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Impact assessment of Alternate Wetting and Drying (AWD) Water-Conserving Irrigation Technique in Rice Crop in Chhattisgarh, India

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ABSTRACT

The rice is one of the essential crops in Chhattisgarh that consume maximum amount of irrigation water, so it becomes a paramount to identify a suitable method of irrigation. The objective of the study was to evaluate the performance of alternate wetting and drying (AWD) water-conserving irrigation technique in rice crop. A field experiment was conducted in Mahamara village, Durg, during the rice growing season of 2020 (January - April). Based on the System of Rice Intensification (SRI) technique, the young seedlings transplanted individually at a wider spacing (25cm x 25 cm) and intermittently irrigated with alternate flooded and dry periods at 10 days interval. The result shows that the AWD save 27.23 % of water and, the grain yield is increased 25.58 % compared with conventional method. The research demonstrates that the AWD method is more efficient in terms of water conservation and yield than the standard method.

1. Introduction

Agriculture is confronted with two big issues, namely, it must expand food production in a sustainable manner to feed a growing global population, and at the same time, this growth must be achieved in the face of increasing water crisis (Bouman, 2007; Thakur et al., 2011). The scarcity of water affecting 4 billion people worldwide (Mekonnen and Hoekstra, 2016), it is critical to develop agronomic approaches that can reduce water use while maintaining or improving yields to sustain a growing population. Also, water for irrigation is becoming increasingly scarce throughout Asia (Rejesus et al., 2011). According to Tuong and Bouman (2003), water scarcity will affect around 2 million hectares of Asia's irrigated dry-season rice and 13 million hectares of irrigated wet-season rice by 2025.

Therefore, as Asia's population increases, more irrigation water may be required in the future to boost total agricultural production and fulfil rising food demand (Rosegrant and Ringler, 1998). To overcome the increasing water scarcity and food demands by growing populations, more efficient water saving technologies or water management practices is required, so that the rice production in India or Asia can increase with optimal use of irrigation water.

Rice (*Oryza sativa L.)* is a key staple crop in the world, with much more than 50 kilograms consumed per capita each year (FAO, 2016; Carrijo et al., 2017; Weerakoon and Somaratne, 2021). In 2014/15, approximately 478 million tons of rice was produced globally, with over 90% of it being consumed directly (USDA, 2016). Rice is important for Asia's as well as global food security; yet traditional rice cultivation on flooded agricultural soil necessitates more water than other cereal crops (Navarathna et al., 2021; Carrijo et al., 2017; Pimentel et al., 2004).

Alternate Wetting and Drying (AWD) is an irrigation management technique that has been demonstrated to reduce water use in rice cultivation (Tian et al., 2021; Lampayan et al., 2015; Linquist et al., 2014; Belder et al., 2004). AWD is an irrigation technique in which water is applied to the field once ponded water has evaporated or disappearance for a number of days. It is in contrast to the

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conventional technique of constant flooding in irrigation (i.e., never letting the ponded water disappear). That means during the rice growth stage, the rice fields are not maintained submerged all of the time, but are permitted to dry out periodically. In AWD the number of days the crop field is allowed to remain non-flooded until irrigation is done and it may range from one to ten days (Rejesus et al., 2011).

System rice intensification (SRI) was established in Madagascar in the 1980s (Laulanie´ 1993; Stoop et al., 2002), has been recognized as having the ability to save water while increasing rice yield (Sato and Uphoff, 2007). SRI management deviates significantly from the approaches for rice production that are commonly suggested. Single young seedlings, severely reduced plant densities, maintaining fields unflooded, using a mechanical weeder that also aerates the soil, and increased soil organic matter are all recommended in SRI (Meyer, 2009; Uphof et al., 2011). The objective of this technique is to provide the plant with the best possible growing environment in order to improve yield and resource productivity (Stoop et al., 2002).

