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EFFECT OF IRRIGATION REGIMES AND METHOD OF ZINC APPLICATION ON GROWTH AND YIELD ATTRIBUTE OF AEROBIC RICE IN LATERITIC SOIL

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Abstract

A field experiment was conducted during summer season of 2016 and 2017 at Palli Siksha Bhavana (Institute of Agriculture) farm Sriniketan, Birbhum, West Bengal to evaluate the effect of different levels of irrigation and zinc management and their effect on growth and productivity of aerobic rice (Sahbhagi Dhan). Data indicated that irrigation regime at 100% of CPE (I_{100}) and irrigation regime at 125% of CPE (I_{125}) improved significantly all growth and yield attributing characters over irrigation regime at 75% of CPE (I_{75}). Application of zinc sulphate through seed priming @ 0.3% and through seed coating @ 1.2% also recorded significantly higher plant height, dry matter accumulation and leaf area index as compared to other method of zinc application. Irrigation regime at 100% of CPE and irrigation regime at 125% of CPE recorded significantly higher grain yield (4246 and 4398; 4306 and 4551 kg/ha) as compared to irrigation regime at 75% of CPE (3109 and 3336 kg/ha) in 1st year and 2nd year, respectively. Application of $ZnSO_4$ through seed coating @ 1.2% and seed priming @ 0.3% recorded significantly higher grain yield (4381 and 4570; 4183 and 4420 kg/ha) over foliar application of @ 0.5% (3938 and 4135 kg/ha), soil application of $ZnSO_4$ @ 20 kg/ha (3775 and 3908 kg/ha) and control (3160 and 3441 kg/ha) 1st year and 2nd year, respectively. So, irrigation regime at 100% of CPE (I_{100}) in combination with seed coating or seed priming may be used to sustain aerobic rice production in lateritic soil.

Key words : Aerobic rice, irrigation, seed coating, seed priming, yield.

Introduction

Rice is one of the most important staple and caloric providing food grains more than half of the world's population and livelihood of the rural people. Rice consumes about half of the fresh water resources. According to Tuong and Bouman (2003), 17 mha of irrigated rice areas may experience "physical water scarcity'' and 22 mha may have "economic water scarcity'' by 2025 in Asia. Therefore, take appropriate approach for development of innovative rice production techniques that can decrease water requirement without hampering yield losses. Scientists have developed several approaches to reduce rice water requirements, like saturated soil culture (Borrel *et al.*, 1997), alternate wetting and drying (Li, 2001 and Tabbal *et al.*, 2002), ground cover systems (Lin *et al.*, 2002), system of rice intensification (Stoop *et al.*, 2002), aerobic rice (Bouman *et al.*, 2002) and raised beds (Singh *et al.*, 2002). Among them 'aerobic rice' is a new term given by the International Rice Research Institute (IRRI) for high-yielding rice grown under nonflooded, nonpuddled and unsaturated (aerobic) soil conditions where rice cultivars should be highly responsive to nutrient supply, can be grown in rainfed or irrigated situations and tolerate occasional flooding (Bouman and Tuong, 2001) and drought conditions. According to several researchers, aerobic rice crop could be successfully raised with 700 to 900 mm of water in summer and monsoon season and can be yielded 6.5 t / ha with 40 to 60 per cent water savings (Castaneda *et al.*, 2002; Belder *et al.*, 2005; Bouman *et al.*, 2005; Zhang *et al.*, 2009). Zinc (Zn) deficiency is now a common problem both in crops and humans (White and Zasoski, 1999).

