Ann. Agric. Res. New Series Vol. 38 (4) : 368-374 (2017)

Growth, productivity and nutrient concentration of aerobic rice (*Oryza sativa* L.) under different planting methods, irrigation schedules and soil adjuvant application

Arjun Singh[1], Anchal Dass[2], C.V. Singh[3], Shiva Dhar[4], S. Sudhishri[5], Kajal Das[6] and Susheel K. Sarkar[7]

Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh, Jharkhand-825302
e-mail: anchal_iari@rediffmail.com

Received : August 2017 ; Revised Accepted: November 2017

Abstract

A field experiment was conducted during *kharif* season of 2016 at Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh, Jharkhand to evaluate the effect of planting methods, irrigation scheduling and soil adjuvant on growth, productivity and nutrient content of aerobic rice. The experiment was laid-out in a split-plot design keeping 8-combinations of 4-irrigation schedules, *viz.*, I_1: Irrigation at 0.9 IW / CPE ratio, I_2: Irrigation at 1.2 IW / CPE ratio, I_3: Irrigation at 1.5 IW / CPE ratio and I_4: Un-irrigated (rainfed) and 2-soil adjuvants (A_1: soil adjuvant applied and A_2: No-soil adjuvant) in the main-plots and 2-planting methods (P_1: Conventional dry seeding at 20 cm row spacing and P_2: Spot-sowing (dibbling of 4-seeds per hill at 20 × 15 cm) in the sub-plots, thus there were a total of 16 treatment combinations. Scheduling irrigation at 1.5 IW / CPE ratio recorded highest plant height (95.4 cm), DMA (1053 g m^{-2}) and LAI (3.44); similarly grain yield increased by 37.3% over rainfed crop, 23% over crop irrigated at 0.9 IW / CPE ratio and 13.5% over 1.2IW / CPE ratio. Effect of irrigation scheduling was found non-significant on nutrient concentration except P concentration in grain and straw. Crop irrigated at IW / CPE ratio 1.5 exhibited significantly higher P-concentration in grain and straw, over irrigation at IW / CPE ratio 0.9 and rainfed crop. Application of soil adjuvant (APSA 80™) didn't bring significant changes in any of the studied parameters. Between the two planting methods, spot-sowing resulted in higher growth and improved grain yield by about 7% over conventional method of sowing, however, effect on nutrient content remained non-significant.

Key words: Aerobic rice. IW / CPE ratio, nutrient concentration, planting methods and soil adjuvant.

Rice (*Oryza sativa* L.) is the staple food of millions of people and provides about 700 calories / day / person for about 3000 million people living mostly in developing countries (Sangeetha and Baskar, 2015; Dass *et al.* 2016; Dass *et al.*, 2017b). It has been estimated that India will require about 130 million ton (mt) of rice production by the year 2025 (Rao, 2012), which envisages that the country need to add 21 mt of rice to its current production level of 109 mt (MoA, 2017). It is also reiterated in several forums that such an increase in rice production will have to be realized from India's depleting resources, particularly land and water (Dass *et al.*, 2016). It is a well established fact that water requirement

**Correspondence address :*
[1&6] *Ph.D. Scholar*
[2, 4] *Principal Scientists, Division of Agronomy*
[5] *Principal Scientist, Water Technology, ICAR-Indian Agricultural Research Institute, New Delhi*
[3] *Senior Scientist, Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh*
[7] *Scientist, IASRI, New Delhi*

