The Bioscan 9(1): 85-88, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

STUDIES ON THE WATER USE EFFICIENCY AND NUTRIENT UPTAKE BY RICE UNDER SYSTEM OF INTENSIFICATION

MD. RITON CHOWDHURY*, VINOD KUMAR, ABDUS SATTAR[1] AND KOUSHIK BRAHMACHARI[2]
Department of Agronomy, [1]Department of Agro-meteorology,
Rajendra Agricultural University, Pusa, Samastipur - 848 125, Bihar, INDIA
[2]Department of Agronomy, Bidhan Chandra Krishi Viswavidalaya, Mohanpur - 741 252 Nadia, W.B., INDIA
e-mail: md.riton@gmail.com

KEYWORDS
Nutrient uptake
Rice
Rice Intensification
Water use efficiency

Received on :
19.05.2013

Accepted on :
11.01.2014

***Corresponding author**

ABSTRACT

All the growth and developmental parameters viz. plant height, leaf area index, crop growth rate (CGR), panicle m^{-2}, grain weight per panicle, grain and straw yield, NPK content in grain and straw as well as nutrient uptake were better influenced by 2.5 cm irrigation 0 days after disappearance of ponded water (DAD) over 6 DAD but were at par with 3 DAD. The test weight was not influenced by irrigation levels. Water-use efficiency (WUE) was favourably influenced by 2.5 cm irrigation 3 DAD over 0 DAD but was at par with 6 DAD. Final soil fertility status (N, P_2O_5 and K_2O ha^{-1}) decreased with increasing levels of irrigation. All the growth and development parameters, grain and straw yield, WUE, NPK content in grain and straw, nutrient uptake , were favourably influenced by 10 t FYM ha^{-1} + 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} (F_2) over all the nutrient levels. Both the gross and net return were significantly higher at 0 DAD over 6 DAD but were at par with 3 DAD while, F_2 was significantly higher over all the nutrient levels. The highest return per rupee of investment was recorded at 2.5 cm irrigation 3 DAD while, it was significantly higher at F_1 (120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}) over all the nutrient levels but was at par with F_2 level.

INTRODUCTION

Rice is the main food of the largest population of the World. About 90 % rice in the world is grown and consumed by the population of the Asian countries which constitute 58 % population of the World. It is grown in an area of more than 135 million hectares in the World. More than 400 million people in rice-producing areas of Asia, Africa and South America still suffer chronic hunger, with the demand for food expected to rise by another 38% within 30 years (Surridge, 2004). This increase in production could be achieved by intensification of paddy cultivation rather than increasing the area. The FAO estimates that rice crop consumes about 4000-5000 liters water per kg of grain produced. Since water for rice production has become increasingly scarce water saving strategies has become a priority in rice research (Raju and Sreenivas, 2008 and Borker *et al.,* 2000). System of Rice Intensification (SRI) developed is another water saving technology with many fold increase in crop yield. By adopting this system of cultivation we could save water, protect soil productivity and could environment by checking methane gas from water submerged rice cultivation practices, bring down the input cost besides improving the production for providing food to the burgeoning population. Careful water management needs to be pursuit. The field should be kept moist and water should not be allowed stagnated and should be kept shallow (up to 2.5 cm) and intermittent irrigation i.e. alternatively drying and wetting shaved about 30-40 per cent water under SRI as compared to conventional rice cultivation. This system of cultivation not only helps to minimize loss of nutrients specially nitrogen but also helps to increase applied nutrient and enhance the tillering of rice plants. Increased soil aeration and organic matter help in improving soil biology leading to better nutrient availability. Therefore, the present study was undertaken to study the growth, yield, water use efficiency and nutrient uptake by rice under system of intensification.