The recent literature recommends the use of AWD irrigation technique merged with SRI for increasing water productivity and crop yield (Budianto et al., 2021; Thakur et al., 2011). As the study area falls under the state of Chhattisgarh, and the rice is used as a primary food. The rice production in Chhattisgarh is much higher than the other agricultural crops. The study region was selected in Durg district of Chhattisgarh, where the continuous flooding is generally used for irrigation in rice field. Therefore, need to identify an effective irrigation technique for increasing the water use efficiency and grain yield. The purpose of this study was to compare the impact of alternate wetting and drying-system rice intensification (AWD-SRI) to the SMP method.

2. Materials and methods

Study area description

The field experiment was conducted for a growing season (January to April) of year 2020 at Mahamara village (21.176384 N, 81.245458 E) of Durg District, Chhattisgarh. The soil of the experimental site was having sandy loam in texture (60 % sand, 17 % silt, and 23 % clay) with pH of 5.6, and soil matter carbon 1.8%.

Experimental design and treatments

The experimental design employed randomized block design (RBD) with two replications and plot sizes of 2 m × 4 m. Rice was cultivated under two alternative crop management systems, firstly, standard management practices (SMP) with continual flooding as currently recommended (ICAR, 2006), and secondly, the System of Rice Intensification (SRI) with alternate wetting and drying (AWD) water management throughout vegetative stage.

After puddling (Fig 1a), levelling, and draining excess water, organic manure (completely digested cow dung) was put over the entire main field. To avoid lateral water seepage and nutrient diffusion across plots, all the plots were enclosed by 50 cm wide bunds, which were followed by 50 cm wide irrigation channels. Rice "*Mestiso 20"* (M20) seedlings were prepared in a nursery (Fig 1b) and then transplanted into a puddled field for SRI at 15 days, with a spacing of 25 × 25 cm (25 plant/m^2) (Fig 2). And after 25 days of nursery preparation, three seedlings per hill were planted with a spacing of 20 × 10 cm (150 plant/m^2) in the SMP field.

Fig 1a: Field preparation

Fig 1b: Nursery after 7 days

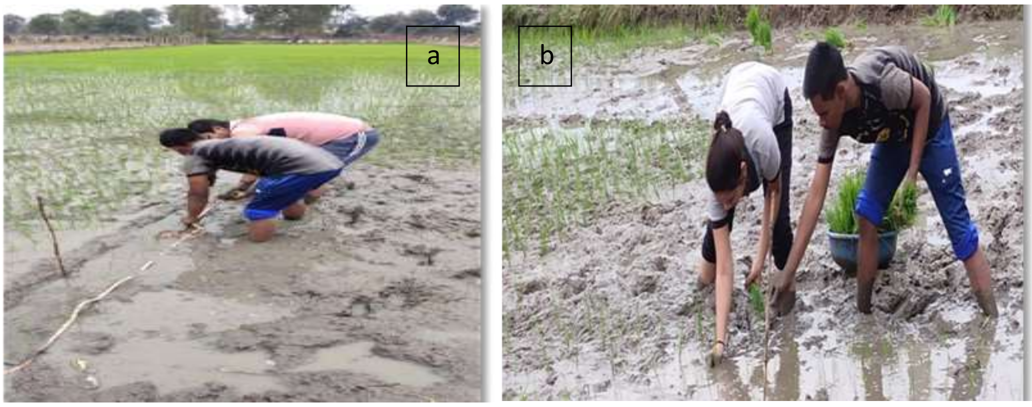

Fig 2 a & b. Transplanting of rice seedling

Irrigation management

Employing scientific management approaches, fields were continually flooded and watered on alternate days to maintain a ponded layer of 5–8 cm of water depth throughout the vegetative stage. The first irrigation in SRI plots was applied 5 days after transplanting to keep the field moist without ponding and the second irrigation were applied after 9 days with the ponding depth of 5cm. Following that, the alternate wetting and drying (AWD) system of irrigation was used; with irrigation water being applied 10 days after the ponded water had vanished. A perforated pipe of 40 cm long and 15 cm in diameter is installed in the field at the depth of 20 cm from the soil surface to measure the moisture/water level in the field (Fig 3). Normal scale is used to measure the water level inside the tube, and when the ponded water level drops 15 cm below the ground level then the irrigation is applied. Water application of SMP was done as per the recommendation of ICAR.

