The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: a Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania

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Abstract

Rice plays a critical role in ensuring food security in developing countries. For majority of the world's small-scale farmers who live in Asia and sub-Saharan Africa, rice is a major source of calories and the single largest source of income. However, increases in rice production are now lagging behind population growth, compounded by effects of climate change and variability. The system of rice intensification (SRI) developed in Madagascar, is a system approach to increase rice productivity through proper management of fewer inputs such as irrigation water and seeds. This study was therefore designed to evaluate the performance of SRI in Mvomero district in Morogoro region, Tanzania by implementing farmer field school (FFS) pilot trials of SRI operated by farmers alongside on-station scientific experiments in Mkindo Irrigation scheme. The experiments were conducted for two consecutive years during the wet season (March- July 2011) and dry season (September 2011- January 2012). One rice variety TXD 306 (SARO) was planted on plots in a randomized complete block design (RCBD) with five treatments based on two water application regimes of flooding and alternate wetting and drying (AWD), while the effects of transplanting age of seedlings and plant spacing (in cm) of 20x20 for T1 and T2, 25x25 for T3, 30x30 for T4, and 40x40 for T5 were evaluated. The plant height, root depth, tillerig, biomass and grain yields, irrigation water use, and wetting and drying intervals were evaluated and results were statistically analyzed using GENSTAT software. Highest grain yield was achieved in 25x25 (T3) and 30x30 (T4) SRI spacing. Under the SRI practice, 62.51%, 63.64%, 64.67%, and 64.07% water savings were noticed for T2, T3, T4 and T5, respectively, compared to the control (T1). SRI practice for planting space of 25x25 to 30x30 cm, wetting and drying interval of three days, and younger seedling of 8-12 days are recommended as good combinations for SRI practice in Mkindo area, Morogoro region.

Key words: Climate change, rice productivity, System of Rice Intensification (SRI), alternate wetting and drying (AWD)

Introduction

Rice crop plays a critical role in ensuring food security for developing nations in Asia and Africa. For majority of the world's small-scale farmers who live in Asia and sub-Saharan Africa, rice is a major source of calories and the single largest source of income. Rice is rapidly becoming a major staple food in much of Sub-Saharan Africa (SSA) and is set to overtake maize, cassava, sorghum, and other cereals in the near future. The demand is driven as much by population growth as by urbanization (Katambara *et al.* 2013). According to FAO (2008a) more than one-half of the world's population depends on rice as their staple food.

Rice is the second widely cultivated cereal food crop in Tanzania after maize. It is grown as a food and cash crop by smallholder and large-scale farmers in almost all regions of Tanzania (FAO, 2008b). It is grown in three agro-ecosystems namely rainfed lowlands, rainfed uplands, and irrigated lowlands (Mghase *et al.*, 2010). The popularity of rice is due to population growth and urbanization, consumer preferences and diet changes. It is also due to convenience and ease of storage and cooking, and consumption increase by 5% per year. Rice farming contributes to household food security as well as poverty reduction to majority of Tanzanians, and sustains livelihood for more than 100 million people in SSA. Despite its importance, rice production in SSA has not kept pace with increased consumption and thus widening domestic deficit, which is met by mainly importation (WARDA, 2007).

Water for agriculture is becoming increasingly scarce, and climate change-induced higher temperatures will increase crops' water requirements, making the water shortages even more serious. By 2025, it is estimated that 15–20 million of the world's 79 million hectares of irrigated rice lowlands, which provide three-quarters of the world's rice supply, are expected to suffer some degree of water scarcity (IWMI, 2007). It is also estimated that to eliminate hunger and undernourishment for the world's population by 2025, the additional water requirements may be equivalent to all freshwater withdrawal used today for agricultural, industrial, and domestic purposes (SIWI, 2005). The System of Rice Intensification (SRI) is a new way of ensuring increased rice yields while using less water.

The SRI was developed in the 1980s by a French priest in Madagascar, Father Henri de Laulanie, who spent 20 years learning about rice-growing practices from local farmers (Uphoff, 2007). SRI is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water, and nutrients, while reducing external inputs. It has been raising yields by 32% to 100%, and sometimes more, with reduced requirements for water, seed, fertilizer, and crop protection (Sato and Uphoff, 2007; Sinha and Talati, 2007). To date, the effects of SRI methodology have been empirically demonstrated in over 30 countries, including most of the rice-producing countries of Asia and many others in Africa and Latin America (Uphoff, 2007). SRI is reported to reduce amount of water applied to the field by about 40% to 70% compared to traditional practice of continuous flooding (Sato and Uphoff, 2007; Sinha and Talati, 2007), and reduce labor input by about 8% (Sinha and Talati, 2007).