MATERIALS AND METHODS

The field experiment was conducted to find out the optimum level of irrigation and nutrient applied through organic and inorganic sources and to work out the water use efficiency and nutrient uptake under SRI cultivation during *kharif* season of 2009 and 2010 at research farm, Rajendra Agricultural University, Bihar, Pusa (Samastipur) situated at 25°58.2′ 43"N latitude, 85°54.2′ 78" E longitude, 52.92 m above mean sea level with 1276.1 mm of average rainfall. The soil of the experimental plot was sandy loam in texture, alkaline in reaction (pH 8.14) and available nitrogen 157 kg ha^{-1}, available phosphorous 19.85 kg ha^{-1} and available potassium 163.2 kg ha^{-1} content.

The experiment was laid out in a split plot design with irrigation in main plot and nutrient in sub plot with three replications. The main plot treatments were I_1- Irrigation up to 2.5 cm at 0 days after disappearance of ponded water (DAD), I_2- Irrigation up to 2.5 cm at 3 DAD, I_3- Irrigation up to 2.5cm at 6 DAD and sub-plot treatments were F_1-120kg N, 60 kg P_2O_5, 40 kg K_2O ha^{-1} [RDF], F_2-FYM @ 10 t ha^{-1} + 100%F_1, F_3- FYM @

10 t ha^{-1} +75%F_1, F_4-FYM @ 10 t ha^{-1} + 50% F_1, F_5- FYM @ 10 t ha^{-1}. The whole amount of P_2O_5 in the form of DAP and K_2O as MOP were applied as basal. Nitrogen was applied in 3 split doses with 1/3 nitrogen as basal in the form of DAP. Rest T! N was given in the form of Urea in two equal split doses, one at active tillering stage and rest at panicle initiation stage. The gross and net plot size were 5 m × 3.5 m and 4 m × 2.5 m respectively with spacing of 25 cm × 25 cm the rice was Rajendra mashuri-1.

Growth attributes and yield components such as plant height (cm), crop growth rate(g m^{-2} day^{-1}), panicles m^{-2}, number of grains $panicle^{-1}$, 1000 grain weight (g), grain yield (q ha^{-1}) and straw yield (q ha^{-1}) were recorded and statistically analysed.

Water use efficiency was determined with the help of the following formula,(Michael, 1981)

$$\text{Water use efficiency (kg ha - cm}^{-1}) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Water requirement (cm)}}$$

Uptake of nutrient (kg ha^{-1}) by a particular crop or plant part was calculated by multiplying the percentage of concentration of concerned nutrient of that particular crop or plant part with yield (kg ha^{-1}).

RESULTS AND DISCUSSION

The data depicted in the Table 1 represents the growth parameters (viz. plant height, LAI and CGR) of rice under SRI. During all the growth stages except at 30 DAT, the maximum plant height, LAI and CGR was recorded in the treatment which received irrigation 2.5 cm at 0 DAD of ponded water i.e. on the same day when the ponded water disappeared and minimum in the treatment 6 DAD of ponded water. Significant increase in plant height due to irrigation has been reported by various workers like Choudhary (2003), Mandal *et al.,* (2009) and Parihar (2004). At all the growth stages i.e. 30, 60, 90 DAT and at harvest plant height increased with increasing levels of nutrients. Nutrient has direct influence in increasing the uptake of N which in turn might have increased the plant height. This was is in agreement with Nelson and Tisdale (1965). Leaf area index (LAI) at flowering is closely related to grain production because it affects the amount of photosynthate (Fagade and De Dutta, 1971). Leaf area index also increased upto 90 DAT which normally coincided with grain formation stage. The photosynthetic activities of the plants are well reflected in their dry matter production. A significant difference was observed in respect of CGR at all the crop growth stages except at 30 DAT with different irrigation levels due to significant increase in plant height, numbers of tillers $hill^{-1}$ and size of leaves. Similar result was also reported by Prasad (2003). The total leaf area of rice population is a factor closely related to grain production because the total leaf area at heading greatly affects the amount of photosynthate available to panicle 75 to 80 percent of the carbohydrates accumulated in the grain. Increase in dry matter accumulation and CGR at all the growth stages due to difference in NPK levels may be attributed to increase in the amount and efficiency of chlorophyll which have influenced the photosynthetic efficiency and formation of other nitrogenous compounds viz. amino-acids, proteins, alkaloids and protoplasm resulting in increase in plant height, numbers of tillers $hill^{-1}$, which contributed towards increased dry matter yield and CGR. These findings are confirmed by the result of Prasad (2003) and Borkar *et al.* (2008).