Fig 3. installed perforated pipe for measurement of field water level

Data accusation and analysis

The different parameters like Initial soil properties, physiological parameters of rice, and yield parameters were recorded during the experiment. Initial soil properties namely texture, bulk density, pH, organic matter and the different physiological parameters of rice like plant height, number of leaf and number of tillering per plant and per m^2 was observed from each plot. And the yield parameters like number of hill/plants, number of panicles/hills, spikelet number/panicle, 1000 grain weight (g), grain yield (t/ha), Straw yield (t/ha), harvest index (%). The harvest index (HI) is calculated by using equation 1:

$$HI = \frac{Grain\ yield\ (t/ha)}{Biological\ yield\ (t/ha)} \qquad (1)$$

Where, the biological yield is the sum of grain yield and straw yield.

The water use efficiency or water productivity is calculated as the ratio of grain yield (g/ha) to the total water consumed (l/ha) by the rice crop (equation 2). In the total water consumed it includes the rainfall and irrigation water. During the crop grown periods, no significant amount of rainfall occurs in the study area.

$$Water\ productivity = \frac{Grain\ yield\ (g/ha)}{Total\ Water\ consumed\ (l/ha)} \qquad (2)$$

The statistical method analysis of variance (ANOVA) was used for the statistical analysis of the data. The F test was used to measure the significance of the treatment effect. And the least significant difference (LSD) was calculated at the 5 % probability level to establish the significance of the difference between two treatment means.

3. Results and Discussion

Initial soil properties

At the beginning of the experiment, the soil physical properties were examined and found that the soil having sandy loam in texture with 60 % sand, 17 % silt, and 23 % clay. Whereas the other soil properties like bulk density, pH, organic matter was found 1.60 g/cc, 5.6, and 1.8 % respectively.

Crop physiological properties

The physiological properties of rice crop like number of tillering per plant and per m^2, plant height, and number of leaves per plant etc. was observed from each experimental plot. Visible changes in plant physiology were identified between AWD-SRI plants and conventionally cultivated flooded rice with standard management practice (SMP) at the critical early-ripening stage. Compared to SMP plants, AWD-SRI plants were having 18 % and 20 % higher in plant height and culm plant height respectively (Table 1). SRI hills had twice as many tillers than SMP hills, although there was marginal difference in tillers per unit area. The result shows that in AWD-SRI plants, the average tiller perimeter was 35 percent higher than in SMP plants (Table 1).

The study shows that, the total number of leaves per unit area and hill was much higher in AWD-SRI plants than in the SMP plants at the flowering stage (Table 2). In the AWD-SRI plants had more than twice the number of leaves per hills than SMP plants. It was also recorded that the AWD-SRI treatments had 30.5 % and 31.2 % longer and wider leaves as compare to SMP treatments. Likewise, the average width and length of flag leaves in AWD-SRI plants were substantially greater than in SMP plants. AWD-SRI plants have a much higher leaf area index (LAI) than SMP plants because to the greater quantity of bigger leaves (Table 2).

Crop growth rate (CGR)

It was measured at the vegetative stage of rice crop grown under AWD-SRI and SMP treatments. Crop growth rate was higher in the SMP plants than in the AWD-SRI plants up to 60 days after germination and after that CGR declined in SMP plants. As a result of unrestricted tillering, CGR in the SRI crop increased steadily throughout the vegetative stage of growth.

Yield parameter estimation

The average number of panicles/hill (12.3 /hill) and per m^2 (410.5 /m^2) was observed higher in AWD-SRI treatments than the SMP treatments (6.2 /hill and 330.2 /m^2) (Table 3). Likewise, in AWD-SRI treatments, the average length of panicles (20.2 cm) was observed significantly higher than the SMP (17.5 cm) treatments (the level of significant at $p < 0.05$).

