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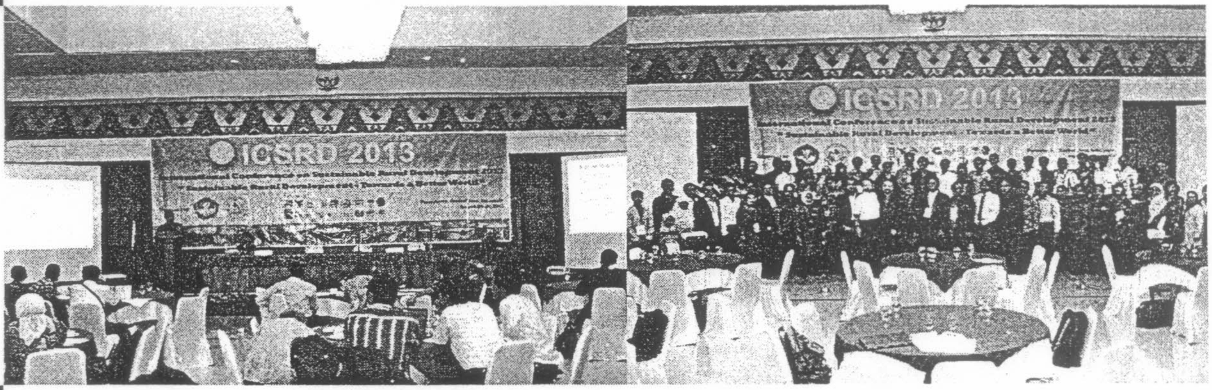

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1st TOPIC
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ENHANCED WATER USE EFFICIENCY FOR IRRIGATED RICE IN INDONESIA WITH SYSTEM OF RICE INTENSIFICATION (SRI)

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ABSTRACT

Conventional rice cultivation with continuous flooding irrigation that commonly used in rice production characterized by insufficient water use because the quantity of irrigation water is usually supplied to the field is greater than plant water requirement. The current study was performed to evaluate System of Rice Intensification (SRI) practice in raising water use efficiency for sustainable rice production in Indonesia particularly in the rainy season. Achieving this goal, a field experiment was conducted in Karang Sari Village, Bekasi, West Java, Indonesia during the first rice season 2007/2008 (December 2007 to April 2008) in the rainy season. Here, two cultivation practices with different regimes were compared i.e., SRI regime and Conventional Practice (CP) regime. As the results, it was clearly observed that SRI regime raised water use efficiency index up to 37.6% by saving water input up to 26.07% compared to CP regime. The SRI regime also reduced excess water through percolation and runoff significantly. The SRI regime also resulted in better yield and crop performance compared to continuous flooding irrigation even if not significant. The main reason is that under SRI with intermittent irrigation, aerobic condition was created. This condition promoted higher activity of the plants for the establishment of a larger and deeper root as reported previous studies. Therefore, the results suggested that SRI is suitable way to raise water use efficiency without decreasing yield for irrigated rice in Indonesia.

Keywords: water management, water use efficiency, paddy fields, system of rice intensification

INTRODUCTION

Rice (*Oryza sativa* L.) has become the most important staple food in Indonesia, and it covers the largest agricultural area. The total harvested area and rice production in 2011 were 13.2 million ha and 65.8 million tons, respectively [1]. Recently, the challenges related to improving rice productivity in Indonesia have been increasing due to the increased population and reduced arable area. In addition, climate change issues have been affecting paddy irrigation water requirements during the rainy and dry seasons [2].

Commonly in Indonesia, rice is cultivated under continuous flooding irrigation by maintaining the depth of water between 2 and 5 cm to control weeds, reduce the frequency of irrigation, and secure against possible future shortage of water due to the unreliable water delivery system. Consequently, agriculture is the largest consumer of fresh water especially for irrigation. The data in 2010 showed that water used for irrigation was 89% following by fisheries (7%), domestic and industrial (4%) and livestock (0.2%) [3]. Continuous flooding irrigation is less efficient because the quantity of irrigation water is usually greater than actual water requirement. This weakens water saving effects, causing large amounts of surface runoff, seepage and percolation [4]. Hence, an alternative rice production with less water input is needed to ensure a sufficient food supply.

