International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 120-124

Received: 13-01-2020
Accepted: 15-02-2020

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Effect of zinc levels and moisture regimes on growth and nutrient uptake of direct seeded rice

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2b.8756

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, and Bihar. The treatments consisted of four moisture regimes in main plots and four zinc levels in sub plots. The result showed that maximum dry matter production (966.27 g/m^2), crop growth rate (13.05 g/m^2/day), straw yield (47.07 kg/ha), total uptake of N (63.71 kg/ha), P (17.48 kg/ha)K (76.59 kg/ha)& Zn (214.61 g/ha)by crop were found to be maximum with I_1 moisture regime which were significantly superior over$I_3$and I_4 but was statistically at par with I_2 except total uptake of N which was significantly superior over I_4 but was statistically at par with I_2 and I_3 but maximum WUE (33.29 kg/ha-cm)was obtained with I_2 which was significantly superior over I_1 and I_4 but was statistically par with I_3.. In context of sub plot treatments maximum dry matter production (955.32 g/m^2), crop growth rate (12.91 g/m^2/day), straw yield (46.42 kg/ha), WUE 33.80 kg/ha-cm), total N (65.06 kg/ha), K (75.80 kg/ha) and Zn (212.95 g/ha) uptake by crop found maximum with Z_3 which were significantly superior over Z_1but were statistically at par with Z_2 and Z_4, except total N uptake by crop which was significantly superior over Z_1andZ_4 but statistically at par with Z_2, while maximum total P (16.11 kg/ha) uptake by crop were recorded with control plot which was significantly superior over Z_3 but was statistically at par with $Z_2$and Z_4.

Keywords: Dry matter production, crop growth rate, WUE, total nutrients uptake

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. DSR, is a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour. Currently, DSR in Asia occupies about 29 million hectare which is approximately 21% of the total rice area (Pandey and Velasco, 2002) [23].

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 is essentially required for protein synthesis and gene expression in plants (Cakmak 2000) [3]. In addition to being essential to plants, it is also an essential mineral nutrient for human beings. In most cases, rice cultivated soils are very low in plant available zinc leading to further decreases in its concentration in rice grain. Its deficiency symptom in rice was observed for the first time in calcareous soil of north-India (Nene 1996). Its deficiency leads to appearance of dusty brown spots on upper leaves, stunted growth of plants, decrease tillering ability and increases spikelets sterility. 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 its 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 reduce its availability. Its 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) [19]. Its efficiency is hardly 2-5% and remaining 98-95% parts are converted to a compound which are not available to plants. 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) [8]. To increase water productivity of rice production the interactions between irrigation practices and fertilizers should be addressed (Hortz and Brown. 2004) [11]. The future of rice production will therefore heavily depends on developing and adopting strategies and practices through efficient use of resources. Such strategies are producing more rice with low inputs of water. Zinc is an essential nutrient and at little extra cost on zinc fertilization combined with macronutrients, a farmer can enhance the yield (Cruz *et al*. 2012) [5].

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 *Burhi Gandak* 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, treatment 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. Rajendra Neelam 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) [18]. 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 6cm 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. Single plot as a sampling unit, five plants or appropriate plant number were taken from each plot excluding 50cm from all sides. A random sampling technique (Gomez and Gomez, 1984) [9] was adopted for recording growth and development of the test crops at various stages of observations. Destructive sampling was done for dry matter accumulation studies. The growth indices of the crop during the experimental year were recorded at regular intervals in order to assess the probable relationship between growth attributes and the final yield. The observations were made at appropriate interval depending upon crop indices to receive a precise observation of growth analysis. For dry matter accumulation studies, five plants from each second row were randomly selected. The samples were washed, sun dried after that, dried in an oven at 70 °C ± 5 °C for 48 hours till constant weight was attained. Finally, the dry matter yield was converted into g/sq. m. This study was made at 30, 60, 90 DAS and at harvest. Samples collected at harvest were used for uptake study. The crop growth rate was calculated for the periodical observation in relation to dry matter production/m^2, using the following formula.

$$\text{CGR (g/m}^2\text{/day)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,
W_2= Dry weight in g/m^2 at the end of the period.
W_1 = Dry weight in g /m^2 at the start of the period.
$(t_2 - t_1)$ = Length of period in days.