Unlike the conventional method of continuous flooding of paddy fields, SRI involves intermittent wetting and drying of paddies as well as specific soil and agronomic management practices. It is based on six principles: i) transplanting a single seedling, ii) transplanting younger seedlings at a 2–leaf stage (8-12 days old), iii) wide plant spacing of 25x25 cm or wider, planted in lines, iv) minimum water applications during vegetative growth period keeping soils moist, but well-drained and aerated, v) frequent weeding with a simple mechanical hand-weeder, and vi) application of organic matter in preference to chemical fertilizer (Laulani´e, 1993; Katambara *et al.*, 2013).

Results of SRI practice in many tropical and sub-tropical countries have shown the significance of SRI methods with respect to increasing grain yield and saving water. Hence the main objective for this study was to examine the potential of using the system of rice intensification (SRI) practices to increase water productivity under Mkindo area soil conditions. Specifically, the study aimed to i) assess the SRI components of transplanting age and spacing that gives maximum productive tillers, and ii) determine the paddy rice irrigation schedule that corresponds to the soil conditions of Mkindo area in Mvomero district, Morogoro region in eastern Tanzania.

Materials and Methods

Study location and climate

The study was conducted at Mkindo farmer-managed irrigation scheme located in Mvomero District in Morogoro region, eastern Tanzania. The district is located between latitude 6°16' and 6°18' South, and longitude 37°32' and 37°36' East and its altitude ranges between 345 to 365 m amsl. Mkindo site is about 85 km from Morogoro municipality (Figure 1). Soils at the experimental site are clayey loam with infiltration rate of 0.12 m/day and average bulk density of 1.4 kg/dm^3. The Mkindo soils have also the following properties: pH = 6.2, K = 12.75 mg/kg, P = 0.532 mg/kg, and N (%) = 1.00.

Rainfall in the study area normally starts in October with increased trend where peak rainfall is attained in March. From March the trend starts to decrease until it stops at the end of May (Figure 2). From mid-June to early September normally there is no rain. During the study year in 2011, rainfalls during the wet planting season of March-April-May (MAM)

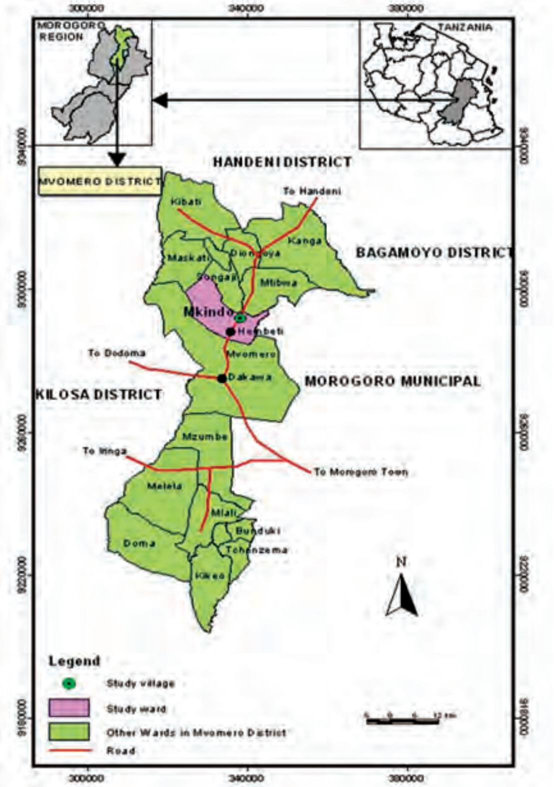

Figure 1: Location map of Mkindo ward in Mvomero District, Morogoro region.

started much earlier, but were moderate as the season progressed in April and May. For dry season growing period of October-November-December (OND), rainfalls started on 29th September and rainfall events were recorded between 21-46, 71-88, 96-102, and 110-120 days after planting. High rainfall events on 110-120 days after seeding were recorded. Hence the 2011 dry growing season of OND (vuli) received more rains than wet season of MAM (masika) under this scenario.