of rice is highest among the field crops and production of one kg of rice grain consumes about 5000 litres of water. Kukal *et al.* (2010) predicted that with the looming water threat and erratic rainfall pattern, an additional 500 litres of water will be required to produce one kg of rice in 2025. This scenario calls for economizing water-use in rice by developing and deploying water conservation and water-saving methods of rice cultivation. Among all water-saving rice technologies, aerobic rice provides the highest yield per unit of water used. Aerobic rice systems can reduce water applica-tion by 44% relative to conventional transplanted systems, by reducing percolation, seepage and evaporative losses, while maintaining yield at an acceptable level of 6 t ha^{-1} (Wang *et al.*, 2002 and Bouman *et al.*, 2005). Out of the total 44 m ha of rice area in the country, 18.8 m ha is under rainfed condition, of which 67% lies in the eastern India including Jharkhand, so aerobic rice has great a scope in this region. In water scarce area, effect of drought further can be eliminated by modifying the properties of irrigation water itself which helps in increasing water holding capacity (WHC) of soil that helps absorb greater amounts of water and retain it for a longer period, this can be achieved by the use of surfactants which increase the speed of water penetration in the soil and reduce water loss through evaporation. Surfactants function at the interface between compounds by lowering the surface tension of a liquid. Their mode of action allows water to penetrate and wet agricultural soils more easily, potentially improving water-use efficiency (WUE) and crop quality (Karagunduz *et al.*, 2001; Krogh *et al.*, 2003). The row to row spacing is an important cultural practice which affects the grain yield quantity and quality in different rice ecosystems. Several studies have proved that proper spacing can maintain the optimum plant population which is essential for the optimization of the yield of the aerobic rice. Reliable information on potential of aerobic rice, planting methods, water-efficient management options are lacking in eastern region of India, therefore an experiment was undertaken to study the effect of planting methods, irrigation regimes and soil adjuvant on growth, productivity and nutrient concentration of aerobic rice.

Materials and Methods

A field experiment was carried out during *kharif* season of 2016 at Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh (23°56′34″ N and 85°21′46″ E with an altitude of 614 m above the mean sea level.), Jharkhand, India. Hazaribagh falls in NARP-classified agro-climatic zone 7 (Eastern Plateau and Hill Regions, and sub region-Central North-eastern Plateau Region of Jharkhand), which is characterized by humid and sub-humid tropical climate. The climate of the districts is warm and humid with mean maximum and minimum temperature of 31.4°C and 13.7°C, respectively. April, May and June are the hottest months and December, January and February are the coldest months. The maximum and minimum relative humidity was 67.4% and 36.3%, respectively. Soil of the experimental field was clay loam in texture having a good water holding capacity. Soil of the experimental site was categorised as medium in organic C (0.62%), low in available N (153 kg ha^{-1}), medium in available P (11.3 kg ha^{-1}) and high in available K (380 kg ha^{-1}). Soil reaction was in neutral range (pH 6.8). Field capacity and permanent wilting point moisture content of experimental field soil was 28.72, 14.87%, respectively. Total rainfall during crop period was 1237 mm which was higher than normal rainfall (1084 mm) of the region.

The experiment was laid-out in a split-plot design keeping 8-combinations of 4-irrigation schedules, *viz.*, I_1: Irrigation at 0.9 IW / CPE ratio, I_2: Irrigation at 1.2 IW / CPE ratio, I_3: Irrigation at 1.5 IW / CPE ratio and I_4: Un-irrigated (rainfed) and 2-soil adjuvants (A_1: soil adjuvant applied and A_2: No-soil adjuvant) in the main-plots and 2-planting methods (P_1: Conventional dry seeding at 20 cm row spacing and P_2: Spot-sowing (dibbling of 4-seeds per hill at 20 × 15 cm) in the sub-plots, thus there were a total of 16 treatment combinations. Sahabhagi Dhan a drought tolerant variety was sown at the rate of 60 kg ha^{-1} in conventional drilling and 30 kg ha^{-1} in spot sowing method. The crop was uniformly fertilized with 120 kg N, 60 kg P_2O_5, and 30 kg K_2O ha^{-1}. Nitrogen was supplied through N-containing fertilizers, urea and di-ammonium phosphate (DAP). Phosphorus and potassium were supplied through DAP and muriate of potash, respectively. A pre-emergence application of pendimethalin @ 1.0 a.i. kg ha^{-1} followed by post-emergence application of bispyribac-Na @ 0.025 a.i. kg ha^{-1} was done for effective weed management. For computing different levels of IW / CPE ratio (0.9, 1.2 and 1.5), IW (irrigation water requirement) was kept constant at 50 mm. However once the CPE (cumulative pan evaporation) reached to a level that would result in desired IW / CPE ratio for deciding timing of irrigation, the quantity of irrigation water to be actually applied was determined taking into account the effective rainfall. Also, irrigations were delayed if sufficient rainfall occurred. Soil adjuvant (APSA 80^{TM}) was applied on soil surface twice @ 450 ml ha^{-1} dissolved in 500 litres of water, once at tillering stage and subsequently at panicle emergence stage. The experimental data were statistically analysed by using the standard technique of analysis of variance (ANOVA). The significance of treatment means was tested using F-test (Gomez and Gomez, 1984). The critical differences (P=0.05) were worked out to compare treatment means.