AWD-SRI management resulted in a 25.58 percent greater grain yield than SMP management due to the significant enhancement in yield components. From the experiment it was observed that the grain yield 5.4 t/ha and 4.3 t/ha by AWD-SRI and SMP management method respectively (Table 4 and Fig. 4). In the report of Singh and Paikra (2014), it was stated that the yield of transplanted rice was 5.5 t/ha for Chhattisgarh region, which is similar to our obtained result. On the other hand, in the present study, the straw yield was observed higher in SMP managements than AWD-SRI management method.

Table 1. Effects of management methods on rice plants height and tiller.

Management practices	Plant height (cm)	Culm height (cm)	Average tiller number (/hill)	Tiller number (/m^2)
AWD-SRI	122.5	83.0	17.2	430.1
SMP	102.3	65.2	10.2	421.2
$LSD_{.05}$	7.8	3.9	2.9	NS

Table 2. Effects of management methods on leaves of rice plants

Management practices	Number of leaf (/hill)	Number of leaf (/m2)	Average length of leaf (cm)	Average width of leaf (cm)	Average length of flag leaf (cm)	Average width of flag leaf (cm)	leaf area index (LAI)
AWD-SRI	75.0	1921.0	61.55	1.65	35.52	1.92	3.55
SMP	33.0	1706.0	40.24	1.33	25.72	1.52	2.60
$LSD_{.05}$	15.2	220.1	5.89	0.25	4.33	0.45	0.26

Table 3. Effects of management methods on panicles of rice plants

Management practices	Average particle number /hill	Panicles (/m^2)	Average length of panicle (cm)	Spikelet number/panicle	1000 grain weight (g)
AWD-SRI	12.3	410.5	20.2	142.5	23.5
SMP	6.2	330.2	17.5	101.3	22.2
$LSD_{.05}$	3.3	56.5	2.5	10.3	0.3

Table 4. Effects of management methods on rice yield

Management practices	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index
AWD-SRI	5.4	6.53	11.93	0.63
SMP	4.3	8.27	12.57	0.52
$LSD_{.05}$	0.22	1.11	1.02	0.05

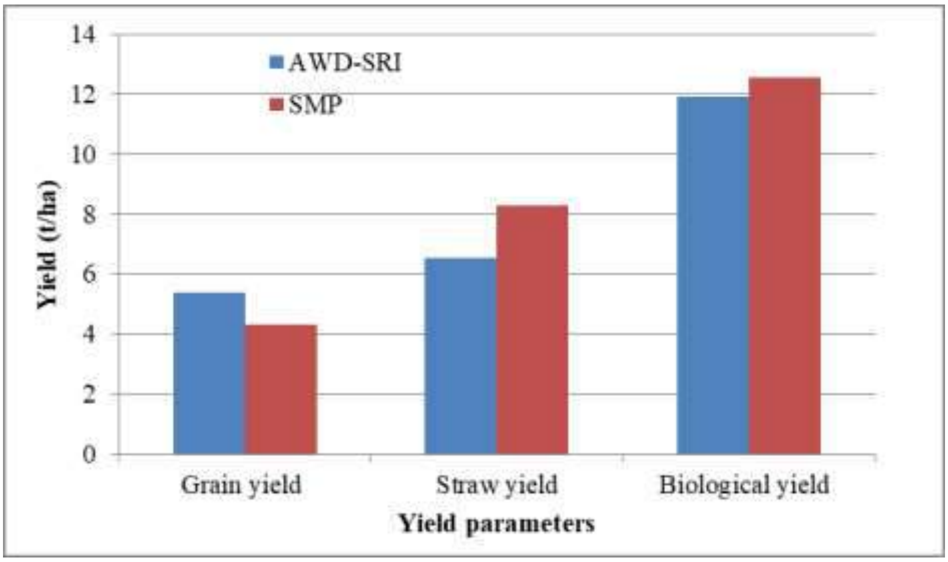

Fig 4. Yield parameters of the rice by both the management methods

Table 5. Effects of rice management on water productivity and conservation

Management practices	Irrigation applied ($\times 10^4$ l/ha)	Total water consumed ($\times 10^4$ l/ha)	Water productivity (g/l)	Water saving with AWD-SRI (%)
AWD-SRI	1065.5	1065.5	0.51	27.23
SMP	1355.7	1355.5	0.32	-