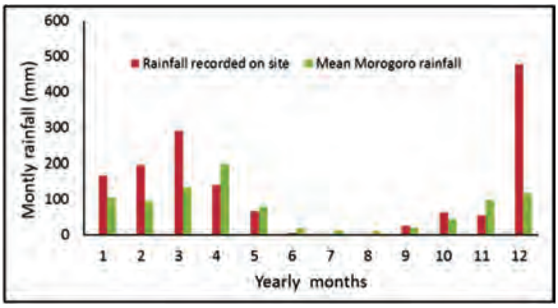

Figure 2: Rainfall recorded during year 2011 and mean monthly rainfall for Morogoro region as obtained from CLIMWAT database.

Experimental design

The experiments were laid out in a Randomised Complete Block Design (RCBD) with three replications (Figure 3). The treatments were: i) using 21 days old (conventional) and 14 days old (SRI) seedlings; ii) planting space at 20 × 20 cm, 25 × 25 cm, 30 × 30 cm, and 40 × 40 cm; iii) irrigation at 5.0 cm depth (conventional) (Nyirenda *et al.* 2010), and 2.0 cm depth on development of hair-line cracks (SRI). The experiments were conducted for two seasons i.e. wet and dry season. The treatment combinations were as shown in Table 1.

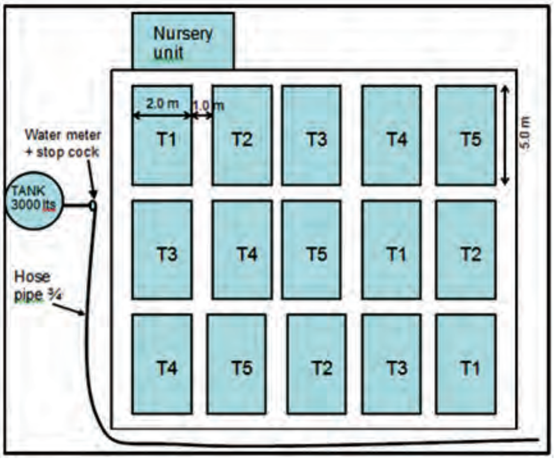

Figure 3: Layout of experimental plots showing treatments in a Randomised Complete Block Design (RCBD).

Table 1: Treatment details on the experimental plots.

Treatment	Cultivation Practice	Irrigation Method*	Transplanting age (days)	Seedling / hill (nos)	Spacing (cm)
T1	Conventional	Flooding	21	3	20x20
T2	Conventional	AWD	21	3	20x20
T3	SRI	AWD	14	1	25×25
T4	SRI	AWD	14	1	30×30
T5	SRI	AWD	14	1	40×40

* AWD = Alternate Wetting and Drying

In addition, experiments were also conducted in farmers' field trials (FFS) whereby farmers performed SRI experiment with a spacing of 25x25 cm (FFS1), 30x30 cm (FFS2), and 40x40 cm (FFS3).

Agronomic practices

Land preparations were carried out in the experimental plots. The fields were well-levelled so that there is good soil structure, water can be spread uniformly, and plant roots can grow easily. Correct levelling helped to achieve uniform wetting of the soil. Adequate drainage channels were maintained for proper water control. Saro (TXD 306) rice variety was chosen as it was well-suited to local conditions of Mkindo. Only seed with good density and formation were used for nursery preparations. To get best seeds, the seeds were submerged in a container of salty water with salt solution in which an egg would float. Any light and inferior seeds that floated in the salty water were discarded. The best seeds were then soaked in clean water for 48 hours (seed priming). The practice of soaking seed before planting enhances the rate of germination and seedling emergence.

The HH2 Soil Moisture Meter Version 2.3 and tension meters were used to monitor volumetric moisture content of the soil. The Moisture Meter type HH2 used was a versatile readout unit that reads instantly soil moisture from the Theta Probe. The 208-mm long Theta probes with 1% measurement accuracy were installed in the soil through inserting them in an augered hole. The hole was pre-drilled at a 45° angle to minimize preferential flows. Each experimental plot had one theta probe. The HH2 soil moisture meter was connected to the Theta Probe to record single point measurements at a depth of 20 mm. The measured data were then transferred to a computer using RS 232 cable for further analysis. Soil moisture measurements were taken on each plot at an interval of 5 days. Tensiometers were used to get estimates of the soil matric potential in each plot, which were then transformed to volumetric moisture content using moisture release curve. The matric potentials were monitored at a stage of development of hair-line cracks on the soil.

