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EFFECT OF AMELIORANT ON GROWTH AND YIELD OF RICE AT TIDAL PADDY FIELD

Pengaruh Amelioran Terhadap Pertumbuhan dan Hasil Padi di Lahan Sawah Pasang Surut

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ABSTRACT

Rice (*Oryza sativa* L.) is the most important and strategic food crop in Indonesia, but low productivity in tidal paddy fields is a serious problem that must be overcome. The application of ameliorant would be worthy to increase the growth and yield of rice in tidal paddy fields. The study aimed to investigate the effect of ameliorant application on growth and yield of rice varieties in tidal paddy fields. The study was arranged in a split plot design with five replications. Rice varieties tested were Inpari 34, Dendang, Inpara 9, Inpari 35, and Ciherang as the main plot, and ameliorant types studied were humic acid, gypsum, zeolite, and organic fertilizer as the subplot. The results showed that the use of different rice varieties and amelioran types significantly increased the growth and yield of rice. Inpara 9 produced 7.6 t.ha^{-1} dry milled grain (DMG) or increased by 33.3% compared to Ciherang variety. Humic acid application at 25 kg ha^{-1} increased grain yield by 21.3% higher than that without ameliorant treatment. The best treatment to increase the growth and yield of rice in tidal paddy field was a combination of humic acid 25 kg.ha^{-1} and Inpari 34 which produced the DMG of 8.6 t ha^{-1} or 41% higher compared to Ciherang without ameliorant.

[Keywords: Ameliorant, growth, rice, tidal swamp, yield]

ABSTRAK

*Padi (*Oryza sativa *L.) merupakan tanaman pangan terpenting dan strategis di Indonesia, namun produktivitasnya yang rendah di lahan sawah pasang surut menjadi masalah serius yang harus diatasi. Penggunaan amelioran dapat meningkatkan pertumbuhan dan hasil padi di lahan sawah pasang surut. Penelitian bertujuan untuk mengetahui keragaan pertumbuhan dan hasil beberapa varietas padi dengan perlakuan amelioran yang berbeda di lahan sawah pasang surut. Penelitian menggunakan rancangan petak terpisah dengan lima ulangan. Varietas padi yang diuji yaitu Inpari 34, Dendang, Inpara 9, Inpari 35, dan Ciherang sebagai petak utama, serta empat jenis amelioran yakni asam humat, gipsum, zeolit, dan pupuk organik sebagai anak petak. Hasil penelitian menunjukkan penggunaan varietas padi dan amelioran yang berbeda berpengaruh nyata terhadap pertumbuhan dan hasil padi. Inpara 9 memberikan hasil gabah kering giling (GKG) 7.6 t ha^{-1} atau meningkat 33.3%, dibandingkan dengan Ciherang. Aplikasi asam humat 25 kg ha^{-1} meningkatkan hasil 21.3% lebih tinggi daripada hasil panen tanpa perlakuan amelioran. Perlakuan terbaik untuk meningkatkan pertumbuhan dan hasil padi di lahan sawah pasang surut ialah kombinasi asam humat 25 kg ha^{-1} dan Inpari 34 yang menghasilkan GKG 8.6 t ha^{-1} atau meningkat 41% dibandingkan dengan hasil varietas Ciherang tanpa pemberian amelioran.*

[Kata kunci: Amelioran, hasil, lahan pasang surut, padi, pertumbuhan]

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and strategic food crop in Indonesia because 95% of Indonesian people are highly dependent on rice as stapple food. In 2018, Indonesia achieved rice self-sufficiency with a rice surplus of 2.85 million tons (Katadata 2019). To maintain sustainable rice self-sufficiency, the government implements a policy of increasing national rice production (Fachlevi et al. 2018). This policy has consequences for optimizing the use of all potential lands, including tidal paddy fields (Subagio 2019).

Tidal paddy fields are rice fields where water is significantly affected by the tides of sea and or river water either continuously or temporarily (Gazali

and Fathurrahman 2019). The results of research by Masganti (2021) showed that rice productivity is strongly influenced by agro-ecosystems and cropping systems; rice productivity decreases by 15.45% if planted in tidal paddy fields. Waterlogging, physical conditions of the land, soil acidity, high organic acids, toxic chemical elements, and low fertility are some essential problems that must be addressed in utilizing the land for rice cultivation (Irwandi 2015).

