COMPARISON OF YIELDS ATTRIBUTES AND WATER PRODUCTIVITY UNDER THE SYSTEM OF RICE INTENSIFICATION (SRI) IN SOUTHERN TAIWAN

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ABSTRACT

Rice (Oryza sativa L.) is the staple food for more than half the world population. With the world population continuously growing, rice production is compelled to grow as well. Unfortunately, due to water scarcity driven by climate change continuous flooding is no longer a reliable option for sustainable water management to meet the food needs of our growing population while at the same time mitigating water scarcity. The System of Rice Intensification with its efficient management of production inputs, especially water, seems to be a possible solution to meet the growing food demand. From December 2017 to April 2018 a field experiment was conducted at the National Pingtung University of Science and Technology (NPUST) to compare water use efficiency and rice yields from the System of Rice Intensification (SRI). The experiment involved using the following four (4) water depths: 2cm water depth (SRI2); 3cm water depth (SRI3); 4cm water depth (SRI4); and 5 cm (SRI5) under intermittent irrigation based on visual observations by estimating soil hairline cracks. The yields of these four water depths were compared to the control plot irrigated at 3cm every week (SRI3/week).

The results of this study revealed that yield attributes like number of spikelets per meter square and percentage of filled spikelets were determinant for the grain yield. SRI3 yielded better with 4,072kg/ha compared to SRI2 (3,448kg/ha), SRI4 (3,081kg/ha and SRI5 (2,604kg/ha). The highest water productivity was recorded in SRI3 at soil hairline cracks (0.19kg/m^3) whereas SRI2 obtained 0.18kg/m^3.

Keywords: System of Rice Intensification (SRI), Yield, Water Productivity, soil hairline cracks

1. INTRODUCTION

The worldwide future demand in rice meets serious difficulties which are: the declining of land and its fertility, the water and labor scarcity and the very high cost of inputs that make rice production expensive. Nowadays, the challenge to be taken is to reduce rice production costs, making it much more profitable to farmers and finding the best way to produce more while mitigating water scarcity. The System of Rice Intensification (SRI), due to its capacity to improve land productivity, labor cost and capital as well as water consumption (Bouman et al., 2002), came as a sustainable solution to this situation.

Since its development in Madagascar more than 25 years ago, SRI system has been considered as an opportunity to improve food security by increasing rice productivity and changing the management of plants, soil, water and nutrients as it reduces the amount of inputs like fertilizers and herbicides (Berkelaar, 2001; Thakur et al., 2009; Uphoff, 2003; Vermeule, 2009) in (Ndiiri, Mati, Home, Odongo, & Uphoff, 2013). SRI