The plant height, number of tillers per plant (and per m2), days to flowering and maturity, and grain and biomass yields (growth and yield parameters) were taken at regular intervals. The parameters were used to assess the treatment effects on crop growth and performance. The number of tillers per hill was taken from a sample of 10 plants/hills for each plot. The average number of tillers per hill on each plot was taken as average count of tillers from ten hills per plot.

Irrigation water management

Plots with treatments T2, T3, T4, and T5 were designed for intermittent irrigation (1–2 cm) with alternate wetting and drying periods, whereas T1 (control) was continuously flooded (up to 5–cm depth) throughout the rice-growing season (Nyirenda *et al.* 2010). Continuous flooding is the irrigation method commonly used by conventional rice growers in Mkindo area. For SRI practice, the importance of keeping the soil unsaturated to get more air to plant roots is evident. Key questions that needed to be answered were on the duration to which the fields would be left without water; how dry can they become; and the role of rainfall in providing water for the fields. Different practices are necessary for different kinds of soil and climate. The indicator for restarting irrigation delivery in this study was after development of hairline cracks appearing on the soil surface of paddy fields. This method was also used to establish the frequency of wetting and drying periods for SRI in other previous studies in Indonesia (e.g. Sato and Uphoff, 2007).

The quantity of water required to maintain appropriate water levels in the treatment plots and control during each irrigation was recorded using water meter and summed up to calculate the total amount of water applied to a plot throughout the cropping season. In all the systems, the total water used was quantified by subtracting the final from the initial readings (m^3) of a normal domestic water meter. Water saving percentage was calculated by using the following formula:

$$Water\ Saving(\%)\frac{Water\ use\ in\ flooded\ plot - Water\ used\ in\ SRI\ plot}{Water\ use\ in\ flooded\ plot\ (control)}x100 \tag{1}$$

Water productivity, defined as crop productivity per unit of water consumed, was calculated as:

$$WP = \frac{Y}{I_{irr}} \tag{2}$$

Where, WP is water productivity (kg/m^3), Y is gain yield (kg/ha), and I_{irr} is irrigation water applied (m^3/ha).

Table 2: Mean plant development parameters.*

Treatment	Tillers /m^2 (no)	Max Tillers/hill (no)	Average tillers/hill (no)	Average Height (cm)
T1	478.8 bc	24.5 a	19.15 a	77.18 b
T2	604.4 c	32.83 ab	24.21 ab	64.22 a
T3	441.3 abc	36.83 b	27.58 b	77.69 b
T4	382.9 ab	41.33 b	31.42 b	79.76 b
T5	275.6 a	56.17 c	43.83 c	76.83 b

* Different letters within a column indicates significant difference at P<0.05.

The mean irrigation water use (m^3/m^2) was calculated as average seasonal amount of water used in a given treatment (monitored by the domestic water meter) divided by average plot size for the three replicates.

Data analysis

The biomass, grain yield, harvest index, irrigation water use, tillering, plant heights and 1000 grains weight data obtained in all the treatments were analyzed using Microsoft Excel 2007 and GenStat 13th Edition statistical software following data analysis procedures for agricultural research as recommended by Gomez and Gomez (1984). Analysis of variance was run in which treatment means were separated using Duncan's Multiple Range Test to determine if there exists a significant difference among the treatments based on p-value of 0.05.

Results and discussions

Plant growth performance

Among the treatment spacing, a wider spacing of 40x40 cm recoded significantly higher number of tillers/hill compared to closer spacing. A statistical comparison of the number of tillers per hill among treatments showed that there were statistical differences at P = 0.05 (Table 2). The mean ranking based on the Duncan Multiple Range Test showed that the average number tillers per hill of T1 (19.15) was statistically different from treatments T3, T4, and T5, but treatments T2, T3, and T4 were not significantly different from each other. Significantly higher number of tillers per hill (43.83, mean for wet and dry season) was recorded under wider spacing of 40x40 cm. The significantly higher number of tillers per hill and better root development (Plate 1) were recorded due to SRI practice like wide spacing, transplanting younger seedlings (14 days), and alternate wetting and drying. Planting in square method with wider spacing resulted in profuse tillering under SRI cultivation, which facilitated plants for better utilization of light, soil nutrients and water. The advantage of SRI method in enhancing numbers of tillers has also been reported earlier by Sato and Uphoff (2007), and Katambara *et al.* (2013).