The yield attributes were presented in Table 2. The grain yield of rice depends on the number of panicles m^{-2}, number of grains $panicle^{-1}$and 1000-grain weight. The yield attributes were significantly superior at I_1 than I_3 but was at par with I_2. The 1000-grain weight did not change with irrigation levels.The relative magnitude of these yield attributes varied substantially with the agronomic practices. The result summerised in Table 2 revealed that the grain yield was increased with increasing levels of irrigation and different levels of nutrient. The respective increase in grain yield due to 2.5 cm irrigation at 0 DAD (I_1) and 3 DAD (I_2) as compared to 6 DAD (I_3) was to the tune of 14.87 and 8.77 percent respectively. This is in conformity with those of Chaudhary *et al.* (2009). The grain yield of a crop is the combined effect of various growth and development parameters. In the present investigation almost all the growth and development characters seemed to be affected by the increasing levels of irrigation while at the moisture stress condition for a long period, the photosynthetic activities were reduced owing to the closure of stomata which resulted the supply of CO_2 and the capacity of protoplasm to carry on photosynthetic efficiency and reduced translocation might have hindered further accumulation of the end products (Yoshida, 1972). While it was reverse in the case of the treatment receiving sufficient water throughout the growing period. This finding corroborates the result of Patjosh and Lenka (1998). The respective increase in grain yield due to only 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} (F_1),10 t FYM ha^{-1} + 100% F_1, 10 t FYM ha^{-1} + 75% F_1 and 10t FYM ha^{-1} + 50% F_1 over only 10t FYM/ha was to be the tune of 32.73%, 49.27%, 37.02% and 31.25%, respectively. Grain yield followed the same trend of growth characters and yield attributing characters. It becomes apparent that the number of panicles m^{-2}, number of grains $panicle^{-1}$, 1000-grain weight played an important role in deciding the grain yield of rice and their progressive response to NPK application resulted in increased yield of grain. It is also in conformity with the result obtained by Raju *et al.* (1999) and Ramakrishna *et al.* (2009). Straw yield increased significantly with increasing irrigation levels. This may be due to increased plant height, LAI and numbers of tillers $hill^{-1}$. Similar result has been reported by Kumar (2006). As the plant height, number of effective tillers $hill^{-1}$ and LAI increased with increasing levels of NPK, the straw yield increased. It was found maximum in F_2 (77.87 q ha^{-1}). Similar results have been reported earlier by Pal *et al.* (2008) and Pandey *et al.* (2009). Grain: straw ratio and harvest index were not found to be significant due to irrigation levels. Both these, parameters are very important determining the success of crop production. Grain: straw ratio varies from 0.706 to 0.670 whereas harvest index from 41.33% to 40.05%. On nutrient levels these two parameters grain: straw and harvest index showed significant difference due to different levels. The value of grain: straw ratio and harvest index were maximum in F_2 (0.723 and 41.96%, respectively). Similar findings have also been reported by Luikham *et al.* (2004).

Table 1: Effect of water and nutrient levels on Plant height, LAI and CGR of rice grown under SRI (data pooled over two years)