Zinc deficiency in soil reduces not only the productivity

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(McDonald *et al.*, 2001), but also the nutritional quality of grain (Cakmak, 2008) and ultimately nutritional quality of human diet (Pooniya and Shivay, 2012). Zn deficiency is the most universal micronutrient deficiency problem in most of the crops. Zn plays a vital role in physical growth and development, the functioning of the immune system, reproductive health, sensory function and neurobehavioral development in humans (Hotz and Brown, 2004). Zn is involved in carbohydrate metabolism, protein synthesis, maintenance of the integrity of cellular membrane, regulation of auxin synthesis and pollen formation (Marschner, 1995). For improving grain yield of rice, Zn plays an important role like other primary nutrients. So, application zinc is necessary to increase rice productivity and to improve human health. There are four main methods of adding micronutrients to crops: soil fertilization, foliar sprays, seed priming and seed coating. Treating seeds with micronutrients potentially provides a simple inexpensive method for improving micronutrient plant nutrition. Application of zinc through foliar application, seed priming and seed coating have many advantages as compared to soil application, *i.e.*, quantity applied are significantly lower than soil applications, uniform application is possible, crop response to applied micronutrient is almost immediate so that deficiency can be corrected relatively rapidly (Mortvedt, 2000). Foliar application, seed priming and seed coating of Zn increase zinc concentration in grain and straw of cereals.

Materials and Methods

The field experiment was conducted during summer season of 2016 and 2017 on well drained sandy loam soil at the Institute of Agriculture Farm, Visva-Bharati, Sriniketan of Birbhum district in West Bengal ($20^0 39^/$N latitude and $87^0 42^/$E longitude with an average altitude of 58.9 m amsl under typical semi-arid tropical climate. Maximum and minimum temperature fluctuated between 41.81^0C and 24.62^0C in summer 2016 and 36.89^0C and 23.64^0C in summer 2017. Relative humidity prevailed between 88.67 and 54.80 per cent in summer 2016 and 89.80 and 50.28 per cent in summer 2017. The maximum and minimum sunshine hours during the experimental period was 8.31 and 3.13 hours in 2016 whereas during 2017, it was 8.48 and 2.33 hours. Rainfall varies from 0.1 mm to 85.2 mm and the total rainfall received during the crop growth period (April to August) 563.06 mm (48 rainy days) during 2016 and rainfall varies from 0.1 mm to 83.8 mm and total rainfall received 63.28 mm (61 rainy days) during 2017. The soil of the experimental field was analysed for alkaline permanganate oxidizable N (Subbiah and Asija, 1956), available P (Bray and Kurtz, 1945), 1 N ammonium acetate exchangeable K (Hanway and Heidel, 1952), organic C (Walkey and Black 1934) and DTPA extractable Zn (Lindsay and Norvell, 1978) and soil was medium in organic carbon (0.52%) and low in available nitrogen (140.0 kg/ ha), medium in available phosphorus (11.9 kg / ha), low in available potassium (161. kg/ ha). The pH of the soil was 6.16 (1:2.5 soil: water ratio) (Prasad *et al.*, 2006). The DTPA extractable Zn in soil was 0.485 mg /kg of soil.

