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Improving Grain Yield, Water Productivity, and Savings of Paddy Rice Production under Regulated Deficit Irrigation (DI) Management through the System of Rice Intensification (SRI) Practices

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ABSTRACT

A study on improving the grain yield, water productivity and savings of paddy rice production under regulated deficit irrigation management through the SRI Practices was carried out and the best suitable deficit irrigation regime compared to Conventional farming method was identified. A total of 12 treatments consisting of four SRI Water Application Levels and three levels of irrigation intervals at different growth stages were conducted. The performance of those treatments in terms of grain yield, water productivity and savings were compared to the conventional farming system. The study revealed that on average, SRI treatments which involved Alternate Wetting and Drying cycles has significantly improved water productivity by 100 – 200 % relative to conventional farming systems that involve continuous flooding. In contrast to the conventional farming system in the current study, SRI practice increased rice yield by about 74.7 %, 68.5 % and 53.8 % at irrigation intervals of 3, 4, and 2-days respectively. The average mean of SRI Irrigation water savings with respect to conventional method varied from 29.4 % to 54.6 %. 25% and 50% deficit water application at vegetative and grain filling stages at 4-day intervals under SRI (T_{12} and T_{11}) were statistically similar and significantly higher with 54.6 % and 52.1 % respectively, while the least value of 29.5 % was recorded for T_1 (no deficit). Generally, the most suitable deficit irrigation regime compared to conventional farming method were at 25 %, 50 % and 75 % at 3-days irrigation intervals and were capable of producing 11.93 t/ha, 11.71 t/ha and 11.37 t/ha of paddy rice, which were 81 %, 77 % and 72 % respectively higher than conventional practice. These treatments also showed 51 %, 48 % and 44 % irrigation water savings and water productivity of 178 %, 206 % and 233 %, respectively.

Keywords: Improving, System of Rice Intensification, Grain Yield, Water Productivity, Irrigation Water Savings, Paddy Rice Cultivation, Deficit Irrigation Interval

INTRODUCTION

Worldwide, the agricultural sector makes the largest demands of any sector on our finite freshwater resources. It is estimated that 69% of worldwide water use goes to irrigation with 15-35% of irrigated withdrawals being unsustainable (Radwan *et al.,* 2010). Within the agricultural sector, irrigated rice production is the largest source of demand for fresh water. Tremendous amount of water is used for rice irrigation under the traditional irrigation technique known as continuous deep flooding irrigation technique. In this technique, the paddy fields are inundated all the time starting from transplanting until near harvesting (Li and Barker, 2004) at a certain water depth that varies from 50 to 100 mm.

As populations continue to grow, water availability in per-capita terms declines each year, until population growth ceases. As economic development proceeds, competing demands for water will make it imperative for agriculture to become more water-economizing in its production methods. Growing evidence indicates that the challenge of reducing water consumption in the rice sector can be met not with a compromise or some second-best solution, but in a positive-sum way with multiple benefits. Practices are available for growing rice with less water so that the productivity of the land, labor and capital used in rice production is raised all at the same time while making water more productive. This comes basically from nurturing roots rather than drowning them (Uphoff, 2006). Moreover, experience with the System of Rice Intensification (SRI) tells us that farmers who grow irrigated rice with continuous flooding of their paddies have been wasting large volumes of water for centuries, even millennia. Fortunately, more rice can be produced by using less water, provided that concurrent changes are made in the way that plants, soil and nutrients are managed (Uphoff and Randriamiharisoa, 2002).

System of Rice Intensification (SRI) is a new system of rice cultivation for increasing rice yield (35 - 100%) with a comprehensive package of practices involving less seed, water, chemical fertilizers and pesticides; inducing larger, better-functioning root systems and more abundant, diverse and active communities of soil biota that live in association with those root systems (Randriamiharisoa *et al.,* 2006). This system of rice intensification was first tried in Madagascar in 1999; and since 2000, it has spread to many countries with spectacular results (Uphoff, 2012). The rapid dissemination of this system lies in the fact that it increases rice yields dramatically without requiring extra seeds, chemical fertilizers or other external inputs (Uphooff, 2012). The SRI efficiently uses scarce land, labour, capital and water resources, protects soil and groundwater from chemical pollution, and is accessible to poor farmers. It is spreading fast because it is versatile and can provide more than double farmers' net income (Uphoff, 2012).

In short, SRI is a method of cultivation that follows the principles of using young and single seedlings per hill at wide spacing, intermittent irrigation, application of organic manures and mechanical weed management (Styger *et al*., 2011) and the productivity is maximized by an increase in the number of tillers per plant, and accelerated growth rate by the shortening of phyllochorons (Nemoto *et al*., 1995).

Nigeria has tremendous potential like good soils, a favorable climate, two growing seasons and an abundance number of farmers whose survival relied on their crop cultivation. Knowing a new concept of increasing its rice production and moving to self-sufficiency in rice cultivation would save the country the huge foreign exchange used for importing rice. Besides, Nigeria can in no distant future join other large producers of rice globally by exporting its own rice to the needy and neighboring countries. However, rice cultivation is still relatively new in the country's farming system and the industries and farmers alike are therefore still hampered by a number of knowledge and information gaps mainly at the production levels. The answer to the above problem is the System of Rice Intensification (SRI) methodology.

The main aim of this study is to investigate the effects of deficit irrigation scheduling on reducing water requirements and increasing the yield of irrigated rice production under the system of rice intensification (SRI) and to identify the best suitable deficit irrigation regime for optimal water-saving and yield output compared to the conventional farming system in the Irrigation Research Station of Kadawa, Garum Malam Local Government, Kano State.

MATERIALS AND METHODS

The Study Area

The experiment was conducted during 2017/2018 and 2018/2019 irrigation farming seasons at the Irrigation Research Station of Kadawa (Figure 1), within the Kano River Irrigation Project (KRIP) Phase I. The Kano River Irrigation Project Phase I lie about 30 km south of Kano city, on either side of the Kano-Zaria express way. The project was commissioned by the Kano State government in 1970. Kano State of Nigeria lies between Latitude 11°30' to 12°03'N and Longitude 8°30' to 09°40'E with an altitude of 486 m above sea level within the Hadeja-Jama're River Basin, covering an area of about 75,000 hectares. Irrigation water from the Tiga dam on the Kano River comes through a 22.5 km canal by gravity flow to the farms. The dry irrigation period normally runs from March to June. The main crops cultivated under irrigation include groundnut, garlic, cotton, guinea corn, millet, maize, rice, cow-pea, wheat and vegetables such as tomato, pepper, onions, cabbage, etc. The major types of irrigation systems practiced are basin, furrow and other border irrigation systems.

