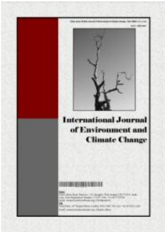

International Journal of Environment and Climate Change

12(10): 419-424, 2022; Article no.IJECC.87274
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Evaluating the Suitability of System of Rice Intensification Practices for Enhancing Rice and Water Productivity in Semi-Arid Environment, Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1030814

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87274

Original Research Article

Received 04 March 2022
Accepted 12 May 2022
Published 13 May 2022

ABSTRACT

In the world of rapid change in climate, irregular rainfall pattern tends to pose serious impact on water availability for agriculture. Rice is one of the important food crops to get affected by the low water availability because of its high water requirement. Various techniques were used in the past to mitigate low water availability and increase productivity but most techniques will improve one aspect at the expense of the other. System of Rice Intensification (SRI) is being tried by many countries with several modifications based on their priorities, with the aim of enhancing productivity besides reducing the water demand for rice cultivation. It is essential to have more insight into the individual and compounding effect of multiple components of SRI on yield, and water productivity of rice for identifying the potential and suitable SRI practices. Investigating the influence of different practices of SRI viz., planting of young and single seedlings per hill in wider spacing, water saving irrigation like Alternate Wetting and Drying (AWD), and weed control using cono-weeders on rice

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using the data obtained from the field experiment carried out during 2021 in Tamil Nadu Agricultural University, Coimbatore, India. Water productivity of rice plants under SRI were compared with conventional practices. The results revealed that plants grown with complete SRI practices had increased water productivity by 0.25 kg grain/m^3 of water which is almost twice that of conventional cultivation system. The yield obtained in SRI treatments was higher about 39% than conventional treatments. The total water savings were 20 % higher in AWD treatments than continuous flooding treatments.

Keywords: Water productivity; SRI; alternate wetting and drying; Cono-weeding; rice.

1. INTRODUCTION

India's food requirement is majorly dependent on rice since green revolution, feeding about half of the country's population. The per capita consumption of milled rice is around 74 kg per year in India [1]. Being a semi aquatic crop, rice is cultivated over 43.5 million hectares in India with productivity of 2722 kg/ha during 2020 [2]. Despite its importance as food crop, water consumption of rice cultivation is about 80 percent of total irrigation water resources in Asia [1], [3]. Rice consumes on average of about 1300 to 1500 mm of water [4] which is very high compared to other major food crops. World is facing water scarcity due to climate change which is expected to worsen in the future, putting water and food security at risk. There is a need for improved crop management practices to increase productivity of rice without depending on more water. System of Rice Intensification (SRI) is one such approach that promises an increase in yields with low external inputs and at the same time reduces water consumption [5]. This system is developed through farmers' participatory experiments conducted by a French missionary named Henri de Laulanie in Madagascar in 1980s-90s [6], [7].

SRI principles generally include good nursery management, careful transplanting of young seedlings, at a wider spacing with one plant per hill in a square pattern, intermittent irrigation to avoid continuous flooding except at the flowering stage, use of mechanical weeding without using herbicides, and improved nutrient management mostly with addition of organic manures. Nevertheless, the SRI practices are not a set of the standardized package of practices but an empirical set that depends on location-specific conditions [5].

SRI is known to increase productivity, while reducing water use through a practice known as Alternate Wetting and Drying (AWD) irrigation. There are reports of water savings from 20% to 50% savings with a small or no reduction in yield while some reported slight increase in yield under AWD irrigation system [8–11]. Water productivity is also increased largely through SRI practices. However, there only a few studies available to explain the combined effect of each SRI practices on yield and water productivity of rice compared to conventional practices. Therefore, the current study aims to fathom out the impacts of alternate wetting and drying irrigation and its influence on yield and water productivity of rice when combined with other principles of SRI.

2. MATERIALS AND METHODS

2.1 Experimental Site Details

The field experiment was undertaken during the summer of 2021 at wetlands of Tamilnadu Agricultural University, Coimbatore, India. The soil in the study area was clay loam with slightly basic pH of 8.2, with 225:54:290 kg/ha of N**:** P: K and about 0.56 percent of available carbon. The site recorded an average maximum temperature of 34°C and a minimum of 23.9°C, with a cumulative precipitation of 121 mm. The average bright sunshine hours were 7.9 hours, average daily evaporation was 6.8 mm d^{-1} and 14.9 MJ m^{-2} solar radiation was observed during cropping period.

