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RICE YIELD AND WATER USE EFFICIENCY GROWN WITH DIFFERENT IRRIGATION REGIMES IN A RICE INTENSIFICATION SYSTEM

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ABSTRACT

The demand for rice increases with population, which is expected to rise by a further 38% globally within thirty years according to United Nations. But the rice yield is reaching at plateau. Rice cultivation needs huge amount of water (120-200cm) which is becoming scarce and costly input day by day. Therefore, farmers are shifting to cultivation of less water demanding crops owing to decline in profitability to high input cost and low price of rice. In such situation, system of rice intensification (SRI) might be suitable alternative to conventional rice cultivation. Keeping in view, a study was undertaken to find out optimum age of seedlings, plant density and irrigation regime which are the most important inputs of SRI. A field experiment was conducted at the Mumtazpur village during kharif seasons of 2022 on sand clay loam soil. The treatments consisted combination of four irrigation regimes and two methods of planting (SRI and traditional planting). Irrigation given one day afar disappearance of water resulted in significantly higher values of dry matter production, number of tillers/hills, LAI, CGR, RGR, number of panicles/hills, length of panicle, number of grains per panicle, weight of grain per panicle, test weight, grain and straw yield in both the years as compared to other level of Irrigation. Irrigation and water requirement of rice higher with irrigation given at continuous submergence of water whereas irrigation water use efficiency was higher with irrigation given five days after disappearance of water and field water use efficiency was higher with irrigation given three days after disappearance of water than other level of irrigation. System of rice intensification recorded significantly higher grain yield to the tune of 11.95 percent as compared to conventional rice in 2022. Net returns and B:C ratio were more under SRI as compared to traditional rice which might be due to high economic yield and comparatively lesser cost of cultivation

***Keywords*:** SRI, Water requirement, Field water use efficiency, irrigation water use efficiency, LAI, CGR, RGR.

Introduction

Rice, one of the world's most consumed staple crops, serves as a vital source of sustenance for nearly half of the global population (Sharma *et al.* 2020). In India, rice occupies a preeminent position in the agrarian landscape, not only as a primary dietary staple but also as a crucial contributor to the nation's economy (FAOSTAT, 2019 and Rana and Bisht, 2023). The cultivation of rice has been woven into the very fabric of Indian agriculture for centuries, and its sustained productivity is essential to ensure food security and economic stability. However, the dynamic interplay between burgeoning population pressures, dwindling natural resources, and the pressing need to enhance agricultural productivity has engendered a paradigm shift in the way rice is cultivated in India (Yadav *et al.*, 2013 and Jain *et al.*, 2014).

Rice accounts for a significant contribution to the total food grain production in India and it is staple food of more than half of the world's population (Swain *et al.*, 2014 and Singh *et al.*, 2011). In India, rice is the most important and extensively grown food crop, occupying around 43.7 million hectares of land (Ministry of Agriculture, 2022). However, the increasing water need for different sectors will put pressure on the availability of water to agriculture in general and rice in particular. The great challenge will be to increase food production with less water, particularly in country with limited water and land resources, by promoting techniques and cropping systems of higher water-use efficiency (WUE) (Singh *et al*., 2002 and Nirmala *et al.,* 2021). There is also much evidence that water scarcity already prevails in rice growing areas in India, where rice farmers need technologies to cope with water shortage and ways must be sought to grow rice with less water. The farmers, especially those, who are resource-poor, are losing interest in rice cultivation as its profitability is declining with the rise in input costs. But, system of rice intensification (SRI) appears to be a viable alternative of rice cultivation that saves the expensive inputs, improves soil health/ quality and protects the environment substantially (Anas *et al.,* 2011 and Reben *et al*., 2016).