To obtain optimum yields in tidal paddy fields, serious efforts have been made including the use of new superior varieties (NSVs) (Syahri and Somantri 2016; Jumakir and Endrizal 2017; Koesrini et al. 2018; Purba and Giametri 2017; Sudarto et al. 2018) and ameliorant applications (Ridho et al. 2014; Handayani et al. 2017). New superior varieties (NSVs) are important component in increasing crop production because of their high contribution (56–75%) compared to other varieties (Juanda 2016; Sianita 2016; Syahri and Somantri 2016). The high contribution of NSVs is largely determined by optimal growth and yield, resistance to pests and diseases, tolerance to environmental stresses, nutrient deficiency, and crop competition (Makarim 2014). Testing of NSVs in tidal swamp land of Banyuasin-South Sumatra (Guwat et al. 2015) using Inpari 15, Inpari 22, Inpari 30, and Inpara 4 showed that Inpara 4 had the highest adaptability and produced grain yield of 7.0 t ha^{-1}. In tidal swamp land of Barito Kuala-South Kalimantan, the field assessment of Inpara 1 to 9 revealed that the yield of the adaptive varieties increased by 31.2% compared to the local variety of Margasari (Koesrini et al. 2018). These results proved that the NSVs have a high suitability in tidal paddy fields as demonstrated by the increased grain yield.

Ameliorant application is one of the cultivation technologies to increase rice productivity in tidal paddy fields. Ameliorant is a soil enhancer from organic, inorganic materials or their combination that can improve soil fertility physically, chemically, and biologically (Sasli 2011; Zuraida 2013; Akhmad et al. 2016; Atmaja et al. 2018; Zheng et al. 2019; Sun et al. 2020). Research in Dafeng District, Jiangsu Province, China showed that the use of ameliorants in the form of cow dung, gypsum, and a new type of ameliorant increased soil pH, organic matter content, and total potassium (Ping et al. 2015). Some organic ameliorants such as manure, organic fertilizer, compost, peat, and humus; and inorganic ameliorants including dolomite, zeolite, and volcanic ash are commonly applied to enhance plant yield (Alfian et al. 2017). Application of ameliorant by spraying compost extract on ratoon rice of Ciherang variety in tidal swamp land of Banyuasin-South Sumatra increased grain yield by 67% (923 kg ha^{-1}) (Suwandi et al. 2012). The use of 2 t ha^{-1} rice straw compost succeeded in increasing the yield of Inpara 5 to 5.73 t.ha^{-1} in tidal swamp land of Pelalawan-Riau (Masganti et al. 2017). Meanwhile, the use of dolomite 2 t ha^{-1} and Inpari 13 variety on tidal land of Cirebon-West Java increased the yield of dry unhulled rice to 3.59 and 2.99 t ha^{-1}, respectively (Atmaja et al. 2018). These results indicate that application of ameliorant is prospective to increase rice yield other than NSVs.

Central Java had 132,532 ha of tidal land that are potential for agricultural farming (Mulyani and Sarwani 2013). The study aimed to investigate the effect of ameliorant application on growth and yield of rice in temporary tidal paddy fields in Kendal Regency, Central Java.

MATERIALS AND METHODS

Plant Materials and Experimental Site

The plant materials used in this study were healthy puddle-tolerant seedlings of Inpari 34, Inpari 35, Inpara 9, Dendang, and Ciherang varieties; and soil ameliorant consisting of humic acid, gypsum, zeolite, and organic fertilizer. These rice varieties were chosen because they are suitable for tidal paddy fields that are sometimes inundated with seawater with high salinity.

The research was conducted in Rowobladon (6°55'42.2"S and 110°14'25.7"E), Purwokerto Village, Brangsong District, Kendal Regency, Central Java. The location is 2 km away from the coastline of the Java Sea and is at an altitude of 8 m above sea level. The average annual rainfall in 2019 was 1,631 mm with an average monthly rainfall of 135.9 mm. The soil type was Inceptisols with a sandy loam texture. The land often experiences inundation, especially during the rainy season in November–April, and can only be used for rice cultivation in the dry season of May–October.