Climatic Condition of the Study Area

Kano State is blessed with abundant fertile land within the Sudan savannah region. The climatic condition is typical of the Sudan savannah ecological zone which divides the years into three distinct periods; the warm-rainy season from June to September, the cool-dry season from November to February, and the hot-dry season from March to June. The southernmost area is characterized by the northern Guinea savannah and the northernmost section is characterized by the Sahel. The state has the tropical wet-and-dry type climate with relatively wide and rapid changes in temperature and humidity. The mean daily maximum and minimum temperatures are 31°C and 21°C, respectively. The year is divided into well marked rainy and dry seasons. The dry season lasts from October to June. During the month of November and January, the Harmattan (dry north-easterly winds) is at its height blowing thin dust over the state from the Sahara Desert, at this time temperature can fall to as low as 15°C. From March to May, however, the dry, cold air humidifies, beaming hot air with temperatures rising to more than 40°C. Rainfall is concentrated between July and September with maximum and minimum of 214.0 mm and 132.7 mm, respectively. The rains are preceded by violent sand storms followed by tornadoes mainly during the months of May and June. The average annual rainfall is 884.4 mm with 60% of which falls in July and August. The five-month period of rainfall and seven-month period of dry season allow farmers to have two to three cropping seasons per year using irrigation water and rainfall (Adamu, 2016).

Soil Condition of the Site

The geology of the project area is belongs to the Northern Nigerian Complex (NADECO, 1976) which is heterogeneous complex of rocks. The dominant rock types are granitic gneisses and schists. In many places the original material is overlain by alluvial and Aeolian material which resulted into different land forms. Generally, the soils of the project area belong to Eutric Cambisol in FAO/UNESCO system (NADECO, 1976). They are moderately deep and well drained with sandy loam textured surface and sandy clay loam textured subsoil. Most of these soils are underlain by iron-pan at depths varying between 80 to150 cm (I.A.R. 1994).

Experimental Design, Field Layout and other Agronomic practices

The experiment was laid out in a randomized complete block design (RCBD) in split-plot arrangement, with three replications and 12 treatment combinations (Figure 2). The treatments include four SRI water application levels (WAL) at sub-plot, i.e.: 0.5 cm (25 %), 1 cm (50 %), 1.5 cm (75 %) and 2 cm (100 %) (Factor A); and three levels of irrigation intervals at 2-days, 3-days and 4-days, at main-plot (at different growth stages of the rice) given a total of 12 treatments and thirty six (36) plots units. The total field area was 1,023 m^2 (46.5 m x 22 m) at two different locations. The dimension of the individual plots was 5 m by 3 m (15 m^2). There will be a bund accounting to 0.5 m width between main plot and sub-plot. Each replication was separated by 1.5 m bund. The crop geometry of rice was 25 × 25 cm^2 (hill to hill and row to row spacing) with one seedling per hill (Figure 2)

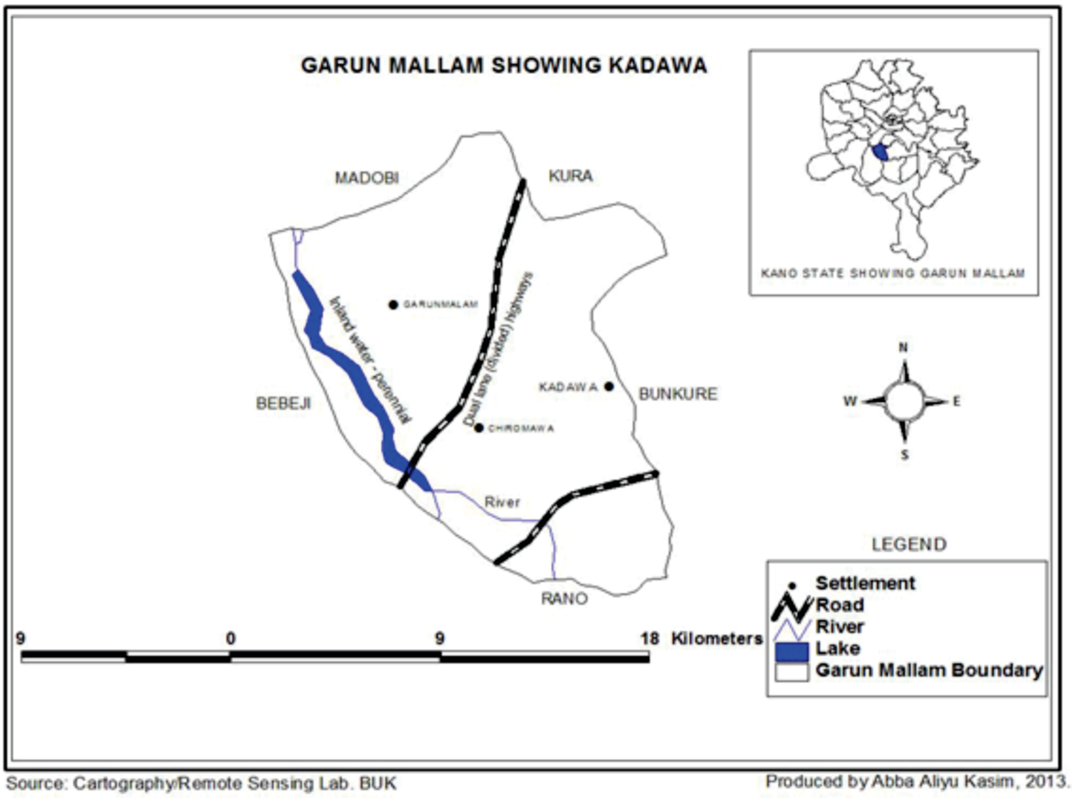
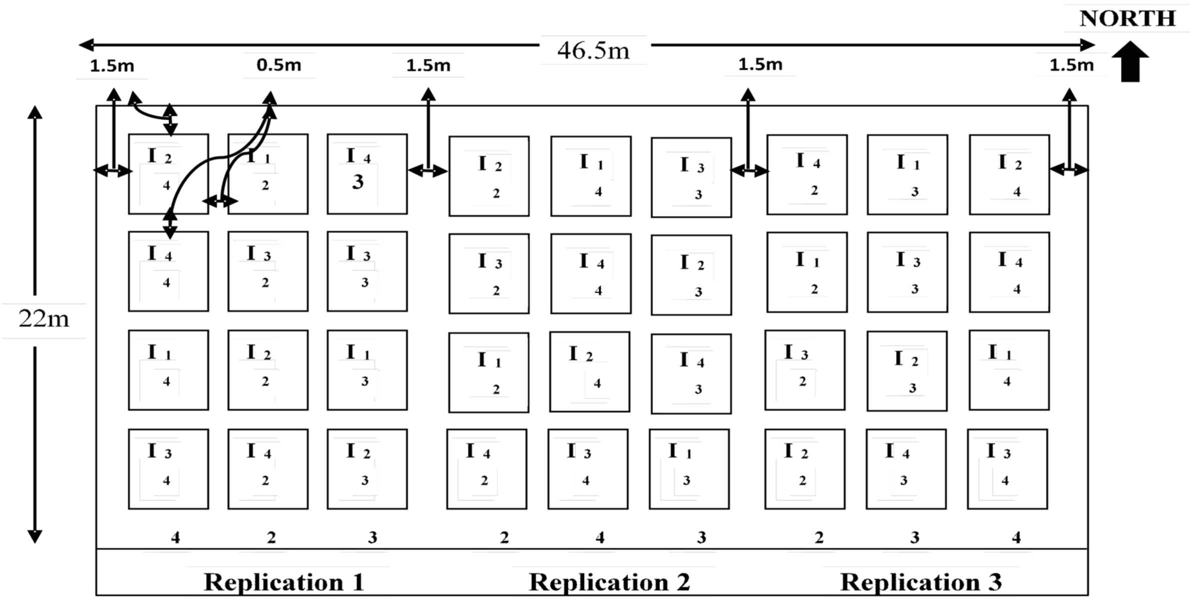


