When harvested	3 wap	6 wap	When harvested
Depth						
50 cm	19.8 a	26.4 a	39.2 a	28.5 a	28.8 a	24.6 a
25 cm	22 a	20.6 a	34 a	27 a	24.9 a	26.7 a
Planting Area						
Raised-bed	14.3 q	17.9 q	29.1 p	27.5 p	30.7 p	25.2 p
Sunken-bed	27.5 p	29.1 p	44.1 p	27.9 p	22.9 q	26.1 p
Interaction	-	-	-	-	-	-
CV (%)	14.41*	20.52*	21.08	5.49	27.70	22.31

Note: (-) no interaction; wap (weeks after planting); (*) the data was transformed; the number followed by the same letter in the same column has no significant different in the Duncan's Multiple Range Test at 5% error level

Treatment of 50 cm and 25 cm of depths did not give significant difference on the leaf chlorophyll content (Table 2) because both conditions had the same water availability with fluctuating salts concentration and not significantly different from total N content. Water availability could help the distribution of nutrients and played important role in the photosynthesis process, whereas the N content was needed by plants for chlorophyll synthesis.

Concentration of Na^+ and K^+ions on leaves, reductase nitrate activity, and proline content

The purpose of Na^+ analysis in tissues was to determine the concentration of Na^+ ions in the leaves absorbed by the plants. The amount of Na^+ ions absorbed by plant tissues showed the possibility of plants caught in salinity. Na^+ acted as a nitrate reductase regulator, stomatal opening, and amino acid citase such as proline and betaine.

Table 2 shows that the concentration of Na^+ions in the leaves of aged 3 and 6 weeks after planting rice planted in sunken-bed was higher than in raised-bed. The concentration of Na^+ ions in the leaves was affected by the amount of EC in the soil and irrigation water. When plants were 3 and 6 weeks after planting, irrigation water EC was ± 2.5 dS.m-1 with soil EC ranging from 2–2.5 dS.m^{-1}. The value of EC illustrated that the condition of irrigation water and soil contained salt. The accumulation of salt in the sunken-bed soil was larger than in the raised-bed (Figure 2). Plants exposed to a combined salinity and submergence was reported to increase Na^+ transport to the shoots than saline aerated roots (Kurniasih *et al*., 2017). Salt accumulation caused the plant to become gripped with salinity. This was

indicated by the increasing of Na^+ ions concentration in the leaves 3 and 6 weeks after planting. Large amount of Na^+ in the soil would enter the root area and cause more Na^+ ions to be absorbed by the plants than other elements. When the plant was gripped with salinity, the presence of Na^+ ions concentration would be inversely proportional to the K^+ ions concentration. Increased absorption of Na^+ ions in the plants caused high accumulation of Na^+ ions in the plant tissues. In such conditions, there would be obstacles for the roots to absorb other elements such as K^+, Ca_2^+, and Mg_2^+ (Mass and Hoffman, 1997). Munns and Tester (2008) stated that salinity caused plants to experience osmotic stress and ionic stress. These stresses caused water absorption and nutrients other than Na^+ ions to be inhibited due to the higher osmotic potential in the cell than the osmotic potential outside the cell. Rice planted in 25 cm and 50 cm of depths showed a concentration of Na^+ ions in the leaves that were not significantly different (Table 2). This is presumably due to the depth treatment, EC of water and soil have a value that is not different so that it affects the plant within the same limit.

The element of K was absorbed by the plants in the form of K^+ ions. The results showed that in general, the concentration of K^+ ions in leaves would be decreased in line with increasing concentration of Na^+ ions. Increased concentration of Na^+ ion in leaves 6 weeks after planting would decrease K^+ ions concentration (Table 2) in sunken-bed planting treatment. Such condition was because Na^+ and K^+ nutrients indicated very similar properties that were mutually inhibiting (Yoshiva and Casteneda, 1969). Therefore, when the Na^+ content was higher, it would be difficult for the plant to absorb K^+ and vice versa.