Treatment	Plant height (cm)				LAI				CGR (g m^{-2} day^{-1})			
	30	60	90	Harvest	30	60	90	Harvest	0-30	30-60	60-90	90-Harvest
I_1	51.45	87.47	107.03	111.40	1.20	3.85	5.10	0.88	4.09	10.19	6.96	3.96
I_2	50.60	80.08	103.47	108.01	1.16	3.56	4.75	0.81	3.97	9.88	6.45	3.77
I_3	50.43	78.25	100.73	103.71	1.11	3.27	4.56	0.73	3.85	9.35	6.05	3.58
S.Em ±	1.31	1.70	1.35	1.60	0.02	0.11	0.15	0.03	0.22	0.22	0.23	0.09
CD (P=0.05)	NS	4.72	3.76	4.45	NS	0.31	0.41	0.09	NS	0.62	0.64	0.25
F_1	52.85	84.22	104.83	108.94	1.22	3.69	4.86	0.82	4.10	9.82	6.76	3.78
F_2	54.43	86.99	109.61	116.47	1.24	3.89	5.25	0.90	4.37	10.21	6.92	4.12
F_3	52.48	84.56	104.84	109.09	1.18	3.74	4.90	0.84	3.98	9.97	6.73	3.91
F_4	50.58	79.32	103.83	105.45	1.13	3.46	4.72	0.80	3.86	9.74	6.27	3.65
F_5	44.78	74.56	96.17	98.63	1.01	2.98	4.28	0.68	3.52	9.30	5.74	3.40
SEm ±	1.44	1.87	0.65	2.16	0.03	0.20	0.18	0.03	0.14	0.25	0.28	0.15
CD (p = 0.05)	2.98	3.86	1.36	4.47	0.09	0.42	0.38	0.06	0.29	0.51	0.57	0.32
SEm ±	1.34	2.08	0.82	3.32	0.05	0.25	0.22	0.02	0.17	0.30	0.34	0.19
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

(I_1):2.5 cm 0 DAD, (I_2): 2.5 cm 3 DAD & (I_3): 2.5 cm 6 DAD; (F_1):120 kg N,60 kg P_2O_5 , 40 kg K_2O/ha, (F_2): 10 t FYM/ha + 100%F_1, (F_3):10 t FYM/ha + 75% F_1, (F_4):10 t FYM/ha + 50% F_1 and (F_5):10 t FYM/ha

Table 2: Effect of water and nutrient levels on yield attributes, yield and economics of rice grown under SRI (data pooled over two years)

Treatment	Panicles m^{-2}	Grains $panicle^{-1}$	1000-Grain weight	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain:straw	Harvest index (%)	Water use efficiency
I_1	279.12	182.76	20.87	52.76	74.52	0.706	41.33	45.38
I_2	267.74	179.73	20.36	49.96	72.18	0.690	40.82	62.18
I_3	254.24	174.03	19.95	45.93	68.29	0.670	40.05	65.09
SEm ±	6.68	2.16	0.25	1.26	1.04	0.014	0.36	2.49
CD (p = 0.05)	18.54	5.99	NS	4.93	4.08	NS	NS	6.93
F_1	266.66	180.31	20.67	50.16	71.36	0.702	41.24	58.16
F_2	287.60	182.53	21.11	56.41	77.87	0.724	41.96	65.20
F_3	268.96	180.66	20.86	51.78	73.16	0.708	41.45	59.79
F_4	265.10	179.15	20.28	49.60	71.70	0.692	40.92	58.54
F_5	243.84	170.60	19.05	39.79	64.44	0.617	38.08	46.15
SEm ±	5.83	1.86	0.23	1.23	0.94	0.015	0.75	1.57
CD (p = 0.05)	12.04	3.85	0.66	3.58	2.75	0.043	1.54	4.58
SEm ±	8.68	1.96	0.39	2.19	1.63	0.025	0.93	2.72
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

(I_1):2.5 cm 0 DAD, (I_2): 2.5 cm 3 DAD & (I_3): 2.5 cm 6 DAD; (F_1):120 kg N, 60 kg P_2O_5, 40 kg K_2O/ha, (F_2): 10 t FYM/ha + 100%F_1, (F_3):10 t FYM/ha + 75% F_1, (F_4):10 t FYM/ha + 50% F_1 and (F_5):10 t FYM/ha

Table 3: Water requirement as affected by different treatments (data pooled over two years)

Treatments	Water applied through irrigation (cm)	Total rainfall (cm)	Total water applied (cm)
I_1	70	48.05	118.05
I_2	32.5	48.05	80.55
I_3	22.5	48.05	70.55