Figure 1: A Map Showing Kadawa, within the Kano River Irrigation Project

The experimental crop used was SIPII (Faro 44) rice variety. It is a long grained high yielding and an average duration rice variety with growth duration of 100-115 days. During the land preparation, 20 cm of the top soil was well loosened. One month later, ploughing, muddying, and leveling activities were conducted. Five (5) tones of organic fertilizer was initially applied before ploughing. N, P and K as well as Zn were applied at 120:80:80:25 kg/ha respectively (from Urea, DAP, MOP and $ZnSO_4$). Full doses of P, K and Zn were applied before the final land preparation as basal fertilizer. Urea was applied in three equal installments, i.e. 60 kg N/ha after seedling recovery (i.e. after the transplanted plant re-germinated) the remaining half dose of 60 kg N/ha was applied in two split doses, 30 kg N/ha at active tillering stage and 30 kg N/ha at panicle initiation stage for all treatments. Nursery was designed exactly like a vegetable plot, i.e. 5 m long and 1 m wide. The seedbed was covered with very loose, light soil with a depth of 15 cm. 1.5 kg of seed was used to sow the seedbed for use in transplanting in the experimental field. Transplanting activities was followed after one week of soil preparation. The



D_1 ($I_{D100\%}$) = 0 % deficit irrigation depth or irrigation at 100 % SRI Water Application Level (WAL), D_2 ($I_{D75\%}$) = 25 % deficit irrigation depth or irrigation at 75% SRI WAL, D_3 ($I_{D50\%}$) = 50% deficit irrigation depth or irrigation at 50 % SRI WAL, D_4 ($I_{D25\%}$) = 75 % deficit irrigation depth or irrigation at 25 % SRI WAL. L_2 = Irrigation interval @ 2-days, L_3= Irrigation interval @ 3-days, L_4 (@4-days) = Irrigation interval @ 4-days.

Figure 2. The layout of Experimental Plots

transplanting work in SRI starts when the seedlings have two leaves (8-12 DAS) and seedlings were transplanted singly. The young seedlings were transplanted in a square grid pattern at 25x 25 cm spacing. The seedlings were lightly placed in the basin gently (at 1-2 cm depth within the mud), in the form of the letter «L». After transplanting, the plot was lightly irrigated to maintain moisture during the first two weeks. Data collected were subjected to statistical analysis of variance. Treatment means and significant differences were evaluated using Duncan's new multiple range test (DMRT) at 1 and 5% significant level.

Data Collection

Data collection from the field experiment was commenced a day of transplanting. Climatic data were collected from a weather station on the site. Phonological data such as dry weight of plant at each growing stage were recorded randomly from 10 hills per m^2 of land area and the average result was calculated every 20 days after transplanting (Figure 3).

At the end of the growing cycle dry grain and biomass yields were computed by harvesting 9 m^2 equally distributed in every plot. The paddy rice was dried, threshed, sun dried, cleaned and again dried to maintain 14% moisture content and the weight of final grain yield (expressed as ton per hectare) was computed for each treatment randomly from the net plot yields. The grain yield per hectare was obtained by subtracting the straw yield from the total biomass. The daily irrigation water use from each plot was determined with the aid of aqua-Crop model from the climatic data collected on the site. Groundwater levels have been noted from each experimental plot every two days from the installed water access-tube.

Irrigation

In this research work, Alternate Wetting and Drying (AWD) irrigation method was used. AWD is a technology for water saving in rice production. Under this practice, the rice paddies are irrigated intermittently during the vegetative growth stage in order to keep the soil moist under aerobic conditions in contrast to the conventional method where the soil is continuously flooded.