Table 3. Nitrate reducates activity (μmol $NO_2^-.g^{-1}.hour^{-1}$) at 7 weeks after planting of Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatment	Reductase nitrate activity (μmol $NO_2^-.g^{-1}.hour^{-1}$)		
	Depth		Average
	50 cm	25 cm	
Planting Area			
Raised-bed	0.27 b	0.05 c	0.16
Sunken-bed	0.10 c	0.94 a	0.52
Average	0.19	0.50	0.34 (+)
CV (%)		15.28	

Note: (+) there is interaction; the number followed by the same letter in the same column is not significantly different in Duncan's Multiple Range Test at 5% error level

Table 4. Prolin content (μmol.g^{-1} fresh weight of leaf) at 7 weeks after planting of Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatment	Proline content (μmol.g^{-1} fresh weight of leaf)		
	Depth		Average
	50 cm	25 cm	
Planting Area			
Raised-bed	3.02 a	0.66 b	1.84
Sunken-bed	0.77 b	0.93 b	0.85
Average	1.90	0.79	1.34 (+)
CV (%)		18.97	

Note: (+) there is interaction; the number followed by the same letter in the same column is not significantly different in Duncan's Multiple Range Test at 5% error level

Nitrate reductase is an important enzyme in the reduction of chain of NO_3^- to NO_2^-, then NO_2^- will experience anomification with the help of nitrite reductase (NiR) enzyme and NH_4^+ will be converted into free nitrogen gas with the help of nitrogenize enzyme. Nitrate reductase enzymes are useful in the formation of amino acids, chlorophyll, and other compounds that contain N (Peni *et al*., 2004). Table 3 shows that raised-bed with 50 cm of height indicated greater nitrate reductase activity value compared to the one with 25 cm of height. The raised-bed with 25 cm of height showed greater nitrate reductase activity value than in sunken-bed treatment with 25 cm of depth. The raised-bed treatment which was 50 cm high showed greater nitrate reductase activity value compared to sunken-bed which was 50 cm deep. In sunken-bed with 25 cm of depth, the nitrate reductase activity value was greater than in raised-bed treatment with 25 cm of height. Such result was due to the concentration of Na^+ ions that had not been toxic for the plant when observed. According to Muflikhah (2018), Na^+ ions at certain concentrations can function as osmotic regulators and are able to carry out cytoplasmic functions by replacing K^+ ions in binding Mo. This prevented nitrate reduktase

activity from disturbance and caused the plant to synthesize chlorophyll in the vegetative phase.

Proline is one of the amino acids produced by plants when they experience salinity stress (Tatar *et al*., 2010). Table 4 shows that raised-bed with 50 cm of height provided the highest proline content compared to other treatments. It was expected that rice plants in raised-bed with 50 cm of height underwent salinity stress due to the accumulation of salt deposited in the soil from irrigation water with fluctuating EC. Fluctuating salt accumulation in the soil due to irrigation water with EC (Figure 1) allowed it to become toxic to plants. The plants produced proline due to salinity stress through cell osmotic balance. When the plant was gripped with salinity, the osmotic potential in the cell got higher than the osmotic potential outside the cell. The high osmotic potential in the cell caused the absorption of water and minerals to become inhibited. This would spur the plants to adapt by increasing their resistance and inducing the accumulation of amino acids in the cytoplasm, prolin (Munns and Tester, 2008). Proline production and accumulation were adaptive forms of plants in response to salinity stress (Gupta *et al*., 2014). Proline increased along with the decreasing of osmotic

Table 5. Plant height (cm) and number of total tiller at 8 weeks after planting, and canopy dry weight (g.clump^{-1}), root dry weight (g.clump^{-1}), and total biomass (g.clump^{-1}) when harvested in Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatments	Plant Height (cm) 8 wap	Number of total tiller at 8 wap	Canopy dry weight (g.clump^{-1}) when harvested	Root dry weight (g.clump^{-1}) when harvested	Total biomass (g.clump^{-1}) when harvested
Depth					
50 cm	91.62 a	13.58 a	21.21 a	12.97 a	33.57 a
25 cm	91.35 a	15.33 a	23.10 a	9.73 a	32.69 a
Planting Area					
Raised-bed	81.27 q	15.75 p	22.48 p	14.45 p	36.58 p
Sunken-bed	101.7 p	13.17 q	21.83 p	7.82 q	29.69 p
Interaction	-	-	-	-	-
CV (%)	6.09	16.49	24.93	29.20	15.36

Note: (-) no interaction; wap (weeks after planting); (*) the data was transformed; the number followed by the same letter in the same column has no significant different in the Duncan's Multiple Range Test at 5% error level

potential in cells. The decrease in osmotic potential in cells caused plants to maintain cell turgor so that the physiological and biochemical processes continue to run even under drought stress conditions (Kurniawati *et al*., 2014; Guo *et al*., 2012).