The higher yields with SRI practices are achieved with any and all rice varieties while using less water and with little use of mineral fertilizers. Because the resulting plant phenotypes are more resistant to damage by pests and diseases. While the mechanisms that make these benefits attainable are not yet fully understood, it appears that SRI effects are the result of greater root growth and of increases in soil biological activity that are induced by different cultural practices (Bouman *et al.,* 2007 and Jayandera *et al*., 2010). Another important aspect in SRI is to keep the soil both moist and aerated, at least during the vegetative growth period, so that roots have access to both oxygen and water. Under continuously hypoxic conditions, rice roots degenerate, with as many as 75% become dysfunctional by panicle initiation (Wang *et al*., 2006). Weeding with a rotating hoe aerates the soil while it prevents weeds' growth by churning them into the soil and enhances the soil aeration. Investigations of the past have clearly brought out the significance of the cultural practices viz. seedling age, crop geometry, irrigation, weeding and nutritional strategies as major determinants of rice productivity under SRI (Cai *et al.,* 2007 and Suryavanshi *et al*., 2012). The system proves to be a promising one on large scale. However, information regarding suitability of this system under different agro-climatic conditions and optimum age of seedling, spacing and irrigation regime etc. to be followed is not properly ascertained (Chai *et al*., 2015). Hence, the present investigation was carried out to compare the advantages of SRI over traditional rice transplanting on growth, yield, economics, water use and its efficiency.

Materials and Methods

A field experiment on was conducted during Kharif season of 2022 to assess the performance of rice under SRI system over traditional transplanting. The field trial was laid out in the Mumtazpur village (Nearest Pataudi Village). It is situated at 28^o 29' latitude and 76^o 78'E longitude at an elevation of 228 meters above the mean sea level. Average annual rainfall is about 650 mm, 74% of which is received in three months, namely July, August and September during south-west monsoon. The treatments compromising two methods of planting viz. system of rice intensification (P1) and traditional practice of transplanting (P2) and four level of irrigation viz. continuous submergence (I_1), one day drainage (I_2), three-day drainage (I_3) and five-day drainage (I_4). In system of rice intensification method, thirteen-day old seedling was transplanted in a square pattern with 30 × 30 cm hectare in traditional transplanting 21-day old seedlings were planted with 20cm row and 15cm plant spacing. Soil of the experimental field was sandy clay loam containing 46.8 % sand, 30.8% silt and 22.4% clay with 7.7 pH and 0.38 EC dS/m. The organic carbon content was 0.78%. Soil was low in available nitrogen, medium in available phosphorus and high in available potassium. The field capacity and permanent wilting point of the soil ranged between 19 to 20% (w/w) and 9 to 12% (w/w) respectively.

Plate 1 : A view of the the study areas in Mumtazpur village and rice crop filed

The variety 'Pusa Sugangh 5' was tested with recommended doses of N P K and Zn @ 120:60:60 and 25 kg/ha respectively. Half of N and full dose of P, K and Zn were applied at basal and remaining half of N was applied in two equal splits at active tillering and panicle initiation stage. Weeding at 25 and 45 DAT was done through cono weeder which facilitated the incorporation of weeds and increased aeration resulting in improvement of physio-chemical and biological properties of the soil. Various crop growth parameters such as plant height, No. of tillers/hill, crop growth rate (CGR), relative growth rate (RGR), leaf area index (LAI) and Dry matter accumulation were recorded at different crop growth stages. Observations on yield parameter were also recorded at crop maturity and standard procedures were used for chemical analysis of soil and plant sample. The economic parameter (Gross return, net return and B: C ratio) were worked out based on prevailing market prices of the input and output. The data relating to each character were analyzed as per the procedure of analysis of variance and significance of al randomized block design (RBD), tested by "F" test (Cochran and Cox, 1957). Standard Error of Means (SEm+) and Least Significant differences (LSD) at 5% level of significance were worked out for each parameter.