In AWD an access tube (Plate Ia) was installed at the center of each basin and the next irrigation was applied when the water within the access tube fall below 15 cm from a ponding depth of 2cm. In this study, the irrigation intervals were determined based on this principle (Plate Ib), and it was discovered that the water level fell within 10-15 cm, 15-25 and 25-30 cm after two, three and four days after irrigation respectively. Therefore, the irrigation intervals of 2, 3, and 4 days were chosen for this study. The initial soil water content at the top of soil during transplanting was assumed to be close to field capacity as a result of pre-irrigation a day before transplanting. However, each treatment was irrigated up to a ponding depth of 2 cm throughout the establishment stage in order

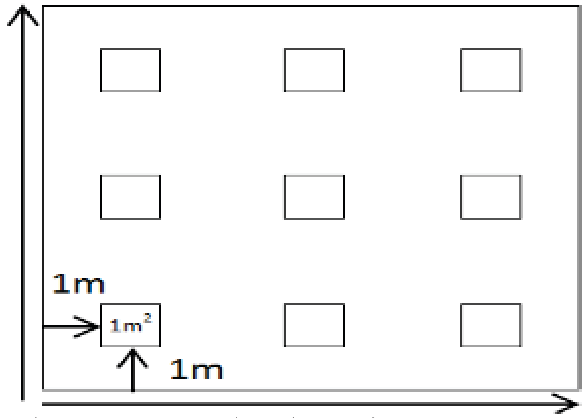


Figure 3: Research Scheme for Harvest across Experimental Plots

to maintain humidity during the first two weeks (since small vegetable seedlings are extremely very sensitive to moisture stress). After two weeks the deficit irrigation treatments were applied to each plot according to the treatments specification (as described in Table 1) from panicle initiation (PI) to grain filling stage. However, during flowering stage, a thin layer of water (2cm) was kept on the entire plots and the normal AWD was continue during grain filling growth stage

Determination of Irrigation Water Productivity

Crop water productivity in terms of crop irrigation water used efficiency was determined as defined by Michael (1978):

$$\textbf{WUE} = \frac{Y}{Qf} \qquad \textbf{(1)}$$

Where,

IWUE is the irrigation water use efficiency in kg/m^3, Y is the crop yield in kg/ha, which may be defined in terms of the dry matter production or marketable product, Q_f is the total amount of water used in the field in m^3/ha.

Determination of Irrigation Water Savings

$$\textbf{IWS} = \frac{SIWU_{SRI} - SIWU_{CONV.}}{SIWU_{CONV.}} \qquad \textbf{(2)}$$

Where,

IWS is irrigation water savings in % $SIWU_{SRI}$ is the seasonal irrigation water use in SRI plots in m^3/ha, $SIWU_{CONV}$, is the seasonal irrigation water use in conventional farming system plots in m^3/ha

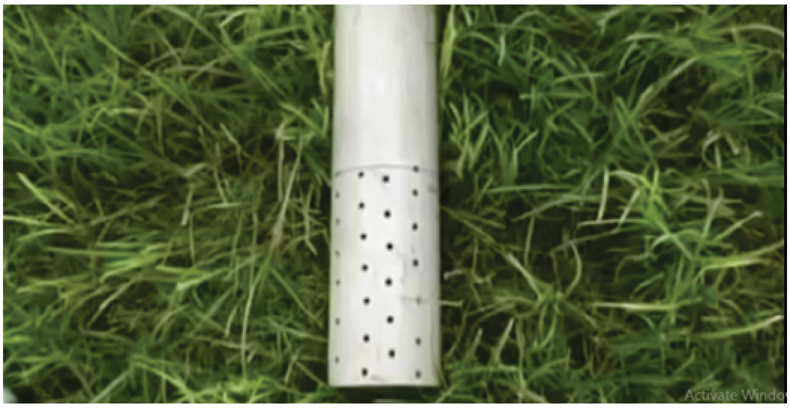


Figure 4: The Fabricated Length of the Water Tube

Figure 5: Safe Alternate Wetting and Drying (SAWD) Method of Irrigation

Table 1. Treatments Details and Symbols

Treatment	Rice Growth Stages				Treatments Description
	Initial	Vegetative	Flowering	Grain filling	
T_1 ($I_{D100\%}$ @ 2Days)	100	100	100	100	Irrigation at 100% of SRI Water Application Level (WAL) at all the growth stages after every 2 days.
T_2 ($I_{D75\%}$ @ 2Days)	100	75	100	75	Irrigation at 75% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 2 days.
T_3 ($I_{D50\%}$ @ 2Days)	100	50	100	50	Irrigation at 50% of SRI WAL during veget ative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 2 days.
T_4 ($I_{D25\%}$ @ 2Days)	100	25	100	25	Irrigation at 25% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growt h stages after every 2 days.
T_5 ($I_{D100\%}$ @ 3Days)	100	100	100	100	Irrigation at 100% of SRI Water Application Level (WAL) in all the growth stages after every 3 days.
T_6 ($I_{D75\%}$ @ 3Days)	100	75	100	75	Irrigation at 75% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 3 days.
T_7 ($I_{D50\%}$ @ 3Days)	100	50	100	50	Irrigation at 50% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages a fter every 3 days.
T_8 ($I_{D25\%}$ @ 3Days)	100	25	100	25	Irrigation at 25% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 3 days.
T_9 ($I_{D100\%}$ @ 4Days)	100	100	100	100	Irrigation at 100 % of SRI Water Application Level (WAL) in all the growth stages after every 4 days.
T_{10} ($I_{D75\%}$ @ 4Days)	100	75	100	75	Irrigation at 75% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 4 days.
T_{11} ($I_{D50\%}$ @ 4Days)	100	50	100	50	Irrigation at 50% of SRI WAL during vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 4 days.
T_{12} ($I_{D25\%}$ @ 4Days)	100	25	100	25	Irrigation at 25% of SRI WAL duri ng vegetative and grain filling and 100% of SRI WAL at initial and flowering growth stages after every 4 days.

Irrigation at 100% SRI WAL = Irrigation at a ponding depth of 20mm (0% deficit irrigation depth), Irrigation at 75% SRI WAL = Irrigation at a ponding depth of 15 mm (25% deficit irrigation depth), Irrigation at 50% SRI WAL = Irrigation at a ponding depth of 10mm (50% deficit irrigation depth), Irrigation at 25% SRI WAL = Irrigation at a ponding depth of 5mm (75% deficit irrigation depth)

RESULTS AND DISCUSSIONS

Preamble

In this section, the results and discussions on grain yield, water productivity and savings of paddy rice production as influenced by the regulated deficit irrigation management through SRI practices were presented.

Effect of SRI Practices on Average Means Grain Yield in the Study Area

The results on the average means grain yields across SRI treatments and the average estimated value of conventional farming method in the 2017/2018 and 2018/2019 irrigation seasons are shown in Table 2. The average means results of SRI treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, and T_{12} relative to conventional farming method show an increase of 44%, 52%, 58%, 63%, 68%, 73%, 78%, 81%, 72%, 70%, 67% and 66 % respectively. The average means grain yield increases of 44 - 81% over the conventional farming system were recorded as a result of the SRI treatments. Moreover, the result agreed with the finding of Randriamiharisoa *et al.,* (2006) who said that "SRI is a new system of rice cultivation for increasing rice yield by 35 – 100 %". The study also was in agreement with the result found by Krishna *et al.* (2008) and Vijaya kumar *et al.* (2001). According to the authors, higher grain yields are achieved in SRI; when younger seedlings transplanted singly at wider spacing, under non-flooded soil conditions were used.