Plant height, number of tillers, canopy dry weight, root dry weight, and biomass

Plant height is an indicator of plant growth as well as the parameter used to measure plant growth due to a given treatment. Table 5 shows that in 8 weeks after planting, rice planted in sunken-bed was taller than in raised-bed. Allegedly, such result was due to more water availability supporting the plant growth by maintaining cell turgidity and helping the cell growth. In addition, it was also because of the fluctuating plant resistance to irrigation water with EC ranged from 1.07–25 dS.m^{-1}, and that rice plants planted in sunken-bed were positioned below and flanked by rice plants. The plants in raised-bed put efforts to look for light used for their photosynthetic material. Thus, in such conditions, the plant became taller.

Table 5 shows that the rice planted in raised-bed in 8 weeks after planting had a greater number of total tillers compared to rice in sunken-bed, although it was not significantly different in both depth treatment. Such a small number of tillers from rice planted in sunken-bed was thought to be due to waterlogging conditions that could suppress their growth. This is consistent with the statements from Zheng (2005); Rivaldi (2015) that waterlogging can inhibit the growth rate of tillers. Waterlogging causes lack of airspace for tillers to surface due to water pressure (Ikhwani *et al*., 2010). Rice planted in 25

cm and 50 cm of depths resulted in number of total tillers that were not different because both treatments were affected by the water availability which waterlogged the plants.

Depth and planting area treatments resulted in no different canopy dry weight (Table 5). This was because rice planted in raised-bed and sunken-bed with 25 cm and 50 cm of depths had a different rate of photosynthesis (Table 1). On account of the same photosynthesis rate, photosynthate produced in both treatments were also the same. The photosynthate produced would be buried in both vegetative and generative organs of plants. Photosynthate was translocated at the same amount in the vegetative organs of the plants in each treatment so as to produce dry canopy weight that was not different between treatments.

Rice was grown in raised-bed showed greater root dry weight than in sunken-bed (Table 5). Allegedly, by reason of limited water availability, the roots of rice planted in raised-bed would try to reach water and nutrients in the soil and experience expansion. Muis *et al*. (2013) stated that when water is lacking, plants will withstand its canopy growth rate and increase its root growth rate. This aims to prevent the amount of water loss, because the root growth rate requires less water than the canopy growth rate that will enlarge the respiration process through formation of the leaf. A higher root growth rate in raised-bed planting resulted in more considerable root dry weight than in sunken-bed.

Table 5 shows the biomass of plants when harvested that was not significantly different between planting field and depth treatments because they did not indicate different photosynthesis rate. The photosynthesis

Table 6. Number of panicles per clump, panicle length (cm), percentage of filled seeds (%), weight of 1,000 grains (g), and harvest index of Inpari 29 variety grown on raised-bed and different depths of sunken-beds

Treatments	Number of panicles per clump	Panicle length (cm)	Filled grain (%)	Weight of 1,000 grains (g)	Harvest index
Depth					
50 cm	11.67 a	24.98 a	60.05 a	16.67 a	0.26 a
25 cm	12.00 a	22.42 a	62.18 a	17.07 a	0.32 a
Planting Area					
Raised-bed	12.83 p	23.71 p	59.88 p	16.33 p	0.10 q
Sunken-bed	10.83 p	23.69 p	62.35 p	17.40 p	0.40 p
Interaction	-	-	-	-	-
CV (%)	6.45	12.19	12.78	7.48	8.82*

Note: (-) no interaction; wap (weeks after planting); (*) the data was transformed; the number followed by the same letter in the same column has no significant different in the Duncan's Multiple Range Test at 5% error level

rate would produce photosynthate before being translocated to vegetative and generative organs of the plant. Photosynthates translocated to the vegetative part of the plant, i.e., the canopy, did not show any significant differences. Albeit not different, the rice planted in raised-bed showed higher biomass because it performed higher rate of root growth than the canopy. Rice planted in 25 cm and 50 cm of depths showed biomass of plants that were not different due to the same water availability. Such water availability in-depth treatment helped the plant roots to absorb nutrients. According to Lakitan (1993), nutrients absorbed by plants through the roots would contribute to the addition of plant weight.

