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Full Length Research Paper

Rice growth and water productivity of newly opened wetlands in Indonesia

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Abstract

Newly opened wetland rice fields require more water because plough pan layer are not developed. Plough pans are established several years and also depending on intensity of planting rice. Plot scale study was conducted at newly opened wetland rice originated from dry land in Panca Agung village, Bulungan District, Indonesia in 2011. Different water pounding depth including 0.5 cm (*macak macak*) and intermittent (two weeks wetting and a week was drying cycle) were tested. Rice growth, rice grains yield and water productivity was observed. Water productivity was computed according to the ratio between rice grains yield and water input. Water input was predicted according to the difference between incoming water and outgoing water. In this study water balance was not taken into account in calculating the water input. The results indicated that pounding water layer did not significantly improve on plant height, but significantly increased rice tiller number and grains yield. The highest tiller number and grain yield were reached by pounding water depth of 0-3 cm. The higher water productivity of about 0.96 and 0.30 gram liter^{-1} were recorded by pounding water depth 0.5 cm followed by pounding water layer of 0-3 cm. In a long term perspective, the implementation of this work would certainly contribute to water management and improve rice grains yield of wetland rice in Indonesia as water become scare.

Keywords: Water productivity, newly opened wetland rice, Bulungan District, water pounding.

INTRODUCTION

The enormous pressure on land resources currently has occurred in Indonesia. These pressures happened due to population growth, industrialization and housing, agricultural land degradation land, and growing demand of healthy or organic foods. In addition, waters getting more limited and expensive because of increasing competition with industry and domestic purposes and increasing water pollution disturbing rice production and food security (Sukristiyonubowo. 2007). Furthermore, water logging, salinization, ground water mining, deforestation and water pollution are increasing pressure water quality. Consequently, according to IWMI (2007) water used for irrigation is facing severe competition with industrial and household purposes. It has to need good water management not only to save water for avoiding push down of agriculture production, but also to have good water quality for domestic purposes like drinking water. Therefore, the great Indonesian agriculture challenge ahead is producing more rice with limited water and land (Sukristiyonubowo *et al.,* 2011).

Rice is the major food crop that can be grown in standing water. In wetland rice, varying amount of water is needed from land preparation to ripening. In general, water in agriculture can be placed in social, ecological and political contexts as the water explicitly addresses multiple use, feedbacks and dynamic interactions between production systems, livelihood support and the environment (IWMI. 2007). Rising of water productivity is cornerstone of any demands of water strategy. Water productivity can be defined as physical or economic output per unit water application or generally is defined

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as crop yield per cubic meter water consumption. It varies from region to region, from field to field depending upon crop patterns and climate factors, irrigation technology, field water management and inputs (Cai and Rosegrant. 2003). The definition of water productivity is also scale dependent; therefore, it can be measured at plant, plot, farm, watershed, regional and basin levels (Kumar *et al.* 2005). According to Molden *et al.* (2003) water productivity also depends on the reability and quality of irrigation water applied in addition to over water delivery. It is reported that among cereals, rice consume more water and inefficient in using water. It is reported that water productivity of lowland rice in India range from 0.50 to 1.10 kg m^{-3} and in Philippines between 1.40 and 1.60 kg m^{-3} (Cai and Rosegrant. 2003; Kijne *et al.,* 2003; Tuong and Bouman. 2002). Furthermore, Cai and Rosegrant (2003) reported that water productivity range from 0.15 to 0.60 kg m^{-3} and other cereals range from 0.20 to 2.40 kg m^{-3}. However, in general the water productivity in India, Philippine and Japan vary between 0.14 to 1.10 g kg $water^{-1}$ (Bhuiyan. 1992; Bhuiyan *et al.,* 1994; Bouman and Tuong. 2001; Cabangon *et al.,* 2002; Cai and Rosegrant. 2003; Tabal *et al.,* 2002; IWMI. 2004). Furthermore, Anbumozhi *et al.* (1998) observed that water productivity in Vitric Andosol (Japan) is a bit better about 1.52 g rice kg $water^{-1}$. Study in Iran found that water productivity of rice was about 0.42 kg m^{-3} (Montazar and Kosari. 2008). In addition, nutrients-use efficiencies in flooded rice are often low because of high losses, resulting in groundwater contamination and high fertiliser cost for farmers. Hence, new water management are required to increase water use efficiency in rice production (Shi *et a*l., 2002)

In order to quantify the water need on newly opened wetland rice field, pounding water depth including *macak macak* and intermittent or alternate wetting and drying were studied. The importance of this study is to save water as water is getting scarce and more expensive. We do hope in a long term perspective, the implementation of this work on water management of newly opened wetland rice would certainly contribute to improve wetland rice and save the water in Indonesia. This paper emphasized on the effect of pounding water depth on rice growth, rice yield and water productivity of newly opened wetland rice field.