The straw from each net plot was air-dried and weighted. The straw yield, thus converted in q/ha. WUE is the expression of the marketable product (grain) obtained by per unit of water applied to the crop. It can be determined with the help of the following formula

$$\text{Water use efficiency (kg/ha-cm)} = \frac{\text{Yield (kg/ha)}}{\text{Water requirement (cm)}}$$

For plant analysis, after harvest the grain and straw sample was separated and oven dried at 65 °C ± 2 ºC for 24 hrs. or till constant weight. Grind the sample in an electric stainless steel grinder. The powdered plant sample of 0.5 g was digested with concentrated H_2SO_4 in presence of digestion mixture ($CuSO_4$ +K_2SO_4 +selenium powder) in digestion unit for 3 hrs. And temperature maintained at 420 °C. The digested sample was further diluted carefully with distilled water to a known volume. Then aliquot was transfer to distillation unit and was steam distilled with 20 ml of 40 percent sodium hydroxide in a semi-micro kjeldhal apparatus. The liberated ammonia was trapped in boric acid mixed indication solution. Then, it was titrated against standard acid (0.01N H_2SO_4) and amount of nitrogen liberated was estimated and expressed the concentration in percentage. Weigh 0.5 g powdered plant sample and digested with Diacid (HNO_3: $HClO_4$) mixture at 9:4 ratio in hot plate till clear solution was observed or till white fumes cease to come out. Cool it and transfer to 50 ml volumetric flask and make volume up to the mark by adding distilled water. Filter it through Whatman No.1 filter paper and a known quantity of aliquot was used for further analysis of phosphorus, potassium and zinc. Phosphorus content in plant was determined by Vanado-molybdate yellow colour method (Koenig and Johnson, 1942) by using spectrophotometer at 660nm wavelength and expressed the concentration in percentage. Potassium content in plant was estimated using flame photometer (Jackson, 1967) and expressed the concentration in percentage. Zinc content in plant was estimated by di-acid mixture ($HNO_3 + HClO_4$) method by using atomic absorption spectrophotometer (Lindsay and Norvell, 1978) [18] and expressed the concentration in ppm.

Results and Discussion

Growth Parameters

The growth parameters, straw yield and WUE vary significantly under varying moisture regimes and zinc levels (Table-1).

Dry matter production: The dry matter accumulation depends upon the photosynthesis and respiration rate, which finally increased the plant growth with respect to increase in plant height, no. of tillers and no. of leaves. Irrespective of the treatments dry matter production increased progressively with maximum at harvest. Significantly higher dry matter production was obtained with irrigation at 1 day disappearance of ponded water which were significantly superior over irrigation at 5 and 7 days disappearance of ponded water but was statistically at par with irrigation at 3 days disappearance of ponded water. The increase in dry matter production is attributed to possible reduction in transpiration rate and normal gas exchange resulted in increased production of photosynthates and translocation to sink. This result is in line with the findings of Edwin and Anal (2008) [7] and Harishankar *et al*. (2016). Significant influence of different zinc levels was noticed on dry matter production. Maximum dry matter production was obtained under soil application of $ZnSO_4$ @ 37.5 kg/ha which were significantly superior over control but were 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 might be due to the proper nourishment of the crop with nutrient supply which increased the activity of meristematic cells and cell elongation. This result is in close conformity with the findings of Kumar and Kumar (2009) [15] and Ali *et al.* (2014) [2].

Crop growth rate: Crop growth rate represents dry matter production per unit area over a period of time and it is considered as the most important growth function. Crop growth rate was influenced by various growth parameters as well as biochemical and physiological activities of plant. Irrespective of treatments CGR increased up to 60-90 DAS and there after decreased at 90 DAS-at harvest. It may be due to accumulation of photosynthates through photosynthesis during period of crop and then it was distributed towards the root and shoot. Irrespective of stages of growth, maximum CGR was recorded with irrigation at 1 day disappearance of ponded water which were significantly superior over irrigation 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 maximum plant height, more numbers of tillers and more number of leaves. Similar results are found by Chowdhary (2003), Kumar *et al*. (2015) [14] and Das *et al*. (2016) [6]. In context of sub plot treatments, highest CGR was recorded with soil application of $ZnSO_4$ @ 37.5 kg/ha which was significantly superior over control but were 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 might be due to the adequate supply of Zn increases the availability and translocation of nutrients during growth and development stages. Similar result has been reported by Alam and Kumar (2015) [1].

Straw yield: Straw yield was increased significantly with increasing irrigation levels and zinc levels. This might be due to increase in plant height, LAI and number of tillers/m^2. Similar result is reported by Kumar *et al*. (2006) [13]. Highest straw yield was recorded with irrigation at 1 day disappearance of ponded water which were significantly superior over 5 and 7 days disappearance of ponded water but was at par with irrigation at 3 days disappearance of ponded water which was due to water scarcity during both vegetative and reproductive phase of crop. These findings are in harmony with Parihar (2004) [25] and Kumar *et al.* (2015) [14]. In case of sub-plot treatments soil application of $ZnSO_4$ @ 37.5 kg/ha produce significantly more straw yield as compared to control 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. The straw yield of rice increased with the zinc application, it could be attributed to the fact that the optimum utilization of all the production factors accelerates photosynthesis resulting in better growth and development of the crop. Similar findings are reported by Niraj *et al.* (2014) [21] and Kulhare *et al.* (2016) [16].

