SHALLOW WATER DEPTH MANAGEMENT TO ENHANCE RICE PERFORMANCES UNDER SYSTEM OF RICE INTENSIFICATION (SRI) FRAMEWORK

PENGELOLAAN GENANGAN AIR DANGKAL UNTUK MENINGKATKAN HASIL PADI DENGAN KERANGKA KERJA SYSTEM OF RICE INTENSIFICATION (SRI)

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ABSTRAK

Sekarang ini, isu kelangkaan air, harga pupuk yang tinggi, dan dampak negatif dari penggunaan bahan kimia yang tinggi pada bidang pertanian sedang berkembang, sehingga memerlukan peningkatkan efisiensi pada budidaya padi. Berdasarkan beberapa penelitian, SRI merupakan pendekatan yang menjanjikan. Pot percobaan dilakukan dengan kerangka kerja SRI dengan variasi irigasi tergenang (CF), sedikit air (SWD), dan kapasitas lapang (FC); diinteraksikan dengan empat dosis pemupukan organik yang berbeda (F 100, F 50, F 0, dan LF). Tujuan dari penelitian ini adalah untuk mengetahui pengaruh pengelolaan air dan pupuk organik terhadap pertumbuhan dan perkembangan padi. Hasil penelitian menunjukkan bahwa Eh tanah berbeda nyata di antara tiga pengelolaan air ($p<0.05$) dimana FC memiliki nilai tertinggi diikuti oleh SWD dan CF. Pemupukan organik tidak berpengaruh nyata terhadap Eh tanah. Jumlah anakan pada SWD berbeda nyata dengan CF dan FC ($p<0.05$). Di sisi lain, pengelolaan air dan pupuk organik tidak berbeda nyata terhadap tinggi tanaman. SWD secara signifikan meningkatkan biomassa dan produksi. Pupuk organik secara nyata menurunkan jumlah anakan, biomassa, dan produksi padi. Sebagai kesimpulan, SWD memberikan kondisi lingkungan tumbuh yang lebih baik untuk pertumbuhan padi dan meningkatkan kinerja tanaman padi, sedangkan pengaruh pupuk organik tidak dapat dibedakan.

Kata kunci: **pengelolaan air, pupuk organik, padi, Eh tanah, biomassa, produksi**

ABSTRACT

Nowadays, the issues of water scarcity, high fertilizer cost, and negative environmental impacts due to high agrochemicals use are escalating so that the improvement of resource efficiency on rice cultivation is necessary. Based on many studies, SRI is a very promising approach. Pot experiment was conducted under SRI framework with continuous flooding (CF), shallow water depth (SWD), and field capacity (FC) irrigation; together with four different doses of organic fertilizer (F100, F50, F0, and LF). The aim of this study is to figure out the effect of water and organic fertilizer managements on rice performances. Our experiment showed soil Eh was significantly different between three water management treatments ($p < 0.05$) where FC gained the highest soil Eh, followed by SWD and CF. Whereas, organic fertilizer management gave insignificant effect on soil EH. Under SWD management, number of tillers was significantly higher than CF and FC. On the other hand, water management and organic fertilization had no significant effect on plant height. SWD significantly increased yield and biomass followed by CF and FC. Organic fertilizer caused significant reduction on number of tiller, yield and biomass. In conclusion, SWD provided better environment for rice growth and enhance the rice performances, while the effect of organic fertilizer was not clearly seen.

Keywords: ***water management, organic fertilizer, rice, soil Eh, biomass, yield***

I. INTRODUCTION

In Indonesia, 90% of the population uses rice as a staple food (Kurdianingsih and Legowo, 2012). Population growth has significant effect to demand of rice production. On the other hand, rice production was unstable. Compared with other tropical countries, the average rice productivity in Indonesia was lower (Rochayati *et al.*, 2011).

Commonly, farmers in Indonesia follow the conventional method of rice cultivation which uses high input of water and agrochemical. Uphoff (2010) reported that rice cultivation is under increasing pressure to economize its water use. Thus, improvement of resource use efficiency is important for farmers, researchers, administrators, and policy makers. In order to improve resource use efficiency, it would be necessary to address the growing concerns of water scarcity, higher fertilizer costs, and negative environmental impacts due to the increasing use of agrochemicals (Tsujimoto *et al.*, 2009).