The experiment was laid out in split-plot design. The treatments consist of three irrigation regimes i.e. I_{75}: Irrigation at 75% of CPE, I_{100}: Irrigation at 100% of CPE, I_{125}: Irrigation at 125% of CPE in the main plot and the sub plots consisting of five method of zinc application Zn_1: Control, Zn_2: Soil application of $ZnSO_4$, $7H_2O$ @ 20 kg/ha, Zn_3: Foliar application of $ZnSO_4$, $7H_2O$ @ 0.5%, Zn_4: Seed priming with $ZnSO_4$, $7H_2O$ @ 0.3% and Zn5: Seed coating with $ZnSO_4$, $7H_2O$ @ 1.2%. The experiment consists of 15 treatment combinations replicated thrice. Seeds were primed with zinc sulphate heptahydrate @ 0.3 per cent solution by using tap water before sowing. Seed weight to solution volume ratio was 1:1.5 (w/v). Seeds were soaked in respective solution for 18 h at 25±2°C. Thereafter seeds were removed, given three surface washing. Thereafter seeds were removed, given three surface washing. Afterwards, primed seeds were allowed to re-dry with forced air under shade near to original weight. Seed rate of rice was @ 60 kg/ha and seeds were sown on 6^{th} April in the first year and 3^{rd} April in the second year, at a spacing of row to row 25 cm. The net plot size was 4 m x 3 m. Thinning and gap filling was done at 20 days after sowing (DAS) for maintaining optimum and uniform plant population in all the plots. For controlling early weeds a pre emergence herbicide pendimethalin 30EC (stomp) @ 1.0 L/ ha was sprayed two days after sowing. For controlling late emergence of weeds a post emergence herbicide bispyribac sodium 10% SC with 40 g /ha was applied at 20 days after sowing (DAS). The dose of nitrogen, phosphorus and potash fertilizer were 100 kg /ha, 50 kg P_2O_5 /ha and 50 kg K_2O / ha by using fertilizers like urea, single super phosphate and muriate of potash, respectively. Full dose of phosphorus and half dose of potash as basal were applied in the rows about 4-5 cm deep before sowing and remaining half dose of the potash was top dressed at 60 DAS. The nitrogen was top dressed in three splits i.e.; half dose of nitrogen at 20 DAS and remaining half dose of nitrogen was applied in two equal split each at 40 DAS and 60 DAS. In the initial stage, roots of the plants were infested by root knot nematode which was successfully controlled by application of chlorantraniliprole18.5 % SC @ 20kg /ha. Irrigation water of 5 cm was applied to all plots for uniform germination thereafter; irrigations treatments were imposed as per treatment details 20 DAS. The time of irrigation is decided by visible symptom i.e initiation of rolling of tip of first top leaves (Parthasarathi *et al.,* 2012). The volume of irrigation water in each plot was calculated by multiplying the USWB Open Pan Class A evaporimeter reading and area of the plot. The irrigation water was measured through 90^0V-notch weirs set up in the pucca channel of the experimental field.

The rate of discharge was calculated as per the formula given below: $Q = 0.0138 \times H^{5/2}$ Where, Q is the rate of discharge (litre per second) and H is the head of the crest (cm). The time of irrigation for every plot was computed by using given depth of irrigation, area of the plot and discharge rate. It was calculated by the formula given below $T = A \times \frac{D}{6Q}$, Where, Q is the rate of discharge (litre per second), A is the area of the plot (m^2), D is the CPE value (mm) and T is the time of irrigation (sec or min).

Plant height of each plot area was recorded at 45 and 75 DAS with the help of meter scale. Ten marked tillers were selected randomly in each plot for measuring the height. The height of plant measured from the ground level up to the tip of the plant. The average height of ten tillers were calculated and expressed in centimetre (cm). For dry matter accumulation, above ground plant parts were taken form 15 cm row length from second row in each plot at 45 and 75 DAS. These samples were dried in oven at a temperature of 65-70°C till constant weights were obtained. Average weight was calculated and expressed as dry matter accumulation in g /m^2. The representative green leaves were taken randomly from each plot during sampling at 45 and 75 DAS under study and the area of the functional leaves were measured with the help of leaf area meter (LI-COR, Model: LI 3000C). The leaf area index was obtained by multiplying leaf factor with dry weight of functional leaves per unit land surface. Leaf area index was calculated as per the formula given by Williams (1946).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Ground area}}$$

The number of panicles was counted from 25 cm row length in each net plot area just before harvesting of the crop. The average value was calculated and expressed as panicles m^{-2}. The total numbers of filled grains were counted from all the sampled panicles. The average value was worked out and expressed as number of filled grains panicle^{-1}. One thousand filled grains were counted randomly from the sample drawn from cleaned produce of each plot. The weight of thousand grains were recorded by using electronic balance in the laboratory and expressed in g. Harvesting was done on 10th August in the first year and 5th August in the second year manually with sickles after leaving the border area. Plants from the demarcated net plot area were harvested, tied in bundles and taken to the threshing floor for sun drying and threshing. The harvested plants were dried for 3–4 days to bring down the moisture content to around 14 per cent. The weight of the harvested plants after sun drying and before threshing was recorded. After threshing, the seeds were cleaned and sundried and their weight was recorded. The yields in kg / plot were converted to kg / ha. All the data obtained from rice crop for consecutive 2 years were statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). LSD values at P = 0.05 were used to determine the significance of differences between treatment means. The analysis of data on growth, grain yield, nutrient uptake and economic for rice was also performed using SPSS software.