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isa combination of management practices including the use of organic manure, reduction of age and planting density, avoiding anaerobic condition during vegetative phase etc., which helps in maintaining the system´s productivity as well as its sustainability (Choudhury et al., 2007). According to its supporters, it increases small-scale farmers' rice yields while using substantially less water and seed (Berkhout, Glover, & Kuyvenhoven, 2015) Many studies carried out since its implementation in Madagascar ((Stoop, Uphoff, & Kassam, 2002); (Nyamai et al., 2012); Ndiiri et al., 2013; Berkhout, Glover, & Kuyvenhoven, 2015)) confirmed the large yields increase and high water productivity of SRI compared to ''conventional'' or ''traditional'' practices, with yield increases between 50%–100% and water use reduction of 25% to 50% or more in some cases. Over more than two decades of research, most of the studies have emphasized on comparing SRI system using AWD and conventional practices in rice production. The use of AWD revealed that water can be saved up to 22.6% (Kassam & Brammer, 2013), 27 and 37% (Bouman et al., 2002), 29% (Chapagain, Riseman, & Yamaji, 2011), between 39 and 47 % (Fonteh, Tabi, Wariba, & Zie, 2013) compared to continuous flooding. However, no clear investigation has been done on an efficient management of water leading to optimum yield. Authors like (Styger, 2012), suggested that irrigation should be done adding a thin layer of water (2 cm) to the paddy, letting the ponded water to disappear over a few days until the soil slightly cracks, after which another thin layer of water is added. The (Uphoff & Randriamiharisoa, 2002), (Uphoff, 2014) standards on water management in SRI is to apply minimum amounts of water to the crop during the vegetative growth phase, and then maintain a shallow layer of water of 1 cm to 2 cm after panicle initiation until ripening. Notwithstanding these applications, (Uphoff & Randriamiharisoa, 2002) stated that there are not yet any fixed recommendations for water management, except the principle of keeping soil well aerated during the vegetative growth phase. The recommendations given, in the case of SRI, are therefore purely empirical and no systematic research has been done on what are the optimal water management practices in combination with other SRI practices (Uphoff, 2014). According to (Uphoff & Randriamiharisoa, 2002), what will be the best water management practices for SRI in terms of amount and timing of water application will depend on soil characteristics as well as the varietal and other differences. The optimum water depth and the irrigation intervals to be applied in SRI to get an acceptable yield, higher than that of the conventional methods of growing rice, while at the same time saving water, are still to be investigated. Very few researches have been done on evaluating the implications of those factors to know how little water can be applied and at what intervals, when plants, soil, and nutrients are being managed according to SRI principles (Bouman et al., 2002). (Uphoff, 2014) stated the optimal water management practices in conjunction with other SRI practices has not been systematically investigated. This is a current issue at present. Investigating the best water management practices is a topic of interest for the promotion of SRI and the improvement of water saving techniques. An attempt made by (Kissou O. J. & Wang, 2017) during rainy season, found that 3cm water depth applied weekly from development stage to ripening, yielded better with less inputs and recorded the best water productivity (40%) under SRI. Previously, (Kima A. S. et al., A. S. Kima, Wen-Guey Chung, Wang, & Traoré, 2014) investigated the efficient water management on rice under AWD taking advantage of rainfalls andfound that 3cm water depth per week was the best water management. Application of 3cm water depth per week during rainy season when taking advantage of rainfalls revealed to be the optimum water depth in Taiwan tropical zone. Taiwan experience two rice cropping season a year: the first one during rainy season and the second one during the dry season where rice fields are fully irrigated due to rainfall scarcity. Therefore, taking full advantage of rainfalls can hardly be used during the dry season in this zone even though the zone records light rainfalls during that period. (Greaves & Wang, 2016) explained in fact that the late cropping season (November to March) in Taiwan coincides with the cooler winter season and is characterized by warm dry spells and lack of rainfall. Because of this, irrigation water applied for crop production in general and particularly for rice remains much more important. Hence, there is a necessity to find out the best irrigation schedule and the best water depth in dry season for high productivity in rice.

The study compared different water treatments (T2, T3, T4 and T5) under SRI and the yields resulting from this in order to find out the optimum water depth and the optimum yield in SRI for specific climatic zone.

2. METHODS

2.1 Experimental Site and Soils

The field experiment was conducted from December 5th to April 3rd, in the NPUST rice experimental farm. The farm is located at 22.39° N latitude and 34.95° E longitude with an altitude of 71m above sea levels. The soil type was loamy-textured (27 % of sand and 24 % of clay) with a wilting point of 15 % volume; field capacity 30.5 % volume; saturation 42.9 % volume; bulk density 1.40 g/cm³; matric potential 11.09 bar; and hydraulic conductivity at 57 mm/h (Kima A. S. et al. et al., 2014).

2.2 Experimental Design and Treatments

The experimental design was a one-way factorial ranged in a complete randomized block design. The plot sizes were 1.5m x 4m, dug at 0.3m of depth. The experiment consisted of 4 irrigation treatments (2cm, 3cm, 4cm, 5cm water depths) irrigated at soil hairlines cracks (Prabha, Thiyagarajan, & Senthivelu, 2011) visual estimation using 3cm water depth as control. Each water treatment was replicated 4 times.

Plots were separated from each other by a consolidated bund of 0.5m. From one block to another stands a consolidated bund of 1m width. The hill spacing as recommended by SRI practice is 25cm by 25cm. These spacing gave a plant population of 75plants per plot and 25plants per square meter. Fertilization was done using only chemical fertilizer NPK (270kg/ha).

2.3 Crop Management and Irrigation

The variety Tainan 11 was transplanted. However, due to the climatic effects, seedlings development delayed from 7 to 10 days. Therefore, 25 days seedlings (two phyllochrons stage) instead of 15 days were transplanted. As for Katayama (1951) and Nemoto et al., (1995) cited by (Uphoff & Randriamiharisoa, 2002) the exact seedlings age limit depends on biological processes, measured in terms of phyllochrons, rather than determining by calendar time. One seedling was planted on each hill. During the seven days after transplanting, dead seedlings were replaced.

