

EFFECTS OF DRIP IRRIGATION SYSTEM FOR ENHANCING RICE (*ORYZA SATIVA* L.) YIELD UNDER SYSTEM OF RICE INTENSIFICATION MANAGEMENT

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Abstract. To increase both water productivity and rice production, research was carried out at the Central Institute of Agricultural Engineering, Bhopal, India, to evaluate the use of drip irrigation together with modifications in rice crop geometry and other cultural practices. Experiments were conducted with five alternative treatments: T₁: Conventional paddy cultivation under continuous flooding, T₂: System of Rice Intensification (SRI) methods which include alternate wetting and drying, T₃: SRI methods with drip-irrigation, the emitters being spaced at 20 cm, T₄: SRI methods with drip emitters spaced at 30 cm, and T₅: SRI methods with drip emitters spaced at 40 cm. Greatest plant height and root length were recorded with SRI under drip irrigation at 20 cm spacing (T₃). Yield and yield-contributing parameters were also significantly higher with this T₃ treatment as compared with conventional practice (TI): productive tillers/m², number of grains per panicle, average panicle length and weight, average grain yield (7 t/ha), and harvest index. Superior performance of the T₃ treatment in terms of water productivity and water-energy productivity was also recorded. Among the drip-irrigated treatments, however, there was no statistically significant difference in grain yield between T₃ and T₄ treatments, indicating that drippers spaced at 30 cm could be recommended to lower the cost of the drip system installation.

Keywords: *water productivity, plant growth parameters, yield contributing parameters, water energy productivity, economics*

Introduction

Rice is the most important global food crop. Year-to-year fluctuations in its production have a direct bearing on food security and on price inflation in the world market. Given its continuing population growth, India should be producing 1.7 million tonnes of additional rice every year to ensure national food security (Dass and Chandra, 2013). Hence, there is a need to increase sustainably the yields and productivity of rice cultivation, doing this to the extent possible with reduced inputs and with less exploitation of natural resources to feed the increasing global population. This is a challenge for rice-growing countries around the world.

For producing rice at present with traditional irrigation techniques, large quantities of water are being used to flood paddy fields with standing water 2-5 cm deep at the different stages of crop growth. Studies have indicated that 3000-5000 liters of water are often used to produce 1 kg of rice (Satyanarayana et al., 2007), but this includes water applications which are clearly excessive. Water requirements for flooded rice production are currently considered to average a little over 1,400 liters per kg of rice (www.knowledgebank.irri.org/step-by-step-production/growth/water-management). This is about three times more than for growing wheat and maize (Riaz, 2001).

Water scarcity is a major challenge affecting rice production all around the globe. More than 80% of the fresh water resources in Asia are used for agriculture, of which

Substantial water savings with higher paddy yields using SRI methods have been confirmed in a meta-analysis of 27 published studies across 8 countries, an average 35% reduction in irrigation water per hectare and a 22% reduction in total water (irrigation plus rainfall) (Jagannath et al., 2013). But these comparisons were all made with modified regimes of flood irrigation. Possibly there could be even greater savings of irrigation water and more gains in water productivity with employment of drip irrigation technology. And if such benefits are possible, how can the productivity of drip irrigation be optimized? These are important considerations for enhancing both the productivity and sustainability of irrigated rice cultivation, and it is these concerns that gave impetus to the research whose findings are reported here.

Study areas

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The climate of Bhopal is pleasant throughout the year. Generally the climate of the study area is hot and humid in nature. The annual rainfall in the region is about 1200 mm. Eighty percent of the total rainfall occurs during the month of June to September in almost every year which is popularly known as monsoon rainfall. The summer months from March to May are very hot and humid, and temperature often rises above 40°C.