Results and Discussion

Plant height

The observations on plant height (cm) recorded at 45 and 75 days after sowing (DAS) were analysed statistically and presented in the (Table 1). Plant height increased gradually towards maturity irrespective of the different irrigation regime and method of zinc application during both the years under study. On the basis of data, the maximum plant height was recorded with irrigation regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) but they were significantly higher than irrigation regime at 75% of CPE (I_{75}). The reduction in plant height at 75% of CPE (I_{75}) irrigation might be due to decline in cell turgor that causes reduction the length of the internodes. The results are in conformity with the findings of Shekara *et al.,* (2011); Nayak (2015) and Duary and Pramanik (2019). Results showed that method of zinc application had a significant effect on plant height over control (Zn_1) at 45 and 75 DAS. Seed priming with $ZnSO_4$ @0.3% (Zn_4) and seed coating with $ZnSO_4$ @ 1.2% (Zn_5) recorded significantly higher plant height over soil application of $ZnSO_4$ @ 20 kg/ha (Zn_2) and or foliar application of $ZnSO_4$ @ 0.5% (Zn_3). Increase in plant height might be attributed to internodal distance as reported by Kaya and Higgs (2002) with Zn application. Similar results regarding plant height due to the seed priming with Zn solution were reported by Arif *et al.,* (2005) and Ali *et al.,* (2007).

Dry matter accumulation

The most important growth parameter for the rice yield determination is the post flowering dry matter production. In respect to irrigation regime, the results showed that the dry matter accumulation was significantly influenced by different irrigation regimes at 45 and 75 DAS (Table 1). Irrigation regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) recorded significantly higher dry matter accumulation than irrigation regime at 75% of CPE (I_{75}). It might be due to effective uptake of water and nutrients resulting in increasing the growth of plants. This was in accordance with the findings of Maheswari *et al*., (2008) and Shekara *et al*., (2010). The lowest dry matter accumulation was recorded by I_{75} at all growth stages during the experiment. This might be due to lower production of plant height with irrigation at 75% of CPE (Duary and Pramanik, 2019). Data showed that seed priming with $ZnSO_4$ @ 0.3% (Zn_4) and seed coating with $ZnSO_4$ @ 1.2% (Zn_5) recorded significantly higher dry matter accumulation over soil application of $ZnSO_4$ @ 20 kg/ha (Zn_2) and foliar application of $ZnSO_4$ @ 0.5% (Zn_3). Increase in dry matter accumulation might be due to increase plant height.

Leaf area index

The higher productivity of crop depends on persistence of high leaf area index over a greater part of its vegetative phase. Results revealed that the irrigation regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) recorded significantly higher LAI than those recorded regime at 75% of CPE (I_{75}) both the years under study (Table 1). The increase in leaf area index under regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) could be due to improve the uptake of nutrients under higher moisture condition resulting in more number of leaf and higher leaf area coupled with more dry matter accumulation. The result is in conformity with the finding of Ramamoorthy *et al.*, (1998) and Maheswari *et al.*, (2008). As regards to method of zinc application, the results revealed that the leaf area index of aerobic rice increased significantly with seed priming of $ZnSO_4$ @ 0.3% (Zn_4) and seed coating with $ZnSO_4$ @ 1.2% (Zn_5) over other method of zinc application both the years under study. Greater leaf area index values may attribute to significant increase in leaf expansion due to good plant height and dry matter production of plants as affected by priming (Zn_4) and coating (Zn_5) with $ZnSO_4$. Increased leaf area might be due to induction of metabolic activities in embryo in a result of seed priming (Wahid *et al.*, 2008).

Yield attributes

The maximum number of panicles m^{-2} (305 and 320;

Table 1: Effect of irrigation regime and method of zinc application on plant height, dry matter accumulation and leaf area index of aerobic rice.