All treatments received the same basal fertilizer which is NPK, supplied at a rate of 162g/plot for a dose of 270 kg/ha followed by (Kissou O. J. & Wang, 2017). Three applications of the same rate were done in addition: the first one at 12 days after transplanting, the 2nd at 40 DAT and the last one at mid-season at 58 DAT. Pesticides was used during the first week after transplanting against mole crickets destroying young seedlings' roots. Manual weeding using hand hoe was performed on 20 and 21 DAT, 40 and 41DAT and 76-77 DAT.

2.4 Irrigation and Water Management

Four water depths were applied: 2cm, 3cm, 4 cm and 5cm water depth as used by (Kima A. S. et al. et al., 2014); (Victoriano J. P. & Wang, 2017b); (Kima E. & Wang,

2017) and (Kissou O. J. & Wang, 2017) irrigated at soil hairlines cracks and 3cm water every week. All plots received 5cm water depth every day after transplanting until 17DAT, followed by 3 days of drying period. On 21 DAT until late season the treatments 2cm, 3cm, 4cm and 5cm were applied using everyday observation on soil surface and the control plot received 3cm water depth per week. Irrigation water was applied using a soft pipe of 2.5cm inner diameter connected to a water tap.

As (Nyamai et al., 2012), a 14-days dry period was observed before harvesting to allow for maximum transfer of nutrients to the grains. To determine the irrigation time for each sub-plot, the water flow rate out of the soft pipe was measured, using a 200 liters bucket. The flow rate (Q= 1/sec) was used to determine the amount of irrigation water to be applied in each plot by calculating the time of irrigation according to the formula (eq.1) by (Jensen, 1980) cited by (Kima E. & Wang, 2017).

$$t = (\boldsymbol{A} \times \boldsymbol{d})/\boldsymbol{Q} \qquad (1)$$

Where, t = Time required to irrigate fields (sec),
A = Area of sub-plot ($6m^2$)
d = Depth of water applied according to the schedule (mm),
Q = Water flow Discharge (l /sec= 0.91 l/s).

The volume of water to be applied to reach the desired depths was obtained also using the following equation according to (Kima A. S. et al. et al., 2014):

$$IR = \boldsymbol{A} \times \boldsymbol{h} \times \boldsymbol{10^3} \qquad (2)$$

Where IR is the amount of irrigation water (liters) for a desired depth above the soil surface,

A is the surface area of the plot (m^2),
And h is the desired water depth above the soil surface (m).

In case of rain to avoid standing water, the required water depth in each plot was maintained using drains to convey water out of the field. Thus, irrigation was planned again estimating soil moisture by observing soil hairlines cracks.

2.5 Measurement of Yield

Yield were estimated at harvest. To determine the yield, data were collected within $1m^2$ set in the middle of each plot. All plants of the $1m^2$ for each replicate were harvested for the determination of yield per unit area. The percentage of ripened grains was calculated by dividing the number of filled grains by the number of total grains on a panicle.

2.6 Assessing Water Productivity Index (WPI)

Total water (TW) received by the experiment plots is the sum of irrigated water (IW) applied and the rainfall water (RW). The total water productivity (TWP), irrigation water productivity (IWP) and rain water productivity (RWP) were calculated using the following equations (Geerts and Raes 2009) cited by (Kima A. S. et al. et al., 2014):

$$TWP = \frac{MY}{TWU}; \qquad IWP = \frac{MY}{IWU}; \qquad RWP = \frac{MY}{RW}$$

Where TWP, IWP and RWP are respectively, the total water productivity, the irrigation water productivity and the rain water productivity expressed in kg/m^3. MY is the marketable yield (kg/ha). TWU, IWU and RW are expressed in m³/ha and stand for the total water used (rain + irrigation), irrigation water used and rain water, respectively. Water productivity was calculated as the weight of grains produced per unit water used. The water used efficiency resulted from the comparison of total water productivity drawn from all the water treatments.

2.7 Data Analysis

Analysis of variance (ANOVA) was performed using SAS 9.4 software version (SAS Institute, Inc., NC). Statistical significance among parameters from water treatment were determined using Fisher's Least Significant Difference (LSD) test at 5% probability level.

