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Response of wet direct-seeded rice to methods of zinc application

Soumya Saha*[1,2], Subhendu Bandyopadhyay[2], Biplab Mitra[2], PS Patra[2] and Tarun Paul[2]

[1]ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad-500030

[2]Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal-736165, India

*Corresponding author (Email: saha.soumya5@gmail.com)

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Abstract

A field experiment was conducted at the Research Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal during the wet season of 2018 and 2019 to study the response of direct-seeded rice to methods of Zn application. Results revealed that, growth attributes like plant height, number of tillers m^{-2} and dry matter accumulation were significantly influenced by methods of zinc application. At maturity, higher number of tillers m^{-2} and dry matter accumulation was recorded with split soil application of $ZnSO_4$ which was closely followed by soil application of $ZnSO_4$ + foliar spray of Zn-EDTA. Significantly higher grain yields of 4796 and 4756 kg ha^{-1} were recorded with split soil application of $ZnSO_4$ ha^{-1} compared to 4145 and 4093 kg ha^{-1} in no Zn application during 2018 and 2019, respectively. Improvement in net return was found to the tune of about 29% in split soil application of $ZnSO_4$; and 23% in soil application of $ZnSO_4$ + foliar spray of Zn-EDTA during both the years.

Keywords: zinc, direct-seeded rice (DSR), Zn-EDTA, foliar spray, split application

Introduction

Rice is the staple food of more than half of the world population and meets 15% of protein and 21% of the energy requirement of human population worldwide (Depar *et al*., 2011; McLean *et al*., 2002). For uprooting, carrying and transplanting the seedlings into the field a substantial amount of human workforce is required in conventional transplanting of rice. Availability of human work force in agricultural sector is getting scarce day by day associated with the hike in wage rate due to urbanization and migration of rural daily paid workers. As a suitable alternative, direct-seeded rice (dry and wet) is becoming popular in different parts of India as well as in the world. DSR reduces input requirements and saves time by timely sowing and shortens the crop duration by 7-14 days than transplanted rice and when managed properly, DSR provides grain yield equivalent to transplanting (Gill *et al*., 2014; Saha *et al*., 2020). Dry-direct seeding in rice is strongly advocated when water tables are high or, soils are fine-textured where puddling is not required to slow down water infiltration. Further in conditions where irrigation water availability is not a problem and light soils predominate, wet-DSR is a suitable option to combat labour scarcity (Weerakoon *et al*., 2011).

Rice is generally very sensitive to Zn deficiency particularly in the wet puddle cultivation system (Wissuwa *et al*., 2008). Zinc has important roles in many fundamental biochemical processes in crop plants which include enzyme activation, protein synthesis, starch, auxin and nucleic acid metabolism, and development of pollen (Marschner, 1995). Soils with low availability of Zn not only reduce crop productivity but also impair the nutritional quality of the produce. Worldwide, the most frequent and widespread micronutrient deficiency problem in crop plants is the deficiency of zinc (Alloway, 2008). Continuous removal of Zn from soils of cereal based cropping systems without adequate Zn supplementation has depleted soils resulting in 49% of Indian soils being Zn deficient (Behera *et al*., 2009). Soil testing by different agencies all over India also indicates the increasing trend of Zn deficient areas and it is estimated that, zinc deficiency in Indian soils is likely to increase up to 63% by the year 2025 (Singh, 2008). The general recommendation to address Zn deficiency in rice crop is the basal application of zinc sulphate in the soil. Foliar sprays of Zn, the combined application of soil+foliar application, seed coating and priming of seeds may also be effective alternatives to combat Zn deficiency in rice, particularly in Zn deficient soils. Since, comparative study on different methods of Zn application comparing soil, foliage and seed treatments of Zn in rice particularly in direct seeding of rice is lacking, an experiment was conducted to study the effect of Zn application methods in direct-seeded rice.

Materials and Methods

The field experiment was conducted during wet (*kharif*) season of 2018 and 2019 at Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal, India (26° 24′ 03″ N and 89° 23′ 13″ E, 43 m above the mean sea-level). The amount of rainfall received during the crop growing season (July to November) was 1414 mm and 1911 mm in the year 2018 and 2019, respectively. The soil was sandy loam in texture and acidic in nature with 58.2 % sand, 29.2% silt and 12.6% clay, low in available N (107.8 kg ha^{-1}), high in available P (34.2 kg ha^{-1}), medium in available K (127.6 kg ha^{-1}), pH of 6.14 and had 0.62 mg kg^{-1} of DTPA (diethylene triamine penta acetic acid)-extractable Zn in soil.

