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Effects of seedling age on the growth and yield of two rice (*Oryza sativa* L.) varieties transplanted in Saline Coastal Area of Baros, Yogyakarta

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Abstract

Marginal land along the coast should be utilized to increase the national rice production. In addition, the use of saline resistant varieties, it is necessary to determine the best seedling age for saline soil. This study aimed to evaluate the growth and yield responses of two rice varieties transplanted at different seedling age on saline soil. The experiment was arranged in a factorial Randomized Completely Block Design (RCBD) with three replications, conducted at saline coastal area of Baros, Yogyakarta, starting from January to June 2017. The first factor was rice varieties, consisting of Dendang and IR-64. Meanwhile, the second factor was the seedling age, consisting of 2 and 4 weeks after sowing (WAS) seedlings. The results showed that the growth and yield of two rice varieties (Dendang and IR-64) showed significant difference, and Dendang showed a better performance than IR-64. The higher yield of Dendang compared to IR-64 was supported by higher plant growth (shoot dry weight) and yield components (number of seeds per panicle, seed weight per plot, and productivity). The 2 and 4 WAS seedlings did not give significantly different effects on nearly all growth variables. However, 2 WAS Dendang rice seedlings had higher shoot dry weight. Meanwhile, IR-64 had higher leaf greenness in 4 WAS seedlings compared to that in 2 WAS seedlings.

INTRODUCTION

The increasing population and the decreasing agricultural land have caused Indonesia to face serious problems regarding food supply, especially rice. Rice is a major source of carbohydrates for Indonesians, with an average consumption of 125 kg per capita per year (Nuryati et al., 2016). Based on data from Badan Pusat Statistik (2016), rice production in Indonesia had increased from 65,756,904 ton per year (2011) to 75,397,841 ton per year (2015). Rice production is expected to increase continuosly.

The decreasing agricultural land is due to land conversion from agricultural land to non-agricultural land. Therefore, marginal land should be utilized. An example of marginal land is coastal area (Putri, 2011), whose area is up to 1,060,000 ha (Balai Besar Pelatihan Pertanian Lembang, 2011). The marginal land along the coast could be utilized to cultivate rice to increase the national rice production.

Marginal land along the coast should be utilized to increase the national rice production in spite of many constraints, such as too high intensity of sunlight, too high air temperature, too high soil temperature, high rate of evapotranspiration, high wind speed, and frequent salt storms (Hidayat, 2013). The constraints existing on the marginal land of coastal area can be overcome by using resistant varieties to these marginal environmental factors. The use of saline resistant varieties is expected to produce yields even though planted in a unfavored marginal environment (Arsyad et al., 2014). In addition

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to the use of saline resistant variety, it is necessary to study the seedling age. The seedling with a younger age is expected to adapt to the environment more quickly (Gani, 2003).

The study aimed to compare optimal growth and yields of rice varieties commonly used by local farmers, namely IR-64 and Dendang, which have been tested adaptive to salinity. Several varieties with different tolerance of salinity have been found. As reported elsewhere, rice varieties could tolerate salinity up to 200 mM NaCl at germination, but only about 100 mM NaCl at later vegetative stage (Kurniasih et al., 2013). Utama et al. (2009) reported rice varieties that were able to survive and produce yield on saline soil or inundation, such as Cisadane, Cirata, Batang Lembang, Cisantana, Punggur, IR-64, IR- 42, Randah Kuning, and Widas. Meanwhile, Thohiron and Prasetyo (2012) reported rice varieties that were able to survive in saline condition, including Banyuasin, Batanghari, Dendang, Indragiri, Punggur, Martapura, Margasari, Siak Raya, Air Tenggulang, Lambur and Mendawak. In addition, Agricultural Research and Development Agency has collected salinity tolerant rice varieties, such as Dendang, Lambur, Siak Raya, Inpari 34 Salin Agritan, Inpari 35 Salin Agritan, Inpari Unsoed 79 Agritan, Inpari 42 Agritan GSR, Inpari 43 Agritan GSR, and Inpari 44 Agritan (Badan Penelitian dan Pengembangan Pertanian, 2016).