The field research was carried out in the dry season of May–October 2019. To meet the water needs for rice cultivation, water was supplied using a pump from the nearest river (Blorong river).

Land and Seed Preparation

Land for seedling nursery was prepared by hoeing the soil manually to a depth of 30 cm. The soil was then leveled and made beds with a width of 1 m and the length adjusted to the existing size of the land. The soil was then added with organic fertilizer of 1 kg m^{-2} and carbofuran to prevent pest attacks.

To obtain healthy seedlings, the seeds were soaked in a salt solution (300 g l^{-1}) for 10–30 minutes. This treatment

was intended to separate the vigor (pig) seeds from unqualified (not pithy) seeds which generally float on the water surface. To remove the effects of salt, the seeds were rinsed 2–3 times (5 minutes each) with clean water, then soaked in clean water for 2–3 days. The seeds were treated with fipronil 10 ml l^{-1} for every 1 kg of seed, then ripened for 24–48 hours and stocked on nursery beds. Germinated seeds were fertilized using NPK 30–35 g m^{-2} at 7–10 days after sowing (DAS). Pests and diseases were controlled using pesticides according to seedling conditions. Seedlings were transplanted to experimental plots at 30 days after sowing.

Field Experiment

The five varieties tested were Inpari 34, Inpari 35, Inpara 9, Dendang, and Ciherang, while the five ameliorants were humic acid (25 kg ha^{-1}), gypsum (250 kg ha^{-1}), zeolite (250 kg ha^{-1}), organic fertilizer (2 t ha^{-1}) and no ameliorants as a control. The experiment was arranged in a split-plot design with five replications in which varieties were as main plot and ameliorants as subplot. Each plot consisted of ± 3,750 plants and the total plants were ± 468,750 plants. The total samples observed were 25 cluster plants or 125 plants per plot that were established randomly.

To explore the effect of ameliorants applied, soil properties before field assay including soil texture (pipette method), pH H_2O (soil solution ratio 1:5), C-organic (Walkey & Black), available N, P_2O_5 (Olsen/ Bray 1), K_2O (Morgan-Wolf), cation exchange capacity (CEC), exchangeable K, Na, Ca and Mg under ISO/IEC 17025-2017 laboratory were observed in conjunction to complete the research data.

The studied area of approximately 3.75 ha was prepared using hand tractor. A week later, the land was flattened using a similar machine and the surface was cleaned to remove sea slug shells. The land was then flooded by fresh water from the river for 2 days and divided into five blocks of 1,500 m^2 in size. Each block was splitted into five plots of 300 m^2 in size and 50 cm plot distance. In each plot, a plastic border was installed with 35 cm beneath and 55 cm above the land surface to prevent the plot from the effect of treatment on other plots.

Rice seedlings were planted in a cluster of 5–6 plants per hill in ± 4 cm depth and 20 cm × 20 cm plant spacing. Fertilizer was applied three times at 7–10, 21–25, and 35–40 days after planting using 250 kg ha^{-1} NPK, 150 kg ha^{-1} SP 36, and 150 kg ha^{-1} ZA. Fertilizer application was accompanied by ameliorants of 25 kg ha^{-1} humic acid, 250 kg ha^{-1} gypsum, 250 kg ha^{-1} zeolite, and 2 t ha^{-1} organic fertilizer per plot according to the treatment. Weeding was conducted before the fertilizers were applied.

Plant growth and development were monitored periodically to observe alteration occurred on plants and initial pest and disease attack. The pests and diseases were controlled using recommended pesticides in appropriate dosages.

Variables observed were soil fertility, plant height (cm), tiller number, panicle length (cm), grain number, filled grain number, empty grain number, 1,000 grain weight (g), harvested dry grains (t ha^{-1}), and milled dry grains (t ha^{-1}) (Masganti et al 2017). Periodical observation and data collection were carried out based on plant growth and development after planting till harvest. Total samples observed were 25 cluster plants or ± 125 plants.

Data Analysis

Data were subjected to analysis of variance (Anova). Significant differences between means were assessed by Tukey test, $P = 0.05$ (Mattjik and Sumertajaya 2006).