3 RESULTS AND DISCUSSION

3.1 Tillers Number, Productive Tillers and Tillering Efficiency

Tillers number is a determinant of yield when assumed that every tiller bears a panicle. Duncan grouping test carried out on the tillers numbers, the productive tillers numbers and the tillering efficiency varied in accordance with the water depths applied as indicated by (Kissou O. J. & Wang, 2017). The maximum tillers number was 25.5 and was recorded in SRI2. The minimum tillers number was found in SRI3 at soil hairline cracks with a value of 23.50. These findings are coherent with that of (Bouman et al., 2002) according to whom averages of 20–30 tillers per plant are fairly easy to obtain and in some well-managed fields 50, even 70 tillers per plant. On the contrary (Kissou O. J. & Wang, 2017) found 18.52 and 16.08 as maximum and minimum tillers number respectively, in SRI, showing that the cropping season may affect the tillers number as well.From these results, tillers number per m^2 reached 589 and 651. This was higher than that of (Gopalakrishnan et al., 2013) who found tillers per m^2 between 221 and 528, but lower to that of (Ndiiri, Uphoff, Mati, Home, & Odongo, 2017) who recorded tillers number per m^2 ranged from 711 to 1,300 tillers in SRI.

Statistical analysis on productive tillers/hill and m^2showed significant differences between SRI3 at soil hairline cracks (20.75/hill and 523.75/m^2) and SRI2 at soil hairline cracks (16/hill and 395/m^2) compared to SRI4 at soil hairline cracks (15.25/hill and 386.25/m^2) and SRI5 at soil hairline cracks (12.75).

The tillering efficiency, consequently, was at the highest point in SRI3 (0.90) and at the lowest point in SRI5 (0.53). Findings showed that in well managed SRI farms, productive tillers/m^2 can reach 600 productive tillers. Current results showed high productive tillers and is coherent with results found with (Ndiiri et al., 2017) in which productive tillers/m^2 was between 692 to 1,235.9 tillers. (Prabha et al., 2011) found lower productive tillers number/m^2 ranged between 401 and 501. Results indicated also that the tillering efficiency in SRI system is high. (Kissou O. J. & Wang, 2017) found that a single seedling used under SRI reached 180% of tillers number.

Wide spacing and low seedling density induce tillers multiplication and growth. They reduce competition among plants for nutrients, water, light, and air, which create optimum conditions for the individual crop. The following table 4 shows the detailed data previously discussed.

3.1.1 Panicles Number, Length and Weight

The panicles number, length and weight are close to the grain yield more than the number of tillers, and can explain it under given conditions. In table 5 (below), some differences were seen in panicles numbers, length and weight from one treatment to another. SRI3 recorded the highest panicles number/hill (20.75) and was significantly different from SRI2 (16), SRI4 (15.25) and SRI5 (12.75) which recorded the lowest value in terms of panicles number/hill. Results showed that the number of panicles were influenced by the different irrigation treatments. Applying the same water levels every week, (Kissou O. J. & Wang, 2017) found no significant differences between the panicle's numbers with 16.67 in T2, 15.62 in T4, 15.5 in T3, and 15.10 in T5. However, the panicles numbers in SRI2 and SRI4 are consistent with their findings. In terms of panicles number/m^2, SRI3 produced an average of 523.75 panicles whereas SRI5 recorded the lowest value with 317.50 panicles, with a gap of 206.25 panicles in the m^2. In this study, panicles number/hill and m^2were close to those of (Amod K. Thakur, Rath, Patil, & Kumar, 2011) who found a number of 16.9/hill and 495.5/m^2 in SRI practice and higher than that of (Amod K.

Table 4. Effect of the different water treatments on the tiller number, productive tiller number and tillering efficiency (N=4).

Treat ments	Ave. Tiller number/h ill	Ave. productive tiller umbers/hill	Ave. productive tiller numbers/m^2	Ave. tillering efficiency/hill
SRI2	25.5±2.5^{a}	16±4^{ab}	395±93^{ab}	0.60±0.08^{b}
SRI3	23.5±1.1^{a}	20.75±2^{a}	523.75±59^{a}	0.90±0.14^{a}
SRI4	24.75±1.4^{a}	15.25±0^{ab}	386.25±1^{ab}	0.63±0.03^{b}
SRI5	24±1.9^{a}	12.75±1^{b}	317.50±20^{b}	0.53±0.02^{b}

NB: Mean values followed by different letter within columns differ significantly at P < 0.05 according to Duncan's Multi-range test.