The use of young seedlings on saline soil is expected to have better root conditions (higher number of roots and longer roots) so that the adaptability to the environment is faster. As stated by Marlina et al. (2017), the use of rice seedlings older than 30 days after transplanting (DAT) with more seedlings would produce poor yields because old seedlings had slow adaptability (growth stagnation) and disturbed rooting system. This caused the rice plant to not optimally grow after transplanting. In contrast, the use of young rice seedlings (aged 15 days) would form active tillers, therefore they could adapt to the environment (Napisah and Ningsih, 2014).

The locations in which the experiment was conducted are often submerged with sea water when tidal water comes so that crop failure is often experienced by farmers (Cahyawati, 2013). As a consequence, the land is abandoned and not utilized. Two rice varieties were examined to determine their suitability for the land. Rice varieties used were Dendang that is salt resistant (Balai Penelitian Pengembangan Pertanian, 2016) and IR-64 that is commonly cultivated around the experimental field. Farmers at Baros used to transplant 4 WAS seedlings because they were considered strong and tall enough when exposed to regular tides of sea.

MATERIALS AND METHODS

The research was conducted on marginal coastal land located in Baros Hamlet, Tirtohargo Village, Kretek Subdistrict, Bantul Regency, Yogyakarta from January to June 2017. The objectives of the study were to evaluate the growth and yield responses of two rice varieties (Dendang tested adaptive to salinity and IR-64 commonly grown by local farmers) in saline coastal area of Baros, and to determine the suitable seedling age of rice when planted in saline coastal area of Baros.

The experiment was arranged in a factorial Randomized Completely Block Design (RCBD) with three replications. The first factor was rice varieties (Dendang and IR-64), and the second factor was seedling age (2 and 4 week after sowing (WAS)). The size of the experimental plot was 3 m × 3 m with plant spacing of 25 cm × 25 cm.

The research included land preparation (field survey, field plot measurement, land cultivation, and plant nursery), transplanting (according to the treatments), and plant observation (observation on plant growth at every two weeks, physiology observation/measurement at weeks after transplanting, and harvesting the rice yield). The data were analyzed using ANOVA and further tested with DMRT (95% confidence level) by using DSAASTAT application.

RESULTS AND DISCUSSION

Soil electrical conductivity and water electrical conductivity

The land was affected by high tides from the sea (flood), in which the Electrical Conductivity (EC) at high tide (flood period) could reach more than 10 $dS.m^{-1}$ (Figure 1). Soil texture at the experimental site was clay. The average temperature during the experiment was 26.8 °C in January, 26.9 °C in February, 27.2 °C in March, 27.5 °C in April, and 27.3 °C in May. Meanwhile, the average air humidity was 63 % in January, 64 % in February, 64 % in March, 67 % in April, and 65 % in May.

Growth variables

Soil salinity is an abiotic factor seriously limiting productivity, plant diversity, and plant growth in arid or semi-arid areas (Kazemi and Eskandari, 2011). The impact of salinity inhibits plant growth and development, thereby reducing plant productivity and quality (Thohiron and Prasetyo, 2012). Salinity inhibits plant growth and development through osmotic stress, nutrient deficiency, inhibition of cell division, inhibition of cell enlargement, plant growth substances unbalance, and metabolic disorders (Levitt, 1980). Plants that live in marginal land will activate responsive genes so that it will change the physiological and biochemical character (Zannati, 2015).

Plant growth is the result of physiological processes involving genotypes and environmental factors. Photosynthate during vegetative phase will be allocated in vegetative organs such as leaves. When entering generative phase, photosynthate will be translocated to the reproductive organs (Gardner et al., 1991). The expansion of leaf area is affected by the supply of assimilate, which is produced from photosynthesis. The assimilate is used for cell division and enlargement to support plant growth. The number and area of the leaves will increase if the photosynthesis rate can proceed well, and the supporting factors such as nutrient and sunlight are sufficiently available.