Effect of SRI Practices on Average Means Water Productivity in the Study Area

The results on the average means Water productivity across SRI treatments and the average estimated value of conventional farming method in the 2017/2018 and 2018/2019 irrigation season are shown in Table 3. The average means results of SRI treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, and T_{12} relative to conventional farming method show an increase of 100%, 128 %, 156 %, 189 %, 178 %, 206 %, 233 %, 261 %, 217 %, 228 %, 244 % and 261 % respectively. On average, SRI treatments which involved Alternate Wetting and Drying Cycle have substantially improved the rice water productivity by 100 – 200 %, compared to conventional farming method that involves continuous flooding on the basis of 5-10 cm water application level at interval of 2 to 3-days. These results agree with that found by Kumar *et al*. (2006) on SRI and traditional farming method. In that research, the researchers found that the water productivity of rice was significantly increased by 91.3 % to 194.9 % by applying SRI with 14-days old seedlings planted at 25-25 cm spacing compared to the conventional method. Chapagain and Yamaji (2009) based on an experiment conducted in Japan reported that combination of practices in the intermittent irrigation plots yielded 1.74 g grain/kg water with SRI management and AWD as compared to 1.23 g grain/kg water from normal planting methods with ordinary water management. The low yield reported in the experiment was probably caused by cold weather.

Table 2. Percentage Difference in Grain Yield of SRI treatments Relative to Conventional Farming Method during 2017/2018 and 2018/2019 Seasons

Treatment	Total Grain Yield (kg/ha)	% Difference of SIWS Relative to Conventional (%)
To (Conventional)	6587.000	-
T1 ($I_{D100\%}$ @ 2Days)	9468.439	44
T2 ($I_{D75\%}$ @ 2Days)	9995.296	52
T3 ($I_{D50\%}$ @ 2Days)	10408.94	58
T4 ($I_{D25\%}$ @ 2Days)	10726.63	63
T5 ($I_{D100\%}$ @ 3Days)	11072.68	68
T6 ($I_{D75\%}$ @ 3Days)	11373.33	73
T7 ($I_{D50\%}$ @ 3Days)	11712.38	78
T8 ($I_{D25\%}$ @ 3Days)	11928.91	81
T9 ($I_{D100\%}$ @ 4Days)	11310.16	72
T10 ($I_{D75\%}$ @ 4Days)	11206.50	70
T11 ($I_{D50\%}$ @ 4Days)	10993.99	67
T12 ($I_{D25\%}$ @ 4Days)	10937.88	66

Source: Field Survey, 2017/2018 and 2018/2019; SIWS = Seasonal Irrigation Water Savings, I_{D100} = 0 % deficit irrigation depth, I_{D75} = 25 % deficit irrigation depth, I_{D50} = 50 % deficit irrigation depth, I_{D25} = 75 % deficit irrigation depth. @ 2days = irrigation interval at 2 days, @ 3-days = irrigation interval at 3-days and @ 4-days = irrigation interval 4-days.

Effect of SRI on Average Means Seasonal Irrigation Water Savings in the Study Area

The percentage increases in the results of average means seasonal irrigation water savings (IWS) across SRI treatments relative to conventional farming method in the 2017/2018 and 2018/2019 irrigation season are shown in Table 4.

These results indicate that SRI treatments were capable of savings 29.5 %, 34.4 %, 39.5 %, 44.6 %, 40.9 %, 44.1 %, 47.5 %, 50.8%, 47.0%, 49.55%, 52.1% and 54.6 % respectively for treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, and $T_{12.}$ On average SRI treatments have recorded a convincing increase of approximately 30 to 55 % over conventional farming method. These results agreed well with the findings reported by Sato and Uphoff (2006) 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 yield loss compared with the traditional practice of continuous shallow submergence if a very thin water layer is maintained at saturated soil condition. Keisuke *et al.* (2007) also reported a 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.,

The Effects of Deficit Irrigation Depth and Irrigation Intervals on Seasonal Means Grain Yield, Irrigation Water Use Efficiency (IWUE) and Irrigation Water Savings (IWS) of Rice under SRI Practice at Kadawa in 2017/2018 and 2018/2019 Irrigation season.

Effect of Deficit Irrigation Depth and Interval on Seasonal Means Grain Yield

The statistical means analyses on the results of total grain yield in SRI practice as affected by deficit irrigation depth and intervals during 2017/2018 and 2018/2019 irrigation seasons were shown in Table 5.

The means grain yield of the paddy rice was not affected by the SRI deficit irrigation depth at both 5 % and 1 % probability level but when the means grain yield was analysed with respect to irrigation interval, there were differences at 5 % probability level. The highest mean grain yields of 11.49 t/ha was recorded at irrigation interval of 3-days which was statistically comparable to 11.08 t/ha recorded at 4-days irrigation interval, while the lowest mean grain yield of 10.20 t/ha was recorded at irrigation interval of 2-days during 2017/2018 irrigation season. However, during 2018/2019 irrigation season, a statistically similar mean result of 11.56 t/ha was recorded at irrigation interval of 3-days which was comparable to 11.15 t/ha recorded at irrigation interval of 4-days, while

Table 3. Percentage Difference of the Average Mean Water Productivity (WP) of SRI Relative to Conventional Farming Method during 2017/2018 and 2018/2019 Irrigation Seasons

Treatment	Total Grain Yield (kg/ha)	Seasonal Irrigation Water Use (m^3/ha)	Water Productivity (kg/m^3)	% Difference
To (Conventional)	6587.00	373340	0.18	0
T1 ($I_{D100\%}$ @ 2Days)	9468.44	264580	0.36	100
T2 ($I_{D75\%}$ @ 2Days)	9995.30	246395	0.41	128
T3 ($I_{D50\%}$ @ 2Days)	10408.94	227603	0.46	156
T4 ($I_{D25\%}$ @ 2Days)	10726.63	209075	0.52	189
T5 ($I_{D100\%}$ @ 3Days)	11072.68	221755	0.50	178
T6 ($I_{D75\%}$ @ 3Days)	11373.33	209698	0.55	206
T7 ($I_{D50\%}$ @ 3Days)	11712.38	197373	0.60	233
T8 ($I_{D25\%}$ @ 3Days)	11928.91	185055	0.65	261
T9 ($I_{D100\%}$ @ 4Days)	11310.16	198895	0.57	217
T10 ($I_{D75\%}$ @ 4Days)	11206.50	189948	0.59	228
T11 ($I_{D50\%}$ @ 4Days)	10993.99	180605	0.62	244
T12 ($I_{D25\%}$ @ 4Days)	10937.88	171523	0.65	261