MATERIAL AND METHOD

Plot scale experiment was carried out in newly opened wetland rice at Panca Agung Village, Bulungan District, East Kalimantan Province, Indonesia in 2011. The site was relatively flat and developed four years ago in 2007. The soil is acidic with low natural level of major plant nutrients including N, P and K, but having Al, Mn, and Fe in toxic levels (Sukristiyonubowo *et al.*, 2011). This soil requires more mineral and organic fertilisers to improve nutrients level (Sukristiyonubowo *et al.* 2011; Sujadi. 1984). Practically, to sustain crop production, proper management practices using more organic matter plus liming, and application of appropriate inorganic fertiliser is often proposed (Fageria and Baligar. 2001; Yan *et al.* 2007; Sukristiyonubowo *et al.* 2011; Sukristiyonubowo and Tuherkih. 2009; Sukristiyonubowo *et al.*, 1993).

Six water pounding depths were tested namely T0: pounding water depth of 0.5 cm locally called *macak macak*, T1: pounding water layer of 0-3 cm, T2: pounding water layer of 0-5 cm, T3: pounding water layer of 0-7 cm, T4: pounding water layer of 0-10 cm, T5: pounding water layer of 0-5 cm + compost, T6: pounding water layer of 0 – 5 cm + compost + dolomite and T7: two weeks watering at 0 - 5 cm followed by one a week drying (intermittent). According to the farmers, water was applied from land preparation to the beginning of ripening phase. To control the pounding water depth, every plot was placed batch and staff gate. The treatments were arranged in Randomized Complete Block Design (RCBD) and replicated three times. Each plot measured were 5m x 5m with the distance among plot 50 cm and between replication 100 cm. Urea, SP-36 and KCl were applied. Based on the direct measurement with Soil Test Kits, the recommendation rate was determined about 250 kg urea, 100 kg SP-36 and 100 kg KCl ha^{-1}. Urea and KCl were applied three times, 50% at planting time, 25 % at 21 days after planting (DAP) and the last 25 % was given at 35 DAP. SP-36 were applied two time, 50 % at planting time and 50 % at 21 DAP. Dolomite ($CaCO_3MgCO_3$) as much as two tons ha^{-1} and rice straw compost of about two tons ha^{-1} were broadcasted a week before planting.

Twenty-one day old *Ciliwung* rice variety, a national high yielding variety, was cultivated as plant indicator crop at spacing of 25 cm x 25 cm. Transplanting with three seedlings per hill was carried out in the end of June 2011 and harvesting in the beginning of October 2011. Rice biomass productions including rice grains, straw, and residues were assessed. On a hectare basis, they were extrapolated from sampling areas of 1m x 1m. These sampling units were randomly selected at every plot. Rice plants were cut about 15 cm above the ground surface. The samples were manually separated into rice grains, rice straw, and rice residues. Rice residues included the roots and the part of the stem (stubble) left after cutting. Fresh weights of rice grain, rice straw, and rice residue were weighed for each sampling unit.

The parameters measured including a) water discharge of incoming water from canal to the field or plot, b) outgoing water from field or plot were observed using the *floating Method* with stop watch (Sukristiyonubowo. 2007), c) pounding water layers were measured from surface to the defined height according to the treatments by putting a small staff gate, and d) rice growth and yield, as well as water productivity. Water productivity was predicted according to the ratio between rice grains yield and water input. Since an evapotranspi-

Table 1. Plant height of *Ciliwung* variety planted on newly opened wetland rice of Panca Agung, Bulungan Disctrict at 30, 60 DAP and harvest

Treatment	Plant Height (cm)		
	30 DAP	60 DAP	Harvest
TO : *Macak-macak* (0.5 cm)	44,20 a	51,73 a	88,83 a
T1 : Pounding Water layer of 0–3 cm	45,27 a	59,53 a	89,53 a
T2 : Pounding Water layer of 0 – 5 cm	42,30 a	53,87 a	90,63 a
T3 : Pounding Water layer of 0 – 7 cm	45,97 a	57, 53 a	91,67 a
T4 : Pounding Water layer of 0 -10 cm	42,80 a	58,30 a	88,83 a
T 5: Pounding Water layer of 0 – 5 cm + Compost	38,47 a	58,20 a	88,17 a
T6: Pounding Water layer of 0 – 5 cm + Compost + Dolomite	45,63 a	54,70 a	91,33 a
T7: Intermittent (two week wet and one dry)	44,23 a	59,13 a	89,17 a
CV (%)	11,80	7,50	8,60