Leaf Area Index (LAI) is a very important growth variable to support plant growth and development as a whole, because photosynthesis takes place in leaf. Photosynthesis will produce assimilates for the needs of plant organs (Gardner et al., 1991). The photosynthesis product in the form of glucose will be converted into a sucrose form. Sucrose will be converted into a form of energy that will be used for plant growth or will be transferred to other plant organs.

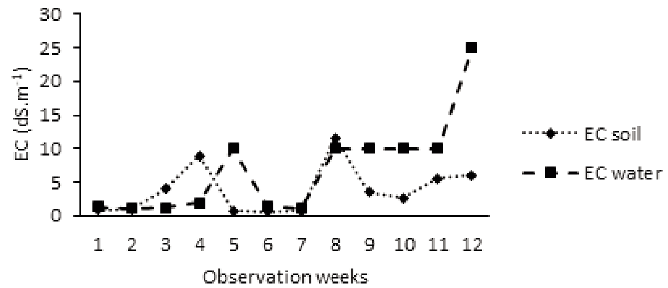

Figure 1. Soil and water Electrical Conductivity (EC) during 12 weeks of experiment

Leaf Area Index (LAI) is related to light interception and photosynthetic rate of a plant (Fageria et al., 2005). The observation at 52 and 70 days after transplanting (DAT) showed no significant difference between rice varieties and seedling ages, and no interaction between both factors (Table 1). These results illustrated that plants in all treatments had relatively equal LAI. An increase in LAI value from initial growth was found at 52 DAT and 70 DAT. The rapid growth of leaf area greatly increased LAI. At 52 DAT, the 2 WAS seedlings of Dendang and IR-64 had higher LAI than the 4 WAS seedlings. However, at 70 DAT, the 4 WAS seedlings of Dendang and IR-64 had higher LAI than that of the 2 WAS seedlings.

Specific leaf weight (Table 2) depicts the leaf thickness. The leaf thickness indicates the amount of biomass that plays a role in the photosynthesis. The result of the research showed that there was no interaction effect of rice varieties and seedling age, and there was no significant effect of each factor. At 52 and 70 DAT, the 2 WAS seedlings of Dendang and IR-64 had higher specific leaf weight than that of the 4 WAS seedlings.

Observation of leaf greenness by using SPAD showed the interaction between factors (Table 3). The leaf greenness of 2 WAS Dendang seedlings was similar to that of the 4 WAS, while the leaf greenness value of 4 WAS IR-64 seedlings was higher than that of the 2 WAS seedlings. Meanwhile, the leaf greenness value of 2 WAS seedlings of Dendang was higher than of IR-64. However,

Table 1. Leaf area index at 52 DAT and 70 DAT

Treatments	Leaf area index	
	52 DAT	70 DAT
Varieties (V)		
Dendang	0.69 a	1.63 a
IR-64	0.63 a	1.45 a
Seedling Age (SA)		
2 WAS	0.76 p	1.41 p
4 WAS	0.56 p	1.67 p
Interaction V×SA	(-)	(-)
CV (%)	22.13	20.58

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5 %, The (-) sign indicates no interaction between rice varieties and seedling age, DAT= days after transplanting, WAS= weeks after sowing

Table 2. Specific leaf weight at 52 DAT and 70 DAT

Treatments	Spesific leaf weight ($g.dm^{-2}$)	
	52 DAT	70 DAT
Varieties (V)		
Dendang	1.06 a	1.71 a
IR-64	1.23 a	2.12 a
Seedling Age (SA)		
2 WAS	1.29 p	2.11 p
4 WAS	1.01 p	1.72 p
Interaction V×SA	(-)	(-)
CV (%)	12.56*	10.77*

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5 %, The (-) sign indicates no interaction between rice varieties and seedling age, (*) shows that the CV was the result of transformed data, DAT= days after transplanting, WAS= weeks after sowing

there was no significant difference between both varieties in the leaf greenness value of the 4 WAS seedlings. High leaf greenness was expected to increase chlorophyll content, thereby improving its important role in the photosynthesis. The different results of leaf greenness and the chlorophyll content in the leaves are possibly due to error in the SPAD used.

