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Effect Application of Sea Sand, Coconut and Banana Coir on the Growth and Yield of Rice Planted at Ustic Endoaquert Soil

Nurdin

Agrotechnology Department, Faculty of Agriculture, Gorontalo State University
Jl. Jend. Sudirman No.6 Kota Gorontalo 96122, Indonesia.
E-mail: nurdin@ung.ac.id

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ABSTRACT

The research was aimed to study effect application of sea sand (SS), coconut coir (CC) and banana coir (BC) on the growth and yield of rice (*Oryza sativa* L.) planted at Ustic Endoaquert soil. The pot experiment was carried out using a factorial design with 3 factors. The first factor was SS consisted of three levels i.e.: 0%, 25%, and 50%. The second and third factors were CC and BC, each consisted of three levels i.e.: 0, 10, and 20 Mg ha^{-1}. Application of SS and BC significantly increased leaf length where the highest increasing percentage was 16.47% which was achieved at 25% SS application. Their effect on leaf numbers and tiller numbers were relatively not similar pattern where leaf number only increased about 65.52% by BC application, while tiller numbers only increased about 10.77% by SS application. Furthermore, the application of CC and BC significantly increased panicle numbers to 29.53% and 29.05%, respectively compared to control. All ameliorants significantly increased panicle numbers, but the best was CC with the increasing up to 46.49% at 20 Mg ha^{-1} CC compared to SS or BC application. However, only coconut coir significantly increased the rice grain numbers.

Keywords: Banana coir, coconut coir, rice plant, sea sand, vertisol

INTRODUCTION

Rate of population growth with a percentage of about 2% per year has resulted in increasing demand for rice consumption. Until 2012, national rice demand reached 34.055 million Mg and paddy production reached 68,956,293 Mg (BPS RI 2012) or equivalent to 37 million Mg of rice (Suswono 2012). Sudaryatno *et al*. (2010) predicted that the need of national rice in 2015 as many as 35,123,000 Mg and 37,021,000 Mg in 2020, or an average rate of rice consumption increased 0.92% per year. Viewing statistics in 2012, it was apparently a surplus as much as 3-4 million Mg of rice at the year. Although the current national rice needed was adequate and surplus, but considering Indonesia's populations that were about 247 million and the increasing rate of population growth, the rice production was needed to be maintained and improved, one through the increasing productivity of paddy soil.

Paddy rice field soil is an ecosystem which water source are dominantly from irrigation and as mainly national rice sources which coverage 2.1 million ha (Toha and Pirngadi 2004). In Paguyaman, Gorontalo Province paddy rice field areas are dominantly classified as Vertisols that developed from lacustrine deposition materials (Hikmatullah *et al*. 2002; Prasetyo 2007; Nurdin 2011). From chemically aspect, Vertisol is classified as nutrient rich soil that has high nutrient sources (Deckers *et al*. 2001). However, the physical properties are limiting factor for plant growth which are heavy clay texture, swelling and shrinking properties, lowest water infiltration, and slow drainage (Mukanda and Mapiki 2001). As a result, it frequently has stunted plant growth and low yields. It is necessary to repair these properties by giving ameliorant materials.

Sand is one type of the ameliorant materials that can be applied to high clay soils. Ravina and Magier (1984); Narka and Wiyanti (1999) showed that application of sand had significantly effect to decline COLE value and soil plasticity index, while soil permeability became large, but the water content availability was low. This was in line with statement of Kusnarta (2012) that sand could improve aggregate and structure stability of Vertisol (*stability quotient*), way of declining clay function mechanism in swelling-shirking processes. Besides, the application of sand about 20% of weight declined COLE values. The SS was used as planting media (Sari *et at.* 2006), but it had high NaCl contents that caused some crops grew abnormally (Kusnarta *et al*. 2014). Walter *et al*. (2000); Oliver and Smetten (2002); Al-Omran *et al.* (2004) has stated sandy texture soil was very influential on status and distribution of water, so it influenced root system and root depth. Further Rajiman (2009) has stated that the sandy texture soil influenced on soil nutrient and pH too.

However, paddy soil cultivation requires medium permeability with sufficient water content, so it needs another ameliorant to fix these properties, such as by using CC and BC. CC has been used as water storage on farms (Subiyanto *et al*. 2003). While, the banana coir is still relatively not used yet. Water absorption of banana coir was relatively high when it was dried because it had pores that were interconnected (Indrawati 2009).