Plate 1: Root growth performance of conventionally grown (left) vs. an SRI-grown rice plant (right).

Grain yield

The lowest grain yield was obtained from T2 for both seasons (Figure 4). The highest grain yield was achieved in T3 and T4. The mean grain yield for two seasons for T3 and T4 were 4.76 tons/ha and 4.68 tons/ha respectively. The grain yields obtained from on farm trials during wet season were 6.30 t/ha for FFS1 (spacing 25x25 cm), 4.93 tons/ha for FFS2 (spacing 30x30 cm), and 3.37 tons/ha for FFS3 (spacing 40x40 cm). However, during dry season the grain yield for T3 was higher with 5.6 tons/ha compared to 4.14 tons/ha for T2.

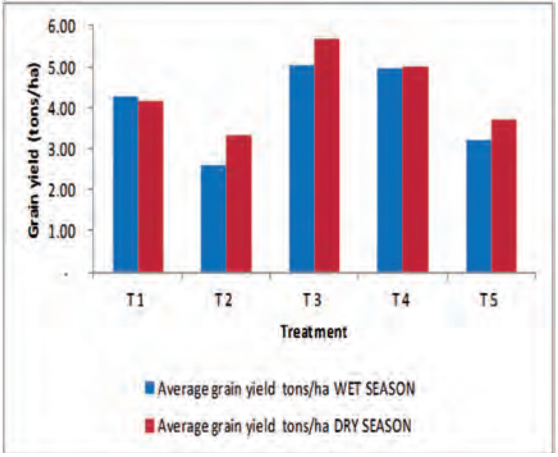

Figure 4: Average Grain yield (Tons/ha) for different treatments during wet and dry season at Mkindo.

The percentage yield increase of the treatments with respect to the reference T1 from the mean of two seasons obtained was -27.68% in T2, 24.28% in T3, 22.19% in T4, and –22.72% in T5. It was noted that at a wider spacing of more than 35x35 cm optimal yields were reduced due to low plant population despite enhanced tillering per plant. The statistical analysis of two seasons' pooled data showed a significant difference for grain yield (Table 3). These results are in agreement with those found by other researchers like Krishna *et al.* (2008), and Vijayakumar *et al.* (2001), that higher grain yields is achieved in the treatment with younger seedlings (14 days old) transplanted singly at wider spacing (25x25 cm^2 to 30x30 cm^2) under non-flooded soil moisture conditions.

Table 3: Comparison of mean grain yield and yield parameters for conventional and SRI practice.

Treatment	Spacing (cm)	Grain Yield* (tons/ha)	Above Ground Biomass* (tons/ha)	Harvest Index* (HI)	1000 grains weight* (g)
T1	20 x 20	3.83 ab	8.92 b	0.43 a	25.42 b
T2	20 x 20	2.77 a	8.00 ab	0.36 a	23.17 a
T3	25 x 25	4.76 b	10.77 c	0.44 a	23.77 ab
T4	30 x 30	4.68 b	9.37 bc	0.50 a	23.85 ab
T5	40 x 40	2.96 a	6.49 a	0.44 a	23.83 ab

* Means with the same letter are not significantly different at p = 0.05.

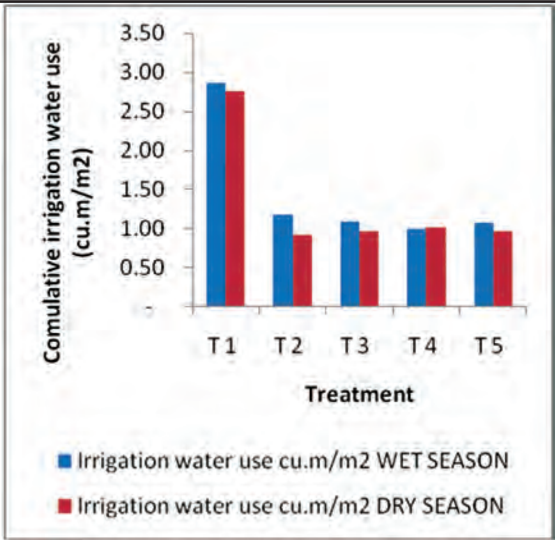

Figure 5: Irrigation water use under different treatments at Mkindo.