The experiment was conducted under puddle soil, with direct sowing of 'MTU 1010' as test variety and laid out in randomized block design with three replications and eight methods of zinc application i.e. T1- no zinc, T2- soil application of 5 kg Zn ha^{-1} as basal through $ZnSO_4.7H_2O$, T3- split soil-application of 2.5 kg Zn ha^{-1} each at basal and at booting stage through $ZnSO_4.7H_2O$, T4- seed coating (1% Zn), T5- seed coating (2% Zn), T6- seed coating (3% Zn), T7- soil application of 2.5 kg Zn ha^{-1} as basal through $ZnSO_4.7H_2O$ + foliar spray of Zn-EDTA at booting stage; and T8- foliar spray of Zn-EDTA at maximum tillering and at booting stage.

Main field for direct seeded rice (DSR) was prepared by deep ploughing once followed by harrowing. A fine puddled structure was achieved by two operations of tractor drawn rotavator with planking after applying an ample amount of irrigation. Two-three seeds were dibbled manually at 20 cm×15 cm spacing in a puddled field with no or negligible standing water on the surface. The recommended dose of 60-30-30 kg $N-P_2O_5-K_2O$ ha^{-1} was applied. Zinc fertilization was implemented treatment wise. Zinc sulphate hepta-hydrate and Zn-EDTA were applied in soil and foliar application, respectively. Diseases and insects were effectively managed by integrated measures. Weed control was achieved by a combination of post - emergence herbicides and hand-weeding.

Observations were recorded on growth and yield attributes. The plant height of rice was measured from the base of the plant to the tip of the tallest leaf. Five hills were selected before the harvest of the crop for recording total dry-matter accumulation by the rice crop. Plant samples were air-dried and further dried in a hot air oven at 60±2°C till constant weight was achieved. The number of tillers was noted by counting from the sampling unit at harvest. After threshing of the produce obtained from one square meter (or net plot area) of harvested area, the grain was cleaned, dried and weighed. The grain yield was finally adjusted at 14% moisture and expressed in kg ha^{-1}. Then weight of the straw was also recorded and was adjusted to oven dry weight. Gross and net returns were calculated based on the grain and straw yield, the minimum support price of grain and prevailing market prices of rice straw in the respective year. B:C ratio or returns per rupee invested was calculated by dividing the gross return by cost of cultivation.

The data obtained from the study were analyzed statistically using the F-test, as per the procedure given by Gomez and Gomez (1984). Critical difference (CD) at P=0.05 was used to determine the significance of the difference between treatment means.

Results and Discussion

Growth and yield attributes

At maturity, two foliar applications with Zn-EDTA at maximum tillering (MT) and booting, and split soil application of $ZnSO_4$ showed greater plant height followed by soil application of $ZnSO_4$ + foliar spray of Zn-EDTA (**Table 1**). Maximum number of tillers m^{-2} was recorded with split soil application (370 and 367) followed by soil application of $ZnSO_4$ + foliar spray of Zn-EDTA (366 and 362) closely followed by two Zn-EDTA sprays at MT and booting (366 and 357). , Split soil application of $ZnSO_4$, soil application of $ZnSO_4$ + foliar spray of Zn-EDTA and foliar application of Zn-EDTA at MT and booting showed better dry matter accumulation (DMA) compared to other methods. The improvement in growth attributes might be due to presence of the zinc as it has an important role in many enzyme systems in rice. These results may also be attributed to the adequate supply Zn through different methods of Zn application and due to higher availability and translocation of nutrients during stages of growth to accelerate the enzymatic activity and auxin metabolism (Alloway, 2008; Sudha and Stalin, 2015).