Source: Field Survey, 2017/2018 and 2018/2019; I_{D100}= 0 % deficit irrigation depth, I_{D75}= 25 % deficit irrigation depth, I_{D50}= 50 % deficit irrigation depth, I_{D25}= 75 % deficit irrigation depth. @ 2-days = irrigation interval at 2-days, @ 3-days = irrigation interval at 3-days and @ 4-days = irrigation interval 4-days.

the lowest mean value of 10.11 t/ha was recorded at irrigation interval of 2-days.

Generally, the highest seasonal average means grain yields of 11.53 t/ha and 11.12 t/ha were recorded at irrigation intervals of 3 and 4-days respectively, while the lowest average mean of 10.15 t/ha was recorded at irrigation interval of 2-days. Moreover, there was no interaction effect recorded among the treatment factors; since deficit irrigation depth x irrigation interval at 5 % probability level are not significant.

Effect of Deficit Irrigation depth and Interval on Seasonal Means Water Use Efficiency

The results of the effects of deficit irrigation depth and irrigation intervals on the seasonal means irrigation water use efficiencies (IWUE) of the rice under SRI practice compared to conventional farming method during 2017/2018 and 2018/2019 irrigation seasons were given in Table 5. Statistically significant variation of seasonal means irrigation water savings relative to conventional farming system were recorded with respect to SRI deficit irrigation depths and irrigation interval.

The analyses of means values of IWUE during 2017/2018 irrigation seasons with respect to irrigation depth indicate that, treatments $I_{D25\%}$ (75 % deficit irrigation) is comparable to $I_{D50\%}$ (50 % deficit irrigation) and showed the highest means values of 0.62 kg/m^3 and 0.56 kg/m^3 respectively; while the least mean value of 0.482 kg/m^3 was observed in treatment $I_{D100\%}$.(0 % deficit irrigation). Moreover, statistically similar results of IWUE were recorded during 2018/2019 irrigation seasons, where the same treatments $I_{D25\%}$ and $I_{D50\%}$ gave the highest means values of 0.60 kg/m^3 and 0.55 kg/m^3 respectively, while the least mean value of 0.47 kg/m^3 was also recorded in treatment I_{D100}. On average, the highest seasonal means water use efficiency of 0.605 kg/m^3 and 0.56 kg/m^3 were recorded at 75 % deficit irrigation depth ($I_{D25\%}$) and 50 % deficit irrigation ($I_{D50\%}$), while the lowest average mean of 0.48 kg/m^3 was recorded at 0% deficit irrigation depth ($I_{D100\%}$). However, when means values of WUE during 2017/2018 irrigation season was analyzed with respect to irrigation interval, the highest mean values of 0.61 kg/m^3 was obtained at 4-days irrigation interval which is comparable to 0.578 kg/m^3 recorded at 3-days irrigation interval. The least mean value of 0.443 kg/m^3 was recorded at 2-days irrigation interval. Similarly, the results of WUE during 2018/2019 irrigation season also recorded the highest means values of 0.601 kg/m^3 and 0.571 kg/m^3 at irrigation interval of 4 and 3-days respectively, while the least mean value of 0.431 kg/m^3 was also observed at 2-days irrigation interval. On average, the highest seasonal means water use efficiency of 0.608 kg/m^3 and 0.575 kg/m^3 were recorded at irrigation intervals of 3 and 4-days respectively, while the lowest average mean value of 0.437 kg/m^3 was recorded at irrigation interval of 2-days. Finally, there was no interaction effect among the treatment factors; since deficit irrigation depth x irrigation

Table 4. Percentage Difference of Average Mean Seasonal Irrigation Water Used (IWU) of SRI Relative to Conventional Farming Method during 2017/2018 and 2018/2019 Irrigation Seasons.

Treatment	Seasonal Irrigation Water Use (mm)	Seasonal Irrigation Water Savings relative to conventional (%)
To (Conventional)	3733.40	-
T1 ($I_{D100\%}$ @ 2Days)	2645.80	29.4
T2 ($I_{D75\%}$ @ 2Days)	2463.95	34.4
T3 ($I_{D50\%}$ @ 2Days)	2276.03	39.5
T4 ($I_{D25\%}$ @ 2Days)	2090.75	44.6
T5 ($I_{D100\%}$ @ 3Days)	2217.55	40.9
T6 ($I_{D75\%}$ @ 3Days)	2096.98	44.1
T7 ($I_{D50\%}$ @ 3Days)	1973.73	47.5
T8 ($I_{D25\%}$ @ 3Days)	1850.55	50.8
T9 ($I_{D100\%}$ @ 4Days)	1988.95	47.0
T10 ($I_{D75\%}$ @ 4Days)	1899.48	49.5
T11 ($I_{D50\%}$ @ 4Days)	1806.05	52.1
T12 ($I_{D25\%}$ @ 4Days)	1715.23	54.6

Source: Field Survey, 2017/2018 and 2018/2019; I_{D100} = 0 % deficit irrigation depth, I_{D75} = 25 % deficit irrigation depth, I_{D50} = 50 % deficit irrigation depth, I_{D25} = 75 % deficit irrigation depth. @ 2-days = irrigation interval at 2-days, interval at 5 % probability level are not significant. The result of this study agreed well with the finding of Uphoff, (2006) which reported that; growing rice with less water in SRI practice helps to increase rice production while making water more productive; which comes basically as a result of nurturing roots rather than drowning them.

Effect of Deficit Irrigation depth and Interval on Seasonal Means Irrigation Water-Saving

The results of the effect of deficit irrigation depth and irrigation interval on the mean Irrigation Water Savings (IWS) of rice in SRI practice compared to conventional farming method at Kadawa during 2017/2018 and 2018/2019 irrigation season were presented in Table 5. Significant variation of seasonal means results of irrigation water savings relative to conventional farming system were recorded with respect to SRI deficit irrigation depths.