Applications of the three ameliorant were allegedly able to mutually improve soil physical and chemical properties of Vertisol under rice cultivation in paddy rice field, so that its productivity could be improved. This research was aimed to study the effect application of sea sand, coconut coir and banana coir on the growth and yield of rice planted at Ustic Endoaquert soil taken from paddy rice field.

MATERIALS AND METHODS

Study Site

The experiment was conducted in the green house of Mathematics and Natural Science Faculty of Gorontalo State University starting in April-August 2012. Meanwhile, the growing media was Ustic Endoaquert Soil taken from Mootilango Sub district, Gorontalo District, Gorontalo Province. Soil description and classification are presented in Table 1.

Coconut and Banana Coir Preparation

Materials were obtained from dried coconut husk that surounded coconut shell inside. Coconut husk was peeled and separated from coconut shell, then, a smooth outer skin was peeled again until remaining coconut coir (CC). Furthermore, CC was milled to 1 mm. Banana coir (BC) materials were obtained from dried banana bark. Banana bark was peeled and separated from trunk up to 10 sheets of rods into core of the BC. Furthermore, the banana peel was grounded into powder with a size of 0.05 mm. The CC and BC obtained were weighed according to dosage of each treatment. Before application, water absorption capacities (WAC) of CC and BC were tested through immersion. Immersion was used to determine maximum WAC of the ameliorant material. Calculation of WAC followed the equation:

$$WAC (\%) = [\text{Pre Weight } (w0)/\text{Dry weight } (w1)] \times 100\%$$

Experimental Designs

A factorial design with 3 factors of ameliorant was used, where each factor consisted of 3 dosages of ameliorant and each had 3 replications, so 81 pot experiments were obtained. Sea sand (SS) factors consisted of 0% (S0), 25% (S1), and 50% (S2). CC factor consisted of 0 (C0), 10 (C1), and 20 Mg ha^{-1} CC (C2). While, the BC factors consisted of 0 (B0), 10 (B1), and 20 (B2) Mg ha^{-1} BC.

Initial properties of the soil at 0-20 cm depth are presented in Table 2. The soil had clay loamy textures, slow of soil permeability, and real of swelling and shrinking. Furthermore, the soil chemical properties indicated that the soil organic matter, total N, available P, and K exchanged were low. Relatively neutral of soil pH, cation exchange capacity and base saturation were high. Thus, based on criterion of Center for Soil Research (1983) the soil fertility status was classified as moderate.

Planting Rice and Its Maintenance

Before planting, basic fertilizers were weighted and applied to the soils. Urea 125 kg ha^{-1} were given twice at ages 0 days after planting (DAP) and 60 DAP, each as much as 62.5 kg ha^{-1}, respectively. Meanwhile, SP36 100 kg ha^{-1} were given twice at ages 0 days after planting (DAP) and 60 DAP, each as much as 50.0 kg ha^{-1}, respectively, whereas KCl 50 kg ha^{-1} were given twice at ages 0 days after planting (DAP) and 60 DAP, each as much as 25.0 kg ha^{-1}, respectively.

Ciherang rice seed variety was tested its quality by soaking in saline solution, then planted in trays which were covered by leaves and soil media containing organic material with a ratio of 1:1 until 10 days. A day before planting, the planting medium was watered so that toxic compounds to the rice seedling were moved down to the bottom of the pot. Rice seeds 10 days aged were transferred into plant growing media. Planting was done in planting hole as deep as 8 cm and followed by application of basic fertilizers. During plant growth and development, the maintenance performed was weed cleaning, watering was done every 7 DAP to end the grain filling phase until flooding, water content was filed capacity. Additication of second basic fertilizers were at 60 DAP. Harvesting was done when plant age was less than 115 days after planting. Observation of plant growth components were plant height, leaf length, leaf number and tiller number. Meanwhile, the observations of yield components were panicle length, panicle number, and rice grain number.

Statistical Analysis

Analyses of Variance (ANOVA) for factorials design were done to study the growth and yield response of rice plants due to application of ameliorant materials. If there was a significant effect, then it was continued by the least significant difference (LSD) test at 5% level.

RESULTS AND DISCUSSION

Growth Components of Rice Plant

The results of variance analysis for rice growth component planted at Ustic Endoaquert showed that CC and BC did not significantly effect to plant high (Table 3), while the SS significantly affected to plant high. The highest plant height was shown at application of 20% SS which significantly increased plant height compared other treatments. However,

Table 1. Soil description and classification of the Experiment Site.