System of rice intensification is one of the rice cultivation methods which use intermittent irrigation. It could affect the oxygen status (redox potential) of the soils might influence rice performances by employing appropriate water and fertilizer managements.

Changes in redox potential (Eh) affect nutrients availability of plants and related to chemical or physico-chemical changes in nutrients (Notohadiprawiro *et al.*, 2006).

In this study, we conducted experiments to evaluate alternative combinations of water and organic fertilizer managements under SRI method. This evaluation can help to determine whether the optimization of SRI. The aim of this study is to figure out differences of water and organic fertilizer managements on rice performances.

II. LITERATURE REVIEW

Since the early 1990s, System of Rice Intensification (SRI) has been promoted as an alternative crop and resource management strategy for ricecultivation to increaseyield with less external input and focused on water and nutrient use efficiency (Krupnik *et al.*, 2012; Stoop *et al.*, 2002).

SRI components consists of (a) Intermittent irrigation, where rice fields are kept moist to minimize anaerobic conditions that hamper the growth of roots and soil organisms; (b) Early transplanting, where rice seedlings are transplanted at younger age lower than 15 days to minimize the transplant shock; (c) Single seedlings, where rice seedlings are planted single to permit better root growth and tillers; (c) Wide spacing, where rice plants are planted in square patterns of a minimum distance of 20 cm x 20 cm in order to keep all leaves photo-synthetically active (Noltze *et al.*, 2012).

Some studies showed that SRI increased productivity significantly compared to conventional method (Lin *et al.*, 2011; Krupnik *et al.*, 2012; Kurdianingsih and Lewogo, 2012; Ndiri *et al.*, 2012; Chen *et al.*, 2013). For example in Cibarengkok village, West Java, Indonesia, rice productivity with SRI method was 7.74 tonha^{-1} GKP, higher than conventional method (5.21 tonha^{-1}GKP) (Kurdianingsih and Lewogo, 2012). These facts imply that SRI can increase yield.

The various components of the SRI package create an environment for crop growth, involving chemical, physical as well as biological soil factors and processes that are completely different from that under a conventional irrigated system (Stoop *et al.*, 2002).

Redox potential (Eh) is commonly used as an index for the oxidation–reduction condition in paddy soil (Minamikawa and Sakai, 2005). Aerobic soil layer can be characterized by high redox potential, whereas anaerobic soil layer can be associated with low or more negative redox potential (Buresh *et al*, 2008).

III. MATERIALS AND METHODS

3.1. Experimental Site

Experiments were conducted from March to August 2013 in Sidorejo Village, Godean District, Sleman, Yogyakarta (7°46'43"S 110°17'28"E). The experiments were conducted in rice pots. Soil material was taken from a rice field with depth of 0-10 cm. The soil was a silty clay with the particle size distribution 10 % sand, 59 % silt, and 31 % clay. C-organic was 2.76%; organic matter 4.77%, total N 0.28%; available N 173.6 ppm; and C/N 10.01 (Anggraini, 2014).

The pots were placed inside a screen house. The mean values of temperature inside and outside screen house were 34.6 ^{o}C and 35.1 ^{o}C, respectively. Daily relative humidity (RH) was 67.26% and 70.06 %, respectively. Daily solar radiation was 9.77 W/m^2/day and 27.03 W/m^2/day, respectively. This difference indicated that the screen had reduced solar radiation in the house.

3.2. Experimental Design

The screen house was built to protect pest, to avoid rainfall, and to eliminate seasonal effects.

Local variety of rice (Oryza *sativa* L; var: rojolele) was used in this experiment.

The experiment was designed asrandomized complete block design (RCBD) with two influential factors: water management and organic fertilizer treatment. The following thre water managements were applied (Fig 1):

1. Continuous flooding (CF), where standing water was maintained at depth of 5 cm during vegetative growth and ripening stages, and then was drained 7 days before harvesting.
2. Shallow water depth (SWD), where standing water was about 1 cm during vegetative growth stage, and followed with continuous irrigation to maintain standing water about 3 cm during reproductive stage, and was drained 7 days before harvesting.
3. Field capacity (FC), where no standing water throughout the experiments.