(I_1): 2.5 cm 0 DAD, (I_2): 2.5 cm 3 DAD & (I_3): 2.5 cm 6 DAD

Table 4: Effect of water and nutrient levels on nutrient uptake by grain & straw and total uptake of rice grown under SRI (data pooled over two years)

Treatments	Nutrient uptake (kg ha^{-1})								
	Grain			Straw			Total		
	N	P	K	N	P	K	N	P	K
I_1	63.493	19.193	14.952	46.015	14.496	107.414	109.567	33..690	122.366
I_2	59.489	16.630	13.174	43.109	13.103	101.346	102.597	29.733	114.521
I_3	53.790	14.061	10.868	40.125	11.556	93.394	93.914	25.617	104.262
SEm ±	2.151	0.943	1.071	1.144	0.563	3.067	3.109	0.983	3.905
CD (p = 0.05)	5.971	2.617	2.973	3.175	1.562	8.513	8.629	2.729	10.840
F_1	61.013	17.279	13.611	43.362	13.820	102.754	104.375	31.099	116.356
F_2	70.588	18.827	15.589	50.453	15.674	116.011	121.041	35.501	131.600
F_3	63.372	17.988	13.972	44.811	13.758	104.769	108.184	31.742	118.741
F_4	56.875	16.816	12.719	41.739	12.644	96.200	98.614	29.460	108.919
F_5	42.772	11.235	9.109	35.047	9.364	83.855	77.819	20.600	92.964
SEm ±	2.138	1.036	0.327	1.258	0.557	2.765	2.762	1.142	2.790
CD (p = 0.05)	4.414	2.139	0.675	2.597	1.50	5.707	5.707	2.357	5.759
SEm ±	2.620	1.541	1.270	0.682	0.400	3.390	3.380	1.400	3.420
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

The data depicted in Table 3 represent the water requirement by rice. It has been found that under treatment I_1 (2.5 cm irrigation 0 DAD) the required number of irrigation was 28 for which applied amount of irrigation water was 70 cm (excluding the rainfall amount), whereas under treatment I_2 (2.5 cm irrigation 3 DAD) and I_3 (2.5 cm irrigation 6 DAD) the values were 32.5 cm and 22.5 cm respectively. The data presented in Table 2 shows significant difference in water use efficiency under different irrigation levels. The value of WUE was found to be the maximum with I_3 (2.5 cm of irrigation at 6 DAD) and the minimum with I_1 (2.5 cm irrigation at 0 DAD). These revealed that WUE increased with decrease in number of irrigation. This was due to the fact that increase in yield was relatively lesser than increase in quantity of irrigation which consequently decreased WUE under higher number of irrigations. Similar results were reported by Prasad (2003), Luikham *et al.* (2004), Tripathi and Jaishwal (2006) and Ramakrishna *et al.* (2007). In case of nutrient levels WUE increased with increasing levels of nutrient in combination with FYM 10 t ha^{-1} + 100% of F_1 (F_2) produced the maximum value of WUE and F_5 the minimum. Similar results were reported by Kumar (2006) and Choudhary *et al.* (2009).

The result illustrated in Table 4 depicts the nutrient uptake. Irrigation and nutrient levels significantly influenced the N, P and K contents in rice grain and straw. It was the maximum in the treatment which received the maximum number of irrigation and highest doses of NPK from the combination of organic and inorganic sources. Increased N, P and K contents with increase in their levels might be due to the fact that higher nutrient level increased the amount of available N, P and K in soil which ultimately increased N, P and K contents in grain and straw. Similar findings have also been reported by Choudhary (2003). At irrigation level I_1 uptake of NPK was found to be the maximum. This may be due to the fact that nutrient uptake by crop is a function of total biomass production and the nutrient content in the biomass. It is also influenced by the chemical nature of the soil including the amount of available nutrients, rate of replenishment of nutrients from soil reserve to available pool, nature of plant and its growth behaviour, management practices affecting the availability of nutrients in soil and other allied factors. Greater amount of N, P, K uptake by rice at higher irrigation levels due to the fact that higher level of irrigation was more conductive for uptake of nutrients by the plants. Similar observation was found by Choudhary (2003). Increase in uptake of NPK might be due to the availability of N, P, K in the soil which ultimately favoured the uptake. Maximum uptake was observed in F_2 in which 100% NPK were applied in combination with organic source i.e 10 t FYM ha^{-1}. Parihar (2004) and Pandey *et al.* (2009) also reported similar results.