Irrigation water use and water saving

The reference/control treatment, (T1), which was irrigated on basis of continuous flooding throughout the crop growing season, had the highest mean irrigation water use of 2.82 m^3/m^2 for the two seasons (Table 4). Other treatments T2, T3, T4 and T5, which involved Alternate Wetting and Drying (AWD) cycle, indicated mean irrigation water use of 1.06, 1.03, 1.00 and 1.01 m^3/m^2, respectively (Table 4, Figure 5). No significant differences were observed for irrigation water use between two seasons because both growing periods received considerable rainfall events (Figure 5). The mean ranking based on the Duncan Multiple Range Test at $p<0.05$ showed that irrigation water use of the reference treatment T1 was statistically different from that of treatment T2, T3, T4 and T5 (Table 4). With SRI practice the water saving accounted for 62.51%, 63.64%, 64.67%, and 64.07% for T2, T3, T4, and T5, respectively. These results agree with findings reported by Sato and Uphoff (2007) under SRI management in eastern Indonesia. Similarly, Chapagain and Riseman (2011) reported that water applied in the field can be reduced by about 40–70% without a significant

Table 4: Comparison of irrigation water use, water productivity and water saving for conventional irrigation and SRI practice.

TREATMENT	Season one (wet)			Season two (dry)		Average (wet and dry)*		
	Spacing (cm)	Irr. Water use (m^3/m^2)	WP (kg/m^3)	Irr. Water use (m^3/m^2)	WP (kg/m^3)	Irr. Water use (m^3/m^2)	WP (kg/m^3)	Irr. Water saving (%)
T 1	20 x 20	2.86	0.15	2.77	0.15	2.82 a	0.14 a	
T 2	20 x 20	1.17	0.22	0.94	0.37	1.06 b	0.27 b	62.51
T 3	25 x 25	1.08	0.47	0.97	0.60	1.03 b	0.47 c	63.64
T 4	30 x 30	0.98	0.51	1.01	0.50	1.00 b	0.47 c	64.67
T 5	40 x 40	1.06	0.30	0.96	0.38	1.01 b	0.29 b	64.07

* Different letters within the same column indicate significant difference at $P<0.05$

yield loss compared with the traditional practice of continuous shallow submergence if a very thin water layer is maintained at saturated soil condition, or by practicing alternate wetting and drying. Keisuke *et al*. (2007) also reported the reduction of irrigation water requirement for non-flooded rice by 20–50% compared to flooded rice, with the difference being strongly dependent on soil type, rainfall, and water management practices.

The amount of water saved through the use of SRI could be used for expanding the scheme to areas that were not receiving adequate irrigated water. This is especially important during the dry season and in in years where rainfall is below normal, when rice farming in Mkindo will need to be sustained mainly through canal irrigation. Hence water saving through SRI means the available water/surplus water saved can command more area than what is being irrigated under conventional practice.

Water productivity

Water productivity was highest (0.47 kg/m^3) in the T4 where SRI practice was applied with wider spacing of 30x30 cm followed by 0.46 kg/m^3 in T3 with spacing of 25x25 cm. Water productivity was lowest (0.136 kg/m^3) in continuously flooded plots with normal seedlings and closer spacing (Figure 6). Statistically at $p<0.05$, water productivity at T1 was significantly different from all other treatments (Table 4).

The seasonal crop water requirement for rice may differ depending on geographic conditions and time of the year. For example in sub-humid climates of

Table 5: Amount of water required to produce 1 kg of rice.

Treatment	Water Productivity (kg/m^3)	Equivalent amount of water used to produce 1kg of rice (lts/kg)*
T1	0.14	7347.54
T2	0.27	3713.33
T3	0.47	2132.65
T4	0.47	2115.95
T5	0.29	3444.71

* Amount of water used to produce 1kg (rice water footprint) as per literature (lts/kg) is 2,500 – 5000 (IRRI, 2009; Mekonnen, and Hoekstra, 2011).