Results and Discussion

Growth parameters

During initial stage of crop growth, the effect of irrigation schedules on growth parameters like plant height, dry matter accumulation (DMA) and leaf area index (LAI) remained non-significant due to the continuous rainfall (Table 1). The slow root development during initial growth stages might be the reason behind the uniformly slow development during the early stages (Singh *et al.*, 2015) across the irrigation treatments. However, all growth parameters were of higher magnitudes when irrigations were scheduled at 1.5 IW / CPE ratio followed by irrigation at 1.2 IW / CPE ratio. This might be due to the positive role of water on plant cell turgidity and adequate availability of nutrients during the plant growing activity (Yadav *et al.*, 2011). At the later stages, the effect of irrigation schedules on all the growth parameters was clearer and was found to be significant. This might be due to the increased cell division, elongation and optimum photosynthesis, which thereby, influenced all the growth parameters. Similar results were also reported by Mannan *et al.* (2012), and Dass and Chandra (2013).The height of aerobic rice was significantly influenced by irrigation schedules at later stages (75 DAS) and at harvest stages, obviously the tallest plants were observed for crop irrigated at 1.5 IW / CPE ratio and shortest ones in rainfed crop. Plant growth involves both cell division, cell enlargement and differentiation and these activities are very sensitive to water stress due to their dependence on turgor pressure (Momolu *et al.*, 2017). The inhibition of cell activity might have affected the heights of rice plants under stressful soil moisture levels. Under stressful conditions plants fail to absorb sufficient nutrients from the soil due to lack of available soil moisture, consequently leading to stunted growth of plants (Werner *et al.*, 2010).

The taller plants with larger tiller number led to the higher leaf area index in crop irrigated at 1.5 IW / CPE ratio compared to rainfed crop and the crop irrigated less frequently (particularly IW / CPE 0.9). The reduction in LAI in crop receiving lower number of irrigations (IW / CPE 0.9) and rainfed might be due to reduced turgor pressure under moisture stress conditions which affected the leaf cell expansion (Ramadass and Ramanathan., 2017). The increased leaf area index under adequate irrigation (IW / CPE 1.5, 1.2) could also be attributed to the increased functional leaf area and delayed leaf senescence by production of phyto-hormones that enhanced cell division and elongation (Elankavi *et al.*, 2009).

Effect of irrigation schedule on dry matter accumulation was significant at later stages of growth (Table 1), and it was highest with the 1.5 IW / CPE ratio. Frequent irrigations under 1.5 IW / CPE ratio might have facilitated higher water and nutrient uptake applied to the crop resulting in increased production of photosynthates, increased plant height, production larger number of tillers that finally resulted in higher dry matter production. The effect of soil adjuvant (APSA-80^{TM}) was non-significant for almost all studied growth parameters. However, higher growth was recorded in adjuvant applied treatments, but increase did not reach to significant level.

Table 1. Effect of irrigation regimes, soil adjuvant and panting methods on growth parameters of aerobic rice