Furthermore, four different doses of fertilizer were applied. Organic fertilizer used was compost made from manure and plant residues. The compost was commonly made by local farmers. Organic fertilizer treatments were as follows:

1. 100 % organic fertilizer (F100) such as recommended by the government amounted to 2 ton/ha as basal fertilizer (before transplanting).
2. 50 % organic and 50 % inorganic fertilizer (F50) in which the organic fertilizer was basal fertilizer and the inorganic fertilizer was given twice after transplanting.
3. 100 % inorganic fertilizer (F0) given twice after transplanting.
4. Local farmer (LF), where inorganic fertilizer was given twice after transplanting with the doses adapted from the local farmers.

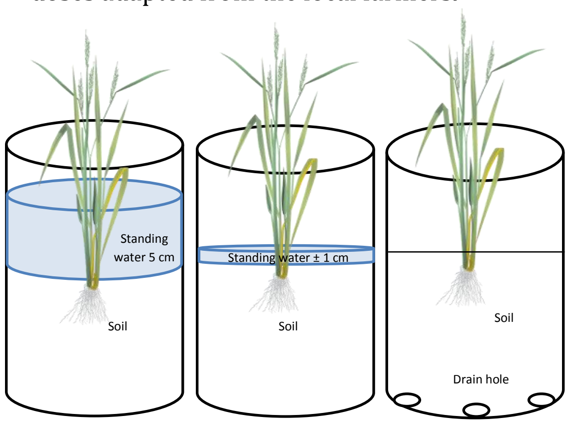

Figure 1 Different Water Management Treatment

3.3. Data Measurement and Analysis

Soil redox potential was measured with a portable oxidation/reduction potential (ORP) meter every week at the depth of 5 cm. Plant height and number of tillers were also measured every week. Total dry weight of plant was obtained at harvest time and collected from three selected pots for each treatment. All rice paddies were dug up with a spade, the roots were washed, and the soil was removed from the plants. Oven with 70 °C for 48 hours was use to dry the samples. Yield and its component (number of grain per panicle, percentage of filled grains, and panicle length) were taken from three pots for each treatment. Dry grain was indicated by 14% volume basis of moisture.

IV. RESULTS AND DISCUSSION

4.1. Soil Redox Potential

Soil Eh fluctuated over time in all treatment (Figure 2). This result has similarity with the previous study (Ponnamperuma, 1972) that when aerobic soil submerges, Eh decreases on the first few days and reaches a minimum; and then it increases, attains a maximum, and decreases again asymptotically.

The highest Eh was FC followed by SWD and CF. CF gained Eh less than –150 mV; SWD about -150 mV, and FC almost positive value. Water management had significant effect on Eh (Table 1) but not the case of fertilizer treatment. This result indicates that water is an important factor to influence Eh.

Table 1 Effect of Water and Organic Fertilizer Managements on Soil Eh

Water	Fertilizer	Soil Eh (mV)
CF	F 100	-183.00 a
	F 50	-174.33 a
	F 0	-170.67 a
FC	F 100	24.67 b
	F 50	94.00 b
	F 0	89.67 b
SWD	F 100	-91.22 c
	F 50	-76.33 c
	F 0	-102.00 c
F value	All	10.585*
	Water (W)	41.980*
	Fertilizer (F)	0.483ns
	W x F	0.428ns

* Significance 5% level ($p \leq 0.05$)

Figure 2 shows Eh under CF has almost the same value for all treatments. At the early stage, Eh under F100 was low due to the consumption of oxygen by microorganism that decomposed organic matter. A large amount of oxygen is required for the decomposition process of organic matter (Nursyamsi and Suryadi, 2000; Arslan *et al*, 2008).