Yield Components

Table 6 shows that the number of panicles per clump, panicle length, percentage of filled grain, and 1,000 grain weight were not significantly different between planting area and depth treatments. Growth of the number of panicles per clump indicated the number of productive tillers of rice plants. According to Sutaryo (2012), a number of panicles per clump illustrated the number of productive tillers and the large number of panicles per clump that could increase grain yield. Table 6 shows that the number of panicles per clump was not different between planting area and depth treatments due to the same source of sink distribution. Panicle length and 1,000 grain weight were not significantly different between the two treatments owing to the same variety of the planted rice. The genetic nature of the variety affected the two variables. The percentage of filled grain was not significantly different between the two treatments by reason of the generative phase; water EC that reached 10–25 dS.m^{-1} with soil EC between 2.5–3

dS.m^{-1}. Waterlogging and submergence with almost the same EC in raised-bed and sunken-bed with 25 cm and 50 cm of depths caused no different percentage of filled grain. Such conditions could become abiotic stresses for plants and lead to fertilization failure and low translocation of photosynthate to become grain.

The harvest index is the ratio of grain weight to the total biomass as the parameter that describes the distribution of photosynthate. Table 6 shows that rice planted in sunken-bed indicated higher harvest index than in raised-bed. This was due to the higher dry weight of grain and lower plant biomass compared to rice plants grown in raised-bed (Table 6). Tubur *et al*. (2012) stated that increasing the value of the harvest index will increase the yield of grain.

Table 7 and Table 8 shows that rice planted in sunken-bed with 25 cm of depth resulted in higher grain weight per clump and grain weight per plot than that with 50 cm of depth. When planted in raised-bed with 50 cm and 25 cm of height, it produced the same grain weight per clump and grain weight per plot. When planted in sunken-bed with 25 cm of depth, it resulted in higher grain weight per clump and grain weight per plot than in raised-bed with 25 cm of height. Rice planted in sunken-bed of 50 cm resulted in higher grain weight per clump and grain weight per plot than in raised-bed of 50 cm.

Grain weight per clump and grain weight per plot was greater in the sunken-bed treatment with 25 cm and 50 cm of depths compared to the raised-bed treatment with 25 cm and 50 cm of height because the first treatment resulted in more panicles per clump and more significant percentage of grain content although it was not significantly different (Table 6). The photosynthate result was sufficient for panicle and seed formation. Limited water given to the

Table 7. Grain weight per clump (g) of Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatment	Grain weight per clump (g)		
	Depth		Average
	50 cm	25 cm	
Planting Area			
Raised-bed	7.18 c	6.62 c	6.90
Sunken-bed	9.53 b	12.82 a	11.17
Average	8.36	9.77	9.04 (+)
CV (%)		3.66	

Note: (+) there is interaction; the number followed by the same letter in the same column is not significantly different in Duncan's Multiple Range Test at 5% error level

Table 8. Grain weight per plot (g) of Inpari 29 rice variety grown on raised-beds and different depths of sunken-beds

Treatment	Grain weight per plot (g)		
	Depth		Average
	50 cm	25 cm	
Planting Area			
Raised-bed	278 c	252 c	265
Sunken-bed	366 b	492 a	429
Average	322	372	347(+)
CV (%)		3.90	

Note: (+) there is interaction; the number followed by the same letter in the same column is not significantly different in Duncan's Multiple Range Test at 5% error level

rice planted in raised-bed caused lower photosynthate produced because the rate of root growth was higher than biomass. Such result was found in plants that were unable to utilize photosynthate for their panicle and seed formation optimally. The sunken-bed treatment with 25 cm of depth resulted in larger grain weight per clump than of 50 cm depth because when the seeds experienced maturation, it required only small amount of water.

Waterlogging on saline field increased grain weight per clump owing to the fact that the canopy of waterlogged rice plant experienced faster growth than the root. The canopy growth rate supported the photosynthesis process which would produce photosynthates that were useful for seed formation, even in small amount. Different depths resulted in significant differences in growth and yield variables. Nevertheless, during the process of seed maturation, less water was needed which led to a higher percentage of filled grain in 25 cm of depth treatment although it was not significant.

CONCLUSIONS

Compared to raised-bed treatment, sunken-bed treatment gave better rice growth. This was indicated by the higher content of chlorophyll a, chlorophyll b, total chlorophyll, nitrate reductase activity, and plants height. It also yielded better results than raised-bed treatment as shown by higher harvest index and grain weight per clump. Meanwhile, rice planted in sunken-bed with 25 cm of depth showed a higher value of nitrate reductase activity, grain weight per clump, and grain weight per plot than that with 50 cm of depth.

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