Note: DAP= Day After Planting

Table 2. Tiller numbers of *Ciliwung* variety planted at newly opened wetland rice of Panca Agung, Bulungan Disctrict at 30, 60 DAP and at harvest

Treatment	Tiller number		
	30 DAP	60 DAP	Harvest
TO : *Macak-macak* (0.5 cm)	12.47 a	13.87 d	13.87 d
T1 : Pounding Water layer of 0–3 cm	14.53 a	20.13 a	21.13 a
T2 : Pounding Water layer of 0–5 cm	13.43 a	17.97 abc	17.97 bc
T3 : Pounding Water layer of 0–7 cm	13.57 a	17.30 abc	17.30 bc
T4 : Pounding Water layer of 0-10 cm	12.53 a	18.53 ab	18.53 b
T 5: Pounding Water layer of 0-5 cm + Compost	13.43 a	17.13 bc	17.14 bc
T6: Pounding Water layer of 0–5 cm + Compost + Dolomite	13.13 a	15.30 cd	15.30 cd
T7: Intermittent (two wet and one week dry)	12.80 a	17.70 abc	17.70 bc
CV (%)	15.00	9.70	8.10

Note: The mean values in the same column followed by the same letter are not statistically different
DAP= Day After Planting

ration was not taken into account, water input was computed according to the different between incoming water and outgoing water.

RESULTS AND DISCUSSION

Effect of pounding water depth on rice growth

The effects of pounding water depth on plant height and tiller number of *Ciliwung* variety are presented in Table 1

Pounding water layer did not significantly increase rice plant height at 30 day after planting (DAP), 60 DAP and at harvest (Table 2). However, the pounding water depth significantly improved tiller number at 60 DAP and at harvest. It did not have any effect on rice plant height maybe because the amount of nutrient from fertiliser and flooded was more than enough to support rice plant height. According to Ponnamperuma (1978), Tadano and Yoshida (1978), Hardjowigeno and Rayes (2005) Widowati and Sukristiyonubowo (2012) flooding improve soil quality by increasing pH, activating microbial activities, increasing P and Ca avaibility, and decreasing Eh or potential redox. Furthermore, the interactions between water depth and fertiliser enhanced the tiller number. According to Zen *et al.* (2002) at 0 cm water depth has a lower effective tillers and panicle per plant and significant increase with water depth up to 6 cm.

Rice grains yield was significantly improved by the pounding water layers (Table 3). Depending on the pounding water depth, the rice grains yields varied from 3.37 to 4.47 tons ha^{-1} with the enhancement were about 0.47 to 1.10 ton ha^{-1}. The highest rice grains yield of 4.47 tons ha^{-1} was indicated by the pounding water depth of 0-3 cm (T1). Compared to the pounding water of 0.5 cm or *macak macak*, the T1 (the pounding water depth of 0-3 cm) increased about 1.10 tons ha^{-1} or 33 %. This probably was due to increasing tiller numbers and the number of spikelet as weel as weigh of 1.000 filled rice grain (data not presented). Further these findings prov

Table 3. Rice grains production of *Ciliwung* variety planted at newly opened wetland rice with different pounding water layer at Panca Agung, Bulungan District

Treatment	Rice grains ($t\ ha^{-1}$)	Yield improvement ($t\ ha^{-1}$)	Yield improvement (%)
TO : *Macak-macak* (0.5 cm)	3.37 d	-	-
T1 : Pounding Water layer of 0–3 cm	4.47 a	1.10	33
T2 : Pounding Water layer of 0–5 cm	4.00 bc	0.63	19
T3 : Pounding Water layer of 0–7 cm	4.01 bc	0.68	20
T4 : Pounding Water layer of 0-10 cm	3.94 bc	0.57	17
T 5: Pounding Water layer of 0–5 cm + Compost	4.07 bc	0.70	21
T6: Pounding Water layer of 0–5 cm + compost + Dolomite	4.20 ab	0.83	25
T7: Intermittent (two week wet and one dry)	3.74 c	0.47	14
CV (%)	5.20		

Note: The mean values in the same column followed by the same letter are not statistically different

Table 4. Water input, rice grains and water productivity of *Ciliwung* variety planted at newly opened wetland rice with different pounding water layer at Panca Agung, Bulungan District.