Results and Discussion

Growth parameters

The results of observations on plant growth characters *viz.* plant height, number of tillers per hill are presented in Table 1 reveal that in SRI (P1) plant height are significantly higher at all the stages compare to traditional(P2) rice cultivation irrespective of level of irrigation. At level of irrigation one DADW (I2) has more plant height compare to other level of irrigation. On an average transplanting of young seedling attained significantly taller plant and higher number of tillers with SRI as compared

to traditional transplanting irrespective of the irrigation schedule followed. Due to anaerobic conditions of the root the numbers of tillers per hill are reduced in continuous submergence. SRI method of planting produced significantly more number of tillers as compare to traditional planting at all stages of crop growth (Table 1). Transplanting of younger seedlings prior to the start of the 4th phyllochron of growth has potential for more tillering and root growth that is reduced by transplanting of older seedlings. On the other hand, Mahajan *et al.* (2009) revealed that significant phenotypic changes occurred in plant structure and function but no significant yield differences were observed in SRI system in comparison to conventional transplanting system. It was observed that wider spacing between plants and single plant/hill in SRI helped in producing profuse root system and tillers resulting in higher grain yield compared to traditional transplanting where 2-3 plants/hill in closer spacing were transplanted (Adam *et al* 2001 and Islam *et al*. 2007).

Table 1 : Effects of planting method and irrigation level on plant height and No. of tillers per hill

Treatments	Plant Height				No. of Tillers per hill			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
Method of Planting (P)								
P_1	68.81	107.80	118.96	125.13	23.58	30.38	24.37	22.63
P_2	66.84	104.0	116.83	115.51	12.28	19.23	14.12	11.90
P_3	0.80	0.26	0.28	0.67	0.25	0.31	0.26	0.13
SEm+	0.80	0.26	0.28	0.67	0.25	0.31	0.26	0.13
LSD (p=0.05)	2.43	0.80	0.87	2.03	0.76	0.95	0.79	0.40
Level of irrigation (I)								
I_1	69.64	108.15	119.86	121.25	19.66	27.68	20.73	18.92
I_2	74.08	110.16	122.92	123.11	20.65	29.13	22.03	20.15
I_3	68.08	106.33	117.80	119.58	17.18	24.30	19.50	16.97
SEm+	1.13	0.37	0.40	0.94	0.35	0.44	0.37	0.18
LSD (p=0.05)	2.42	1.13	1.22	2.86	1.08	1.35	1.12	0.56

Leaf area index and dry matter accumulation

The data on dry matter accumulation and leaf area index as affected by method of planting and level of irrigation are presented in Table 2. It is evident that under SRI dry matter production and leaf area index were significantly higher as compare to traditional practice. It was mainly due to higher number of tillers and more number of leaves because soil remains both moist and aerated, at least during the vegetative growth period so that roots have access to both oxygen and water and therefore, the aerobic conditions in SRI promote root growth substantially over continuous submerged situations. The maximum dry matter accumulation was found between 60 and 90 DAT in both method of planting and all four level of irrigation. Scheduling of irrigation based on one day after disappearance of water (DADW) produce significantly high dry matter than other irrigation schedules. In general, LAI increased progressively with time attaining maximum at 60 DAT and decline thereafter. Dry matter is the resultant effect of the growth characters viz. plant height, leaf area and tillers per hill. Irrigation regime I 2 registered significantly higher number of panicles per hill, length of panicle, number of grains per panicle, weight of grains per panicle and test weight resulting in more dry matter accumulation than other irrigation regimes. Balasubramanian (1998) also reported the similar effects of irrigation regimes on overall growth parameters. Leaf area index was also significantly higher under SRI.

Table 2 : Effect of material of planting and level of irrigation on dry matter accumulation (g/hill) and leaf area index (LAI)

Treatments	Dry Matter Accumulation (g/hill)				Leaf Area Index		
	30 DAT	60 DAT	90 DAT	At Harvest	30 DAT	60 DAT	90 DAT
Method of Planting (P)							
P_1	7.33	13.51	34.69	36.36	2.47	5.63	4.37
P_2	7.04	12.71	31.75	33.85	2.32	5.21	4.20
P_3							
SEm+	0.09	0.10	0.19	0.20	0.01	0.022	0.02
LSD (p=0.05)	0.27	0.32	0.59	0.62	0.03	0.067	0.59
Level of Irrigation (I)							
I_1	7.45	13.32	34.91	36.16	2.42	5.52	4.32
I_2	7.80	14.08	37.03	38.63	2.49	5.66	4.50
I_3	7.01	13.10	31.78	33.95	2.39	5.40	4.23
SEm+	0.12	0.15	0.27	0.29	0.015	0.032	0.027
LSD (p=0.05)	0.38	0.45	0.83	0.88	0.04	0.09	0.08

