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Research Article

Utilization of organic fertilizer to increase paddy growth and productivity using System of Rice Intensification (SRI) method in saline soil

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Abstract: Soil salinity has negative effect on soil biodiversity as well as microbial activities. Hence, rice growth also effected by salinity. Application of organic fertilizer and adoption of System of Rice Intensification (SRI) cultivation might improve the (biological) soil properties and increase rice yield. The aim of this study was to evaluate the effect of two different rice cultivation methods namely conventional rice cultivation method and System of Rice Intensification (SRI) rice cultivation method and two kinds organic fertilizer on improvement of soil biological properties and rice yield. In this study, a split plot experimental design was applied where rice cultivation method (conventional and SRI) was the main plot and two kinds of organic fertilizer (market waste and rice straw) was the sub plot. The treatments had four replicates. The results showed that SRI cultivation with market waste organic fertilizer could increase soil biological properties (population of microbe, fungi and soil respiration). The same treatment also increased rice growth and production. Combination of SRI and market waste organic fertilizer yielded the highest rice production (7.21 t/ha).

Keywords: *organic fertilizer, rice cultivation, saline soil, soil biological properties*

Introduction

Utilization of coastal lands as agricultural production lands is constrained by soil properties that are not supportive for agriculture. Main problem of coastal lands for rice cultivation is the soil salinity due to salt's accumulation in dry seasons (Sumarsono et al., 2006). Soil health problems become the factor of low crop yield in saline land. Farmers around coastal lands can only produce 4 t/ha dry unhusked rice only if there are no tidal waves during cultivation season.

Problem faced by farmers around Karawang coast is the soil physical, chemical, and biological properties that do not support plant productivity, especially rice (Sunarto, 2001). Soil ability to hold water and nutrients in coastal saline land is relatively low due to soil sandy texture characterized by large soil pore that causes high water infiltration rate. One of soil chemical properties that is not favourable for soil biology is high salinity that causes reduction in rice yield. Basic principles for rice cultivation by SRI method are (1) utilization of young seedlings, generally 8-12 days old , one seedling per each planting point, (2) wider planting distance (25 cm x 25 cm), (3), utilization of moist instead of flooded soil. According to Barison and Uphoff (2010), organic fertilizer can be applied to this method to develop organic farming, even though combination of organic and inorganic fertilizer is still widely used.

High amount and long-term addition of inorganic fertilizer can lead to disruption of soil fertility. Sholahudin (2010) reported that farmers in Magelang used urea fertilizer up to 300 kg/ha compared to normal dose of 150 kg/ha. Utilization of straws as organic fertilizer can recover soil fertility (physical, chemical, and biological properties). Straws also have high potassium content because 80% of nutrient absorbed by plants can be found in straws. Retrieval old straws to rice fields can provide potassium thus decreasing the use of KCl fertilizer.

Daily volume of waste produced by men is around 0.5 kg/capita thus for big cities with 10 million inhabitants will produce around 5000 ton of waste daily (WBIO, 2013). If the waste is not handled properly, the cities will be flooded by waste which results in enviromental problems and increased disease cases. Because of that, city waste management is crucially needed.

Rice cultivation using SRI method in tidal lands in South Kalimantan showed better results in soil nutrients content as well as better N, P, and K efficiency and uptake compared to conventional method (Razie et al., 2013). Addition of organic fertilizer enriched by *Azotobacter* resulted in decreased utilization of inorganic fertilizer as high as 25% less NPK. Ciherang rice productivity using SRI was almost 22% higher compared to conventional method by adding organic fertilizer enriched by *Azotobacter* (Razie et al., 2013). Bakrie et al. (2010) also showed that SRI method could increase rice yield up to 32.6% when used in rice fields in Situgede, Bogor

Biological characteristics improvement in saline land as well as optimal rice yield can be reached by utilization of straws and market waste as organic fertilizers. Rice cultivation system that supports soil's health such as utilization of straws and market waste as organic fertilizers is expected to improve biological properties of saline land in Karawang as well as increase its rice yield so the rice demand can be fulfilled even though many farm lands have been converted to non farming uses.

The aim of this study was to evaluate the effect of two different rice cultivation methods, namely conventional rice cultivation method and System of Rice Intensification (SRI) rice cultivation method and two kinds organic fertilizer on improvement of soil biological properties and rice yield.