Thakur, Mandal, Mohanty, & Ambast, 2018). The management practices followed in SRI method of cultivation produced significantly a greater number of panicles/m^2 (Prabha et al., 2011), even though (Amod Kumar Thakur, Rath, & Mandal, 2013) reported lower panicles number/m^2 (202.3 and 330) under SRI. As for the panicle length, the highest record was observed in SRI2 (19.75cm) followed by SRI3 (19.50cm). Both averages in SRI2 and SRI3 were significantly different from SRI4 (17.75cm) and SRI5 17.50cm. Almost same results are found in previous studies with (Amod K. Thakur et al., 2011) recording 22.5cm, (Chutia & Borah, 2012), from 19.38cm to 19.58 cm, (Gopalakrishnan et al., 2013) from 17.7cm to 22.8cm,(Lestari, Suwarno, Trikoesoemaningtyas, Sopandie, & Aswidinnoor, 2015)from 19.42cm to 27.15cm in and (Kissou O. J. & Wang, 2017)recording from 21cm to 21.7cm. Higher panicle length (from 21.3cm to 25.2cm) were found in (Ndiiri et al., 2017). In terms of panicle weight, no significant differences were observed among the different treatments. SRI3 recorded the highest panicle weight (2.83g) whereas SRI5 recorded the lowest one (2.45g), which makes a gap of 0.38g. These are supported by (Lestari et al., 2015) with weights ranged between 1.92g and 3.97g and (Kissou O. J. & Wang, 2017) that recorded weights between 1.92g and 2.65g.

Table 5. Effect of the different water treatments on the panicles number, length and weight.

Treatm ents	Ave. panicle num/hill	Ave. panicle num/m^2	Ave. panicle length (cm)	Av. Panicle weight
SRI2	16±4^{ab}	395±92.7^{ab}	19.75±0.4^{a}	2.75±0.18^{a}
SRI3	20.75±2^{a}	523.75±59^{a}	19.50±0.2^{a}	2.83±0.08^{a}
SRI4	15.25±0^{ab}	386.25±1.3^{ab}	17.75±0.5^{b}	2.60±0.17^{a}

SRI5	12.75±1^{b}	317.50±20.2^{b}	17.50±0.2^{b}	2.45±0.12^{a}

NB: Mean values followed by different letter within columns differ significantly at P <0.05 according to Duncan's Multi-range test.

3.2 Comparison of Spikelet Numbers/Panicle, Filled Spikelets and 1,000 Grains Weight

According to (Yoshida, 1981), while the combined yield components (number of spikelets per square meter, filled-spikelet percentages and 1,000 grain weight) accounted for 81% of the yield variation, number of spikelets per square meter alone explained 60% of the variation, and filled-spikelet percentage and grain weight together accounted for 21.%. Whereas the combined number of spikelets and percentage of filled spikelets accounted for 75% in the yield, combined number of spikelets and grain weight supported the yield for 78%. The importance of the three yield components are therefore relevant for grain yield.

In table 6, analysis showed that in terms of Spikelets number per hill and per m^2, SRI3 recorded the best with 157 spikelets per hill and 3928 spikelets per m^2 and SRI5 the lowest values with 132.75 spikelets per hill and 3318 spikelets per m^2. Significant differences were observed between SRI3 when compared with SRI2, SRI4 and SRI5. No significant differences were observed between SRI2 and SRI4. These results are corroborated by (Amod K. Thakur et al., 2011) who recorded a spikelet number of 151.6 per panicle, and (Amod Kumar Thakur et al., 2013) who found numbers between 118.8 and 285.3 in different N (nitrogen) treatments under SRI. Similar results are also found with (Ranawake, Amarasingha, & Dahanayake, 2013). On the contrary, (Ndiiri et al., 2017) recorded lower spikelets number per panicle (from 74 to 115).