From previous findings, rice is highly possible to be produced by water saving regimes under system of rice intensification (SRI) in which continuous flooding irrigation is no longer essential to gain high yields and biomass production [5, 6, 7]. SRI is well-known as a set of crop management practices for raising the productivity of rice by changing the management of plants, soil, water, and nutrients. Although some critics were dismissed to SRI [8, 9, 10], its benefits have been validated in 42 countries of Asia, Africa and Latin America [11]. In SRI paddy fields, intermittent irrigation is applied in which the field is allowed to dry during particular time instead of keeping them continuously flooding, a practice called alternate wetting and drying irrigation [12].

Many researchers have been conducted to verify this system. As the results, it was clearly observed that this system can increase water use efficiency significantly by saved water input as provided data for different countries, e.g., in Japan [13], 38.5% in Iraq [14], 43.9% in China [7]. The results revealed that the increasing water use efficiency by SRI varied among different countries. This was due to different climate, rice variety and soil type among the countries.

However, only few information have been reported on enhancing water use efficiency under SRI compared to conventional practice in Indonesia, e.g. Sato et. al [6] in eastern Indonesia. The aim of the current study is to investigate enhancing water use efficiency by SRI practice in western Indonesia particularly in the rainy season.

METHODOLOGY

Field Location and Rice Cultivation

This study was conducted in the paddy fields in Karang Sari village, district of Cikarang Timur, Bekasi, West Java, Indonesia during the first rice season 2007/2008 (December 2007 to April 2008) in the rainy season. The soil was alluvial and had a heavy clay texture with a soil pH of 5.8 and a low organic matter content (1.7%). Here, we prepared six plots and each plot was a 9.6 m x 18 m rectangular shape. All plots were planted with the local variety of rice (*Oryza sativa* L), *Sintanur*, a hybrid rice variety.

Three plots were planted by SRI practice consisting some elements such as single planting of young seedling (10 days after seedling) spaced at 30 x 30 cm, using an organic fertilizer at 7 tons/ha and no chemical fertilizer. Moreover, indigenous microorganisms grown in a bamboo sprout and fruits mixture were supplied to the field 10, 20, 30, 40 and 50 days after transplanting (DAT). The indigenous microorganisms enhance the biological activity of the soil [15]. Meanwhile, others plots were planted by conventional practice with some elements such as old seedling (30 days after seedling), spaced at 20 x 20 cm, using chemical fertilizer based on guideline of agricultural department officer.

Plant growth was observed and recorded every ten days, starting from 15 DAT. For each plot, we measured plant height and number of tillers/hill to assess effects of cultivation practices on plant performances.

Irrigation Regimes

The detail irrigation regimes, SRI and Conventional practice (CP) were illustrated in Figure1. Here, the experimental design was a single factorial design with three replications. Data were analyzed by one-way analysis of variance (ANOVA) hypothesizing irrigation regime to be the significant source of variation.

For the SRI regime, the soil was kept moist but with no standing water during vegetative stage, i.e., stage I (initial) and stage II (crop development stages), then shallow standing water ranging in depth from −5 to 2 cm was applied during reproductive stage (stage III) and finally water was drained to maintain saturated soil until harvesting day (stage IV). Meanwhile, for CP regime, the field was maintained by ponding water with the interval 2-5 cm water depth during planting period except stage I, then in the stage IV, water was drained to maintain saturated soil until harvesting day.

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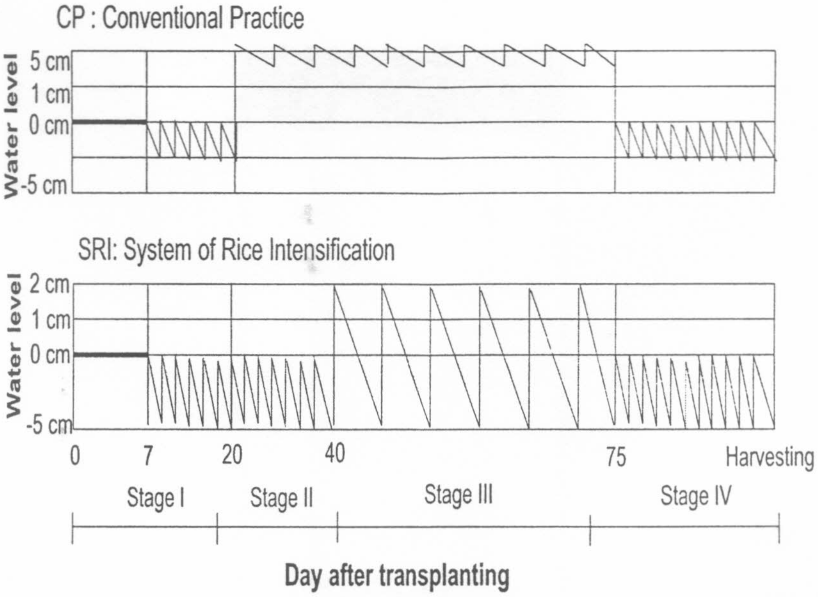