2.2 Experimental Design and Treatments

Each practice of SRI was added to conventional cultivation to create different treatment combinations for observing their influence on rice yield and water productivity as given in the Table 1. Randomized block design with four replications was used for this experiment.

2.3 Field Preparation and Crop Management

Nursery was raised with 4 kg of seeds in 10 m^2 area where 1 kg of DAP was applied as basal fertilizer. The main field preparation involved trimming and plastering, followed by puddling of the field. The plots were laid out with buffer zones to prevent water flow across the plots. Pre-emergence herbicide butachlor was applied at a rate of 1.25 kg ha^{-1} broadcasted after mixing with sand. Recommended dose of fertilizers (150:50:50 N: P: K) was applied to all treatments [12].

2.4 Irrigation and weeding

For AWD treatments, irrigation was done to fill up to a thin water layer once the water level reaches 10 cm below soil layer. The irrigation level was monitored with the help of field water tube [13] installed in the plots as shown in the Fig 1 and Fig 2. A practice named "safe-AWD" given by [14] was adopted where the field was irrigated sufficiently during the week of peak flowering to prevent yield losses due to water stress. Cono weeding was done four times starting from 10 days after transplanting at ten days interval in a criss-cross pattern. Manual weeding also was carried out once in 10 days. The buffer and irrigation channels were weeded manually to keep weed growth low. The amount of water supplied to treatments were measured using partial flume installed in the irrigation channel.

Table 1. Treatment details of the experiment

T1	Square planting (25 cm x 25 cm) of 2 leaf stage single seedling
T2	T1 + Cono-weeding four times on 15, 25, 35 and 45 days after planting
T3	T1 + Alternate wetting and Drying (AWD) method of irrigation
T4	T2 + Alternate wetting and Drying (AWD) method of irrigation (complete SRI)
T5	21 days old seedling @ 2–3 seedlings/hill -spacing 15 cm x 10 cm (conventional)
T6	T5 + Alternate wetting and Drying (AWD) method of irrigation

T_4 = complete SRI, T_5 = conventional

Fig. 1. Field water tube installed in AWD plots to monitor water depth

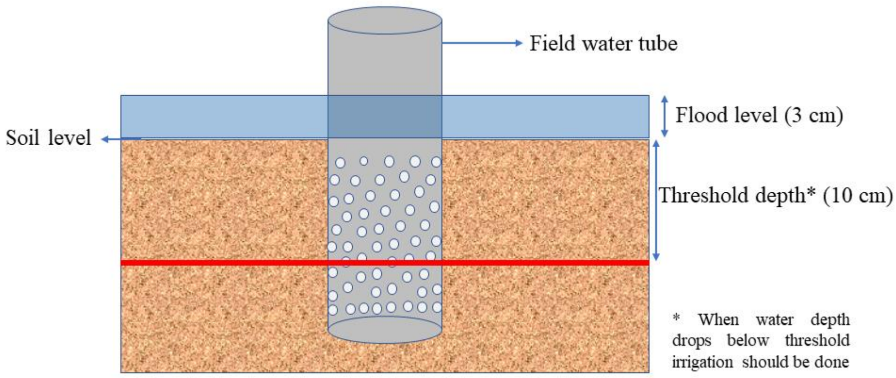

Fig. 2. Alternate wetting and drying irrigation management using field water tube

2.5 Harvesting Index

Harvest index (HI) was calculated as ratio between economical yield (grain weight) to biological yield (grain weight + stover weight) expressed as percentage, as given by the following equation (1):

$$HI = \frac{Economical\ yield}{Biological\ \ yield}\ x\ 100 \quad (1)$$

2.6 Yield Attributes

The plots were harvested at maturity using a quadrant and the total weight was measured after harvesting. The plants were threshed to separate the grains and the grains are dried for two days and weighed as grain yield. The weight was then converted to kg/ha.

2.7 Water Productivity

Water productivity is the ratio of total yield of the crop to the total amount of water supplied to the crop including irrigation and rainfall during the cropping period [15]. It can be expressed by the equation (2) given below:

$$WP = \frac{grain\ \ yield}{total\ water\ supplied} \quad (2)$$

2.8 Statistical Analysis

The observed data were statistically analysed for significance using analysis of variance (ANOVA) as per randomized complete block design. The mean dataset was then arranged in descending order and grouped or differentiated using Duncan multiple range test (DMRT) with 5% significance level and the results are presented in Table 2.