Treatments	Plant height (cm)				Dry matter accumulation (g m^{-2})				LAI			
	45 DAS		75 DAS		45 DAS		75 DAS		45 DAS		75 DAS	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation regimes												
I_1: Irrigation at 75% CPE	47.1	47.8	75.9	79.4	206.0	245.9	559.7	602.9	2.04	2.27	2.62	2.74
I_2: Irrigation at 100% CPE	53.6	61.2	85.4	86.0	241.1	288.1	740.0	806.9	2.75	2.91	3.27	3.31
I_3: Irrigation at 125% CPE	55.1	53.7	85.0	87.0	244.2	275.1	730.7	771.1	2.73	2.82	3.23	3.31
SEm (±)	0.7	1.0	1.1	1.2	4.1	7.4	11.7	21.3	0.03	0.03	0.04	0.09
LSD at 5%	2.8	4.0	4.4	4.8	16.3	29.0	46.1	83.6	0.13	0.13	0.17	0.37
CV (%)	5.2	7.3	5.3	5.6	7.0	10.6	6.7	11.3	5.31	4.81	5.45	11.66
Method of zinc application												
Zn1: Control	49.6	48.1	79.3	81.2	174.5	212.5	526.4	598.9	2.13	2.30	2.64	2.71
Zn_2: $ZnSO_4$ application at soil @ 20 kg/ha	52.1	51.7	81.2	83.7	224.6	276.8	618.6	683.3	2.47	2.61	3.04	3.14
Zn_3: Foliar application of $ZnSO_4$ @ 0.5%	50.4	50.4	81.2	82.1	225.0	207.3	682.1	752.2	2.15	2.23	2.87	2.90
Zn_4: Seed priming with $ZnSO_4$ @ 0.3%	53.8	59.9	83.6	85.4	245.1	310.4	748.3	782.6	2.85	3.06	3.19	3.26
Zn_5: Seed coating with $ZnSO_4$ @ 1.2%	53.8	61.0	85.3	88.3	283.0	341.5	808.7	817.9	2.94	3.14	3.46	3.59
SEm (±)	0.8	0.9	1.0	1.3	6.6	8.5	14.2	21.6	0.03	0.04	0.04	0.07
LSD at 5%	2.2	2.7	3.0	3.7	19.3	24.8	41.5	63.1	0.09	0.11	0.11	0.21
CV (%)	4.4	5.2	3.8	4.6	6.6	9.5	6.3	8.9	3.68	4.20	3.76	6.99

302 and 315), spikelets panicle^{-1} (102 and 110; 104 and 110) and test weight (22.1 and 22.5 g; 21.7 and 22.1 g) was recorded with irrigation regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) over irrigation regime at 75% of CPE (I_{75}) in first year and second year, respectively (Table 2). The higher number of panicles m^{-2} under 100% of CPE (I_{100}) and at 125% of CPE (I_{125}) might be due to high moisture regimes which promoted higher dry matter production and nutrient uptake. This was in accordance with findings of Thomas *et al. (*2003), Shekara *et al., (*2010) and Balamani *et al.,* (2012). The decrease in number of spikelets panicle^{-1} and test weight under irrigation regime at 75% of CPE (I_{75}) might have hampered the supply of photosynthates from source to sink resulting in poor setting of spikelets panicle^{-1} poor filling of grains. This was in conformity with the findings of Narolia *et al.,* (2014) and Sandu and Mahal (2014). The decrease in test weight under irrigation regime at 100% of CPE (I_{100}) and at 125% of CPE (I_{125}). Seed priming of $ZnSO_4$ @ 0.3% (Zn_4) and seed coating with $ZnSO_4$ @ 1.2% (Zn_5) recorded the maximum number of panicles m^{-2} (306 and 312; 316 and 318), spikelets panicle^{-1} (103 and 110; 106 and 112) and test weight (22.1 and 22.5 g; 23.0 and 23.4 g) over other method of zinc application both the years under study. The significantly higher value of yield attributes with seed priming of $ZnSO_4$ @ 0.3% (Zn_4) and seed coating with $ZnSO_4$ @ 1.2% (Zn_5) might be due to effective effect on reproductive development, and it can cause increasing the potential number of grain ovule. Less filled grains formation in control plot (without zinc solution) represents a crucial role of zinc in the development of the anthers and pollen viability (Khurana and Chatterjee, 2001). This result is in line with the finding of Afzal *et al.,* (2013).