Crop growth rate and relative growth rate

It is evident from the data presented in Table 3 that the crop growth rate (g/day/hill) and relative growth rate (g/g/day) were significantly affected by method of planting and level of irrigation. In general, it was observed that the CGR was more during 60-90 DAT in both the method of plantings and irrigation schedules. Higher crop growth rate (CGR) was recorded by irrigating the rice at one day after disappearance of water (DADW) over other irrigation regimes. Data on relative growth rate (g/g/ day) show that irrigation given three day after disappearance of water (DADW) produce higher growth rate at 30 DAT. However, there was no significant difference in CGR amongst different irrigation level at 30-60 DAT. The crop growth rate (CGR) and relative growth rate (RGR) were maximum during 60-90 DAT. This might be due to higher LAI and dry matter accumulation during that growth period. Nonetheless, CGR and RGR were significantly higher in system of rice intensification as compared to conventional rice (Bottomley *et al.*, 1994 and Tuti *et al.*, 2022). It might be due to incorporation of weeds into soil converting in to organic nutrient source at later stage (Table 3).

Yield attributes and yield

The data pertaining to yield attributing parameters and yield influenced by planting method and irrigation regimes are given in Table 4. Irrigation applied one day after disappearance of water (DADW) produced maximum panicle length and panicle weight as compare to other irrigation regimes irrespective of method of planting. Through the length of panicle, panicle weight, grain weight/ panicle, were more with the system of rice intensification as compare to conventional method. Similarly, the biological yield of rice was significantly influenced by level of irrigation and method of planting. It was observed that irrigation given one day after disappearance of water (DADW) yielded significantly higher biological, grain and straw yields compare to continuous submergence, three and five days after disappearance of water (DADW). The higher grain yield may be attributed to significantly higher yield contributing attributes such as panicle length, panicle weight, grains/panicle etc (Jain *et al.*, 2014 and Gathorne Hardy *et al.*, 2016).

Balasubramanian and Krishnarajan (2000) also obtained highest grain yield with one day drainage compared to other irrigation schedules. Average biological yield, grain yield, straw yield and harvest index under system of rice intensification found to be significantly superior over conventional method of rice cultivation and there is also significant difference present in grain yield at each irrigation level in SRI. The increased grain yield in SRI might be due to cumulative effect of higher growth and yield attributes (Anas *et al*., 2011).

Table 3 : Effect of method of planting and level of irrigation on crop growth rate and relative growth rate of rice

Treatments	CGR (g/day/hill)			RGR (g/g/hill)		
	30-60	60-90	90-harvest	30-60	60-90	90-harvest
Method of Planting (P)						
P_1	0.20	0.74	0.05	8.9	14	0.6
P_2	0.18	0.65	0.047	8.5	13	0.63
SEm_+	0.004	0.007	0.004	0.2	0.16	0.6
LSD (p=0.05)	0.011	0.02	0.013	0.6	0.5	0.17
Level of Irrigation (I)						
11	0.19	0.70	0.050	8.3	13.8	0.61
12	0.21	0.76	0.053	8.6	14	0.61
13	0.20	0.68	0.054	9	13.6	0.68
SEm+	0.005	0.009	0.006	0.3	0.23	0.08
LSD (p=0.05)	0.016	0.03	0.018	0.8	0.71	0.25