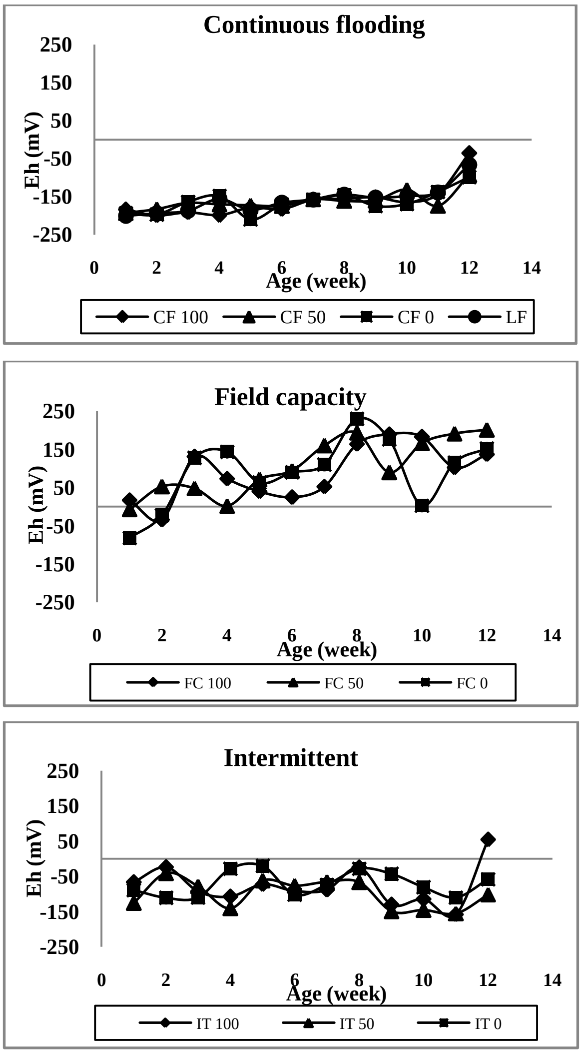

Figure 2 Soil Redox Potential (Soil Eh) under Water and Organic Fertilizer Managements

Eh under SWD was higher than that under CF. A small amount of oxygen could enter into soil causing higher Eh. Figure 2 shows Eh under SWD fluctuated with the addition of inorganic fertilizer (F50 and F0). Before the application of inorganic fertilizer, Eh in each water management increased. After fertilization, Eh decreased. At final stage, Eh increased due to dry condition. This result indicates that with the presence of oxygen, ammonium (NH_4) from inorganic fertilizer transformed into nitrate (NO_3^-) decreasing Eh. NO_3^- was not readily denitrified (reduced) in the aerated soil, and it might consequently accumulate (Buresh *et al*., 2008).

Under FC, Eh was always higher compared with other treatments. Oxygen could enter easily into the soil pores due to the absence of standing water. Flooding the soil can change this condition drastically if water replaces the air in the pore spaces (Datta, 1981; Buresh et al, 2008). The addition of inorganic fertilizer (F50 and F0) under FC have had similar result with SWD, where Eh decreased after the application (week 5-7) and then gradually increased till harvest time (week 12).

The present study demonstrates that the water management has a significant effect on soil Eh, where the organic fertilizer was not significant (Table 1). This result was similar with previous study (Cyio, 2008; Lin et al, 2011). Eh decreased when flood water increased and rapidly decreased when organic matter was added.

4.2. Rice Performances

The number of tillers increased during vegetative phase and decreased at final stage. The greatest number of tillers was under LF due to the higher input of inorganic fertilizer. Under different water management, SWD shows the highest number of tillers followed by CF and FC (Table 4), indicating that SWD provided more conducive environment for rice growth. Plant height also showed similar result.

FC lead to lower plant height and number of tillers due to soil moisture availability. If the soil is too dry, roots is difficult to take up water and will affect growth (IRRI, 2012). Sekhan *et al.* (1988) stated that under 60% field capacity condition (soil Eh= 343 mV), plant height was significantly lower compared to flooded condition (soil Eh= -91 to 70 mV).

Previous study also showed that under SRI practice with intermittent irrigation increased the number of tillers (Stoop *et al*., 2002; Kalsim *et al*., 2007; Balai Penelitian Tanah, 2011; Gopalakrishnan *et al*., 2013). The greater number of tillers might be largely due to wider spacing and transplanting of young and single seedlings. Thus, plant is able to complete more phyllochrons before anthesis due to the favorable growth conditions (Stoop *et al*., 2002; Thakur *et al*., 2013).