Figure 1. Irrigation regimes in this study

Water Balance and Water Use Efficiency in the Field

Water balance analysis was performed to determine the water supply and water use within the crop season in daily basis based on the following equation:

$$\frac{dS}{dt} + WL = P(t) + I(t) + Gw(t) - Qr(t) - DP(t) - ETc(t) \qquad (1)$$

where $\frac{dS}{dt}$ is the change in water depth (mm), WL is water level measured from soil surface (mm), P is precipitation (mm), I is irrigation water (mm), Gw is groundwater (mm), Qr is runoff (mm), DP is deep percolation (mm) and ETc is crop evapotranspiration (mm). Here, Gw, water that comes from the ground, was assumed to be zero due to the negligible rate.

Here, precipitation (P) was measured by a rain gauge and water level (WL) was measured by a piezometer. Meanwhile, runoff was defined as excess water from precipitation that was removed from the field artificially to maintain desired water levels during the planting period and its rate was measured by a water meter. Then, the change in water depth was calculated based on a soil retention curve by using Genuchten model [16].

To calculate and estimate the other parameters, such as percolation, crop evapotranspiration, and irrigation water, Microsoft Excel's Solver was used as described by Abdel-Fattah et al. [17] and the guide to use it could be referred to Morrison [18]. In this study, we tried to find the combination of the parameters to minimize the following error:

$$\text{Error for the period} = \Sigma\left|S_o - S_m\right| \qquad (2)$$

where, S_o is daily-observed soil water storage (water depth mm), S_m is model based soil water storage (mm) estimated by the Excel Solver estimation.

Water use efficiency index is defined as a measure of crop yield (dry matter) per unit water supplied, by following equation [12]:

$$\text{WUE (kg/ha/mm)} = \frac{\text{Yield(kg/ha)}}{\sum \text{Irrigationwater(mm)}} \qquad (3)$$

Furthermore, we calculated water productivity (WP) to look up another water-rice production relationship. In paddy fields, WP is calculated using the following equation [12]:

$$\text{WP (kg/ha/mm)} = \frac{\text{Yield (kg/ha)}}{\text{ETc (mm)}} \qquad (4)$$

where, ETc is crop evapotranspiration (mm) derived from water balance analysis previously.

RESULTS AND DISCUSSION

Plant Growth and Yield

Plant performance between two cultivation practices are shown in Figure 2. In the SRI practice, with the same physiological age, the plant height was higher than that in the conventional practice. This is probably due to the plant had greater growth potential of root and shoot by the application of young seedling and wider spacing [11]. Moreover, SRI promotes increased plant activity in roots and shoots due to optimal water and oxygen availability under mostly aerobic soil conditions [19]. However, in the last growth stage, both the plant heights were comparable with the maximum plant height of 136 cm for both practices.

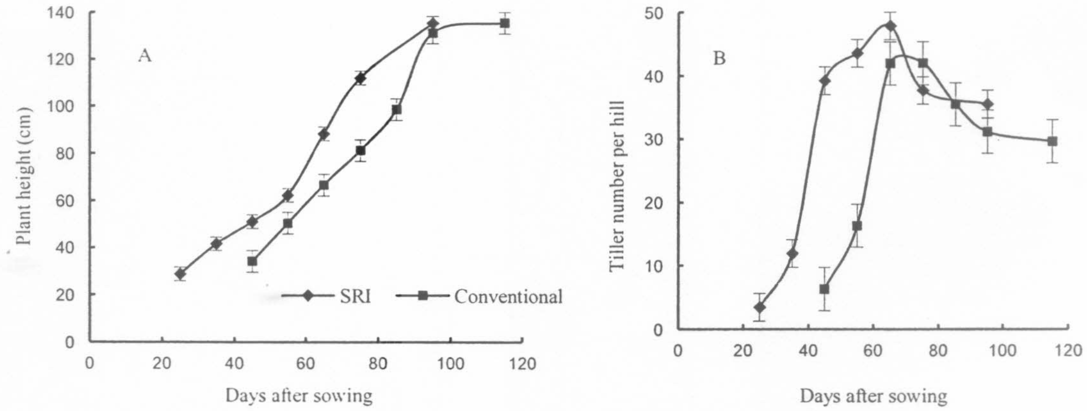

Figure 2. Comparing plant growth between SRI practice and conventional practice: (A) plant height, (B) tiller number per hill