Treatments	Panicle length(cm)	Panicle weight(g)	Grain yield(t/ha)	Straw yield(t/ha)	Biological yield(t/ha)	Harvest index(%)
Method of Planting (P)						
P_1	31.64	2.21	4.87	15.34	20.21	24.15
P_2	31.52	2.16	4.35	14.74	19.09	22.78
SEm_+	0.35	0.011	0.058	0.139	0.120	0.210
LSD (p=0.05)	NS	NS	0.18	0.422	0.39	0.64
Level of Irrigation (I)						
1_1	31.67	2.20	4.86	15.80	20.66	23.55
1_2	32.20	2.33	5.05	16.38	21.41	23.58
1_3	31.57	2.16	4.57	15.0	19.58	23.35
SEm+	0.49	0.016	0.072	0.196	0.18	0.30
LSD (p=0.05)	1.50	0.05	0.22	0.61	0.55	0.91

Table 5 : Effect of method of planting and level of irrigation on nitrogen and protein content of rice

Treatment	Grain nitrogen (%)	Straw nitrogen (%)	Grain Protein (%)
Method of Planting (P)			
P_1	1.38	0.55	8.24
P_2	1.35	0.53	8.08
SEm+	0.008	0.006	0.035
LSD (p= 0.05)	0.017	0.014	0.10
Level of irrigation (I)			
I_1	1.38	0.56	8.26
I_2	1.44	0.57	8.58
$!_3$	1.34	0.53	8.00
SEm+	0.011	0.01	0.05
LSD (p= 0.05)	0.03	0.02	0.15

N concentration and crude protein content in grain and straw (%)

The data pertaining to N concentration in grain and straw of rice as influenced by level of irrigation and method of planting are given in Table 5. Data indicate that irrigation given one day after disappearance of water (DADW) recorded significantly high nitrogen content in grain compared to other irrigation schedule but for straw there is no significant differences present in nitrogen content between continuous and one day after disappearance of water (DADW). Nitrogen content both in grain and straw was significantly increased by system of rice intensification as compared to conventional method of rice cultivation. The data pertaining to protein concentration in grain of rice as influenced by level of irrigation and method of planting are given in Table 5. Irrigation given 1-DADW recorded significantly high protein content in grain compared to continuous submergence, irrigations given three and five day after disappearance of water (DADW). Protein content in grain was significantly increased by system of rice intensification as compared to conventional method of rice cultivation irrespective of the irrigation schedule followed.

Irrigation requirement, water requirement and saving of irrigation water

The different components of water requirement of rice under different irrigation regimes and planting methods are given in Table 6. It was found that irrigation given five day after disappearance of water (DADW) consumes least amount of water (400) mm as compared to irrigation given three day (520 mm) and one day after disappearance of water (680 mm) in both system of rice intensification and traditional transplanting. The highest irrigation requirement was recorded with continuous submergence (880 mm) in both methods of rice cultivation. On an average saving of irrigation requirement was 22.7% in one day after disappearance of water, 40.91% in three day after disappearance of water and 54.55% in five day after disappearance of water in comparison to continuous submergence. The average irrigation requirement at all four level of irrigation was 620 mm in both methods of planting. Further it was observed that irrigation given five days after disappearance of water (5 DADW) has least water requirement (990 mm) followed by 3 DADW (1095 mm) and 1DADW (1240mm) under both system of rice intensification and traditional transplanting. However, highest water requirement was recorded with continuous submergence (1410 mm) in both methods of rice cultivation. On an average there was a saving 12.06%, 22.34% and 22.34% in 1, 3 and 5 DADW respectively in comparison to continuous submergence.

Table 6 : Effect of different level of irrigation on water use efficiency in System of Rice

Level of irrigation (I)	System of Rice Intensification					
	Irrigation requirement (mm)	Saving of irrigation requirement	Water requirement (mm) %	Saving of water requirement (%)	Irrigation use efficinecy (kg grain/m^3 water	Field water use efficiency (kg grain/m^3 water)
I_1	880	-	1410	-	0.57	0.36
I_2	680	22.73	1240	12.06	0.77	0.42
I_3	520	40.91	1095	22.34	0.94	0.45
Traditional						
I_1	880	-	1410	-	0.54	0.32
I_2	680	22.73	1240	12.06	0.71	0.39
I_3	520	40.91	1095	22.34	0.81	0.39