RESULTS AND DISCUSSION

Soil Properties

Soil in the studied area had clay texture with medium pH, high organic C, very low available N, very high available P and P_2O_5, medium available K_2O, medium CEC, low exchangeable K, Ca, and Mg, and medium exchangeable Na (Table 1). The problems faced in this soil were low in N content and exchangeable bases, especially K, Ca, and Mg.

Based on soil analysis data (Table 1), waterlogging conditions did not cause a serious negative effect on soil chemical properties, especially soil acidity (pH). Results of research conducted by Subagyo (2012) showed that in general, tidal swamp land is acidic (pH < 5.5), has a low fertility, and lacks microelements. This unaffected soil acidity (pH) is thought to be due to the inundation period at the study site which was only a few days a year, so that the soil pH was relatively the same as the initial conditions before the study. Application of all types of ameliorants increased soil CEC. This is in line with the research results of Subiksa et al. (2014), that ameliorant application in mineral soils with low fertility significanly increased soil CEC.

Ameliorant application did not cause a negative effect on soil chemical properties which would impact on the growth and yield of rice. In the ultisol soils in this study, compost application had a very significant effect on increasing available P, organic C, total N, CEC, and base saturation. Dolomite administration had a

Table 1. Soil properties of tidal paddy field before and after ameliorant application.

Soil properties	Unit	Before amelioration	Nutrient status*	After amelioration			
				Humic acid	Gypsum	Zeolit	Organic fertilizer
Soil texture			Clay soil				
Sand	%	1.33		-	-	-	-
Silt	%	15.56					
Clay	%	83.11					
pH H_2O		6.27	Slightly acid	6.60	6.58	6.70	4.79-
C-organic	%	2.64	Medium	2.11	2.14	1.84-	1.83-
Available N	%	0.30	Medium	0.24	0.25	0.24	0.22
Available P	Ppm	52.56	High	-	-	-	-
P total	mg 100^{-1} g	63.14	High	37.19	39.54	41.20	27.22
K total	mg 100^{-1} g	130.14	Very high	136.09	145.08	162.11	152.12
CEC	cmol(+) kg^{-1}	8.39	Low	27.58	32.81	31.15	28.44
Exchangeable K	cmol(+) kg^{-1}	0.03	Very low	0.10	0.09	0.10	0.10
Exchangeable Na	cmol(+) kg^{-1}	0.33	Low	1.44	1.42	1.41	1.47
Exchangeable Ca	cmol(+) kg^{-1}	1.80	Very low	0.79	0.42	0.70	0.67
Exchangeable Mg	cmol(+) kg^{-1}	0.64	Low	0.82	0.81	0.83	0.84

* The soil criteria were summarized from Balittanah (2009).

significant effect on total N, CEC, and base saturation, but had no significant effect on organic C. The interaction of applying compost and dolomite has a significant effect on increasing soil H_2O pH (Syahputra et al. 2015). The use of dolomite and biochar improved soil physical properties (water retention, porosity, and soil aggregation) and soil chemical properties (pH, Ca^{2+}, K^{+}, Ca-dd, K-dd, and base saturation) (Haryati and Erfandi 2019).

Soil properties before and after the study demonstrated that generally there was no significant and consistent change due to ameliorant treatments. Positive change was observed in soil CEC, where ameliorant treatments increased soil CEC and the highest increase occurred in gypsum. Balittanah (2009) reported that soil ameliorant increased exchangeable Na from low to very high status.

Plant Growth and Yield

Plant growth and development performed well till harvest. The plant height of 29–35 cm in the initial planting grew to be 58–70.1 cm at 35 days after planting (DAP), 92–125.8 cm at 60 DAP, and 99.9–127 cm at 90 DAP and the highest growth was found in Inpara 9 (Figure 1A). Tiller number were 8.8–9.7 tillers per cluster at 15 DAP, 17.6–19.4 tillers at 35 DAP, 18.8–21.9 tillers at 60 DAP, and 18.3–24.4 tillers per cluster at 90 DAP (Figure 1B). The average tiller numbers of Dendang and Inpari 34 were high, and those for the remaining varieties were low due to less panicles produced. The better growth performances were exhibited by Inpara 9 (Figure 1B).