Rice plants grown under standing water, as in the case of CF, encountered hypoxic (anoxic) soil conditions and affected on root vigor. Vigorous roots with high supply of nutrient are responsible for greater number of tillers (Thakur *et al*., 2010). The root systems were healthier with SRI method (50% organic and 50% inorganic) under intermittent condition. It confirmed that SRI methods support better root growth and contributed to increase number of tillers (Gopalakrishnan *et al*., 2013).

Statistical analysis also showed that organic fertilizer had significant effect to number of tillers (Table 2). Added organic fertilizer significantly decreased the number of tillers (Table 4). While as, inorganic fertilizer could be use easily by rice plant. The present study illustrates that shallow water depth irrigation significantly increased number of tillers.

Rice yield and biomass was significantly affected by water and organic fertilizer managements (Table 2). SWD gained the highest yield followed by CF and FC conditions (4.61 ton/ha, 3.38 ton/ha, 3.26 ton/ha, respectively) because SWD produced the higher number of effective tillers (Fig 3). Fig 3 also shows that LF formed higher yield and biomass than F0, F50, and F100 because high input of inorganic fertilizer. There were positive correlations between number of tillers, yield, and biomass (Table 3). The greater number of tillers increased more yield and biomass.

Post hoc test describes that SWD significantly increased the yield and biomass, and added organic fertilizer decreased them (Table 4). FC treatment also significantly decreased yield and biomass (Table 4) because the soil moisture content was limited under FC which then affected plant growth.

Rice yield components illustrates that both water and organic fertilizer managements gave significant effect on the percentage of filled grains and panicle length. However, they gave no significant effect on number of grains. SWD significantly increased the percentage of filled grains (Table 4). The addition of organic fertilizer also decreased the percentage of filled grains and panicle length (Table 4). However, there were no significant differences of panicle length under CF and SWD. SWD significantly increased the yield component.

Some studies reported that a combination of intermittent irrigation with 50% organic + 50% inorganic fertilizer under SRI practiced could increase productivity significantly compared to the conventional method (Lin *et al*., 2011; Krupnik *et al*., 2012; Gopalakrisnan *et al*., 2013). Present study is consistent with that result. This study also found that the addition of organic fertilizer decreased the rice yield (Table 4) because of the slower decomposition of the organic fertilizer to supply available nutrient for plant.

Rasco *et al* (2013) also reported during 3 years study (2003-2006), organic fertilizers were not enough to provide the nutrients needed by the rice plant, and that why inorganic or chemical fertilizers were still needed for getting a higher yield.

The nutrients from the organic fertilizer are converted first into inorganic form before plants can absorb them (Buresh and Dobermann, 2010; Rasco *et al*, 2013). Gopalakrishnan, et al (2013) suggested that the repeated application of organic fertilizer over several years is often required to buildup sufficient soil fertility especially where inorganic fertilization has been applied in the past because it affected soil biota. In several years since the first application of organic fertilizer, significant reduction in rice yield was reported by Yadav et al. (2000) and Gopalakrishnan et al (2013). The recession in crop yields during an initial phase of transition from conventional to organic agriculture and recovery in the yields after 2–3 years was reported by Sharma and Singh (2004).

Table 2 Statistical Analysis at Harvest Time

Treatment	Height (cm)	Tillers	Yield (ton/ha)	Biomass (ton/ha)	Total grains / panicles	Percentage of filled grains (%)	Panicle length (cm)
	p						
All	0.709 ns	0.001*	0.002*	0.000*	0.045 ns	0.000*	0.001*
Water (W)	0.224 ns	0.001*	0.002*	0.000*	0.034 ns	0.000*	0.000*
Fertilizer (F)	0.866 ns	0.003*	0.000*	0.003*	0.132 ns	0.000*	0.027 ns
W x F	0.891 ns	0.059 ns	0.542 ns	0.074 ns	0.151 ns	0.007 ns	0.298 ns

*Significance 5% level ($p \leq 0.05$)
ns No significant

Table 3 Correlation Analysis of Plant Height, Number of Tillers, Yield, and Biomass

Parameters	r^2 and p value			
	Yield	Tillers	Height	Biomass
Yield	-	0.003	0.328	0.001
Tillers	0.801*	-	0.156	0.002
Height	-0.162	-0.356	-	0.446
Biomass	0.72*	0.818*	0.049	-

*Significance 5% level ($p \leq 0.05$)
Left side is r^2 (correlation) and right side is p (significance)