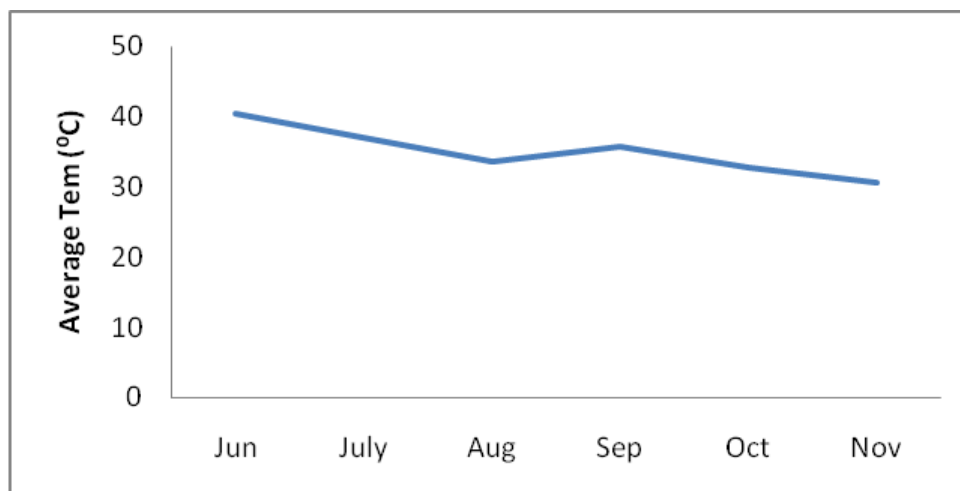


Figure 2. Average temperature (°C) of ten years

Five treatments were considered in the study: T₁: Conventional practices with continuous flooding, T₂: System of Rice Intensification (SRI) crop and water management methods, T₃: SRI management with drip irrigation emitters spaced at 20 cm, T₄: SRI with drip emitters spaced at 30 cm and T₅: SRI with drip emitters spaced at 40 cm. Puddling was carried out in the T₁ and T₂ plots, but the T₁ plots had continuous flooding, while T₂ plots had alternate wetting and drying. Young seedlings 10 days old were transplanted manually in the T₂, T₃, T₄ and T₅ treatments at 30 x 30 cm spacing with single plants per hill and a seed rate of 10 kg ha⁻¹. Transplanting in T₁ was carried out on the 30th day after seeding, and 3-4 plants per hill were transplanted at a spacing of 15 x 5 cm spacing, with a seed rate about 100 kg ha⁻¹. The dates of transplanting for all the treatments were the same. Each treatment plot was replicated four times, and each plot was surrounded by bunds 0.5 m wide in order to arrest any lateral seepage and nutrient diffusion from adjoining treatments.

Inorganic fertilizers were applied to all the plots with the recommended doses of 150 kg N, 100 kg P and 120 kg K per ha in the form of Urea, Di-Ammonium Phosphate (DAP) and Murate of Potash (MOP), respectively. Half of the recommended dose of nitrogen and all of the phosphorus and potash were applied at sowing, while the remaining N was applied at the time of tillering through broadcasting in the T₁ and T₂ treatments and through the drip irrigation system in T₃, T₄ and T₅ treatments using water-soluble fertilizers. Rates and kinds of soil nutrient supplementation were thus not a variable in this experiment.

During the crop growing period, T₁ treatment plots were under fully ponded conditions (to a depth of 4-5 cm) for a total of 34 days during the growing season, while T₂ plots were under ponded conditions for a total of 25 days during their alternating periods of drying and wetting of the plots at six-day intervals. The drip-irrigated

treatments T3, T4 and T5 were operated for 15 min, 23 min and 30 min, respectively, for a cumulative period of 60 days. Weeds were controlled by manual weeding after transplanting on the 20th, 40th, 60th and 80th days, so weed control was also not a variable evaluated in these trials even though mechanical, soil-aerating weeding is recommended as part of the recommended SRI protocol.

Monocrotophos (400 ml per acre) was applied for controlling stem borer at 25 DAS and Gandhi bug at 70 DAS in all treatments. Bacterial blight was controlled by the application of Streptocyclin along with Copper Oxi-Chloride (6g+250g per acre) at 30-35 DAS in rice.

At the time of transplanting, five plants were randomly selected from each plot to be used for recording plant height, number of tillers, number of effective tillers, root length, panicle length, and panicle weight, number of grains per panicle, 1000-grain weight, grain yield, and straw yield. The data collected were analyzed by using Fisher's analysis of variance technique, and a Randomized Block Design (RBD) test with the confidence level set at 5% was used to compare the differences among treatment means (Steel et al., 1997).