Materials and Methods

The study was conducted in rice fields around coast at Tempuranz Sub-District of Karawang District. Analysis of soil biological and chemical properties was conducted in the Laboratory of Soil Biotechnology, and the Laboratory of Chemistry and Soil Fertility, Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University (IPB. Electrical conductivity of the soil was 7.41 mmhos. Materials used for this study were rice straw and market waste as organic fertilizers, rice seedling of Ciherang variety, basal inorganic fertilizers of N (Urea 250 kg/ha), P (SP36 200 kg/ha) and K (KCl 100 kg/ha).

A split-plot design was employed using cultivation system as main plot and organic fertilizer as sub-plot., for with four replicates. The main plot was composed of 2 levels which were SRI method (10 days old seedlings, one seedling per point, planting distance of 25 cm x 25 cm, intermittent watering system) and conventional (20 days old seedlings, 5 seedlings per point, planting distance of 20 cm x 20 cm, flooded watering system). Fertilizer types were composed of 3 levels which were no applied organic fertilizer, 6.25 t rice straw /ha, and 6.25 t market waste/ha. The organic fertilizers were applied by incorporating them into the soil.

Parameters observed in this study were rice growth, productivity, and yield components using 'ubinan' (a sampling area of 1 m x 1 m) method. Plant height was measured four times at 39, 53, 67, and 81 days after sowing (DAS). Soil samples were collected from the depth of 0-20 cm. Total microbial population included total bacterial population grown in Nutrient Agar (NA) media and total fungal population grown in Potato Dextrose Agar (PDA) media; both used pour plate method and population counting referring to get total CFU/g of soil. Microbial activity was measured by soil respiration rate using acid-base titration (Widyastuti and Anas, 2013). Soil salinity was measured by Electric Conductivity Meter (Oaklon EC Tester 11'Series).

Results and Discussion

Rice Plant Growth

Data presented in Table 1 showed that there was interaction between cultivation system and organic fertilizer type with plant height. The highest plant was obtained in SRI + straw organic fertilizer treatment at 39, 53, and 67 DAS. However, observation at 81 DAS showed the highest plant in SRI + waste organic fertilizer. Conventional treatment without organic fertilizer consistently resulted in lowest plants at 53, 67, and 81 DAS.

Data presented in Table 2 show interaction between cultivation system and organic fertilizer type with plant tillers. SRI method consistently showed the highest number of tillers over observation time. Addition of waste organic fertilizer in SRI method resulted in the higher seedling number compared to other fertilizer treatments. There was no significant effect of organic waste on seedling number between SRI and conventional methods.

Pratiwi et al. (2009) stated that plant height differences between SRI and conventional methods were resulted by plant root competition of nutrient and water. Soil nutrient availability significantly determines number of tillers where less competition gives the plants opportunity to maximize seedling. Doberman and Fairhust (2000) stated that plant root development and tiller number are affected by plant ability to absorb nutrient, especially phosphate.

Table 1 Effect of cultivation system and organic fertilizer type to plant height

Treatments	Plant height (cm)							
	39 DAS		53 DAS		67 DAS		81 DAS	
SRI	49.29	abc	99.20	a	117.58	a	127.45	a
SRI + straws organic fertilizer	51.14	a	101.45	a	118.51	a	128.05	a
SRI + waste organic fertilizer	50.95	ab	98.87	a	118.32	a	129.41	a
Conventional	45.95	c	84.27	b	96.36	b	113.21	b
Conventional + straws organic fertilizer	44.80	c	86.44	b	102.26	b	119.11	b
Conventional + waste organic fertilizer	46.67	abc	87.53	b	101.60	b	115.97	b

Note: Numbers followed by same letters in the same column have non-significant difference based on DMRT test with α = 0.05. DAS = Days After Sowing

Table 2 Effect of cultivation system and organic fertilizer type to number of tillers

Treatments	Number of tillers							
	39 DAS		53 DAS		67 DAS		81 DAS	
SRI	13	a	19	a	20	a	21	a
SRI + straws organic fertilizer	14	a	18	a	20	a	20	a
SRI + waste organic fertilizer	15	a	19	a	21	a	22	a
Conventional	7	b	13	b	15	b	15	b
Conventional + straws organic fertilizer	7	b	13	b	14	b	15	b
Conventional + waste organic fertilizer	7	b	11	b	14	b	14	b

Note: Numbers followed by same letters in the same column have non-significant difference based on DMRT test with α = 0.05. DAS = Days After Sowing.

