Effect of Zinc Levels and Moisture Regimes on Yield and Economics of Direct Seeded Rice

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Abstract: ***A field experiment was conducted during rainy (kharif) season of 2017 in Split Plot Design with three replications at Crop Research Centre of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar.The treatments consisted of four moisture regimes in main plots and four zinc levels in sub plots. The result showed that among the moisture regime treatments ,maximum value for no. of panicles/m^2 (225.58), grain yield (33.14q/ha),harvest index (41.30%),gross return (70193 ₹/ha) was found with I_1which was significantly superior over I_3 and I_4 but was statistically at par with I_2 but maximum value for water productivity (3.51 ₹/m^3), net return (34067 ₹/ha) and B:C ratio (0.99) was found with I_2which was significantly superior over I_4but was statistically at par with I_1 and I_3except water productivity which was significantly superior over I_1 and I_4 but was at par with I_3. Test weight was not influenced significantly by moisture regime treatments. In context of sub-plot treatments maximum no.of panicles/m^2(223.87), grain yield (32.57 q/ha), harvest index (41.23 %), water productivity (3.46 ₹/m^3), gross return (69048 ₹/ha), net return (33464 ₹/ha) and B:C ratio (0.94) was found with Z_3which was significantly superior over Z_1 but was statically at par with Z_2 and Z_4 except gross return which was superior over Z_1 and Z_4 but statistically at par with Z_2.Test weight was not influenced significantly by zinc levels.***

Keywords: Zinc levels, Moisture regimes, Water productivity, Gross return, B:C ratio, Net return

1. Introduction

Rice (*Oryza sativa* L.) is one of the most staple food crop for more than half of the world population by providing 25% calories and 20% protein. More than 2 billion people get 60-70% of their energy requirement from rice and its derived products. In Asia, irrigated agriculture uses 80-90% of the freshwater and about 50% of that is used in rice farming (IRRI, 2001), large amount of water input in rice culture has led to over exploitation of ground water as indicated by alarming fall in water table. Thus, there is a need to explore alternate techniques that can sustain rice production and are resource conservative. On the face of global water scarcity, the future of rice production is under threat, direct seeded rice (DSR) offers an attractive alternative. Currently, DSR in Asia occupies about 29 million hectare which is approximately 21% of the total rice area (Pandey and Velasco, 2002). DSR under no/reduced tillage is an efficient resource conserving technology holding good promise in coming day due to following advantages over transplanted rice- save labour up-to 40%, water upto (60%), energy upto (60%), reduce cost of cultivation about 5000- 6000/ha and increases nutrient use efficiency (Pathak *et al*., 2011).

Rice is the world's most important cereal and potentially important source of Zn for people who eat mainly rice. Plant uptake Zn in the form of Zn^{2+}, however it is a micronutrient but plays a vital role in growth and metabolism of plant. It has been estimated that about 10% of the proteins in biological system need Zn for their structural and functional integrity (Andreini*et al.* 2006). In most cases, rice cultivated soils are very low in plant available zinc leading to further decreases in it's concentration in rice grain. It's deficiency symptom in rice was observed for the first time in calcareous soil of north-India (Nene 1996). At present 40% area at national level (www.Zincorg.in) and 45% area in Bihar are zinc deficient (www. Krishisewa.com). Deficiency symptoms are prolonged during early growth stage due to immobilization of zinc,it's deficiency in rice crop is commonly known as *Khaira* disease. The DTPA extractable Zn values in the drain water treatment were twice as high as the AWD and flood water treatments. It is usually more available to plant in acid soil than alkaline soil. Calcareous soils are particularly more prone to it's deficiency, at high pH and in waterlogged condition it forms an insoluble compound such as $Zn(OH)_2$ and in calcareous soil due to presence of $CaCO_3$ it forms $ZnCO_3$ leading to reduced it's availability. It's deficiency may be corrected by application of zinc fertilizers, among the different zinc fertilizers zinc sulphate (36% Zn) is the most efficient and cheapest source of correcting zinc deficiency. Among different methods of zinc application, soil application through broadcast or its placement below seed, invariably proved more effective except as low levels while foliar application proved equally efficient. Foliar feeding is a relatively new and controversial technique of feeding plants by applying liquid fertilizer directly to their leaves (Mahdi *et al*.2011).Among various yield limiting factors, irrigation water management and zinc deficiency are the most important variables affecting growth, yield and quality of rice (Fageria *et al*. 2008; Shivay *et al*. 2010). To increase water productivity of rice production the interactions between irrigation practices and fertilizers should be addressed (Hortz and Brown. 2004).