It can be concluded that, irrigating the rice crop grown under system of rice intensification upto 2.5 cm at 3DAD of ponded water and application of FYM @ 10 t ha^{-1} + 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} is recommended for higher productivity and profitability.

REFERENCES

Borker, R., Dawe, Toung, T. P., Bhuiyan, S. I. and Gerra, L. C. 2000. The outlook for water resources in the year 2020: challenges for research on water management in rice production. *Int. Rice Comm. Newsl.* **49:** 7-21.

Chaudhary, D. K. 2003. Effect of water regimes and NPK levels on mid duration rice. (*Oryza sativa L*). M.Sc.(Ag.). Thesis, RAU, Pusa, Bihar.

Fagade, S. O. and De Dutta, S. K. 1971. Leaf area index, tillering capacity and grain yield of tropical rice as affected by planting density and nitrogen levels. *Agron. Journal.* **63:** 503-06.

Kumar, P. 2006. Response of fine aromatic rice (*Oryza sativa* L.) to moisture regimes and NPK levels. M.Sc. (Ag.) Thesis, RAU, Pusa.

Lukham, E., Krishanranjan, J. and Premshekhar, M. 2004. Irrigation and nitrogen application schedule for hybrid 'ADTRH 1' rice *(Oryza sativa)* in Tamil Nadu. *Indian J. Agroomy.* **49(1):** 37-39.

Michael, A. M. 1981. Irrigation Theory and Practice. Vikas Publishing House Pvt. Ltd., New Delhi.

Nelson, W. L and Tisdale, S. L. 1965. Soil fertility and fertilizer. The Ma-Cmillan Company. New York.

Pal, S., Banerjee, H., Basu, B. and Maity, S. 2008. Studies on nutrient management practices in rice-rice sequence under new alluvial zone of West Bengal. *Oryza.* **45(1):** 125-128.

Pandey, N., Verma, A. K. and Tripathi, R. S. 2009. Effect of planting dates and levels on N concentration in leaf, grain, yield and N uptake by hybrid rice. *Oryza.* **45(1):** 18-22.

Parihar, S. S. 2004. Effect of crop establishment method, tillage, irrigation and nitrogen on production potential of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian J. Agronomy.* **49(1):** 1-5.

Patjosh, A. K. and Lenka, D. 1998. Determination of water management practices and effective rainfall in direct seeded medium land rice under varying water table situation. *Oryza* **35(2):** 145-47.

Prasad, D. 2003. Response of early rice levels of irrigation and nitrogen. M. Sc (Ag.) thesis R.A.U, Pusa, Bihar.

Raju and Sreenivas 2008. Agronomic evaluation of system of rice intensification in Godavari delta. *Oryza.* **45(4):** 280-283.

Raju, R. A, Reddy, K. A. and Reddy, M. N. 1999. Potassium fertilization rice varieties of Godavari flood plains. *Indian J. Agronomy.* **38(4):** 293-297.

Ramakrishna, Y., Singh, S., and Parihar, S. S.2007. Influence of irrigation regime and nitrogen management on productivity, nitrogen uptake and water use by rice (*Oryza sativa*). *Indian J. Agronomy.* **52(2):** 102-106.

Surridge, C. 2004. Rice cultivation: feast or famine? *Nature.* **428:** 360-61.

Tripathi, H. P. and Jaishwal, L. M. 2006. Effect of nitrogen on yield and yield attributes of rice hybrids under irrigated condition. *Oryza,* **43(3):** 249-250.

Yoshida, S. 1972. Physiological aspects of grain yield. *Ann. Rev. Plant Physiol.* **23:** 437-64.