Chlorophyll is a leaf pigment in chloroplast. Chloroplast is an important organelle of photosynthesis. The results showed that there was no interaction effect rice varieties and seedling age nor single effect of each factor on the chlorophyll a, chlorophyll b, total chlorophyll and photosynthesis rate (Table 4). These results proved in spite of the significant interaction effect on the value of leaf greenness, the chlorophyll content did not follow the same pattern. However, the results of this study indicated that the photosynthetic rate had a positive correlation with the value of leaf greenness (0.321), chlorophyll b (0.496), total chlorophyll content (0.492), and leaf area index (0.209).

The crop growth rate (CGR) is an increase in the dry weight of plants at a specific time interval. CGR will increase with the increase in leaf area so that the sunlight will be more captured and can be used

Table 3. Leaf greenness by using SPAD at 78 DAT

Varieties	Leaf greeness by using SPAD		Mean
	2 WAS	4 WAS	
Dendang	43.20 a	43.40 a	43.30
IR-64	38.90 b	42.60 a	40.75
Average	41.05	43.00	(+)
CV (%)			2.90

Remarks: Values followed by the same letters are not significantly different based on the DMRT at α= 5%, The (+) sign indicates interaction between rice varieties and seedling age, WAS= weeks after sowing, DAT= days after transplanting.

Table 4. Chlorophyll content at 107 DAT and photosynthesis at 70 DAT

Treatments	Chlorophyll ($mg.g^{-1}$)			Photosynthesis ($\mu mol\ CO_2.m^{-2}.s^{-1}$)
	a	b	Total	
Varieties (V)				
Dendang	0.34 a	0.30 a	0.64 a	41.98 a
IR-64	0.35 a	0.32 a	0.68 a	39.84 a
Seedling Age (SA)				
2 WAS	0.34 p	0.31 p	0.65 p	37.50 p
4 WAS	0.35 p	0.32 p	0.67 p	44.32 p
Interaction V×SA	(-)	(-)	(-)	(-)
CV (%)	23.89	9.24*	10.07*	14.70

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5 %, The (-) sign indicates no interaction between rice varieties and seedling age, (*) shows that the CV was the result of transformed data, DAT= days after transplanting, WAS= weeks after sowing.

Table 5. Crop growth rate at age 5 WAT – 7 WAT and 7 WAT – 10 WAT

Treatments	Crop growth rate ($g.cm^{-2}$ per week)	
	5 WAT – 7 WAT	7 WAT – 10 WAT
Varieties (V)		
Dendang	0.73 a	1.98 a
IR-64	0.82 a	1.53 a
Seedling Age (SA)		
2 WAS	0.65 p	2.00 p
4 WAS	0.91 p	1.51 p
Interaction V×SA	(-)	(-)
CV (%)	10.36*	10.91*

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5 %, The (-) sign indicates no interaction between rice varieties and seedling age, (*) shows that the CV is the result of transformed data, WAT= weeks after transplanting, WAS= weeks after sowing for photosynthesis. The results of the CGR (Table 5) showed no interaction effect of rice varieties and seedling age nor significant effect of each factor. The data showed that CGR observed at 5 weeks after transplanting (WAT) to 7 WAT and 7 WAT to 10 WAT showed an increase in value. It would affect the increase of shoot dry weight indicated by positive correlation (0.767). The presence of high leaf area resulted in increased sunlight capture.