2. Materials and Methods

A field experiment was conducted during rainy (*kharif*) season of 2017 at Crop Research Centre, Department of Agronomy, Dr. Rajendra Prasad central Agricultural University, Pusa Farm, is situated in Samastipur district of North Bihar on the Southern and Western bank of the river *BurhiGandak* at 25° 59′ North latitude and 85°48′ East longitude with an altitude of 52.92 meters above mean sea level. It has sub-tropical and sub humid monsoon climate. The average rainfall of the area is 1276.1 mm out of which nearly 1026.0 mm is received during the monsoon between

June to September. The experiment was laid out in split plot design (SPD) with three replications. In main plots, treatments were I_1-Irrigation at 1 day disappearance of ponded water,I_2-Irrigation at 3 days disappearance of ponded water,I_3-Irrigation at 5 days disappearance of ponded water,I_4-Irrigation at 7 days disappearance of ponded water and in sub plots, tratments were Z_1- Control, Z_2 -Application of $ZnSO_4$ @ 25 kg/ha, Z_3-Application of $ZnSO_4$ @ 37.5 kg/ha, Z_4- Foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering.RajendraNeelam was taken as test cultivar. Soil of the experimental plot was sandy loam in texture, alkaline in reaction (pH 8.7), low in available N - 154 kg/ha (Alkaline permanganate method, Subbiah and Asija, 1956), P_2O_5- 20.51 kg/ha (Olsen's method, Olsen *et al*., 1954), K_2O- 122 kh/ha (Flame photometer method, Jackson, 1967) and zinc- 0.69 ppm (DTPA extractable and observed with AAS, Lindsay and Norvel, 1978).The crop was fertilized with 120-60-40 kg/ha (N-P_2O_5-K_2O) and $ZnSO_4$. Half dose of nitrogen and full dose of phosphorus, potash and zinc (25 kg/ha and 35 kg/ha) were applied as basal and remaining dose of nitrogen was applied in two equal splits (25% at tillering and 25 % at panicle initiation stage), foliar application of $ZnSO_4$ @ 0.5% was done at tillering, pre-flowering and flowering. Irrigation was given when the ponded water is depleted as per treatment. Water was measured through Parshall flume of 7.5 cm throat size set up at the experimental field applying 6 cm of water at each irrigation.The required cultural practices and plant protection measures were done as per recommended package. In order to determine the effect of different treatments, a number of observations on growth and yield attributing characters of crop were recorded at different stages of crop growth.The number of panicles per meter square was counted from each plot using iron frame square meter. For test weight calculation, grains samples were drawn from the field of five selected hills and dried in sun. The weight of 500 grains was recorded in gram and then converted into thousand grain weight. The data was taken at 14 per cent moisture level of grains.The yield of clean and dry grains in the net plot was recorded in kg/plot and was later converted into q/ha to give the grain yield.Harvest index is the ratio of grain yield (economical yield) and biological yield. It was calculated by using formula given by Donald (1958).

$$\text{Harvest index} = \frac{\text{Grain yield (q/ha)}}{\text{Grain yield (q/ha)} + \text{straw yield (q/ha)}} \times 100$$

$$\text{Water productivity} = \frac{\text{Water productivity was calculated for each irrigation treatments and expressed in (₹/m}^3\text{). The Net return (₹/ha)}}{\text{Total water consumed in m}^3\text{/ha including effective rainfall}}$$

Total income of the produce (grain + straw) was estimated at prevailing market rate and thus gross returns were calculated in ₹ /ha by using formula;

Gross return = Value of the product (Grain yield + Straw yield)

Net return was obtained by subtracting the cost of cultivation from the gross return obtained by selling the produce (grain + straw).Net return per rupee of investment was calculated by dividing the net return with cost of cultivation.

3. Result and Discussion

No. of panicles/m^2-The number of panicles/m^{2}is the most important yield attributing component. As the number of panicle/m^2 increases the yield/ha also increases. Maximum number of panicles/m^2 was observed with irrigation at 1 day disappearance of ponded water which was statistically at par with irrigation at 3 days disappearance of ponded water. This might be due to higher number of tillers with adequate moisture supply. Minimum panicles/m^2 was observed with 7 days disappearance of ponded water which attributed moisture stress at active tillering stage which increased the mortality of productive tillers and reduced the number of panicles/m^2. These results are supported by Harishankar*et al.* (2016); Nayak *et al.* (2016) and Kumari*et al.*(2018). In sub plot treatments, the highest number of panicles/m^2 was counted with soil application of $ZnSO_4$ @ 37.5 kg/ha which was at par withsoil application of $ZnSO_4$ @ 25 kg/ha. These results are in accordance with the findings of Kumar and Kumar (2009) and Mustafa *et al*. (2011).