Treatment	Plant height (cm)			Dry matter accumulation (g m^{-2})			Leaf area index		
	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	Harvest
Irrigation (IW/CPE ratio)									
0.9	46.4	73.9	86.1	198	633	934	1.81	5.10	3.14
1.2	47.1	76.3	91.1	206	649	973	1.86	5.28	3.32
1.5	50.7	80.1	95.4	214	690	1053	2.03	5.60	3.44
Rainfed	45.2	70.1	84.6	187	601	872	1.69	4.79	2.93
SEm±	1.28	1.94	2.11	6.2	18	14	0.05	0.14	0.037
CD (P=0.05)	NS	5.88	6.40	NS	54	43	0.145	0.423	0.112
Soil adjuvant									
A_1	47.5	76.3	90.4	203	646	963	1.86	5.21	3.23
A_2	47.1	73.9	88.2	200	641	954	1.83	5.18	3.19
SEm±	0.91	1.37	1.49	4.4	12.6	10.1	0.03	0.099	0.026
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting method									
P_1	46.4	73.4	87.2	195	633	940	1.81	5.07	3.16
P_2	48.4	76.8	91.4	208	653	977	1.89	5.31	3.25
SEm±	0.69	1.19	1.11	3.8	6.7	7.1	0.03	0.08	0.035
CD (P=0.05)	NS	3.28	3.34	11.4	20.1	21.2	NS	0.227	0.105

In the present investigation higher plant height, LAI and dry matter accumulation was observed in spot sowing method in which 4-seeds per hill were dibbled at 20 × 15 cm spacing. This might be due to higher availability of nutrients, light and moisture to the crop plants that led to vigorous growth, less competition for nutrients, light and moisture between the plants due to less plant population in spot-sowing method than the conventional dry seeding at 20 cm row spacing.

Yields, harvest index and nutrient concentration

The better growth characteristics were reflected in the significantly higher grain, and straw yields in crop irrigated at 1.5 IW / CPE ratio (Table 2) compared to rainfed crop and the crop irrigated at IW / CPE ratio 1.2 and 0.9. The highest grain yield (4.12 t ha^{-1}) was observed with irrigation scheduled at 1.5 IW / CPE ratio which was significantly greater than all other treatments, the increase being 37.3% over rainfed crop, 23% over crop irrigated at 0.9 IW / CPE ratio and 13.5% over crop irrigated at 1.2 IW / CPE ratio. Irrigation at 1.2 and 0.9 IW / CPE ratio also caused significant improvement in grain yield over rainfed crop. Similarly, straw yield was highest with irrigation at IW / CPE ratio 1.5 due to higher dry matter accumulation in the crop under this irrigation schedule (Table 2). The physiological efficiency of rice plants to convert dry matter into grain is measured in terms of harvest index (HI). In the present investigation, HI of aerobic rice was affected signi-ficantly by the application of irrigation and it was found to be highest in treatment where irrigations were applied at 1.5 IW / CPE ratio (Table 2); the lowest HI was observed in rainfed treatment. Content of nutrients in grains and straw were higher when irrigations were scheduled at 1.5 IW / CPE ratio, which enhanced grain yield and quality. Soil moisture regimes affect the availability and uptake of nutrients (Hazra and Chandra 2014; Dass *et al.*, 2017a). Effect of irrigation was found to be non-significant for N and K concentration, however, the concentration of P in grain and straw was found to be significantly higher with irrigations at 1.5 IW / CPE ratio (Table 2). This might be due to higher availability of P under well irrigated plots. Results are in close proximity to those of Edwin and Anal (2008) and Dass and Chandra (2012).

Table 2. Effect of irrigation regimes, soil adjuvant and panting methods on yield, harvest index and nutrient concentration in aerobic rice.

Treatment	Yield (t ha^{-1})			Harvest index (%)	N-concentration (%)		P-concentration (%)		K-concentration (%)	
	Grain	Straw	Biomass		Grain	Straw	Grain	Straw	Grain	Straw
Irrigation (IW/CPE ratio)										
0.9	3.35	5.98	9.35	35.9	1.14	0.47	0.137	0.094	0.29	1.47
1.2	3.63	6.10	9.88	37.3	1.18	0.48	0.141	0.099	0.30	1.49
1.5	4.12	6.41	10.53	39.1	1.20	0.49	0.149	0.104	0.31	1.51
Rainfed	3.00	5.72	8.72	34.4	1.13	0.45	0.134	0.089	0.27	1.45
SEm±	0.10	0.13	0.20	0.63	0.028	0.013	0.003	0.003	0.008	0.008
CD (P=0.05)	0.30	0.40	0.60	1.90	NS	NS	0.010	0.008	NS	0.024
Soil adjuvant										
A_1	3.55	6.08	9.63	36.7	1.17	0.47	0.141	0.098	0.29	1.48
A_2	3.50	6.03	9.54	36.6	1.16	0.47	0.140	0.096	0.29	1.47
SEm±	0.07	0.09	0.10	0.44	0.020	0.009	0.002	0.002	0.006	0.022
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting method										
P_1	3.41	5.99	9.40	36.1	1.15	0.47	0.139	0.095	0.26	1.47
P_2	3.64	6.12	9.77	37.2	1.17	0.48	0.141	0.098	0.30	1.48
SEm±	0.05	0.06	0.07	0.49	0.019	0.009	0.002	0.001	0.004	0.015
CD (P=0.05)	0.15	NS	0.21	NS	NS	NS	NS	NS	NS	NS