The differences in varieties and ameliorants tested had a significant effect on plant growth and yield. This fact is in accordance with the results of the study by Guwat et al. (2015) and Sinaga et al. (2017) who reported that NSVs showed better growth performance and higher yields in swamps and tidal swamps due to the higher tiller number, longer panicle length, higher grain number of per panicles, and higher 1,000 grain weight than the other varieties. Inpara 9 and Inpari 35 were suitable to be developed in tidal paddy field. Inpara 9 has a longer panicle length (27 cm) and highest grain number per panicle (170 grains). Inpari 35 had the best performance in filled grain number per panicle (89%) and 1,000 grain weight (30.6 g). Inpara 9 and Inpari 35 produced comparable yields of 7.6 and 7.5 t ha^{-1} of milled dry grain (MDG), respectively, or 33% and 32% higher than Ciherang (Table 2).

Application of 25 kg ha^{-1} humic acid produced the best growth and yield performances. Humic acid application significantly increased most of the observed variables (Table 3). Humic acid is an organic substance that has a complex molecular structure with high molecular weight containing an active group. Humic substances (humic, fulvic acid) attract positive ions, form chelates with micronutrients, and release them slowly when required by plants (Ahmed et al. 2013).

Application of humic acid in flooded rice fields provided the best grain yields, which was 7.4 t ha^{-1} or 21.3% higher than that without ameliorant treatment. Application of gypsum, zeolite, and organic fertilizers increased grain yields by 13.1%, 11.5%, and 4.9%, respectively from that without ameliorant. Result of the study was in line with those of previous studies that ameliorants enhance growth and yield of rice because the materials enhance base saturation, pH, P, Ca, K,

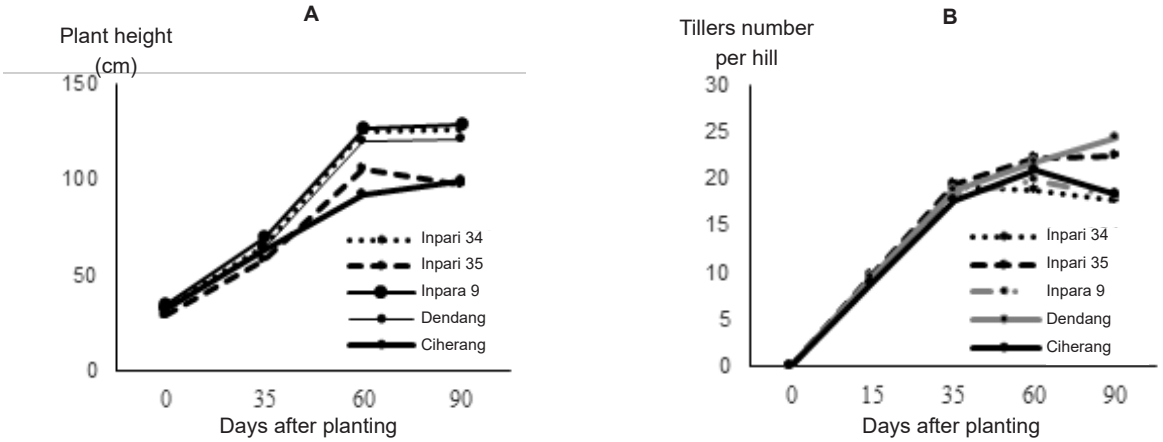

Figure 1. Growth performances of rice varieties in the tidal area; A = plant height, B = tiller number per hill.

Table 2. Yield components of some rice varieties cultivated in tidal paddy field.

Variety	Panicle length (cm)	Grain number per panicle	Filled grain number per panicle	Empty grain number per panile	Weight of 1,000 grains (g)	Milled dry grains (t ha^{-1})
Inpari 34	26.2 b	154.6 c	135.6 b	18.9 c	26.3 c	7.1 b
Dendang	24.4 d	139.5 d	116.0 d	23.5 b	24.5 e	5.8 c
Inpara 9	27.0 a	169.7 a	137.5 b	32.3 a	26.7 b	7.6 a
Inpari 35	25.0 c	163.8 b	145.8 a	18.1 c	30.6 a	7.5 a
Ciherang	24.0 d	136.2 d	124.4 c	11.7 d	24.9 d	5.7 c
CV (%)	2.01	4.75	6.06	27.52	1.31	4.94

Means followed by different letters are statistically different based on Tukey at p = 0.05.