Location		:	Sidomukti Village, Mootilango Subdistrict, Gorontalo District, Gorontalo Province
Soil classification			
Taxonomy (USDA 2010)		:	Ustic Endoaquert
PPT System		:	Eutric Cambisol
FAO-UNESCO System		:	Cambisol
Parent material		:	Lacustrine
Position physiographic		:	Foot slope, Depression
Topography		:	Flat-Ramps, slopes <2%
Elevation		:	58 m sl
Drainage		:	Poor
Ground water depth		:	Shallow
Vegetation		:	Rice (*Oryza sativa* L.)
Depth (cm)	Horizon		Descriptions
0-12	Apg1		Gray (10YR 5/1); clay loamy; massive structure; very sticky, plastic; smooth roots, a lot; clear flat.
12-31	Apg2		Gray (10YR 5/1); clays; angular blocky structure, smooth, Weak; very sticky, plastic; rusty brown (10YR 5/3), plain, smooth, clear, spots, sharp; rooting smooth, much; gradually average
31-53	Bwg1		Gray (10YR 5/l); clay; moderate, angular blocky structure, weak; very sticky, plastic; rooting smooth, slightly; frosted flat.
53-71/92	Bwg2		Gray (10YR 6/l); clay; angular blocky structure, rough, weak; very sticky, plastic; obviously choppy.
71/92-119	Bwssg		Dark gray (10YR 4/1); clay moderate, angular blocky structure, moderate; very sticky, plastic; slickenside; rusty brown (10YR 5/3), plain, smooth, clear, tube, clear; frosted flat.
119-150	BCg1		Dark gray (10YR 4/1); clay; angular blocky structure, harsh, strong; very sticky, plastic; rusty brown (10YR 5/3), plain, smooth, clear, tube, clear; clear flat.
150-200	BCg2		Dark gray (10YR 4/1); clay, very sticky, very friable; frosted flat.

Table 2. Initial soil properties of ustic endoaquert at 0-20 cm depth.

Soil Properties	Values	Criterion*
Texture:		
Sand (%)	27	
Clay (%)	35	Clay Loamy
Silt (%)	38	
Soil permeability (cm hour^{-1})	1.59	Slow
COLE value	0.98	Real swell-shrinking
Water content availability	8.47	
C-organic (%)	0.69	Very low
Total N (%)	0.06	Very low
C/N ratio	11.62	Moderate
Available-P, Bray 1 (mg P kg^{-1})	3.80	Very low
pH H_2O	6.48	slightly acid
NH_4OAo 1 *N* pH 7 Extraction:		
K(cmol+ kg^{-1})	0.24	Very low
Ca (cmol+ kg^{-1})	14.90	High
Mg (cmol+ kg^{-1})	6.05	High
Na (cmol+ kg^{-1})	0.50	Moderate
CEC (cmol+kg^{-1})	30.93	High
Base saturation (%)	70.08	High
Extract KCI 1 *M*:		
Al^{3+} (cmol+ kg^{-1})	0.00	
H^+ (cmol+ kg^{-1})	0.06	

*Center for Soil Research (1983).

the plant height still lower than normal growth as reported by Supriatno *et al.* (2007), that plant height of Ciherang varieties were ranged from 107-115 cm.

The highest increasing of plant height was indicated at application of 25% SS which increased plant height by 11.80%, while the lowest one was shown at application of 10 Mg ha^{-1} CC which only increased by 0.83%. At growth phase, especially plant height it needed sufficient water availability. Application of 25% SS had not yet reduced water storage in soil, so it did not effect on water availability, but it could increase plant height. At application of 50% SS, the plant height decreased until 2.45%. Mishra *et al.* (2012) reported that water available significantly decreased with the increasing of sand in mixture. Water shortages did not apparent at the beginning of vegetative phase and it still could stimulate root development, but at next vegetative phase, plant would be stunted (Sholeh and Riajaya 2000).

Furthermore, Yakup (2008) reported that plant height was significantly affected by soil water availability. In the water-saturated state, despite resistance by soil particles, no water could be absorbed by the soil except in certain plants such as paddy (Kasli and Efendi 2011).

Test results of WAC of both ameliorant showed that CC had a high WAC (71.77%), while BC was only 28.23%. Wuryaningsih *et al.* (2008) who conducted a study of growth *Anthurium andraeanum* in pot by using coconut bulk media reported that its physical properties were: a very high water content (1,314.41%), low-bulk density (0.09%), high total porosity (120.31%), and high pores water holding (116.6%). In additional, soil texture was classified as clay loamy (Table 2), so the soil puddling and flooding would become more easily dispersible and soil was relatively compact (Isnaini and Suwarno 2005).