The analyses of seasonal means irrigation water savings relative to conventional farming system with respect to deficit irrigation depth shows that, the highest mean value of irrigation water savings of 50.74 % was recorded at $I_{D25\%}$ (75 % deficit irrigation depth), while the lowest mean value of 39.54 % was found at $I_{D100\%}$ (0 % deficit irrigation depth) during 2017/2018 irrigation season. A statistically similar result was also recorded during 2018/2019 irrigation season, where the highest and lowest mean irrigation water savings of 49.24 % and 38.69 % were recorded at $I_{D25\%}$ and $I_{D100\%}$ respectively. On average, the highest mean results of Irrigation Water Savings (IWS) of 49.99 % was found at $I_{D25\%}$ (75 % deficit irrigation depth), while the lowest mean of 36.95 % was recorded $I_{D100\%}$. (0 % deficit irrigation depth)

When Irrigation Water Savings (IWS) was analyzed with respect to irrigation intervals, the means values of IWS at 4-days intervals was significantly higher with 51.45 % followed by 3-days interval with 46.32 %, while the least mean value of 37.52 % was recorded at 2-days irrigation intervals during 2017/2018 irrigation season. Similarly, the means results of IWS during 2018/2019 irrigation season, were also significantly higher at 4-days irrigation interval with a mean values of 49.73 % followed by 3-days irrigation interval with a mean value of 45.36 %, while the least mean value of 36.39 % was recorded at 2-days irrigation intervals. On average, the highest mean results of Irrigation Water Savings (IWS) of 50.59 % was found at 4-days, while the lowest mean of 36.95 % was recorded at 2-days irrigation intervalrespectively.

The interactions effects among the treatments factors, deficit irrigation depth x irrigation interval, during both 2017/2018 and 2018/2019 irrigation interval were found significant at 5 % probability level. The means results of Irrigation water savings varied from 29.87 % to 55.39 % and 28.99 % to 53.76 % respectively for the two seasons. During 2017/2018 irrigation season, Treatment T_{12} (irrigated at 75% deficit depth at 4-days irrigation interval) which is comparable to treatment T_{11} (irrigated at 50 % deficit depth at 4-days interval) were significantly higher with means values of 55.39 % and 52.83 % respectively, while the least mean value of 29.87 % was recorded in treatment T_1 (irrigated at 0 % deficit depth at 2days interval irrigation). During the irrigation season 2018/2019, treatment T_{12} also had the highest mean value of 53.76 % which is comparable to 51.37 % recorded in treatment $T_{11,}$ while the least mean value of 28.99 % was recorded for treatment T_1. On the average, the means results of irrigation water savings varied from 29.43 % to 54.57 %. Treatment T_{12} and treatment T_{11} were comparable and significantly higher with the means values of 54.57 % and 52.60 % respectively, while the least mean value of 29.5 % was recorded in treatment T_1

The Most Suitable Deficit Irrigation Regime for Optimal Water-Saving and Water productivity

The first suitable deficit irrigation regime compared to conventional farming system, were at 25 %, 50 % and 75 % at 3-days irrigation interval and were capable of producing 11.93 t/ha, 11.71 t/ha and 11.37 t/ha of paddy rice, which is respectively 81 %, 77 % and 72 % increase compared to conventional method. The treatments also recorded 51 %, 47.5 % and 44 % respectively of irrigation water savings and 178 %, 206 % and 233 % respectively of water productivity. The next suitable deficit irrigation regime compared to conventional farming system were at 75 % and 100 % at 4 days irrigation interval which produced 11.31 t/ha and 11.23 t/ha of paddy rice which is respectively 70 % and 71 % increase compared to conventional method. The treatments also recorded 49.5 % and 47 % respectively of irrigation water savings and 244 % and 261 % respectively of water productivity.

CONCLUSION

The study reveals that, on average, SRI treatments which involved Alternate Wetting and Drying Cycle significantly improved the water productivity by 100 to 200%, relative to conventional farming systems that involved continuous flooding on the basis of 5-10 cm water depth at an interval of 2 to 3 days. SRI practices increased rice yield by 74.70 %, 68.48 % and 53.79 % at irrigation interval of 3, 4, and 2-days, respectively. The average mean of Irrigation water savings varied from 29.4 % to 54.6 %. Treatment T_{12} (irrigated at 75 % deficit depth at 4-days interval) and treatment T_{11} (irrigated at 50 % deficit depth at 4days interval) were statistically similar and had values of 54.6 % and 52.1 % respectively water saving, while the least value of 29.5 % was recorded in treatment T_1 (irrigated at 0 % deficit depth at 2-days interval).

The most suitable deficit irrigation regime compared to conventional farming method were at 25 %, 50 % and 75 % at 3-days irrigation interval and were capable of producing 11.93 t/ha, 11.71 t/ha and 11.37 t/ha which are

81 %, 77 % and 72 % higher than conventional farming method. The treatments also recorded 51 %, 47.5 % and 44 % respectively of irrigation water savings and 178 %, 206 % and 233 % respectively of water productivity.

This implies that; SRI practice could be used to achieve a suitable water management in a more efficient and sustainable way and all the SRI treatments combination that involved Alternate wetting and drying cycle could be used to attain a better yield compared to conventional farming system in the study area.

Table 5. The Statistical Means of Grain Yield, Irrigation Water Use Efficiencies (IWUE) and Irrigation Water Savings (IWS) as Affected by Deficit Irrigation Depth and Irrigation Interval at Kadawa under SRI in 2017/2018 and 2018/2019 Irrigation Season.