Rice Yield Component and Productivity

Data presented Table 3 show that there are more panicle number in SRI method compared to conventional cultivation system, but the difference was not significant in type of organic fertilizer. The highest panicle number (15 panicles) was obtained from SRI + waste organic fertilizer while lowest number (11 panicles) was obtained from conventional rice cultivation method without organic fertilizer. However, it was not significantly different to the result of conventional method using organic fertilizer. The highest grain number per panicles (253 grains) was resulted from SRI cultivation + straw organic fertilizer and the lowest (158 grains) was from conventional method without organic fertilizer. The highest weight of 1000 grains (32.87 gram) was resulted from SRI cultivation + waste organic fertilizer and the lowest (21.82 gram) was from conventional method without organic fertilizer. Seedling age affects the rice generative phase. Younger seedlings will have faster adaptation time compared to older seedlings thus affecting time of panicle generation. Berkelaar (2001) showed that earlier seedling would have longer phyllochrons generation period before panicle initiation. Increased rice yield components supports rice productivity, thus the plants need to be treated carefully since early cultivation to get better yield.

It was also showed by Berkelaar (2001) that rice productivity using SRI cultivation was higher than conventional rice cultivation method, supported by higher yield components in SRI. Rice cultivation method and types of organic fertilizer also gave significant result in rice productivity (Table 4). The highest productivity was resulted from SRI + waste organic fertilizer with harvest dry grain (HDG) of 7.21 t/ha while the lowest productivity was from conventional method without organic fertilizer (4.67 t/ha).

Table 3 Effect of cultivation system and organic fertilizer type to rice yield components

Treatments	Yield Components					
	Number of Panicles (stems)		Number of grains /panicle (grains)		Weight of 1000 grains (g)	
SRI	13	ab	209	ab	22.69	c
SRI + straws organic fertilizer	14	ab	253	a	24.72	bc
SRI + waste organic fertilizer	15	a	195	bc	32.87	a
Conventional	11	b	158	c	21.82	c
Conventional + straws organic fertilizer	11	b	164	bc	24.87	bc
Conventional + waste organic fertilizer	11	b	163	bc	30.44	ab

Note: Numbers followed by same letters in the same column have non-significant difference based of DMRT test with $\alpha = 0.05$.

Table 4 Effect of cultivation system and organic fertilizer type to rice productivity

Treatment	Productivity (t/ha)			
	Harvest Dry Grain (HDG)		Mill Dry Grain (MDG)	
SRI	5.86	c	4.91	b
SRI + straws organic fertilizer	6.51	b	5.21	b
SRI + waste organic fertilizer	7.21	a	5.97	a
Conventional	4.67	e	3.74	d
Conventional + straws organic fertilizer	5.06	d	4.05	d
Conventional + waste organic fertilizer	5.42	d	4.53	c

Note: Numbers followed by same letters in the same column have non-significant difference based on DMRT test with $\alpha = 0.05$.

Rice productivity on saline land can be increased by SRI cultivation method enriched by organic fertilizer. Usual productivity of saline lands in Karawang District is around 4 t/ha, but by utilizing the SRI and adding waste organic fertilizer, the productivity can be increased. The increase from SRI method was resulted from watering management pattern that gives advantages to rice rhizosphere. Flooding will disturb aeration in the soil because roots will develop aerenchyma for oxygen distribution to other organs. Aerenchyma development will hamper nutrient distribution from root to other organs (Berkelaar, 2001).

SRI method can increase rice productivity by efficient plant, soil, water, and nutrient management (Suswadi and Suharto, 2011). Soil health maintenance was done to preserve rhizosphere availability that can support root growth and provide nutrient for plants. Enrichment by organic fertilizer can increase soil health. Its utilization in SRI method helps providing nutrients as well as helping roots to absorb nutrient by improvement of soil physical properties. Mutakin (2007) stated that organic fertilizers have excellent nutrient content for plants if applied in the right time.

Soil Biological Properties

The observed soil biological properties in this study were total microbial population and soil respiration. Observation was conducted in three plant phases, i.e. vegetative phase (40 DAS), generative phase (80 DAS) and harvest time (126 DAS). Figures 1 and 2 show that there was no significant effect of rice cultivation method and organic fertilizer types on total microbial population.

For both bacteria and fungi, the highest population number on every phase was acquired in SRI + waste organic fertilizer. The highest total bacteria population on vegetative phase, generative phase, and harvest time were 2.43, 5.77, and 11.65 x 10^6 CFU/g, respectively while the highest total fungi population on vegetative phase, generative phase, and harvest time were 6.31, 8.15 and 7.90 x 10^5 CFU/g, respectively.