Results and Discussion

Plant growth parameters

The influence of different treatments on rice crop growth parameters on the 60th day after transplanting is given in *Table 1*, and the actual condition of the crop is shown in *Plate 1*. The different irrigation practices along with associated crop management had a significant effect on plant height. The greatest average plant height was recorded with treatment T3 (76.45 cm) possibly due to optimizing plant population and geometry under SRI with drip emitters spaced at 20 cm which gave more even distribution of water to the plants. Similarly, the greatest number of tillers m⁻² area was also recorded under T3 (240.75), followed by T4 (232.50) and T5 (223.50). The lowest number of tillers was recorded with T1 (217.25). However, chlorophyll values as measured by a SPAD meter did not significantly vary across the different treatments. Root length was also greatest under T3 (18.23 cm), followed by T4 (16.08 cm), while the lowest root length was recorded under T1 (14.10 cm).

Table 1. Influence of growth parameters by different irrigation practices

Treatments	Plant height at 60 DAT (cm)	Number of tillers at 60 DAT	SPAD Values	Root length (cm)
T1	73.45	217.25	44.81	14.10
T2	73.60	218.20	44.67	15.30
T3	76.45	240.75	45.12	18.23
T4	75.80	232.50	45.00	16.08
T5	74.70	223.50	44.85	15.50
SEM±	0.85	2.92	0.68	0.68
CD (p=0.05)	2.51	8.60	NS	2.01



Conventional paddy (L), SRI (R)



Drip-irrigated paddy emitters spaced at 20 cm (L), 30 cm (M) and 40 cm (R) at 60 dayI (R)

Plate 1. *Experimental crops under different cultivation and irrigation practices at 60 days*

Intermittent irrigation creates favourable soil physical, chemical and biological properties that support plant growth under mostly aerobic soil conditions, encouraging deeper rooting depth and creating favourable micro-climates in the soil, which support abundance of micro-organisms and more availability of micro-nutrients. Better root systems provide good anchorage for the plants and sustain effective use of applied fertilizers by checking losses from leaching (Stoop et al., 2002). Optimum availability of soil moisture plays a key role in the processes of mineralization and solubilisation, affecting the availability and uptake of nutrients, and contributing to plant growth and yield (Venkateswarlu et al., 1997). Greater root capacity also supports a higher photosynthetic rate by supplying sufficient amounts of nutrients to the shoots, thereby enabling high productivity (Osaki et al., 1997). Sharda et al. (2016) observed in their study that root length and density were maximum in the drip irrigated crop than flood irrigated crop.

Yield-contributing parameters

It has been seen in many studies that flooding is not the most favourable condition for growing rice crops (Belder et al., 2004; Sahrawat, 2000; Gani, 2001; Borrel et al., 1997). The findings of the present study confirm that different irrigation methods and regimes have a significant influence on crop yield parameters. System of Rice Intensification methods adapted with drip irrigation emitters spaced 20 cm apart gave the highest number of productive tillers at maturity (264.75 m^{-2}), also the highest number of grains per panicle (161.75), longest panicle length (27.52 cm), and highest panicle weight (3.41 g), as seen in *Table 2*.

These findings are consistent with the results reported by Yang et.al. (2004) indicating that intermittent irrigation and maintaining moist, mostly aerobic soils not only enhances tillering but also the root system's development and functioning. However, 1000-grain weight and straw yield (t/ha) were not found to differ significantly among the five treatments. Treatment T3 also had a significant effect on grain yield and

on the harvest index. SRI methods with drip at 20 cm spacing gave the highest grain yield, 7.07 t ha⁻¹, while conventional practices (T1) with flood irrigation, older seedlings, and greater plant density resulted in the lowest grain yield, 3.14 t ha⁻¹. Harvest index calculated for T3 was the highest (61.9), while that for T1 was the lowest (40.7), a very large difference.