There was a significant interaction effect of rice varieties and seedling age on the flowering time (Table 6). In Dendang, the 2 WAS seedlings showed later flowering time compared to the 4 WAS seedlings, furthermore, IR-64 showed the same result. The 2 WAS seedlings of Dendang Variety had later flowering time compared to those of IR-64 Variety. However, the 4 WAS seedlings of IR-64 and Dendang Variety had similar flowering time. Factors causing rapid flowering time include genetic factors and extreme changes in environmental factors (Aztrina et al., 2014). In addition, according to Yoshida (1981), Zeng et al. (2001), and Grattan et al. (2002), rice plants were more sensitive to saline conditions at nurseries, panicle initiation times, and at flowering stage. Transplanting when the seedlings were 4 WAS accelerated flowering time due to their slower adaptation to the environment compared to the 2 WAS seedling. It was supported by the CGR data. As a result, the seedlings transplanted at 4 WAS sped up the flowering to accelerate their life cycle. As stated by Kurniasih et al. (2008), the defense mechanism of a variety under stress conditions is by speeding up its life cycle.

Shoot dry weight illustrates the amount of biomass that can be accumulated by plants. The plant dry weight is the result of net accumulation of CO_2 assimilation carried out during plant growth and development (Larcher, 1975). According to the research by Anggraini

Table 6. Flowering age

Varieties	Flowering time (DAT)		Mean
	2 WAS	4 WAS	
Dendang	60.0 a	48.0 c	54.0
IR-64	53.0 b	48.0 c	50.5
Average	56.5	48.0	(+)
CV (%)			0

Remarks: Values followed by the same letters are not significantly different based on the DMRT at α= 5 %. The (+) sign indicates interaction between rice varieties and seedling age, DAT= days after transplanting.

Table 7. Shoot dry weight at 52 DAT and 70 DAT

Treatments	Shoot dry weight (g)	
	52 DAT	70 DAT
Varieties (V)		
Dendang	4.70 a	16.88 a
IR-64	4.72 a	18.48 a
Seedling Age (SA)		
2 weeks	5.85 p	17.80 p
4 weeks	3.57 p	17.57 p
Interaction V×SA	(-)	(-)
CV (%)	15.86*	19.99

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5 %. The (-) sign indicates no interaction between rice varieties and seedling age. (*) shows that the CV is the result of transformed data, DAT= days after transplanting.

et al. (2013), a highe value of shoot dry weight is due to the high leaf area index. If the plant grows well, it will produce an increasing dry weight as well. Rice plants need leaves for photosynthesis. The development of leaves can be seen from the leaf area index and the specific leaf weight. Low LAI will tend to produce lower plant dry weight.

There was no significant interaction effect of rice varieties and seedling age nor effect of each factor on the shoot dry weight at 52 and 70 DAT (Table 7). Dry weight is the result of the absorption and utilization of solar radiation available throughout the growing period (Gardner et al., 1991). Dry weight reflects the accumulation of organic compounds optimally synthesized plants from inorganic compounds, especially water and carbon dioxide (Lakitan, 1996).

The observation on the plant dry weight at 114 DAT (Table 8) showed that there was significant interaction effect of rice varieties and seedling age. The data showed that Dendang transplanted using 2 WAS seedlings had higher dry weight values compared to that transplanted using 4 WAS seedling. Meanwhile, the variety of IR-64 transplanted using 2 WAS and 4 WAS seedlings showed similar plant dry weight. Dry weight is a reflection of biomass in plant tissue. This biomass shows the amount of light captured during photosynthesis (Harjadi, 1991). The dry weight of Dendang Variety transplanted using 2 WAS seedlings had the highest value supported by CGR. The shoot dry weight and CGR had a positive correlation (0.767).

Yield component

Plants would produce output in the form of yield. Optimal yield would be produced when there are no significant obstacles found during the growth and development of plants. However, the environmental stress during the plants life cycle will decrease the yield. The growth and development of rice plants

Table 8. Shoot dry weight at 114 DAT

Varieties	Shoot dry weight (g)		Mean
	2 WAS	4 WAS	
Dendang	65.67 a	50.27 b	57.97
IR-64	49.50 b	56.13 b	52.82
Average	57.58	53.20	(+)
CV (%)			6.77

Remarks: Values followed by the same letters are not significantly different based on the DMRT at α= 5 %. The (+) sign indicates interaction between rice varieties and seedling age, WAS= weeks after sowing, DAT= days after transplanting.