Figure 3 shows that in all phases, the highest soil respiration was observed in SRI + waste organic fertilizer with CO_2 count of 22.62 mg/kg, 53.65 mg/kg, and 81.07 mg/kg, respectively, but it was not significantly different from SRI + straw organic fertilizer treatment. The highest soil respiration was obtained in the last measurement of the harvest time. SRI with waste organic fertilizer can increase soil biodiversity because it will provide better oxygen and nutrient for microbes compared to the flooded conventional method. Saraswati (2008) showed that rice field flooding results in repressed microbial activity and decreased population. Number of CO_2 produced is linear with total microbial population, higher population results in higher CO_2 produced. Microbial activity in the soil is affected by soil organic matter content as stated by Ardi (2010) that soil microbial activity is influenced by organic matter, humidity, aeration, and energy source. If microbial activity is high, more CO_2 will be produced.

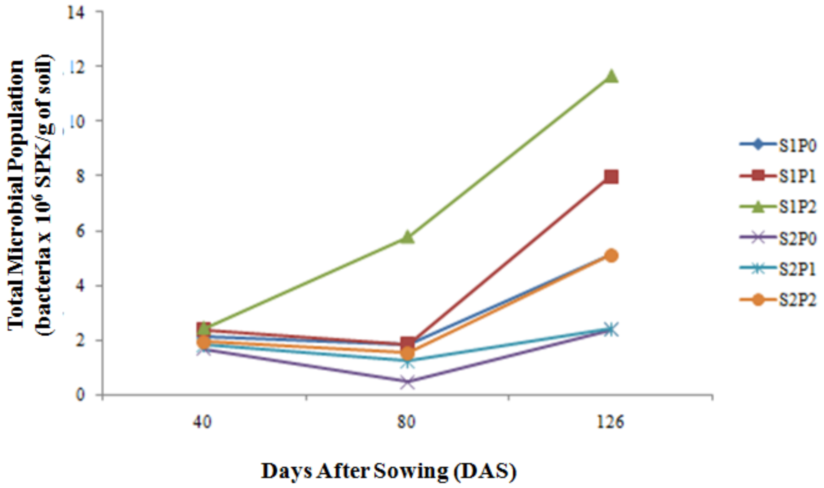

Figure 1. Effect of cultivation system and organic fertilizer on total microbial population (bacteria x10^6 SPK/g soil) in different plant phases. S1P0 (SRI); S1P1 (SRI + straw organic fertilizer); S1P2 (SRI + waste organic fertilizer); S2P0 (Conventional); S2P1(Conventional + straw organic fertilizer); S2P2 (Conventional + waste organic fertilizer); DAS: Days After Sowing

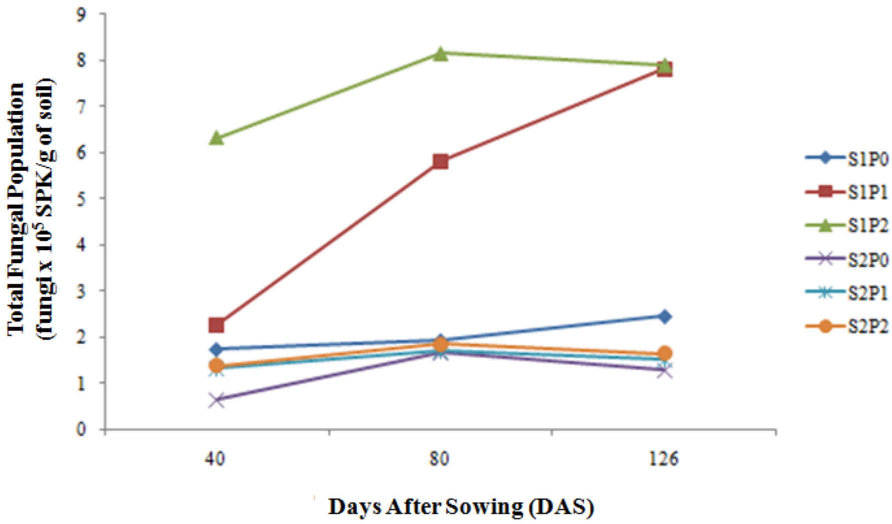

Figure 2. Effect of cultivation system and organic fertilizer on total microbial population (fungi x10^6 SPK/g soil) in different plant phases. S1P0 (SRI); S1P1 (SRI + straw organic fertilizer); S1P2 (SRI + waste organic fertilizer); S2P0 (Conventional); S2P1(Conventional + straw organic fertilizer); S2P2 (Conventional + waste organic fertilizer); DAS: Days After Sowing.