The number of panicles m^{-2} was significantly influenced by methods of zinc application. A higher number of panicles m^{-2} (293 and 286 in 2018 and 2019, respectively) were observed with split soil application of $ZnSO_4$ followed by $ZnSO_4$ application at basal+ Zn-EDTA spray at booting (287 and 284) and two foliar applications of Zn-EDTA (284 and 281). Higher number of filled grains per panicle was also recorded with split soil application of $ZnSO_4$ and soil application of $ZnSO_4$ + foliar Zn-EDTA

Table 1: Effect of methods of Zn application on growth attributes of rice at maturity

Treatment	Plant height (cm)		No. of tillers m^{-2}		DMA (g m^{-2})	
	2018	2019	2018	2019	2018	2019
T1-No zinc	103.6	100.5	307.4	303.0	999.8	981.1
T2-$ZnSO_4$ application as basal	116.2	113.7	353.0	344.4	1151.2	1111.9
T3-Split application at basal and booting	119.1	115.7	370.4	366.7	1211.8	1179.5
T4-Seed coating 1% Zn	112.5	109.5	337.0	325.7	1090.6	1049.5
T5-Seed coating 2% Zn	114.2	110.6	344.4	334.1	1118.0	1090.8
T6-Seed coating 3% Zn	116.5	112.2	351.9	344.1	1132.0	1100.2
T7-$ZnSO_4$ as basal+ Zn-EDTA at booting	118.5	117.6	366.2	361.7	1200.0	1168.4
T8-Zn-EDTA spray at MT & booting	119.3	117.2	365.6	357.4	1187.2	1162.8
SEm±	2.8	2.7	11.1	12.0	36.3	36.2
CD (P=0.05)	8.5	8.3	33.5	36.5	110.0	109.9

DMA = dry matter accumulation

spray during 2018 and 2019 (**Table 2**), respectively. Different Zn management methods increased per cent filled grain per panicle compared to no Zn application and the highest fertility percentage was recorded with the application of 2.5 kg Zn through $ZnSO_4.7H_2O$ as basal soil application + foliar sprays of Zn-EDTA at booting. Improvement in different yield attributes of rice with the application of Zn might be due to sufficient supply of zinc that might have increased the uptake and availability of other essential nutrients. Higher uptake of Zn as a result of Zn application which resulted in higher biomass accumulation ultimately showed improved yield attributing characters (Shivay *et al*., 2008)

Yield and harvest index

The split soil application of $ZnSO_4$ was found statistically at par in terms of grain yield with $ZnSO_4$ application at basal+ Zn-EDTA spray at booting, foliar application of Zn-EDTA at MT and booting, and basal application of 5 kg Zn ha^{-1}. Seed coating 2% (4421 and 4397 kg ha^{-1}) and 3% (4561 and 4512 kg ha^{-1}) with Zn resulted in significantly higher grain yield than no Zn application during both the years (**Table 3**). The highest straw yield (6352 and 6257 kg ha^{-1}) was registered with split soil application of $ZnSO_4$. Data revealed no significant variation of harvest index during both the years of study.

The positive influence of applied Zn on grain and straw yield might be due to its stimulatory effect on many of the metabolic processes of plants (Mandal *et al*., 2009). Significant improvement in the grain yield of rice due to coating of rice seeds with $ZnSO_4$ was recorded by Mondal *et al*., (2020). Increased grain and straw yield recorded in soil + foliar application of Zn as compared to single basal soil application might be due to better absorption of Zn through stomata of leaves in later phase of the crop and initially with soil application which led to higher photosynthesis. These results have close conformity with the findings of Naik and Das (2008).

Table 2: Effect of methods of Zn application on yield attributes of rice

Treatment	Number of panicles m^{-2}		1000-grain weight (g)		No. of filled grains $panicle^{-1}$		% filled grains $panicle^{-1}$	
	2018	2019	2018	2019	2018	2019	2018	2019
T1-No zinc	249.1	241.2	22.25	22.34	74.3	73.2	67.3	70.1
T2-$ZnSO_4$ application as basal	277.2	278.3	22.46	22.50	79.6	78.2	74.5	74.7
T3-Split application at basal and booting	293.1	286.1	22.32	22.32	83.0	78.8	75.2	76.6
T4-Seed coating 1% Zn	267.3	265.8	22.51	22.26	77.1	75.1	70.5	72.4
T5-Seed coating 2% Zn	272.0	272.8	22.33	22.38	77.8	76.1	72.2	73.6
T6-Seed coating 3% Zn	278.5	278.8	22.33	22.30	79.1	76.7	73.4	74.1
T7-$ZnSO_4$ as basal+ Zn-EDTA at booting	287.4	284.0	22.47	22.53	82.7	80.3	76.2	76.6
T8-Zn-EDTA spray at MT & booting	284.3	280.9	22.37	22.45	80.6	78.2	75.0	75.8
SEm±	8.1	8.0	0.67	0.67	1.6	1.3	1.3	1.3
CD (P=0.05)	24.7	24.3	NS	NS	4.7	4.1	4.0	4.0