Treatment	Water input ($l\ season^{-1}$)	Rice Grains ($t\ ha^{-1}$)	Water Productivity ($gr\ liter^{-1}$)
T0: Macak-macak (0.5 cm)	35×10^5	3.37 d	0.96
T1: Pounding water layer of 0 – 3 cm	15×10^6	4.47 a	0.30
T2: Pounding water layer of 0 – 5 cm	25×10^6	4.00 bc	0.16
T3: Pounding water layer of 0 – 7 cm	35×10^6	4.01 bc	0.12
T4: Pounding water layer of 0 – 10 cm	50×10^6	3.94 bc	0.08
T5: Pounding water layer of 0 -5 cm + compost	25×10^6	4.07 bc	0.16
T6: Pounding Water layer of 0–5 cm + compost + Dolomite	25×10^6	4.20 ab	0.17
T7: Intermitent (two week wet and one week dry)	18×10^6	3.74 c	0.21
CV (%)		5.20	

that pounding water depth of rice cultivation can be arranged depending on available irrigation water. In these case the weeding should be concerned specially on water depth below 0 -5 cm.

The calculation of water input during rice growth and development, started from land preparation to the beginning of ripening stage indicated that about 35×10^5 to 50×10^6 litter irrigation water was added to the field (Table 4). From Table 4, it was shown that water needed for growing rice depending on the water pounding depth as well as the way of cultural practices. The more water depth the higher the water requirement of the crop. At the pounding water layer of 0.5 cm (*macak macak*), the irrigation water was the lowest, about 35×10^5 litter, and it reduced about 115 to 465 x 10^5 l $sesaon^{-1}$ compared to the other treatments (Table 4). On the other hand, conventional rice cultivation with pounding water layer 0-10 cm consumed highest amount of water (50×10^6 l $season^{-1}$) followed by pounding water layer 0-7 cm (35×10^6 l $season^{-1}$). Meanwhile, maximum water saving was recorded with pounding water depth 0.5 cm locally named *macak macak* followed by pounding water layer 0-3 cm. The highest grains yield, about 4.47 t ha^{-1}, was observed at the water pounding layer of 0-3 cm (T1). This may be attributed probably to a significant difference tiller number and number of filled spikelet as well as weight of 1.000 filled grains (data not presented)

In addition, addition of lime and compost from straw with pounding water of 0-5 cm indicated promising rice yield although the water productivity remained low. However, it was good to be researched for future on water management in newly opened wetland rice field to save water.

Water productivity of newly opened wetland rice field ranged between 0.08 and 0.96 g litre^{-1} depending on the water depth (Table 4). At the pounding water depth of 0.5 cm and 0-3 cm, the water productivity were 0.96 and 0.30 g litre $^{-1}$ and will be the options to be demonstrated to save the water. The results were similar to rice producing countries (Bhuiyan, 1992; Bhuiyan *et al.,* 1994; Bouman and Tuong, 2001; Cabangon *et al.,* 2002; Cai and Rosegrant. 2003; Taball *et al.,* 2002; IWMI, 2004). With respect to water productivity, cultivation of rice with pounding water depth 0.5 cm or *macak macak* registered the higher water productivity of about 0.96 gram liter^{-1} followed by rice cultivation with pounding water layer 0-3 cm (0.30 g litre $^{-1}$).

CONCLUSION

Study on rice growth and water productivity in newly opened wetland rice indicated that water pounding layer affected the tiller number, rice grain and water productivity. At the water depth of 0-3 cm, rice tiller number and grains were increased and the highest. The water productivity at the pounding depth of 0.5, 0 – 3 cm and 0-5 cm + compost + dolomite indicated the best option to be demonstrated on wider scale. In long term the irrigation water can be managed properly to save water and of course high rice yield in wetland rice.

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REFFERENCE

Anbumozhi V, Yamaji E, Tabuchi T (1998). Rice crop growth and yield as influenced by changes in pounding water depth, water regime and fertigation level. Agricultural Water Management. 37: 241-253

Bhagat RM, Bhuiyan SI, Moody K (1996). Water, tillage and weed interactions in lowland tropical rice: a review. Agricultural Water Management. 31: 165-184

Bhuiyan SI, Sattar MA, Tabbal, DF (1994). Wet seeded rice: water use efficiency, productivity and constraints to wider adoption. Paper presented at the International Workshop on constrains, opportunities, and innovations for wet seeded rice, Bangkok, May 31 – June 3, 1994, 19 pp.