Table 4 Post Hoc Analysis at Harvest Time

Number of tillers	F 100	F 50	F 0	LF	Average
CF	12	15	10	21	14.50a
FC	10	13	19		14.00a
SWD	18	20	18		18.67b
Average	13.33a	16.00ab	15.67b	21.00b	-
Yield (ton/ha)	**F 100**	**F 50**	**F 0**	**LF**	**Average**
CF	1.81	3.42	3.44	4.83	3.38a
FC	2.53	3.49	3.75		3.26a
SWD	3.87	4.05	4.96		4.29b
Average	2.74a	3.65ab	4.05b	4.83b	-
Biomass (ton/ha)	**F 100**	**F 50**	**F 0**	**LF**	**Average**
CF	4.24	6.35	5.68	7.67	5.99a
FC	2.99	5.54	5.9		4.81a
SWD	7.53	6.52	8.15		7.40b
Average	4.92a	6.14ab	6.58b	7.67b	-
Percentage of filled grain (%)	**F 100**	**F 50**	**F 0**	**LF**	**Average**
CF	81	85	85	85	84.00a
FC	84	86.5	84.4		84.97ab
SWD	86	86	87.5		86.50b
Average	83.67a	85.83ab	85.63b	85.00b	-
Panicle length (cm)	**F 100**	**F 50**	**F 0**	**LF**	**Average**
CF	35	33.5	32.5	33	33.50b
FC	31.25	29.5	28		29.58a
SWD	33	30.5	32.5		32.00ab
Average	33.08b	31.17ab	31.00a	33.00ab	-

* Significance 5% level ($p \leq 0.05$)
CF continuous flooding, LF local farmer, FC field capacity, and SWD shallow water depth.
F 100 100% organic fertilizer, F 50 50% organic fertilizer and 50% inorganic fertilizer, F 0 100% inorganic fertilizer, and LF local farmer

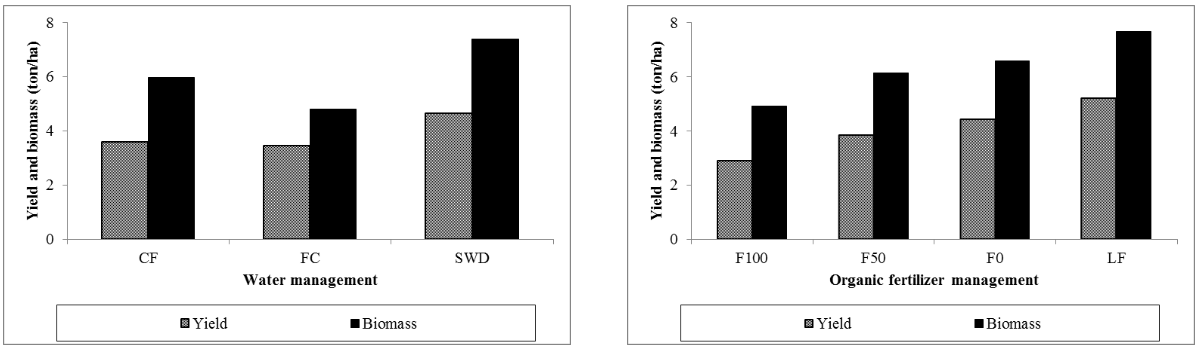

Figure 3 The Effect of Water and Organic Fertilizer Managements on Rice Yield and Biomass

The present study describes that water management is more important factor on rice production compared to organic fertilizer managements. Also, SWD enhance rice performances under SRI. In order to increase water use efficiency, SWD is recommendable on rice cultivation.

V. CONCLUSION

In the present study, shallow water depth management increased the rice performances under system of rice intensification. This might be affected by a conducive soil redox potential during plant growth. This shallow water depth provided alternations of aerobic and anaerobic conditions during the plant growth. Here with a favorable soil Eh was achieved to support the growth. Under SWD, rice biomass and yield was higher than CF and FC. The addition of organic fertilizer resulted in lower biomass and yield. SWD provided better soil environment for the plants though the organic fertilizerdid not give immediate positive effect to the growth. Further effects of water management and organic fertilization on soil fertility and rice performance should be examined continuously.

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