Concerning the percentage of filled grain, no significant differences were observed in the different water treatments. SRI3 still recorded the highest value and SRI5the lowest percentage. These results are supported by (Amod K. Thakur et al., 2011) with a percentage of 89.6%, (Ranawake et al., 2013) with percentages between 55.9% and 90.9%, (Amod Kumar Thakur et al., 2013) from 71.4% to 79.2% and (Ndiiri et al., 2017) from 45.67% to 89.1%. Grain weight was obtained out of 13% grain moisture content after having dried panicles for 72 hours at 70°C. Analysis of these data per treatment (see Table 24) shows no significant differences between the treatments. SRI3 recorded the highest 1,000 grain weight (20.55g). No statistical significant differences were observed between SRI2 (19.35g), SRI3 (20.55g) and SRI4 19.29g at soil hairline cracks. SRI5 recorded the lowest weight (18.74g). In other words, water treatments at soil hairline cracks did not significantly affect the 1,000 grain weight. Current findings are supported by (Kissou O. J. & Wang, 2017) who found the highest grain weight as 20.37g in T4 and the lowest grain weight as 16.19 in T2. Results are also in agreement with those of (Kar et al., 2018) but lower compared to (Amod K. Thakur et al., 2011) who found 24.7g of 1,000 grain weight, (Amod Kumar Thakur et al., 2013) who recorded grain weight between 23.45g and 24.66g and (Amod K. Thakur et al., 2018) that found an average of 24.1g as grain weight. The low weight recorded in 1,000 grain may be attributed to the water stress the crop faced during its cycle. One of the negative effect of water stress on crop is a bad grain filling which reduces grain weight.

Table 6. Effect of the different water treatments on the spikelets number, filled grain and 1,000 grain weight (N=4)

Treatments	Av.Spikelet number/panicle	Av.Spikelet number/m^2	% filled spikelets	1,000 grain weight
SRI2	148±7.4^{ab}	3,701±182^{ab}	86±6.3^{a}	19.35±1.2^{ab}
SRI3	157±2.6^{a}	3,928±66^{a}	87.75±2.2^{a}	20.55±1.6^{ab}
SRI4	145.75±9.3^{ab}	3,640±232^{ab}	87.25±9.2^{a}	19.29±0.5^{ab}
SRI5	132.75±5.7^{b}	3,318±144^{b}	84.75±5.40^{a}	18.74±0.5^{b}

NB: Mean values followed by different letter within columns differ significantly at P < 0.05 according to Duncan's Multi-range test.

3.3 Grain Yield and Water Productivity

Grain yield performance is determined by different yield attributes like number of panicles/m^2, total number of grains/panicles, grain-filling%, and 1000-grain weight (Amod K. Thakur et al., 2018) but at different percentages (Yoshida, 1981). Like the other parameters, grain yield was influenced by the different water depths investigation carried out under SRI. Grain yield analysis (Table 7) shows that the highest yield advantage was realized by SRI3 at soil hairline cracks (4072kg/ha), followed by SRI2 at soil hairline cracks (3448kg/ha) and SRI3 per week (3340kg/ha). The last grain yield was recorded in SRI5 at soil hairline cracks. These yields may be explained with the results of the yield attributes particularly the spikelets numbers per m^2 recorded in each treatment. According to (Yoshida, 1981) the 1,000-grain weight may affect yield to some extent but rarely becomes limiting under most conditions. Therefore, under given conditions it is important to examine the causes of yield variation in components, particularly spikelet number per square meter and filled-spikelet percentage (Yoshida, 1981). Grain yields were low compared to (Prabha et al., 2011), (Amod K. Thakur et al., 2011), (Victoriano J. P. & Wang, 2017a), (Kissou O. J. & Wang, 2017), (Amod K. Thakur et al., 2018) in SRI. The yield reduction may be explained by the weather conditions (low temperatures) that delayed the development stage, and the water stress imposed to the plants. According to (Bouman et al., 2002), climatic discrepancies impact on crop production and their productivity. Liu et al. (2006), reported by (Rang, Jagadish, Zhou, Craufurd, & Heuer, 2011), rice is sensitive to drought stress particularly during flowering stage, resulting in severe yield losses.

Table 7. Effect of the different water treatments on the grain yield and water productivity (N=4).