Table 3: Effect of methods of Zn application on yield and harvest index of rice

Treatment	Grain yield ($kg\ ha^{-1}$)		Straw yield ($kg\ ha^{-1}$)		Harvest index (%)	
	2018	2019	2018	2019	2018	2019
T1-No zinc	4145	4093	5642	5589	42.33	42.27
T2-$ZnSO_4$ application as basal	4587	4548	6248	6136	42.34	42.56
T3-Split application at basal and booting	4796	4756	6352	6257	43.02	43.17
T4-Seed coating 1% Zn	4358	4344	5969	5812	42.21	42.77
T5-Seed coating 2% Zn	4421	4397	6011	5943	42.39	42.50
T6-Seed coating 3% Zn	4561	4512	6121	5990	42.71	42.99
T7-$ZnSO_4$ as basal+ Zn-EDTA at booting	4699	4657	6349	6254	42.54	42.69
T8-Zn-EDTA spray at MT & booting	4665	4592	6310	6172	42.50	42.65
SEm±	80	79	127	118	0.74	0.36
CD (P=0.05)	243	241	386	359	NS	NS

Economics

The highest cost of cultivation was incurred in the treatment with two foliar applications of Zn-EDTA at maximum tillering and at the booting stage (**Table 4**). Higher cost of cultivation of Zn-EDTA treatment in comparison to $ZnSO_4.7H_2O$ was due to the higher price of Zn-EDTA (Ghasal *et al*., 2015). Higher gross and net return was obtained with split soil application of $ZnSO_4$ at basal and at booting stage compared to the rest of the treatments. However, soil (2.5 kg Zn ha^{-1} at basal) +foliar application of Zn-EDTA at booting stage was also found with comparable benefits. Among three seed coating treatments, the coating of rice seeds with 3% Zn was found better than other two and resulted in slightly higher net monetary return

Table 4: Effect of methods of Zn application on economic of rice cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})		Gross return (Rs. ha^{-1})		Net return (Rs. ha^{-1})		B:C (Return per rupee invested)	
	2018	2019	2018	2019	2018	2019	2018	2019
T1-No zinc	43298	43583	78176	80993	34878	37411	1.81	1.86
T2-$ZnSO_4$ application as basal	45298	45583	86515	89911	41217	44328	1.91	1.97
T3-Split application at basal and booting	45298	45583	90287	93822	44989	48239	1.99	2.06
T4-Seed coating 1% Zn	43728	44013	82228	85811	38500	41798	1.88	1.95
T5-Seed coating 2% Zn	43888	44173	83387	86931	39499	42758	1.90	1.97
T6-Seed coating 3% Zn	44048	44333	85946	89075	41898	44742	1.95	2.01
T7-$ZnSO_4$ as basal+ Zn-EDTA at booting	45581	45922	88584	92023	43003	46102	1.94	2.00
T8-Zn-EDTA spray at MT & booting	45863	46260	87954	90754	42091	44494	1.92	1.96

compared to that of 5 kg Zn ha^{-1} applied at basal (soil) through $ZnSO_4.7H_2O$. Farooq *et al*., (2018) observed significant improvement in net benefit and B:C ratio with seed coating and foliar application of Zn in dry-DSR system. Higher net monetary benefit from the split application of Zn might be due to higher yield obtained in that treatment along with no additional cost incurred for application. Mandal *et al*., (2009) obtained higher additional net returns when Zn was applied in splits along with the recommended dose of NPK. Naik and Das (2008) also observed higher net profit and cost-benefit ratio with split application of 10 and 20 kg Zn ha^{-1} as $ZnSO_4$, over the corresponding basal applications.

Based on the experimental findings, it can be concluded that, in wet-direct-seeded rice, split soil application of 2.5 kg Zn ha^{-1} each at basal and at booting stage through $ZnSO_4.7H_2O$ was superior among all Zn management treatments in terms of grain yield and economics. However, coating of rice seeds with 3% Zn was found comparable with a single basal application of Zn in terms of grain yield and net return.

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