The effect of soil adjuvant (APSA-80^{TM}) was again found non-significant for yield as well as nutrient concentration in grain and straw; however adjuvant applied plots showed higher yield. Maintaining a critical level of rice plant population in field is necessary to obtain high yields. The number of panicles is the most important component of yield, which contributes 89% of the variations in yield (Dass and Chandra, 2013). Between two planting methods, spot-sowing increased grain yield by about 7% and biomass yield by about 4% over conventional method of sowing. Harvest index remained unaffected by the soil adjuvant application and planting methods.

Conclusion

Scheduling irrigation at 1.5 IW / CPE ratio significantly increased growth parameters, yield (grain and straw), and P- concentration in grain and straw, over other irrigation treatments, the increase in grain yield being 37.3% over rainfed crop, 23% over crop irrigated at 0.9 IW / CPE ratio and 13.5% over 1.2IW / CPE ratio. Soil adjuvant (APSA 80^{TM}) did not bring significant improvement in any studied parameters of aerobic rice. Between the two planting methods spot-sowing resulted in higher growth and increased grain yield by about 7% over conventional method of sowing, however, effect on nutrient content remained non-significant.

References

Bouman, B.A.M., Peng, S., Castaneda, A.R. and Visperas, R.M. 2005. Yield and water-use of irrigated tropical aerobic rice systems. *Agricultural Water Management* **74**: 87-105.

Dass, A. and Chandra, S. 2012. Effect of different components of SRI on yield, quality, nutrient accumulation and economics of rice (*Oryza sativa* L.) *in tarai* belt of northern India. *Indian Journal of Agronomy* **57**(3):250-25.

Dass, A., Chandra, S., Choudhary, A.K., Singh, G. and Sudhishri, S. 2016. Influence of field re-ponding pattern and plant spacing on rice root-shoot characteristics, yield, and water productivity of two modern cultivars under

SRI management in Indian Mollisols. *Paddy and Water Environment* **14**: 45-59.

Dass, A., Chandra, S., Uphoff, N., Choudhary A.K., Bhattacharyya, R. and Rana, K.S. 2017a. Agronomic fortification of rice grains with secondary and micronutrients under differing crop management and soil moisture regimes in the north Indian Plains. *Paddy and Water Environment* DOI 10.1007/s10333-017-0588-9.

Dass, A., Shekhawat, K., Choudhary, A.K., Sepat S., Rathore, S.S, Mahajan G. and Chauhan, B.S. 2017b. Weed management in rice using crop-competition. *Crop Protection* **95**: 45-52.

Dass, A. and Chandra S. 2013. Irrigation, spacing and cultivar effects on net photosynthetic rate, dry matter partitioning and productivity of rice under system of rice intensification in Mollisols of northern India. *Experimental Agriculture* **49**(4): 504-523.

Edwin, L. and Anal, P.S.M. 2008. Effect of irrigation regimes and nitrogen management practices on uptake of nutrients and grain yield in hybrid rice (*Oryza sativa* L.). *Environment and Ecology* **26**: 1146-1148.

Elankavi, S., Kuppuswamy, G., Vaiyapuri, V. and Raman, R. 2009. Effect of phytohormones on growth and yield of rice. *Oryza* **46**(4): 310-313.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. Second Edition.An International Rice Research Institute Book. A Wiley-Inter-science Publication, John Wiley & Sons, New York.