The same trend was seen for the tiller number per hill. The tiller number in the SRI was higher than that in the conventional particularly in the initial, crop development and late stages. It showed that under SRI with wider spacing, the ability of rice tillering could be enhanced to some extent when the plant had a wider space to grow. Rice tillering could also be enhanced by application of straw mulching under non-flooded irrigation as reported by the previous study [20]. Overall, in both practices, rice tiller number gradually increased and reached a peak at about 65 days after sowing (Figure 2B). The maximum tiller number per hill was 48 and 42 for the SRI and conventional practices, respectively.

Water availability in the field

Both cultivation practices were irrigated to maintain the water level at the interval level during the crop season, as described previously (Figure 1). However, measurement of the actual water level was quite different from that of the desired water level, as affected by high precipitation in the rainy season as shown in Figure 3 and Figure 4. This occurred when the restarting of irrigation time was determined visually and the natural environment was unpredictable, particularly in terms of precipitation. Even if it was kept saturated for 7 to 20 days after transplanting (DAT), the actual water level dropped below the soil surface, particularly within 12 to 17 DAT due to the high evaporation that occurred on some days. Furthermore, the actual water level increased dramatically on 20 DAT and reached approximately 10 cm above the soil surface in both regimes. This was caused by a high amount of precipitation (136 mm) over three days.

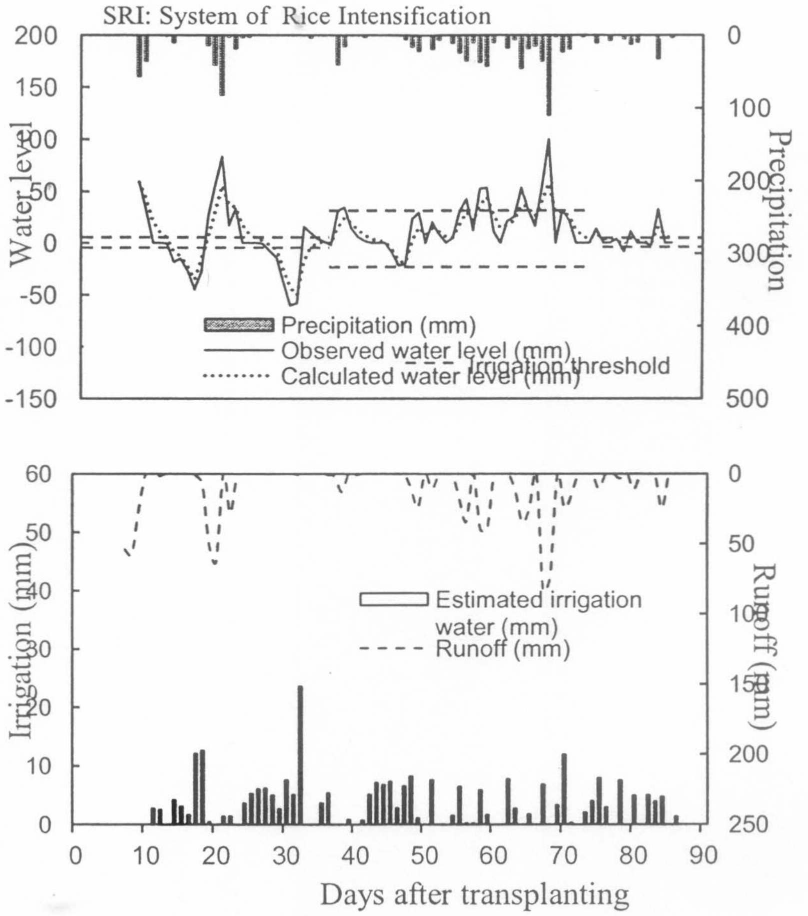

Figure 3. Water availability of SRI in the field

Within the period of 20 to 40 DAT, water stresses were likely to exist for both water management regimes, as illustrated by the lowest water level in Figure 2 and Figure 3. At that time, the water level reached 5.8 cm below the soil surface and 0.8 cm above the soil surface for the SRI and the CP practices, respectively. This condition occurred when precipitation was limited within this periods and minimum irrigation was supplied to the field.