Table 9. Yield components at harvesting

Treatments	TGW (g)	NSP	SWH (g)	SWP (kg)	FG (%)	Productivity ($ton.ha^{-1}$)	Harvest index
Varieties (V)							
Dendang	17.83 a	74.33 a	16.88 a	2.25 a	58.92 a	2.51 a	0.22 a
IR-64	17.20 a	47.83 b	10.00 a	1.48 b	49.40 a	1.65 b	0.14 a
Seedling Age (SA)							
2 WAS	17.95 p	61.17 p	13.31 p	1.78 p	55.18 p	1.97 p	0.16 p
4 WAS	17.13 p	61.00 p	10.71 p	1.95 p	53.14 p	2.20 p	0.20 p
Interaction V×SA	(-)	(-)	(-)	(-)	(-)	(-)	(-)
CV (%)	4.77	8.86	16.00*	8.69	15.18	9.09	5.75*

Remarks: TGW (weight of 1000 grains), NSP (the number of seeds per panicle), SWH (the seed weight per hill), SWP (the seed weight per plot), % FG (the percentage of filled grain), WAS (weeks after sowing). Values followed by the same letters in the same column are not significantly different based on the DMRT at α= 5%. The (-) sign indicates no interaction between rice varieties and seedling age. (*) shows that the CV is the result of transformed data.

grown in marginal place will be disrupted, which subsequently affects the formation of assimilates to be translocated from the source to the sink. At the time of grain filling, the starch substances in plants derived from photosynthesis before flowering are stored in the tissues of stems and leaves, which are then converted into sugar and transported to the grain. Percentage of filled grain per plant affects the rice productivity.

According to the research in greenhouse and field experiments by Grattan et al. (2002); Motamed et al. (2008); and Dauphin et al. (2010), salinity decreased the number of seeds per panicle and seed weight. In thisstudy, there was no significant interaction effect of both factors nor effect of each factor on the weight of 1000 grains, the seed weight per hill, the percentage of filled grain, and harvest index.

Based on Table 9, there was no interaction effect of both factors nor single effect of seedling age on the productivity. However, rice varieties significantly affected productivity. Dendang Variety had a higher productivity than IR-64 Variety. This result was supported by the higher number of seeds per panicle in 'Dendang' compared to in IR-64. As compared to the description of Dendang Variety, productivity values obtained during the experiment (2.51 $ton.ha^{-1}$) showed lower value than the description of Dendang (4 $ton.ha^{-1}$). This lower productivity was obtained when Dendang was grown on marginal land of coastal sand. However, Dendang was still capable of producing 63 % yield compared to its description. Meanwhile, IR-64 was only capable of producing 33 % of its description. The data concluded that Dendang was suitable for farmers to grow in the saline coastal area.

In the treatment of seedling age, the result showed that the cultivation of 2 WAS and 4 WAS seedlings had no significantly different effect on the productivity. However, Dendang tended to be better to be cultivated by using 2 WAS seedlings, supported by higher shoot dry weight. Meanwhile, IR-64 varietiy showed higher leaf greenness when transplanted using 4 WAS seedlings.

CONCLUSIONS

The results of the research concluded that the two rice varieties (Dendang and IR-64) showed significantly different growth response and yield. Dendang Variety had a higher yield compared to IR-64. This result was seen from the value of seed weight per plot and productivity. These results were supported by plant growth (shoot dry weight) and yield components (number of seeds per panicle, and seed weight per hill). There was no significant effect of seedling age on nearly all growth variables, growth analysis or yield component. However, the 2 WAS seedlings of Dendang tended to show better growth as shown in shoot dry weight. Meanwhile, the 4 WAS seedlings of IR-64 had higher leaf greenness than that of the 2 WAS seedlings.

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