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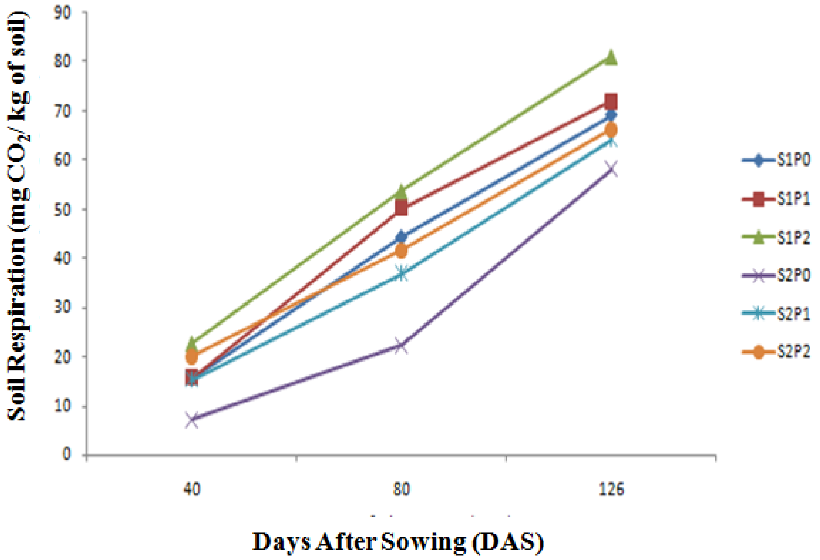

Figure 3. Effect of cultivation system and organic fertilizer type on soil respiration in several rice's phase. Note: S1P0 (SRI); S1P1 (SRI + straws organic fertilizer); S1P2 (SRI + waste organic fertilizer); S2P0 (Conventional); S2P1(Conventional + straws organic fertilizer); S2P2 (Conventional + waste organic fertilizer); DAS = Day After Seeding

Soil Salinity

Overall treatment combinations of organic fertilizer with cultivation system resulted in decreased soil salinity as shown by decreased conductivity from initial soil analysis to final phase (harvest) observation. Sampling was done in three plant growth phases and the conductivity value fluctuated in different phases (Table 5). Initial conductivity analysis showed the value of 7.41 mmhos. The lowest conductivity value was obtained in SRI cultivation without organic fertilizer addition (3.95 mmhos), while on generative phase, the lowest conductivity value was obtained in SRI + waste organic fertilizer (2.62 mmhos) but during harvest, the same treatment showed increased conductivity to 4.30 mmhos. The electrical conductivity measurement during harvest showed the lowest value in SRI + straw organic fertilizer (2.80 mmhos).

Table 5 Effect of cultivation system and organic fertilizer type on soil electrical conductivity

Treatment	**Electrical Conductivity (mmhos)**		
	40 DAS	**80 DAS**	**126 DAS**
SRI	3.95 a	3.05 a	3.65 ab
SRI + straws organic fertilizer	4.32 a	2.92 a	2.80 b
SRI + waste organic fertilizer	4.35 a	2.62 a	4.30 a
Conventional	4.47 a	3.72 a	3.47 ab
Conventional + straws organic fertilizer	4.82 a	3.00 a	3.62 ab
Conventional + waste organic fertilizer	4.75 a	3.35 a	3.67 ab
Coefficient of variation (%)	25.60	29.12	19.27

Note: Numbers followed by same letters in the same column have non-significant difference based on DMRT test with 5% degree. DAS = Days After Sowing.

SRI + waste organic fertilizer gave consistent electrical conductivity in saline lands, even though it was not significantly different compared to other treatments. Electrical conductivity fluctuation was expected as result of tidal waves. During high tide, electrical conductivity increases while during low tides, electrical conductivity gradually decreases. Razie et al. (2013) stated that application of SRI cultivation system in coastal lands is rather difficult due to difficulty in withholding water out during high tides. When the soil is not flooded (oxidative), Fe, Al, and Mn solubility will increase and affecting soil pH thus damaging the plants. That challenge can be handled by utilization of straw organic waste that serves as ameliorating agent. When utilized as fresh rice straws, in tidal fields during flooding (reductive) state the straw increases Fe^{2+} concentration and soil pH (Fahmi, 2006), thus utilization in the form of organic fertilizer will be favoured.

Conclusion

Utilization of aste organic fertilizer could increase rice yield cultivated in saline lands in Karawang using SRI cultivation method. SRI cultivation combined with organic fertilizer addition could increase soil total microbial number and respiration in saline soil.

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