3. RESULTS AND DISCUSSION

3.1 Yield

Yield variation obtained from the treatments with SRI as well as conventional cultivation practices is presented in the Table 2. Yield was higher in the SRI based cultivation rather than conventional method. Complete SRI cultivation practice (T_4) registered the maximum yield of 6,499 kg/ha which was followed (5,925 kg/ha) by square planting with cono weeding treatment (T_2). Conventional cultivational practices registered the lower yield as compared to SRI methods. Complete conventional practices (T_5) showed the lowest yield of 3,919 kg/ha which was on par (4,136 kg/ha) with conventional method with altered wetting and drying treatment (T_6). There are multiple experimental reports of increased yields in SRI treatments [9], [16], [17] and also farmers surveys indicating yield gains through SRI [7], [18]. The yield increase in SRI treatments might have been influenced by increased water and nutrient uptake and longer vegetative growth and less transplanting shock of young seedling when compared to conventional treatments.

3.2 Harvest Index

Ratio of grain yield to total dry matter produced gives the harvest index (HI) which was considered as reproductive efficiency of the crop. It was influenced by interaction between genotype, atmospheric condition and crop cultivation practices. Complete SRI practices gave the maximum HI of 47.05%. The conventional methods, T_5 and T_6 produced the least HI of 37.27% and 39.81% respectively. [19] found that the harvest index varied among cultural practices wherein SRI cultivation produced higher HI than conventional methods. Higher harvest index indicates higher allocation of biomass to sink (grain) than in other parts of plant after flowering. This led to higher grain yield to dry matter ratio. The conventional treatments had lower harvest index and also lower yield attributing characters. There were more filled grains per panicle in SRI treatments than in conventional treatments leading to higher yield and harvest index.

Table 2. Effect of SRI practices on yield, harvest index and water productivity of Rice

Treatment	Yield (kg/ha)	Harvest Index (%)	Water productivity (kg grain/cu. m water)
T1	$4588^{d} \pm 269.88$	$47.16^{a} \pm 4.10$	$0.29^{e} \pm 0.02$
T2	$5925^{b} \pm 278.64$	$44.98^{ab} \pm 2.39$	$0.37^{c} \pm 0.02$
T3	$5525^{c} \pm 142.68$	$42.88^{b} \pm 0.98$	$0.43^{b} \pm 0.01$
T4	$6491^{a} \pm 284.34$	$47.05^{a} \pm 2.84$	$0.51^{a} \pm 0.02$
T5	$3911^{e} \pm 192.45$	$37.27^{c} \pm 2.05$	$0.25^{f} \pm 0.01$
T6	$4136^{e} \pm 346.69$	$39.81^{c} \pm 3.81$	$0.32^{d} \pm 0.03$

$^{a-f}$ Mean with the different superscript letters show significant differences ($p < 0.05$)

3.3 Water Productivity

Water productivity was higher in the SRI based cultivation methods compared to conventional cultivation methods. Complete SRI method of cultivation (T_4) produced about 0.51 kg of biomass per cubic meter of water whereas the lowest water productivity was obtained in complete conventional method of cultivation with 0.25 kg per cubic meter of water. The square planting with alternate wetting and drying cropping practice recorded 0.43 kg per cubic meter of water. [20] found that SRI treatments showed almost twice the increase in water productivity compared to conventional treatments and AWD further enhanced water productivity when combined with SRI. Increased soil aeration and nutrient pathways may have led to more root growth and ultimately increased the yield per unit of water consumed.

4. CONCLUSION

Water productivity of rice has increased twice with alternate wetting and drying than conventional flooding irrigation. It is inferred that drying the soil at a protective level for rice crop without subjecting the plants to moisture stress will not reduce the rice productivity and may even increase yield to some extent. AWD can also increase soil aeration which leads to increased root growth and eventually boosted the productivity of rice crop. AWD in combination with other practices of SRI, could increase both yield and water productivity in semi-arid regions which experience frequent water shortages leading to reduction in yield or even crop failures.

ACKNOWLEDGEMENT

This work was financially supported by Department of Science and Technology (DST), Ministry of Science and Technology, Government of India (GOI) through project entitled "Building Resilience to Climate change and Improving Food Security through climate smart solutions". The funding agency had no role in work design, field experiment and analysis, or in preparation of the manuscript. The Authors also acknowledge the support of Dineshkumar Palaniappan and Dr. K. Bhuvaneshwari.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87274