Treatments	Grain yield (kg/ha) + SE	Rain (m^3/ha)	Irrigation (m^3/ha)	RWP (kg/m^3)	IWP (kg/m^3)	TWP (kg/m^3)
SRI2	3,448±831^{a}	2,200	16,600	1.55	0.21	0.18
SRI3	4,072±320^{a}	2,200	19,300	1.83	0.21	0.19
SRI4	3,081±431^{a}	2,200	18,000	1.38	0.17	0.15
SRI5	2,604±455^{a}	2,200	19,700	1.17	0.13	0.12

NB: Mean values followed by different letter within columns differ significantly at P < 0.05 according to Duncan's Multi-range test.

The main goal of SRI is to reduce production input especially water consumption and keep an acceptable yield. Water productivity is used to assess water economy. Water productivity is that quantity of crop 1m^3 of water can produce. Table 25 (above) displays the rain water productivity (RWP), the irrigation water productivity (IWP) and the total water productivity (TWP). During the cropping season the amount of rainfall recorded was 2230m^3. The highest rainwater productivity (1.83) was recorded in SRI3 at soil hairline cracks. In terms of irrigation water productivity, the highest values (0.21) were recorded in SRI2 and SRI3 at soil hairline cracks. In terms of total water productivity, SRI3 was the treatment that recorded the highest water productivity

(0.19). It is observed that SRI3 at soil hairline cracks did not differ from SRI2 at soil hairline cracks (0.18). In general, water productivities in this study were lower compared (Prabha et al., 2011), (Amod K. Thakur et al., 2011), (Victoriano J. P. & Wang, 2017a), (Kissou O. J. & Wang, 2017), (Ndiiri et al., 2017), (Amod K. Thakur et al., 2018). When rice growing cycle extends due to climatic conditions, the immediate consequence is the increase of irrigated water use which can reduce water productivity.

SRI4 and SRI5 at soil hairline cracks received higher water levels compared to the other treatments with 2,0200m^3/ha and 2,1900m^3/ha respectively. However, they recorded the lowest yields of 3,081kg/ha and 2,604kg/ha respectively and the lowest water productivities. With (Kissou O. J. & Wang, 2017), T5 and T4 yielded respectively 6,300kg/ha and 5200kg/ha. The low yields in this study can be explained by a high rate of water loss through percolation. In fact, the wide hairline cracks on soil surface lead to the water run-off into the gaps created by the cracks. The more the water level is high, the deeper the water is conveyed into the soil, limiting the water uptake by the plants. According to this study, using high water levels with soil hairline cracks is not beneficial.

Taking into account the grain yield and the water productivity as mentioned above, we argue that SRI3 at soil hairline cracks can be maintained as the optimum treatment that can reduce water consumption and keep an acceptable yield. This finding was corroborated by (Kima A. S. et al. et al., 2014), and (Kima, Chung, & Wang, 2014) who found 3cm water depth application per week to be the optimum treatment in rainy season capable of saving water and keeping rice yield acceptable.

4. CONCLUSIONS

Application of 2cm, 3cm, 4cm, 5cm water depth following soil hairline cracks showed on the one hand that significant differences were observed in some growth and yield parameters. On the other hand, the different water treatments affected parts of the development stages.

Concerning the yield attributes assessment such as number of tillers per hill, number of reproductive tillers per hill and per m^2, panicle length and weight, panicle number per hill and per m^2, number of spikelets per panicle and per m^2 and 1,000 grain weight, significant differences were observed in some treatments. Some parameters did not show significant differences between the water treatments. However, SRI3 at soil hairline cracks showed better results in most cases. Spikelets number per m^2 and filled-spikelet percentage was much more responsible for the grain yield more than the grain weight. Grain yield were different from one treatment to another with no significant difference between them. Yet, SRI3 yielded better (4072kg/ha) than SRI2, SRI4, SRI5. Grain yield was sensitive to the water stress applied in this irrigation management which led to yield decline in all the treatments. The yield decline was greater in SRI5 notwithstanding the level of water it received. In terms of water productivity, SRI3 recorded the highest total water productivity with 0.19kg/ha and can be considerd the optimum treatment to save water and maintain rice yield in dry season. The study revealed that the wide cracks led to severe water stress, inducing low yields. ..The study suggests that, in order to increase yield and water productivity, rice should be grown during a period of optimum temperatures and irrigation be applied on the development of hairline cracks on soil surface.

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