Hazra, K.K. and Chandra, S. 2014. Mild-to prolonged-stress increased rice tillering and source-to-sink nutrient translocation under SRI management. *Paddy and Water Environment* **12**: 245-250.

Karagunduz, A., Pennell, K.D. and Young, M.H. 2001. Influence of a non-ionic surfactant on the water retention properties of unsaturated soils. *Soil Science Society of America Journal* **65**: 1392-1399.

Krogh, K.A., Halling, S.B., Mogensen, B.B. and Vejrup, K.V. 2003. Environmental properties and effects of nonionic surfactant adjuvants in pesticides: a review. *Chemosphere* **50**: 871-901.

Kukal, S. S., Yadav, S., Humphrey, E., Kaura, A., Singh, Y., Thaman, S., Singh, B. and Timsina, J. 2010. Factors affecting irrigation water savings in raised beds in rice and wheat. *Field Crops Research* **118**: 43-50.

Mannan, M.A., Bhuiya, M.S.U., Akhand, M.I.M. and Zaman, M.M. 2012. Growth and yield of basmati and traditional aromatic rice as influenced by water stress and nitrogen level. *Journal of Science Foundation* **10**(2): 52-62.

McCauley, G.N. (1993). Non-ionic surfactant and supplemental irrigation of soybean on crusting soils. *Agronomy Journal.* **85**(1), 17-21.

MoA. 2017. Agricultural Statistics Division, Directorate of Economics and Statistics. Ministry of Agriculture and Farmer Welfare, Govt. of India.GOI. http://pibphoto.nic.in/documents/rlink/2017/may/p20175902.pdf.

Momolu, E.P., Lamo, J. and Katuromunda, S. 2017. Soil moisture stress and nitrogen supply affect the growth characteristics and yield of upland rice cultivars. *International Journal of Plant & Soil Science* **15**(5): 1-10.

Ramadass, S. and Ramanathan, S.P. 2017. Evaluation of drip fertigation in aerobic rice-onion cropping system. *International Journal of Current Microbiology and Applied Sciences* **6**(4): 2623-28.

Rao, Y.Y. 2012. Rice seed production scenario in India rice knowledge management portal. Directorate of Rice Research, Hyderabad. (https://www.scribd.com/document/74797351/Rice-Seed-Production-Scenario-in-India-0).

Sangeetha, C. and Baskar, P. 2015. Influence of different crop establishment methods on productivity of rice-A review. *Agricultural Reviews* **36**(2) 2015: 113-124.

Sikuku, P.A., Netondo, G.W., Onyango, J.C. and Musyimi, D.M. 2010. Effects of water deficit on physiology and morphology of three varieties of rainfed rice (*Oryza sativa* L.).

Journal of Agricultural and Biological Sciences **5**(1): 23-28.

Singh, D.K., Pandey, P.C., Priyanker, Q.A. and Gupta, S. 2015. Nitrogen management strategies for direct seeded aerobic rice (*Oryza sativa* L.) grown in mollisols of Uttarakhand (India). *International Journal of Applied and Pure Science in Agriculture* **1**(7): 2394-5532.

Wang, H.Q., Bouman, B.A.M., Zhao, D.L., Wang, C. and Moya, P.F. 2002. Aerobic rice in northern China: opportunities and challenges. In: Bouman, BAM, Hengsdijk, H, Hardy, B, Bindraban, PS, Tuong, TP, Ladha, JK (Eds.). Proc of the International Workshop on Water-wise Rice Production, 8-11 April 2002. pp. 143-54. International Rice Research Institute, Los Banos, Philippines.

Werner, T., Nehnevajova, E., Köllmer, I., Novák, O., Strnad, M., Krämer, U. and Schmülling, T. 2010. Root-specific reduction of cytokinin causes enhanced root growth, drought tolerance, and leaf mineral enrichment in Arabidopsis and tobacco. *The Plant Cell* **22**: 3905- 20.

Yadav, P.V., Kumari M. and Ahmed Z. (2011) Seed priming mediated germination improvement and tolerance to subsequent exposure to cold and salt stress in Capsicum. *Research Journal Seed Science* **4**: 125-136.