Treatment	Grain Yield (t/ha)		IWUE (kg/m^3)		IWS (%)	
	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Irrigation Depths						
$I_{D100\%}$	10.63	10.60	0.48cd	0.47cd	39.54cd	38.69d
$I_{D75\%}$	10.83	10.89	0.52bc	0.51bc	43.14c	42.18c
$I_{D50\%}$	11.01	11.07	0.56ab	0.55ab	46.96b	45.74b
$I_{D25\%}$	11.21	11.19	0.62a	0.59a	50.74a	49.24a
CV (%)	5.004	4.471	6.301	5.487316	2.735	2.465
Significance	**NS**	**NS**	**	**	**	**
Irrigation Interval						
2-Days	10.195c	10.11c	0.44c	0.43c	37.52c	36.39c
3-Days	11.49a	11.56a	0.58ab	0.57ab	46.32b	45.36b
4-Days	11.08ab	11.15ab	0.61a	0.60a	51.45a	49.73a
CV (%)	5.376	5.221	8.799	7.865	4.180	2.574
Significance	*	**	**	**	**	**
Interaction						
$I_{D100\%}$ **@2Days**	9.51	9.42	0.36	0.36	29.87i	28.99i
$I_{D100\%}$ **@3Days**	11.12	11.02	0.51	0.50	41.22ef	40.52f
$I_{D100\%}$ **@4Days**	11.27	11.35	0.58	0.57	47.54d	46.55cd
$I_{D75\%}$ **@2Days**	10.04	9.95	0.41	0.40	34.79h	33.92h
$I_{D75\%}$ **@3Days**	11.34	11.41	0.55	0.54	44.58de	43.71de
$I_{D75\%}$ **@4Days**	11.11	11.30	0.60	0.59	50.06bc	48.91bc
$I_{D50\%}$ **@2Days**	10.44	10.38	0.47	0.46	40.05fg	38.88fg
$I_{D50\%}$ **@3Days**	11.62	11.81	0.60	0.60	48.01cd	46.97c
$I_{D50\%}$ **@4Days**	10.97	11.02	0.62	0.6	52.83ab	51.37ab
$I_{D25\%}$ **@2Days**	10.79	10.67	0.53	0.51	45.39d	43.74d
$I_{D25\%}$ **@3Days**	11.87	11.98	0.66	0.65	51.45bc	50.23b
$I_{D25\%}$ **@4Days**	10.971	10.904	0.66	0.633	55.39a	53.76a
CV (%)	5.004	4.471	6.300	5.487	2.735	2.465
Significance	NS	NS	NS	NS	*	*

Source: Field Survey, 2017/2018 and 2018/2019; Means followed by the same letter (s) in a column of any treatment group are not statistically different at 5 % probability level using DMRT. ** = significant at 1 % level, * = significant at 5 % level difference, NS = not significant, cv = coefficient of variation, IWUE = Irrigation water Use Efficiency, IWS = irrigation Water Savings I_{D100} = 0 % deficit, I_{D75} = 25 % deficit, I_{D50} = 50 % deficit, I_{D25} = 75 % deficit. 2, 3 and 4-days = Irrigation Intervals

REFERENCES

Adamu I.A. 2016. Simulation of Soil Water Balance Response to Water Stress and Yield of a Furrow Irrigated Tomato Using FAO Aqua-crop Model. Unpublished PhD Dissertation in the department of Agricultural Engineering Ahmadu Bello University, Zaria, Nigeria.

Chapagain, T., and Riseman, A. 2011. Assessment of System of Rice Intensification and Conventional Practices under Organic and Inorganic Management in Japan. *Journal of Rice Science*, 18,311-320 http://dx.doi.org/ 10.1016/s 1672 - 6308(12)60010-9

Chapagain, T. and Yamaji, E. 2009. The effects of irrigation method, age of seedling and spacing on crop performance, productivity and water-wise rice production in Japan. *Paddy and Water Environmental*, 8, 81-90.

I.A.R., 1994. Farmer-Managed Irrigation System: A Diagnostic Analysis of Large Scale Irrigation Projects in Nigeria. *Final Technical Report (Phase-I).* Institute for Agricultural Research (IAR) ABU Zaria, Nigeria Ford Foundation Grant No. 870-873.

Keisuke S, Yamaji E, Sato S, Budhiharto P S, Mzoguchi 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 6th International Conference on Sustainable Rural Development and Management. Seoul: Seoul National University: 25–37.

Krishna, A., Biradarpatil, N. K and Channap pagoudar, B. B. (2008) Influence of System of Rice Intensification (SRI) cultivation on seed yield and quality. *Karnataka J Agric Sci,* 21(3): 369–372.

Kumar, D., Swarup A. and Kumar V. 2006. Influence of levels and methods of N application on the yield and nutrition of rice in a sodic soil. *J. Ind. Soc. Soil Sci*. 44 (2): 259-260

Li, Y. and Barker, R. 2004. Increasing water productiv- ity for paddy irrigation in China. *Paddy and Water Envi- ronmental*, 2, 187-193.

NEDECO, 1976. Kano River Irrigation Project, (KRIP) Main Report. Part VIII. Ministry of Agriculture and Natural Resources, Kano, Nigeria, pp: 63.

Michael, A.M., 1978. Irrigation Theory and Practice. Vikas publishing House PV,T LTD pp 585-611.

Nemoto, K., Morita S. and Baba T.. 1995. Shoot and root development in rice related to the phyllochron. *Journal of Crop Science* 35: 24–29.

Radwan H.A., Elattar S. and Khmes, R. 2010. "Global Water Resources" Agricultural Engineering Research Institute, Department of Bio-Engineering. Cairo, Egypt.

Randriamiharisoa, R., Joeli B. and Uphoff N., 2006. Soil biological contributions to System of Rice Intensification. In: *Biological Approaches to Sustainable Soil systems*, eds. N. Uphoff, A. Ball, E.C.M. Fernandes, H. Herren, O. Husson, M. Laing, C.

Styger, E., Aboubacrine G., Attaher M.A. and Uphoff N., 2011. The system of rice intensification as a sustainable agricultural innovation: Introducing, adapting and scaling up SRI in the Timbuktu region of Mali. *International Journal of Agricultural Sustainability*, 9(1): 67-75.

Uphoff, N. and Randriamiharisoa 2002. Changes and evolution in SRI methods. In: Assessments of the System of Rice Intensification. Proceedings of an international conference, Sanya China, April 1-4.

Uphoff, N. 2006. The system of rice Intensification as a methodology for reducing water requirements in irrigated rice. *International Dialogue on Rice and Water*: *Exploring Options for Food Security and Sustainable Environments*, IRRI, Los Baños, 7-8 March 2006.

Uphoff, N. 2012. Supporting food security in the 21st century through resource-conserving increases in agricultural production. *Agriculture and Food Security*, 1:18. http://www.gricultureand foodsecurity.com/content 1/1/18

Vijayakumar, M., Ramesh S., Chand B., and Thiyagarajan T.M.. 2001. Effect ofsystem of rice intensification (SRI) practices on yield attributes, yield and water productivity of rice (*Oryza Sativa* L.). *Research Journal of Agriculture and Biological Sciences*, 2: 236-242.

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