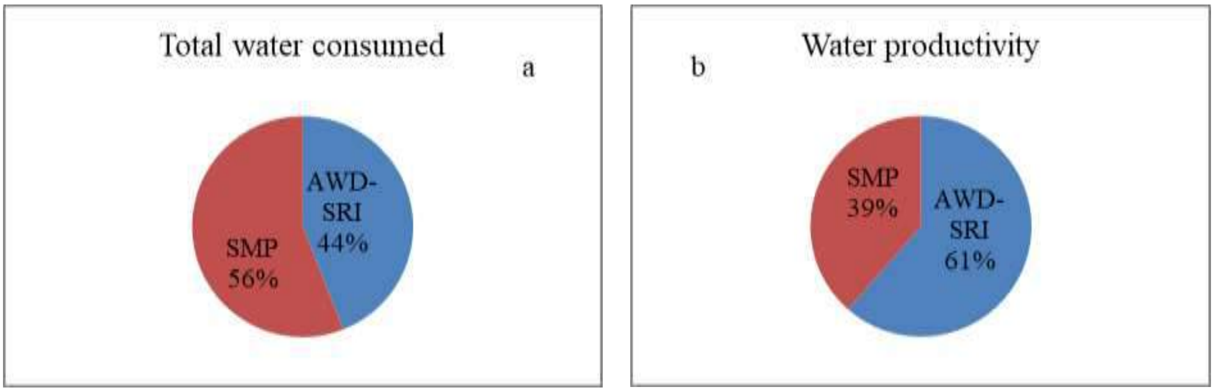

Fig 4 a). Total water consumed and **b)** water productivity by the AWD-SRI and SMP method

Water productivity and conservation

During the growing season of the crop, marginal rainfall (<2 mm) was received in the study area, which does not have any significant effect on the water requirement crop. And the consumptive use of water for the rice crop is met by using irrigation water (Table 5 and Fig. 5a). The water productivity of AWD-SRI was found significantly higher (0.51 g/l) than SMP management method (0.32 g/l) also it was observed that AWD-SRI conserved 27.23 % of water than flooding SMP method for the rice crop (Table 5 and Fig 5b). This saving of water may be due to reduction in application of excess water, seepage, and percolation loss. The observed water productivity and water saving with ADW-SRI was similar with other study of Eastern India (Orissa) (Thakur et al., 2011). Similar study done for the rice crop using AWD shows reduction in hours of irrigation (38%) and conservation of water (Rejesus et al., 2011; Carrijo et al., 2017)

4. Conclusion

AWD technique for irrigated rice is a well-recognized cost effective and water-saving approach in Asia. The System of Rice Intensification (SRI) method along with ADW conserves 27.23 % of water and, the grain yield is increased 25.58 % as compared to the conventional flooding SMP method. The study also shows that under AWD-SRI, the physiological parameters of the plants *viz.* plant height, tillering, number of leaves etc. was enhanced than SMP management method. The research demonstrates that the AWD method is more efficient in terms of water conservation and yield than the standard method. Rotational irrigation scheduling must be perfectly alright with the recommended safe AWD to prevent pre-emptive flooding and severe drought of the rice fields. This method can be used by the farmers of Chhattisgarh as it saves higher amount of water than conventional method.

5. Author Contributions

A.S. & A. C. conducted the study. A.S. & S.D. wrote the original and the revised manuscript. All authors have read and agreed to the published version of the manuscript.

6. Funding

This research received no external funding.

7. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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9. Conflicts of Interest

The authors declare no conflict of interest.

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