Table 1. Water balance components between the practices

Water balance components	SRI	CP
Inflow:		
Precipitation (mm)	920±0a	920±0a
Irrigation water (mm)	289±32a	390±11b
Total Inflow (mm)	1209±32	1310±11
Outflow:		
Crop evapotranspiration (mm)	292±6a	290±5a
Runoff (mm)	808±34a	876±11b
Percolation (mm)	108±10a	143±1b
Total Outflow (mm)	1208±50	1309±17
Error between inflow and outflow (%)	1.61%	0.54%

the values showed the average ± standard deviation a, b significant at p<0.05

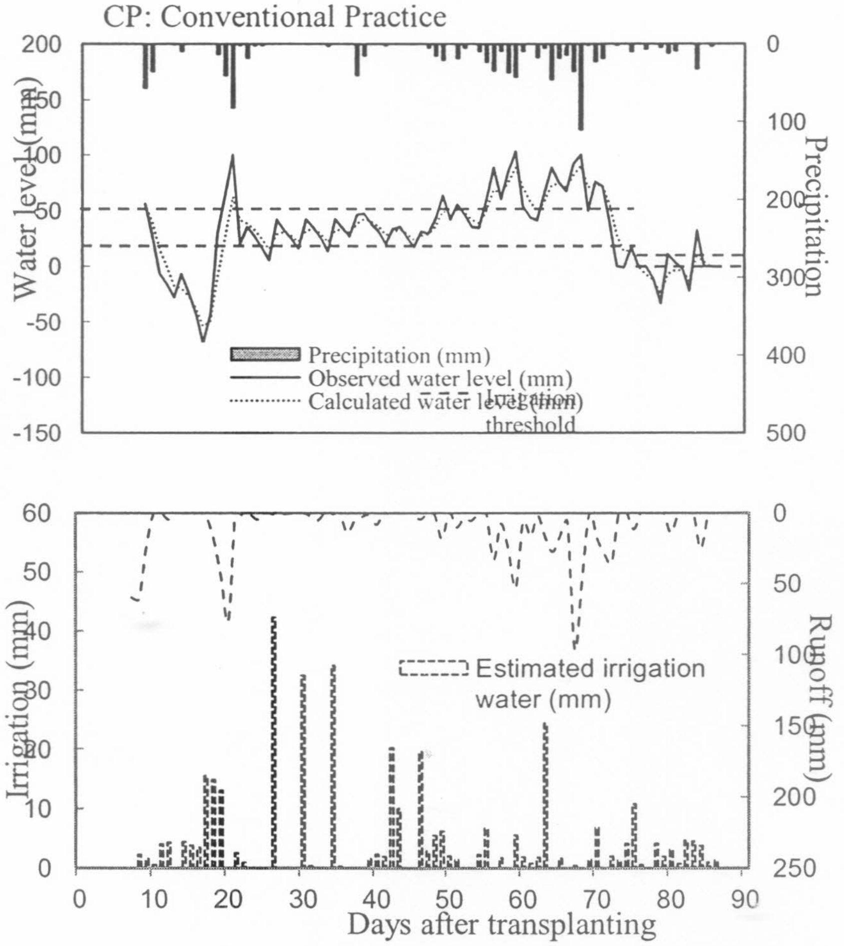

Figure 4. Water availability of conventional practice in the field

The Excel Solver estimation was able to estimate all of the non-measurable variables with high accuracy shown as low cumulative error values of 1.61% and 0.54% for the SRI and the CP, respectively (Table 1). The higher water input in the CP regime did not result in higher water consumption represented by crop evapotranspiration. Instead, this regime significantly increased the water loss through percolation by up to 24% (Table 1). Thus, the SRI regime can be considered as an alternative way to reduce percolation during the crop growth period, as also investigated in a previous study [21]. The percolation rate depends on the physical soil condition and it rate increases when the depth of water standing in the field increases [22, 23, 24]. The increasing standing water in the field will increase hydrostatic pressure, thus this situation stimulate downward movement of excess water in the soil to be percolation. Consequently, the CP regime with ponding water 2-5 cm in the field contributed to higher percolation rate compared to the SRI regime. Moreover, the CP regime also contributed to higher runoff significantly compared to the SRI regime (Table 1). These results suggested that the application of continuous flooding irrigation for irrigated rice was insufficient in water use because more excess water occurred through percolation and runoff.