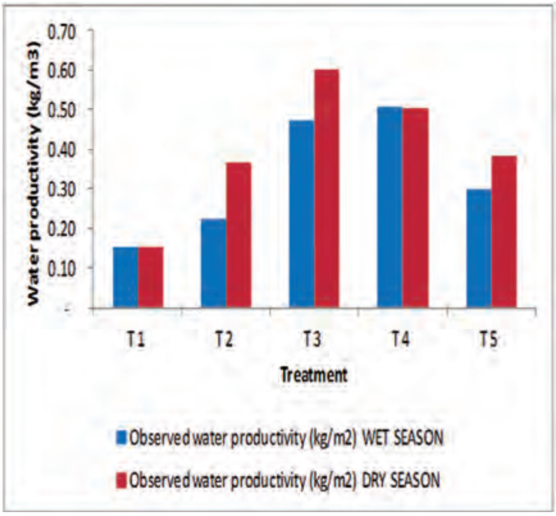

Figure 6: Water productivity under different treatments during wet and dry season at Mkindo.

south India it requires 586-599 mm (Mohan *et al*, 1996), while in semi-arid conditions it may require up to 800 mm (Ahmad *et al*, 2005). Generally according to FAO (1986) approximate values of seasonal crop water needs for paddy rice is between 450-700 mm.

Water requirement for crop production can also be estimated on the basis water footprint concept (e.g. Mekonnen and Hoekstra, 2011) whereby the amount of water used to produce 1 kg of rice is calculated. Based on literature, it takes about 2,500-5,000 litres water to produce 1 kilogram of rice (IRRI, 2009; Mekonnen and Hoekstra, 2011). The contribution of paddy rice to the total water footprint of crop production is estimated as 13% (Mekonnen, and Hoekstra, 2011). For treatment T1 a WP of 0.136 kg/m^3 is equivalent to a water footprint of 7347 litres per 1 kg of rice. For T4 where WP was 0.47 kg/m^3, it is equivalent to 2132 litres to produce one kg of rice, which is far below the world approximate values (Table 5). The higher irrigation water use for T1 might be caused by the soil type in Mkindo area whereby the soils have high infiltration rates of 12cm/day.

SUMMARY AND CONCLUSION

Field experiments and testing of SRI practice have demonstrated the potential of SRI to increase rice yields and water productivity in Mkindo area, Morogoro region in Tanzania. The testing, which involved both on-station scientific experimental plots and farmers field trials (FFS), were conducted during the wet and dry seasons. Results have indicated that SRI techniques results in higher grain yield (4.7 - 6.3 tons/ha) than the conventional practice (3.8 tons/ha).

Optimum SRI spacing for Mkindo area that gave best results was found to be 25x25 cm up to 30x30 cm. The appropriate intermittent irrigation with alternate wetting and drying intervals of three days was observed to be a suitable irrigation scheduling for Mkindo soils in the absence of rainfall. The indicator for restarting irrigation delivery after development of hairline cracks on the soil surface in Mkindo soils was quantified soil matric tension of 20 cent bars measured by tensionmeter, which is equivalent to 35% moisture content volume. SRI demonstrated water saving of up to 63.72% for Mkindo area. This implies that it is possible to reduce significantly the amount of water used for rice cultivation. The water saving and higher water productivity (0.47 kg/m^3) from SRI practice compared to conventional practice of continuous flooding (0.14 kg/m^3) also indicated that SRI practice can potentially be used to grow paddy rice in water-scarce environment. Notwithstanding, experiments need to be done to customize the components of SRI practice in different geographic locations as parameters such as plant spacing and alternate wetting and drying regimes depend on soil conditions and other biophysical factors. Therefore, further on-farm participatory research will be required in different parts of the country to introduce site-specific adaptations and expose farmers and extension agents to the SRI practice.

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REFERENCES

Ahmad, M.D., Masih, I. and Turral, H. (2004). Diagnostic analysis of spatial and temporal variations in crop water productivity: A field scale analysis of the rice-wheat cropping systems of Punjab, Pakistan. J. Appl. Irrig. Sci. 39: 43-63.

Chapagain, J. and Riseman, A. (2011). Achieving more with less water: alternate wet and dry irrigation (AWDI) as an alternative to the conventional water management practices in rice farming. Journal of Agricultural Science 3(3): 3-13.

FAO, (1986). Irrigation Water Management: Irrigation Water Needs. A training manual No. 3 of the United Nation's Food and Agriculture Organization. FAO, Rome, Italy. [http://www.fao.org/docrep/s2022e/s2022e00.htm#Contents] accessed 31/07/2014.

FAO, (2008a). Climate Change, Water and Food Security. Technical background document from the expert consultation held on February 26-28, 2008. FAO, Rome, Italy. [www.fao.org/nr/water/docs/HLC08-FAOWater-E.pdf accessed on 20/11/2011]

FAO, (2008b). Food and Agriculture Organization: Agricultural production data. FAOSTAT, FAO. [http://faostat.fao.org accessed on 01/04/2013].