Irrigation use efficiency and field water use efficiency

The data pertaining to irrigation and field water use efficiencies of rice as influenced by level of irrigation and method of planting are given in Table 6 and Figures 1 to 4. Under SRI system irrigation given five days after disappearance of water (5 DADW) recorded highest irrigation use efficiency (1.07) as compared to irrigation given to 3 and 5 DADW. The least irrigation and field water use efficiencies were recorded with continuous submergence. However, the maximum water use efficiency under SRI was recorded when irrigation was scheduled three days after disappearance of ponded water. In traditional transplanting, field water use efficiency and irrigation use efficiency were less than the SRI. Nevertheless, in traditional planting irrigation given 5DADW recorded highest irrigation use efficiency (0.81) as compared to three and one day DADW. Under traditional planting lowest irrigation and field water use efficiency were observed under continuous submergence of water and maximum field water use efficiency was observed at one and three day after disappearance of water DADW. Among the four irrigation regimes under SRI irrigation given five days after disappearance of water registered lesser irrigation and water requirement as compared to other levels of irrigation. Highest irrigation and water requirement was recorded with continuous submergence in both SRI and conventional rice (recommended practices). On an average the irrigation and water requirement in both methods of planting were same but the irrigation use efficiency and field water use efficiency were higher in SRI as compared to traditional rice cultivation which was due to higher economic yield.

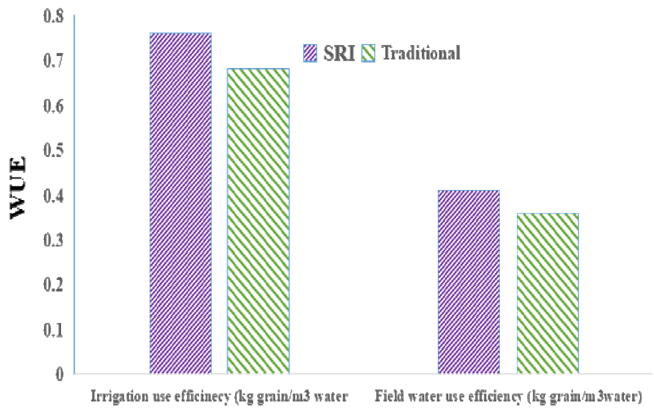

Fig 1. Effect of different planting method on water use efficiency of rice

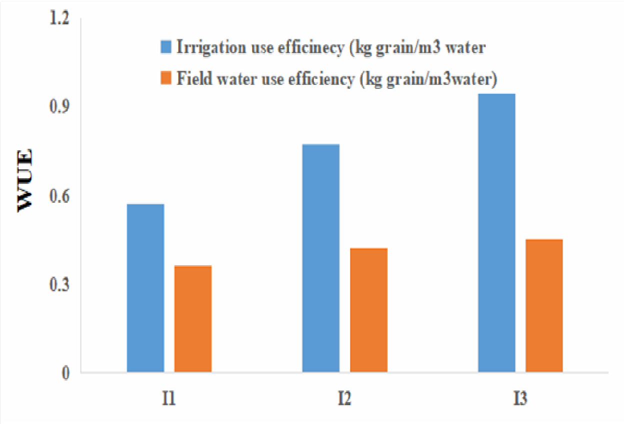

Fig 2. Effect of level of irrigation on irrigation and field water use efficiency

Conclusions

System of rice intensification (SRI) recorded significantly higher growth parameter, yield attributes, grain yield and harvest index as compared to conventional transplanting of rice. Similarly, irrigation given one day after disappearance of ponded water resulted significantly grain yield and harvest index as compared to other level of irrigations. Further it was observed that 5-day drainage period resulted in significantly low yield as compared to 1- and 3-day drainage period. Total water use and water use efficiency were higher with SRI irrespective of the irrigation schedule adopted than traditional transplanting. In case of irrigation level, 3 day after disappearance of ponded water resulted in higher water use efficiency in comparison to one day and continuous submergence.

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