Water Use Efficiency
Table 2 presents the water use efficiency index, water saving, and productivity in both irrigation regimes. It was clearly observed that the SRI can save a substantial amount of water, so the water use efficiency index can be increased significantly up to 37.6%. The higher value of the index was due to the minimum irrigation water in the SRI with comparable amounts of water consumption in both regimes (Table 2). Also, the excess water through percolation and runoff can be minimized by the application of the SRI. The increasing of water use efficiency index also was affected by high precipitation in the rainy season. Therefore, minimum irrigation water was needed especially for the SRI. However, for the dry season with different pattern of precipitation and weather conditions, the increasing of water use efficiency index for SRI is probably different with the current values.

In addition, the current study revealed that water productivity for both regimes was not significantly different (Table 2). The comparable values of water productivity were caused by the comparable crop evapotranspiration and yield between the SRI and the CP regimes (Table 2). The comparable yield was obtained from the similar plant performances between the regimes, as shown in Figure 2, which reveals no significant differences in plant height and number of tillers/hills during the crop season. The similar result was also reported by the previous study [25]. They reported that during two rice seasons in China (1999 and 2000), there was no significant difference in yield between continuous flooding and intermittent irrigations.

As early mention, SRI resulted in better yield and plant performances compared to conventional practice even if not significant. The main reason is that under SRI, aerobic condition was created. This condition promoted higher activity of the plants for the establishment of a larger and deeper root system [15]. Also, this condition enhanced shoot activities when optimal water and oxygen available under intermittent irrigation [19]. These results suggested that SRI is suitable way to increase water use efficiency without decreasing yield at the same time.

CONCLUSIONS

The main findings of this study were that SRI enhanced water use efficiency index significantly by up 37.6% in the rainy season. Also, this regime can save water input up to 26.07% compared to conventional practice (CP). The SRI regime reduced excess water through percolation and runoff significantly. The SRI regime also resulted in better yield and crop performance compared to CP regime even if not significant. The main reason is that under intermittent irrigation, aerobic condition was created. This condition promoted higher activity of the plants for the establishment of a larger and deeper root reported previous studies. Therefore, the results suggested that intermittent irrigation is suitable way to raise water use efficiency without decreasing yield for irrigated rice in Indonesia particularly in the rainy season. More experiments particularly in the dry season will be meaningful to examine water use efficiency index under SRI regime with different pattern of precipitation and weather conditions.

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REFERENCES

[1] Statistics Indonesia. "Production, Harvested area, Productivity of Rice and Crops in Indonesia", 2011. Accessed from http://www.deptan.go.id/Indikator/tabel-1-prod-lspn-prodvitas-padi-palawija.pdf. 4 April 2013

[2] De Silva CS, E K Weatherhead, J W Knox, J A Rodriguez-Diaz. Predicting the impacts of climate change—A case study of paddy irrigation water requirements in Sri Lanka. *Agric Water Manag 93* pp.19-29., 2007, doi:10.1016/j.agwat.2007.06.003

[3] Radhika, S. Amirwandi, Ratna Hidayat, Muhammad Fauzi, Waluyo Hatmoko. Kebutuhan air di Indonesia. Kolokium Hasil Litbang Sumber Daya Air 2012. Bandung 2 May 2012

[4] Bouman B.A.M. Water-efficient management strategies in rice production. *International Rice Research Note 26* (2) pp. 17-22, 2001

[5] Zhao LM, Wu LH, Wu MY, Li YS. Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with reduced irrigation. Paddy Water Environ 9 (1) pp. 25-32. 2011, doi:10.1007/s10333-011-0257-3

[6] Sato S, Yamaji E, Kuroda T. Strategies and engineering adaptions to disseminate SRI methods in large-scale irrigation systems in Eastern Indonesia. Paddy Water Environ 9 (1) pp. 79-88. 2011, doi:10.1007/s10333-010-0242-2

[7] Lin XQ, Zhu DF, Lin XJ. Effects of water management and organic fertilization with SRI crop practices on hybrid rice performance and rhizosphere dynamics. Paddy Water Environ 9 (1) pp. 33-39. 2011, doi:10.1007/s10333-010-0238-y