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research: An International Rice Research Institute Book. Wiley Interscience Publications, John Wiley and Sons, Inc. New York, USA.

IRRI, (2009). How much water does rice need? Rice Today 8(1): 28-29. International Rice Research Institute, ISSN 1655-5422.

IWMI, (2007). International Water Management Institute. Rice: Feeding the Billions, Chapter 14: Water for Food, Water innovations: Stockholm, Sweden.

Katambara, Z., Kahimba, F.C., Mahoo, H.F., Mbungu, W.B., Mhenga, F., Reuben, P., Maugo, M., Nyarubamba, A. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. Agricultural Sciences 4(8): 369-375.

Keisuke, S., Yamaji, E., Sato, S., Budhiharto, P. S., & Mizoguchi, M. (2007). Sustainability of System of Rice Intensification: Benefits of SRI focusing on effects of intermittent irrigation on yield increase and water savings. In: Proceeding of PAWEES 2007 6th International Conference on Sustainable Rural Development and Management (pp. 25-37), 18 October 2007. South Korea: Seoul National University.

Krishna, A., Biradarpatil, N.K. and Channappagoudar, B.B. (2008). Influence of system of rice intensification (SRI) cultivation on seed yield and quality. Agricultural Sciences 21(3): 369–372.

Laulanı´e, H. (1993). Technical presentation on the System of Rice Intensification, based on Katayama's tillering model. Unpublished paper, translated from French, available from Cornell International Institute for Food, Agriculture and Development, Ithaca, NY.

Mekonnen, M.M. and Hoekstra, A.Y. (2011). The green, blue and grey water footprint of crops and derived crop products. Hydrol. Earth Syst. Sci. 15: 1577–1600.

Mghase, J.J., Shiwachi, H., Nakasone, K., and Takahashi, H. (2010). Agronomic and socio-economic constraints to high yield of upland rice in Tanzania. African Journal of Agricultural Research 5(2): 150-158.

Mohan, S., Simhadrirao, B. and Arumugam, N. (1996). Comparative study of effective rainfall estimation methods for lowland rice. Water Res. Manage. 10: 35-44.

Nyirenda, M.E., Tarimo, A.K.P.R. and Kihupi, N.I. (2010). Yield response of different local and hybrid rice varieties to different ponding depths of water. Comprehensive Assessment of Water Management in Agriculture. Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda.

Sato, S. and Uphoff, N. (2007). A review of on-farm evaluation of system of rice intensification (SRI) methods in Eastern Indonesia. In: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. Commonwealth Agricultural Bureau International, Wallingford, UK.

Sinha, S.K., and Talati, J. (2007). Productivity impacts of the system of rice intensification (SRI): a case study in West Bengal, India. Agricultural Water Management 87:55–60.

SIWI, (2005). Stockholm International Water Institute (SIWI) policy institute for seeks sustainable solutions to the world's escalating water crisis. [www.siwi.org/documents/Resources/Water accessed on 10/11/2013].

Tabbal, D.F., Lampayan, R.M. and Bhuiyan, S.I. (1992). Water-efficient irrigation technique for rice. In: Proc. International workshop on soil and water engineering for paddy field management. Asian Institute of Technology, Bangkok, Thailand. 28–30 January 1992.

Uphoff, N. (2007). The system of rice intensification: using alternative cultural practices to increase rice production and profitability from existing yield potentials. International Rice Commission Newsletter, Number 55, UN. Food and Agriculture Organization, Rome.

Vijayakumar, M., Ramesh, S., Chandrasekaran, B., and Thiyagarajan, M. (2001). Effects of system of rice intensification (SRI) practices on yield attribute and water productivity of rice (Oryza sativa l.). Res J Agric Biol Sci. 2(6):236–242.

WARDA, (2005). Rice, a strategic crop for food security and poverty alleviation. [www2.slu.se/cigar/CGIAR_WARDAppt] accessed on 01/08/2014.

WARDA, (2007). Africa Rice Centre. Medium Term Plan 2008-2010. Charting the Future of Rice in Africa. Africa Rice Center (WARDA), 01 B.P. 2031, Cotonou Benin. [http://www.adrao.org/publications/MTP/MTP2008-2010.pdf] accessed on 01/08/2014.