Table 2. Yield and yield-contributing characters influenced by different irrigation practices

Treatments	Number of effective tillers (per m ²)	Number of grains per panicle	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T1	222.25	133.50	25.67	2.78	32.30	3.14	4.30	40.73
T2	242.0	141.0	25.97	3.02	32.96	4.04	4.18	48.08
T3	264.75	161.75	27.52	3.41	33.51	7.07	4.60	61.93
T4	256.25	151.5	26.96	3.37	32.71	6.72	4.34	60.98
T5	253.0	149.0	25.87	3.16	32.59	5.95	4.43	57.72
SEM±	4.49	4.09	0.40	0.07	0.41	0.31	0.13	2.57
CD (p=0.05)	13.25	12.07	1.18	0.22	NS	0.90	0.39	7.59

It is worth noting that the 1st, 2nd, 5th and 7th sets of bar graphs in *Figure 3* all follow the same sequential pattern: T3 > T4 > T5 > T2 > T1. This pattern is seen throughout the data gathered and analyzed. Detailed measurements made of grain characteristics and milling quality (grain length, breadth, eccentricity, perimeter and milling efficiency) revealed no significant differences when the data were analyzed statistically (data not shown). However, there was a rather consistent rank-ordering of the results seen across all these measurements: T3 > T4 > T5 > T2 > T1.

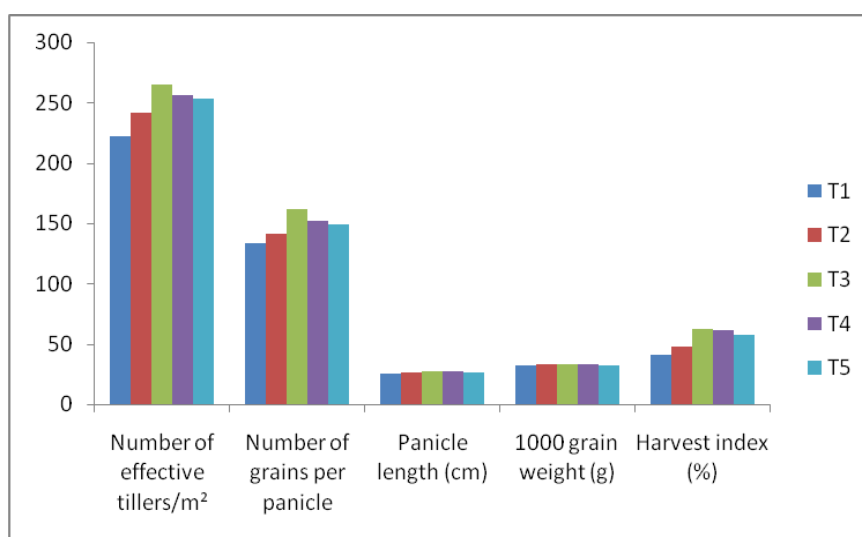


Figure 3. Yield-contributing characteristics as influenced by different irrigation practices

Water productivity and water-energy productivity

Efficient water management is key to higher paddy yields and greater net income with the System of Rice Intensification as this key input influences the effects of other

inputs as well. Water productivity and water-energy productivities for the selected treatments were analyzed and are presented in *Figure 4*. Water productivity is the amount of grain yield obtained per unit of irrigation water supplied to the crop. Water-energy productivity is the amount of grain yield that is obtained from a unit of energy (kWh) consumed during the irrigation.

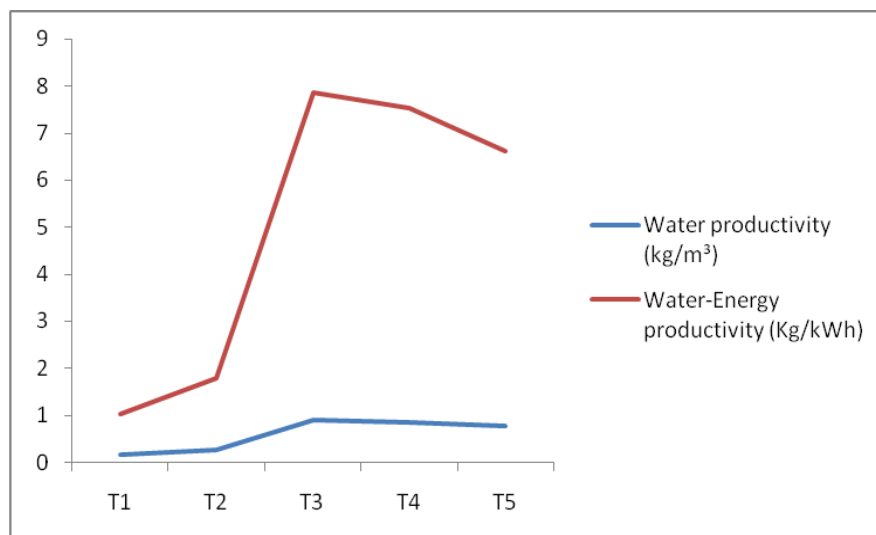


Figure 4. Water productivity (kg of rice per m³ of irrigation water) and water-energy productivity (kg of rice per kilowatt-hour of electricity) as influenced by the irrigation practices evaluated