Bhuiyan SI (1992). Water management in relation to crop production: case study on rice. Outlook Agriculture. 21: 293-299

Bouman BAM, Peng S, Castaneda AR, Visperas RM (2005). Yield and water use of irrigated tropical aerobic rice systems. Agricultural Water Management. 74: 87-105

Bouman BAM, Tuong TP (2001). Field water management to save water and increase its productivity in irrigated lowland rice. Agricultural Water Management. 49: 11-30

Cabangon RJ, Tuong TP, Abdullah NB (2002). Comparing water input and water productivity of transplanted and direct-seeded rice production systems. Agricultural Water Management. 57: 11-31

Cai X, Rosegrant MW (2003). World water productivity: Current situation and future options.In: Water Productivity in Agriculture: Limit and opotunities for improvement eds: J.W. Kijne, R. Baker and D Molden. CAB International. 1-16 p.

Fageri NK, CV Balligar (2001). Improving nutrient use efficiency of annual crops in Brazilian acid soils for sustainable crop production. Communication Soil Science Plan Analysis. 32 (7 and 8): 1301 - 1319

Hardjowigeno S, Rayes L (2005). Tanah Sawah. Bayumedia Publishing. 205 p.

IWMI (International Water Management Institute). 2004. Water facts. IWMI Brochure.

IWMI (International Water Management Institute) 2007. Comprohensif assessment water management in agriculturre. London: eartfscan and Colombo, IWMI 48 p.

Kijne JW, Barker R, Molden D (2003). Water productivity in agriculture: limit and opprtonity for improvement. CABI Publishing, Wallingford.

Molden David, Hammond Murray-Rust, R Sakthivadivel, Ian Makin (2003). A water productivity for understanding and action. In: Jakob Kijne et al (Editor). Water productivity in agriculture: Limit and opportunitis for improvement. Comprehensive assessment of water productivity. CABI Pubhlishing in assosiation with Internation Water Management insitute

Montazar A, Kosari H (2008). Water productivity analisis of some irrigated crops in Iran. 109-120

Ponnamperuma FN (1978). Electrochemical changes in submerged soil and the growth of rice. IRRI. Los Banos, Philippines.

Shi Qinghua, Zeng X, Li M, Tan X, Xu F (2002). Effect of different water management practices on rice growth. In: Bouman, BAS, Hengsdijk, H., Hardy, B., Bindraban, PS., Tuong, TP., Ladha, JK. (Editors). Water-wise rice production. IRRI and Plant Research International. p: 3-13

Sujadi M (1994). Masalah kesuburan tanah Podsolik Merah Kuning dan Kemungkinan pemecahannya. *Dalam* Prosiding Penelitian Pola Usahatani Menunjang Transmigrasi. badan Litbang Pertanian, Jakarta. Hal: 3 – 10 (in Indonesia)

Sukristiyonubowo, Mulyadi, P Wigena, A Kasno (1993). Effect of organic matter, lime and NPK fertilizer added on soil properties and yield og peanut. Journal of Indonesian Soil and Fertilizer. 11: 1 – 7 (in Indonesia)

Sukristiyonubowo, Tuherkih E (2009). Rice production in terraced paddy field systems. Jurnal Penelitian Pertanian Tanaman Pangan. 28(3): 139-147

Sukristiyonubowo (2007). Nutrient balances in terraced paddy fields under traditional irrigation in Indonesia. PhD thesis. Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium. 184 p.

Sukristiyonubowo, Ibrahim AS, T Vadari, Agus S (2011). Management of inherent soil fertility of newly opened wetland rice field for sustainable rice farming. Ournal of Plant Breeding aand Crop Science, 3 (8): 146 - 153

Taball DF, Bouman BAM, Bhuiyan SI, Sibayan EB, Sattar MA (2002). On-farm strategies for reducing water input in irrigated rice; case study in the Philippines. Agricultural Water Management. 56: 93-112

Tadano T, S Yoshida (1978). Chemical changes in submerged soils and their on rice growth. The International Rice Research Institute.

Widowati LR, Sukristiyonubowo (2012). Dynamics1 of pH, ferrum and mangan, and phosphorus on newly opened paddy soil having soil organic matter on rice growth. Joournal of Tropica Soils. 17 (1): 1-8

Yan D, D Wang, L Yang (2007). Long term effect chemical fertiliser, straw and manure on labile organic matter in a paddy soil. Biol. Fertil. Soil Journal. 44:93-101

Zen LTH, Seneratne R, Michael Z, Mainul H, Meskountavon (2002). Effect of depth water and duration of inudation on rice – weed competitation and grain yield of rice in the central plain of Thailang. Deutcher Tropentag, October 9 – 12, Wiszenhausen.