Test weight- The potential grain weight is mostly dependent on genotype, but may be limited to some extent by post anthesis assimilates. The effect of moisture regimes on test weight was found to be non-significant. Amongst the moisture regimes treatment 1 day disappearance of ponded water recorded maximum value followed by 3, 5 and 7 days disappearance of ponded water. Similar results are also reported by Parihar (2004) and Kumar *et al.* (2015). Zinc level treatments showed a tendency to increase in test weight but difference could not reach the level of significance with maximum in soil application of $ZnSO_4$ @ 37.5 kg/ha followed by soil application of $ZnSO_4$ @ 37.5 kg/ha and foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering. Increased test weight of rice due to zinc fertilization might be due to its involvement in the carbonic anhydrase activity and more carbohydrate accumulation in seeds. Similar results are reported by Saha*et al.* (2013) and Singh *et al*. (2017).

Grain yield -Yield is the direct outcome of the crop efficiency as influenced by various management practices.Grain yield was influenced significantly due to moisture regimes and zinc levels. Maximum value was recorded with irrigation at 1 day disappearance of ponded water which was significantly superior overirrigation at 5 and 7 days disappearance of ponded water but was statistically at par with irrigation at 3 days disappearance of ponded water. This might be due to higher number of tillers/m^2 and dry matter production under better moisture regimes. These findings are collaborated with the results of Kumar *et al*. (2015), Das *et al*. (2016), and Naya*et al*. (2016). Among the different zinc level treatments plant grown with soil application of $ZnSO_4$ @ 37.5 kg/ha produced significantly more grain yield which was significantly superior over foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering and control but was statistically at par with soil application of $ZnSO_4$ @ 25 kg/ha this might be due to the combined effect of many yield components, like-number of panicles/m^2, panicle length and test weight as Zn application enhanced synthesis of carbohydrate and transport to the site of grain production. Minimum grain yield was recorded in control plot and this might be due to the non-availability of zinc. These findings are in line with Mustafa *et al.* (2011); Qaisrani (2011) and Saha*et al.* (2016).

Harvest index-Harvest index reflects the partitioning of photo-synthates between the grain and the vegetative part, and improvement in the harvest index emphasizes the important of carbon allocation for grain production. Among the different moisture regimes, harvest index was recorded maximum with irrigation at 1 day disappearance of ponded water which was superior over irrigation 7 days disappearance of ponded water but was at par with irrigation 3 and 5 days disappearance of ponded water. Data pertaining to harvest index among the different Zn level treatments showed significant effect due to difference in grain and straw yield. Maximum harvest index was recorded withsoil application of $ZnSO_4$ @ 37.5 kg/ha which was at with soil application of $ZnSO_4$ @ 25 kg/ha and foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering.

Water productivity -Water productivity was varied significantly due to moisture regimes and zinc levels. The maximum water productivity was found with irrigation at 3 days disappearance of ponded water which was statistically at par with irrigation at 5 days disappearance of ponded water. Irrigation at 1 day disappearance of ponded water gave lower water productivity though its grain yield was higher. This might be due to higher use of water but yield did not increase relatively to the water applied. These findings are in line with the findings of Nayak*et al.* (2016) and Kumari*et al.* (2018). The maximum water productivity was recorded for soil application of $ZnSO_4$ @ 37.5 kg/ha which was significantly superior over control plot but was statistically at par with soil application of $ZnSO_4$ @25 kg/ha and foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering.

Gross return-Gross return is the directive of total biological (grain + straw) yield of any crop. Data recorded under different components revealed that gross return was increased with increasing biological yield of direct seeded rice obtained under different treatments. Gross return was maximum with irrigation at 1 day disappearance of ponded water which was superior over irrigation at 5 and 7 days disappearance of ponded water but was statistically at par irrigation at 3 days disappearance of ponded water.These results are in line with Kumar *et al.* (2013) and Kumari*et al.* (2018).In case of zinc level treatments, maximum gross return was recorded with soil application of $ZnSO_4$ @37.5 kg/ha which was superior over control plot and foliar application of 0.5% at tillering, pre-flowering and flowering but was statistically at par with soil application of $ZnSO_4$ @ 25 kg/ha. This was due to significant increase in grain and straw yield. This result is in accordance with the findings of Kumar and Kumar (2009) and Kumar *et al.* (2014).