Table 3. Effect of ameliorant on growth and yield of rice in tidal paddy field.

Ameliorant	Panicle length (cm)	Grain number per panicle	Filled grain number per panicle	Empty grain number per panicle	Weight of 1000 grains (g)	Milled dry grains (t ha^{-1})
Humic acid	25.8 a	154.5 a	136.0 a	22.0 a	25.9 b	7.4 a
Gypsum	25.5 ab	154.2 a	134.2 ab	20.3 a	26.7 a	6.9 b
Zeolite	25.2 bc	147.6 b	128.1 b	21.3 a	26.9 a	6.8 b
Organic fert	25.1 bc	153.5 a	131.2 ab	20.4 a	26.7 a	6.4 c
Without Amelioran	24.9 c	154.1 a	129.8 ab	20.6 a	26.8 a	6.1 d
CV (%)	2.01	4.75	6.06	27.52	1.31	4.94

Mean value followed by different letter was statistically different based on Tukey test, p = 0.05.

Na, Mg and nutrient uptake in soil, improve soil salinity, regulate soil physical properties, and improve soil nutrients, organic C, C/N ratio, soil microbial biomass carbon, and soil microbial biomass nitrogen (Sasli 2011; Zuraida 2013; Akhmad et al. 2016; Atmaja et al. 2018; Zheng et al. 2019; Sun et al. 2020). Improvement of soil physical, chemical, and biological properties has a great influence on plant growth and productivity.

Combination of Inpari 34 and humic acid produced the highest yield of 8.6 t ha^{-1} compared to other treatment combinations and increased grain yield by 41% compared to Ciherang without ameliorant. The interaction effect of varieties and ameliorans on the yield is presented in Table 4. Humic acid affects plant growth and development directly or indirectly. Indirect effects involve improvements of soil properties such as aggregation, aeration, permeability, water holding capacity, and micronutrient transport and availability. Direct effects are those, which require humic substance uptake into plant tissue resulting in various biochemical effects (El-Bassiouny et al. 2014).

Another combination that succeeded in inducing maximum growth and yield was Inpari 35 and Inpara 9 with humic acid, achieving yields of 8.1 and 8.0 t ha^{-1}, respectively. These results indicate that Inpari 34, Inpari 35, and Inpara 9 could be alternative varieties in tidal swamp land to the existing Ciherang and Dendang. The use of these three varieties combined with humic

Table 4. Interaction effect of rice varieties and ameliorants on milled dry grain yield.

Ameliorant	Grain yield (t ha^{-1})				
	Inpari 34	Inpara 9	Inpari 35	Dendang	Ciherang
Humic acid (25 kg ha^{-1})	8.6 a	8.0 a	8.1 a	6.3 a	6.1 a
Gypsum (250 kg ha^{-1})	6.9 b	7.7 ab	7.8 a	6.0 a	5.9 a
Zeolite (250 kg ha^{-1})	7.0 b	7.6 ab	7.8 a	5.9 ab	5.8 a
Organic fertilizer (2 t ha^{-1})	6.6 bc	7.4 ab	7.0 b	5.4 bc	5.5 ab
Without ameliorant	6.1 c	7.1 b	6.9 b	5.3 c	5.1 b
CV (%)	4.50	5.32	5.07	4.28	5.76

Means followed the same letter in the same column are not significantly different based on Tukey at $p = 0.05$.

acid ameliorant influenced the growth and yield of rice compared to the existing varieties. This is in line with the results of research by Mindari et al. (2018), that the use of humic acid from peat increased rice yields by 10–20% supported by the suitability of soil pH, nutrient availability, and soil salinity.

CONCLUSION

The use of different rice varieties and ameliorants significantly affected the growth and yield of rice in tidal paddy field. Inpara 9 variety produced the highest grain yield compared to Inpari 34, Inpari 35, Dendang, and Ciherang. Humic acid at 25 kg ha^{-1} was the suitable ameliorant to increase the growth and yield of rice. The best combination to increase rice growth and yield in tidal paddy field was Inpari 34 and humic acid at 25 kg ha^{-1}.

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