Unlike the application of CC, the application of SS and BC had significant effect to leaf length (Table 3). The largest increasing of leaf length was shown at SS application as much as 25% (16.47%) and it was significantly different with control. It seems that application of 25% SS had not yet reduced water storages in soil but it might increase soil pores, so the leaf length was the highest. With the application of 50% SS, the leaf length decreased

Table 3. The rice plant growth components with the application of sea sand, coconut coir and banana coir planted at Ustic Endoaquert soil.

Treatments	Plant Height (cm)	Leaf length (cm)	Leaf number	Tiller number
Sea sand				
0%	27.74a	20.64a	10.29ns	12.07a
25%	3097b	24.04b	14.18	13.37b
50%	30.23ab	23.01ab	14.04	13.29ab
Coconut coir				
0 Mg ha^{-1}	29.57ns	21.99ns	11.88ns	12.37ns
10 Mg ha^{-1}	30.02	22.92	13.29	13.29
20 Mg ha^{-1}	29.32	22.78	13.33	13.07
Banana coir				
0 Mg ha^{-1}	30.95ns	23.89a	9.89a	l2.56ns
10 Mg ha^{-1}	29.29	21.43b	16.37b	13.19
20 Mg ha^{-1}	28.65	22.37ab	12.26ab	13.00
Interaction	ns	ns	ns	ns
$LSD_{0.05}$	3.21	2.42	4.57	1.25

Note: Number that following by same latter in same column did not significantly different at LSD level of 0.05; ns=not significant effect at F level test 0.05.

until 11.48%. Mishra *et al.* (2012) reporting that the water available decreased significantly with increasing sand in mixture. The lowest leaf length was shown at the 0 Mg ha^{-1} CC (0.62%) and it was not significantly different with 10 and 20 Mg ha^{-1} CC.

Fazeli *et al.* (2007) stated that effect of a turn single of water availability would reduce growth. Furthermore, Kasli and Effendi (2011) stated that effects of water shortages on some physiological processes of plants were seen in a slow accumulation of dry matter, decreasing leaf expansion rate, and limiting stomata closure photosynthesis. In addition, short-term leaves and leaf area in plants were thought to be influenced by the intensity of the light received in green house where the research took place. The present of trees around the green house allegedly indirectly affected the reception of light by the plant, even though the distance was about 6 feet from the green house. Anggarwulan *et al.* (2008) stated that light played an important role in the physiological processes of plants, especially photosynthesis, respiration, and transpiration. The plants required quite diverse intensity of light.

The applications of SS and CC did not have significantly effect to leaf number, but BC had significantly effect (Table 3). Application of 10 Mg ha^{-1} BC had significantly increased leaf number by 65.52% and it was significantly different with control. This was presumably due to the ability of BC to maintain soil moisture and water availability. Indrawati (2009) stated that the stem of BC was strong fiber and resistant to water. It also had pores that were interconnected, and when dry a material would be having absorption and high shelf.

The application of CC and BC did not have significant effect to tiller number, but application of SS had significant effect to it (Table 3). Application of 25% SS increased significantly tiller numbers by l0.77%. Indrawati (2009) stated that the flooding growing media as high as 5 cm was also associated with the formation of tiller numbers. This was in line with reports of Utomo and Rudi, (2000) in Kaseli and Effendi (2011) that the flooding up to approximately 3-5 cm above soil surface condition that considered as good for formation of tillers and at foll phase the flooding would inhibit seedling establishment. The results were reinforced by reports Astuti (2010) that the tiller numbers produced from crops by flooding system were more than by intermittent and kemalir systems. However, in contrast with results of Shi *et al.* (2002) that at the maximum tillering growth phase, the highest tiller numbers were in kemalir water management compared to intermittent and continuous floodings.

Sumardi *et al.* (2007) that water use efficiency for rice cultivation without flooding condition were as much as 19.581%, while with continuously flooding its efficiency was as much as 70.907% only. In this study also showed that the higher the plant would be followed by a greater tiller numbers. This was in contrast with the result of Aldi *et al*. (2004); Hartati and Suwarta (2004); Rahayu and Harjoso (2010) who reported that tiller number showed contrary to values of plant height, where the higher tiller number was the lower plant high.

Although it had not significant effect to tiller numbers, but application of 10 Mg ha^{-1} CC and BC increased tiller number by 7.44% and 5.04%, respectively compared to control. This was related a to high ability to absorb water of CC and BC, so that they would enough moisture and water availability. Ramesh *et al.* (2010) reported that combination of soil and coconut coir as much as 4% showed changes in the nature of Catton black soil compactness better that control. Contribution of ameliorant effect to plant growth was in order of SS > BC > CC.