Water productivity was found highest under T3 (0.90 kg m⁻³) followed by T4 (0.86 kg m⁻³). The lowest water productivity was recorded under T1 (0.16 kg m⁻³), with no difference between T4 and T3 in terms of water productivity. Similarly, the highest water-energy productivity was observed under treatment T3 (7.85 kg kWh⁻¹), with the lowest productivity found for treatment T1 (1.02 kg kWh⁻¹). This difference was highly significant statistically. However, among the treatments T3, T4 and T5, the calculated differences in water productivity and water-energy productivity were not significant.

Economics of drip-irrigated paddy

In the present study, the economics of drip-irrigated paddy were compared with conventional paddy cultivation practices and with standard System of Rice Intensification. The annual cost of drip irrigation system was calculated with the assumption that the life of the physical infrastructure would be 10 years with 10 per cent annual depreciation. The cost components considered included seeds, fertilizer, labour, electricity charges per unit, farm yard manure, harvesting and threshing. Uniform cost values were considered for all the treatments depending upon the respective quantity of input in each treatment.

The findings of the study indicated that the highest net return (\$ 2442/ha/year) and B:C (3.23) ratio can be obtained under SRI management with drip irrigation emitters spaced at 20 cm, followed by SRI with drip irrigation emitters spaced at 30 cm (*Table 3*). The lowest net return (\$ 853/ha/year) and lowest Benefit: Cost (2.18) ratio was

obtained with conventional practice of paddy cultivation. Based upon his research in Madagascar, Andrianaiivo (2002) reported that optimal water use can enhance returns from System of Rice Intensification with enhanced labour productivity and far higher net income than traditional methods for the cultivation of rice. The findings of the present study are consistent with Andrianaiivo's analysis and that of many other studies.

Table 3. *Economic and water productivity of paddy cultivation with drip irrigation systems over conventional system*

Treatments	Annual cost of cultivation (\$/ha/year)	Gross monetary return (\$/ha/year)	Net monetary return (\$/ha/year)	Benefit:Cost ratio
T ₁	1125	2170	1045	1.92
T ₂	920	2769	1849	3.00
T ₃	822	4782	3960	5.81
T ₄	796	4562	3766	5.73
T ₅	782	4041	3258	5.16

Assumptions: Revenue received is \$ 667 per tonne of grain produced, and Rs. 17 per tonne for straw yield, based on prevailing market prices

Conclusions

The present study found consistent evidence that the adoption of drip irrigation combined with paddy transplanted and managed according to System of Rice Intensification practices offers substantial agronomic and economic advantages. Plant growth and yield-contributing parameters such as effective tillers, number of panicles m⁻², and grain yield were found to be significantly higher in drip-irrigated treatments. Apart from higher yield, water productivity and water-energy productivity were both higher in the case of drip-irrigated paddy cultivation with young single seedlings transplanted at 30 x 30 cm spacing with drip emitters spaced at 20 cm.

Among the drip-irrigated treatments, there was no significant difference in grain yield between the T3 and T4 treatments which indicate that spacing drippers at 30 cm can be recommended as the cost of installing a drip system would be relatively cheaper with more widely-spaced drippers. These results should be further tested with further experimentation and evaluation because the implications of this work could be rather far-reaching. The evidence assembled and analyzed here suggests that System of Rice Intensification crop management with drip irrigation is a promising adaptation for reducing the rice-crop's demand for water and energy, which are increasingly demanded and costly, while at the same time it raises grain yield. However, long-term, multi-location trials will be needed to arrive at percentages of water and energy saving that are achievable under varied and specific conditions.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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