Water use efficiency: The maximum WUE 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 but was significantly superior over rest of the treatments. Irrigation at 1 day disappearance of ponded water gave lower WUE 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 confirmed by Nayak *et al.* (2016) [20] and Kumari *et al.* (2018) [17]. The maximum water use efficiency was recorded for soil application of $ZnSO_4$ @ 37.5 kg/ha which was statistically at par with soil application of $ZnSO_4$ @25 kg/ha but was significantly superior over rest of the treatments.

Total nutrients uptake: Nutrient uptake is the function of total biomass production and nutrient content in the biomass and total nutrient uptake is the sum of uptake by grin and straw.

Total N uptake: The maximum total N uptake was recorded for irrigation at 1 day disappearance of ponded water which was significantly superior over irrigation at 7 days disappearance of ponded water but was statistically at par with irrigation at 3 and 5 days disappearance of ponded water. Similar finding is reported by Das *et al*. (2016) [6]. In context of sub-plot treatments plants fertilized with soil application of $ZnSO_4$ @ 37.5 kg/ha resulted in higher total N uptake which was significantly superior over control plot and foliar application of $ZnSO_4$ @ 0.5% at tillering, pre-flowering and flowering but was statistically at par with soil application of $ZnSO_4$ @ 25 kg/ha.

Total P uptake: The maximum total P uptake was recorded for irrigation at 1 day disappearance of ponded water which was significantly superior over irrigation at 7 days disappearance of ponded water but was statistically at par with irrigation at 3 and 5 days disappearance of ponded water. Similar finding is reported by Das *et al*. (2016). In case of sub-plot treatments maximum total P uptake (16.11 kg/ha) was recorded for control plot which was significantly superior over soil application of $ZnSO_4$ @37.5 kg/ha but were 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.

Total K uptake: The maximum total K uptake was recorded for irrigation at 1 day disappearance of ponded water which was significantly superior over irrigation at 7 days disappearance of ponded water but was statistically at par with irrigation at 3 and 5 days disappearance of ponded water. Similar finding is reported by Das *et al*. (2016) [6]. In context of sub-plot treatments plants fertilized with soil application of $ZnSO_4$ @37.5 kg/ha resulted in higher total K uptake which was significantly superior over control plot and foliar application of $ZnSO_4$ @0.5% at tillering, pre- flowering and flowering but was statistically at par with soil application of $ZnSO_4$ @25 kg/ha.

Total Zn uptake: The maximum total K uptake was recorded for irrigation at 1 day disappearance of ponded water which was significantly superior over irrigation at 7 days disappearance of ponded water but was statistically at par with irrigation at 3 and 5 days disappearance of ponded water. Similar finding is reported by Das *et al*. (2016) [6]. In context of sub plot treatments plants fertilized with soil application of $ZnSO_4$ @ 37.5 kg/ha resulted in higher total Zn uptake which was significantly superior over rest of the treatments.

Table 1: Growth parameters, straw yield and WUE as affected by different treatments

Treatments	Dry matter (g/m^2)	Crop growth rate (g/m^2/day)	Straw yield (q/ha))	WUE (kg/ha-cm)
Moisture regimes				
I_1	966.27	13.05	47.07	27.48
I_2	916.98	12.39	46.02	33.29
I_3	868.69	11.68	41.43	31.76
I_4	810.82	10.84	32.86	28.50
S Em±	35.18	0.50	1.56	0.95
CD (P=0.05)	121.73	NS	5.39	3.28
Zinc levels				
Z_1	752.36	10.00	33.14	23.46
Z_2	937.58	12.63	44.95	32.70
Z_3	955.32	12.91	46.42	33.80
Z_4	917.50	12.42	42.88	31.07
S Em±	13.41	0.19	0.93	0.72
CD (P=0.05)	40.20	0.58	2.79	2.17

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, sssssZ_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.

Table 2: Total N, P, K (kg/ha) and Zn (g/ha) uptake by crop as affected by different treatments

Treatments	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)	Total Zn uptake (g/ha)
Moisture regimes				
I_1	63.71	17.48	76.59	214.61
I_2	62.02	16.56	72.49	203.60
I_3	57.20	14.50	64.50	163.81
I_4	44.40	11.17	49.45	104.26
S Em±	3.07	0.84	3.26	9.26
CD(P=0.05)	10.63	2.91	11.28	32.03
Zinc levels				
Z_1	45.11	16.11	50.25	103.65
Z_2	62.64	15.40	71.05	193.97
Z_3	65.06	12.38	75.80	212.95
Z_4	58.51	15.81	66.13	175.70
S Em±	2.15	0.42	2.58	5.03
CD(P=0.05)	6.45	1.25	7.72	15.09

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% at tillering, pre-flowering and flowering.

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