[8] Sinclair TR, Cassman KG. Agronomic UFOs. Field Crop Res 88 (1) pp. 9-10. 2004. doi:10.1016/j.fcr.2004.01.001

[9] Sheehy JE, Peng S, Dobermann A, Mitchell PL, Ferrer A, Yang JC, Zou YB, Zhong XH, Huang JL. Fantastic yields in the system of rice intensification: fact or fallacy? Field Crop Res 88 (1) pp. 1-8. 2004. doi:10.1016/j.fcr.2003.12.006

[10] Dobermann A. A critical assessment of the system of rice intensification (SRI). Agr Syst 79 (3) pp. 261-281. 2004. doi:10.1016/S0308-521x(03)00087-8

[11] Uphoff N, Kassam A, Harwood R. SRI as a methodology for raising crop and water productivity: productive adaptations in rice agronomy and irrigation water management. Paddy Water Environ 9 pp. 3-11. 2011. doi:10.1007/s10333-010-0224-4

[12] Van der Hoek W, Sakthivadivel R, Renshaw M, Silver JB, Birley MH, Konradsen F. Alternate wet/dry irrigation in rice cultivation: a pratical way to save water and control malaria and Japanese encephalitis? Research Report 47. International Water Management Institute, Colombo, Sri Lanka, 2001.

[13] Chapagain T, E Yamaji. The effects of irrigation method, age of seedling and spacing on crop performance, productivity and water-wise rice production in Japan. *Paddy Water Environ 8 pp.*81-90. 2010, doi:10.1007/s10333-009-0187-5

[14] Hameed KA, Mosa AKJ, Jaber FA. Irrigation water reduction using System of Rice Intensification compared with conventional cultivation methods in Iraq. *Paddy Water Environ 9* (1) pp. 121-127. 2011, doi:10.1007/s10333-010-0243-1

[15] Uphoff N, and Kassam, A. Case study: The system of rice intensification. *Cornell International Institute of Food Agriculture and Development (CIIFAD)* NY 14853, USA. 2008

[16] Van Genuchten MT. A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. *Soil Sci Soc Am J 44* pp. 892-898, 1980

[17] Abdel-Fattah YR, El-Enshasy HA, Soliman NA, El-Gendi H. Bioprocess Development for Production of Alkaline Protease by Bacillus pseudofirmus Mn6 Through Statistical Experimental Designs. *J Microbiol Biotechn 19* (4) pp. 378-386. 2009. doi:10.4014/jmb.0806.380

[18] Morrison FA. Using the Solver add-in in Microsoft Excel®. Michigan Technological University Web. http://www.chem.mtu.edu/~fmorriso/cm4650/Using_Solver_in_Excel.doc. 2005

[19] Yang JC, Zhang JH. Crop management techniques to enhance harvest index in rice. J Exp Bot 61 (12) pp. 3177-3189. 2010, doi:10.1093/jxb/erq112

[20] Wang D, Li H. X, Qin J. T, Li D. M, Hu F. Growth characteristics and yield of late-season rice under no-tillage and non-flooded cultivation with straw mulching. Rice Science, 17(2) pp. 141-148. 2010

[21] Mao Zhi. Environmental impact of water-saving irrigation for rice. In Irrigation scheduling: From theory to practice. *Proceedings of the ICID/FAO Workshop on Irrigation Scheduling*, Rome, Italy, 12-13 September 1995. Rome: FAO. 1996.

[22] Tuong TP, Bhuiyan SI. Increasing water-use efficiency in rice production: farm-level perspectives. *Agr Water Manage 40* (1) pp. 117-122, 1999.

[23] Guerra LC, Bhuiyan SI, Tuong TP, Barker R. Production more rice with less water from irrigated systems. SWIM Paper 5. *International Water Management Institute*, Colombo, Srilanka, 1998.

[24] Kalita PK, Kanwar RS, Rahman MA. Modeling Percolation Losses from a Ponded Field under Variable Water-Table Conditions. *Water Resour Bull 28* (6) pp. 1023-1036. 1992, doi:10.1111/j.1752-1688.1992.tb04014.x

[25] Belder P, Bouman B A M, Spiertz J H J, Peng S, Castaneda A R, Visperas R M. Crop performance, nitrogen and water use in flooded and aerobic rice. *Plant Soil 273* pp.167–182. 2005. doi:10.1007/s11104-004-7401-4