Yield Components of Rice Plant

Analysis of variance for rice yield component resulted that application of CC and BC had significantly increased panicle numbers, but application of SS did not have significantly effect to panicle numbers. It seems that percentage of panicle numbers with CC and BC application were relative similar. However, the different between treatments were increasing of percentage figures. Application of 20 Mg ha^{-1} BC significantly increased panicle number by 20.47% compared to 10 Mg ha^{-1} BC and by 23.4l compared to control. This suggested that BC application was able to maintain water availability due a to high ability to absorb water. The BC was quite strong and resistant to water and had pores that where interconnected and when dry, a material would be having absorption and high shelf (Indrawati 2009). Meanwhile, although it had not significantly effect to panicle numbers, but application of 50% SS increased tiller numbers by 19.36% compared to control.

Soil sand fraction was clay loamy textures, so that application of 50% SS to the soil could reduce weight to light fraction, particularly declined COLE index. Sand textures affected status and distribution of water, so affecting root system and root depth (Walter *et al*. 2000; Oliver and Smettem 2002). Thus, the plant root system was not disturbed due to lock of the possibility of soil cracking, so the process of water and nutrients absorption could be better.

Application of 20 Mg ha^{-1} CC significantly increased panicle numbers by 29.54% compared to 10 Mg ha^{-1} CC. This was presumably related to soil water availability. The WAC level of CC was high and would be able to absorb and retain water availability in the soil, so that more CC would be followed by the greater panicle numbers. This was consistent with statement of Dachban (2012) that rice storage water for 4 days at generative periods and following 2 weeks was a sensitive periods to water storages.

In addition, the SS, CC and BC significantly increased panicle length. Application of 10 Mg ha^{-1}

Table 4. The rice yield component at application of sea sand, coconut coir and banana coir planted at Ustic Endoaquert soil.

Treatments	Panicle number	Panicle length (cm)	Rice grain number
Sea sand			
0%	2.48ns	8.97b	8.64ns
25%	2.59	7.35a	7.98
50%	2.96	8.28ab	9.07
Coconut coir			
0 Mg ha^{-1}	2.59ab	6.41a	7.14a
10 Mg ha^{-1}	2.37a	8.80b	9.52b
20 Mg ha^{-1}	3.07b	9.39b	9.04ab
Banana coir			
0 Mg ha^{-1}	2.52ab	7.33a	7.49ns
10 Mg ha^{-1}	2.41a	9.49b	9.48
20 Mg ha^{-1}	3.11b	7.78a	8.72
Interaction	ns	ns	ns
$LSD_{0.05}$	0.63	1.24	2.05

Note: Number that following by same latter in same column did not significantly effect at LSD level of 0.05; ns=not significant effect at F level test 0.05.

BC significantly increased panicle length by 29.47% compared to control and by 21.8% compared to 20 Mg ha^{-1} BC. This was presumably related to soil water availability of each treatment. The research conducted by Dachban (2012) showed that the panicle length at level of 3 mm, 2 mm, and 1 mm decreased long panicle length by 0.77%, 5.80%, and 45.10% respectively, due to reduction of plant yields because of water. In fact, Astuti (2010) reported that panicle length and rice grain numbers were not affected by irrigation, but each variety had panicle length and rice grain numbers per panicle significantly different due to the genetic. Meanwhile, 10 Mg ha^{-1} CC significantly increased rice grain numbers by 33.33% compared to control but did not have significantly different with 20 Mg ha^{-1} CC (Table 4). Apparently, long panicles would be relatively followed by a greater rice grain numbers. It was in line with Setiobudi *et al.* (2008) that the rice grain numbers was determined by genetic properties of plants especially panicle length, tassel branch, and a differentiation rice grains.

CONCLUSIONS

Application of sea sand and banana coir significantly increased leaf length where the highest increasing percentage of 16.47% was achieved at 25% SS application. Their effect on leaf numbers and tiller numbers were relatively not similar pattern where leaf number only increased about 65.52% by banana coir application, while tiller numbers only increased about 10.77% by sea sand application. Furthermore, the application of coconut coir and banana coir significantly increased panicle numbers up to 29.53% and 29.05%, respectively compared to control. All ameliorants significantly increased panicle numbers, but the best was coconut coir that could increase up to 46.49% at 20 Mg ha^{-1} CC compared to sea sand and banana coir application. Only coconut coir significantly increased the rice grain numbers.

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