Net return-Irrigation at 3 days disappearance of ponded water showed significantly higher net return as compared to irrigation at 7 days disappearance of ponded water but was statistically at par with 1 and 5 DAD. This was due to higher yield and lower cost of cultivation with 3 days disappearance of ponded water as compared to other irrigation treatment. Similar result is reported by Balasubramanian and Krishnaranjan (2001). Among the zinc level treatments maximum net return was recorded with soil application of $ZnSO_4$ @37.5 kg/ha which was superior over control plotbut was statistically at par with soil application of $ZnSO_4$ @ 25 kg/ha and foliar application of $ZnSO_4$ @0.5% at tillering, pre-flowering and flowering. This was due to significant increase in grain and straw yield. Similar trend are observed by Kumar andKumar(2014) and Kumar *et al.* (2017).

B: C ratio -The maximum B: C ratio was recorded with irrigation at 3 days disappearance of ponded waterwhich was statistically at par with 1 and 5 DAD and minimum was recorded with 7 days disappearance of ponded water. These finding are in agreement with Nayak*et al.* (2016) and Kumari*et al.* (2018). This might be due to more net return per unit of cost involved in 3 days disappearance of ponded water as compared to others treatments. In sub plot treatments maximum B:C ratio was recorded with soil application of $ZnSO_4$ @37.5 kg/ha which was at par with soil application of $ZnSO_4$ @ 25 kg/ha and foliar application of $ZnSO_4$ @0.5% at tillering, pre-flowering and flowering. The similar findings are reported by Kumar and Kumar (2009) and Kumar *et al.* (2017).

Table 1: Yield attributes, Grain yield and Harvest index as affected by different treatments

Treatments	Number of panicles/m^2	Test weight (g)	Grain yield (q/ha)	Harvest Index (%)
Moisture regimes				
I_1	225.58	24.64	33.14	41.30
I_2	218.11	24.53	32.28	41.21
I_3	198.86	24.51	28.85	41.03
I_4	188.41	24.50	27.70	40.81
SEm±	5.00	0.75	0.96	0.08
CD (P=0.05)	17.29	NS	3.32	0.27
Zinc levels				
Z_1	175.53	24.49	22.86	40.77
Z_2	218.98	24.56	31.54	41.22
Z_3	223.87	24.61	32.57	41.23
Z_4	212.58	24.52	30.00	41.14
SEm±	3.18	0.65	0.66	0.07
CD (P=0.05)	9.52	NS	1.96	0.21

I_1- Irrigation at 1 day disappearance of ponded water, I_2- Irrigation at 3 days disappearance of ponded water,I_3- Irrigation at 5 days disappearance of ponded water,I_4- Irrigation at 7 days disappearance of ponded water,Z_1- Control,Z_2- Application of $ZnSO_4$ @ 25 kg/ha,Z_3- Application of $ZnSO_4$ @ 37.5 kg/ha,Z_4- Foliar application of $ZnSO_4$ @ 0.5% attillering, pre-flowering and flowering.

Table 2: Water productivity,Gross return(₹/ha), Net return(₹/ha) and B:C ratio as affected by different treatments

Treatments	Water productivity (₹/m^3)	Gross return (`₹/ha)	Net return (`₹/ha)	B:C ratio
Moisture regimes				
I_1	2.64	70193	31808	0.82
I_2	3.51	68444	34067	0.99
I_3	3.07	61289	27912	0.83
I_4	2.13	48329	16953	0.53
SEm±	0.20	2026	2026	0.06
CD (P=0.05)	0.69	7013	7013	0.20
Zinc levels				
Z_1	1.59	48687	16023	0.48
Z_2	3.28	66868	31847	0.90
Z_3	3.46	69048	33464	0.94
Z_4	3.02	63653	29407	0.85
SEm±	0.15	1387	1387	0.04
CD (P=0.05)	0.46	4157	4157	0.13

I_1- Irrigation at 1 day disappearance of ponded water, I_2- Irrigation at 3 days disappearance of ponded water,I_3- Irrigation at 5 days disappearance of ponded water,I_4- Irrigation at 7 days disappearance of ponded water,Z_1- Control,Z_2- Application of $ZnSO_4$ @ 25 kg/ha,Z_3- Application of $ZnSO_4$ @ 37.5 kg/ha,Z_4- Foliar application of $ZnSO_4$ @ 0.5% attillering, pre-flowering and flowering.

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