Grain yield

The highest grain yield (4246 and 4398 kg /ha) was recorded with I_{100} which was at par with I_{125} (4306 and 4551 kg /ha) and the lowest grain yield (3109 and 3336 kg /ha) was recorded with I_{75} in first year and second year, respectively (Table 2). The higher grain yield with I_{100} and I_{150} might be due to favourable situation for efficient water and nutrients uptake which boost their growth and yield attributes through supply of more photosynthates towards the reproductive sink. This result was in corroborates with the findings of Maheswari *et al.,* (2008); Sekhara *et al.,* (2010); Mandal *et al.,* (2013) and Duary and Pramanik (2019). Reduction of grain yield under irrigation regime at 75% of CPE could be due to the significant reduction in photo synthetic rate resulting in reduced production of assimilates for growth. This result was in corroborates with the finding of Sudhir *et al.,* (2011). The maximum grain yield was recorded with zinc sulphate coated seed (4381 and 4570 kg /ha) and zinc sulphate primed seed (4183 and 4420 kg /ha) over foliar application of $ZnSO_4$ (3938 and 4135 kg/ha), soil application of $ZnSO_4$ (3775 and 3908 kg/ha) and control in first year and second year, respectively. The lowest

Table 2: Effect of irrigation regime and method of zinc application on number of panicle, spikelets per panicle, test weight and grain yield of aerobic rice.

Treatments	Number of panicle per m^2		Number of spikelets per panicle		Test weight (g)		Grain yield (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation regimes								
I_1: Irrigation at 75% CPE	262	259	91	96	20.3	20.6	3109	3336
I_2: Irrigation at 100% CPE	305	320	102	110	22.1	22.5	4246	4398
I_3: Irrigation at 125% CPE	302	315	104	110	21.7	22.1	4306	4551
SEm (±)	3.02	3.76	2.25	1.35	0.29	0.29	83	92
LSD at 5%	11.8	14.8	8.85	5.32	1.13	1.13	327	360
CV (%)	4.03	4.89	8.83	4.98	5.24	5.15	8.3	8.7
Method of zinc application								
Zn1: Control	249	263	90	96	20.0	20.3	3160	3441
Zn_2: Soil application of $ZnSO_4$ @ 20 kg/ha	287	295	94	104	20.4	20.7	3775	3908
Zn_3: Foliar application of $ZnSO_4$ @ 0.5%	291	302	100	104	21.3	21.8	3938	4135
Zn_4: Seed priming with $ZnSO_4$ @ 0.3%	306	312	103	110	22.1	22.5	4183	4420
Zn_5: Seed coating with $ZnSO_4$ @ 1.2%	316	318	106	112	23.0	23.4	4381	4570
SEm (±)	3.20	2.27	2.71	1.37	0.35	0.33	72	77
LSD at 5%	9.32	6.62	7.91	4.00	1.01	0.97	210	224
CV (%)	3.31	2.29	8.22	3.91	4.87	4.59	5.5	5.6

grain yield was recorded with control plot (3160 and 3441 kg/ha) which was significantly lower than other method of zinc application under the study. Increased in the grain yield might be attributed to better nutrition and early seedling growth of the plant that receives Zn through seed priming with zinc sulphate solution and coating with zinc sulphate. This result was in corroborates with the finding of Mukherjee and Pramanik (2017).

Conclusion

From the present investigations, application of irrigation water 100% of CPE and seed coating with zinc sulphate @ 1.2 % or seed priming with zinc sulphate @ 0.3 % may be recommended for higher productivity of aerobic rice (Sahbhagi Dhan) in lateritic soil of West Bengal.

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